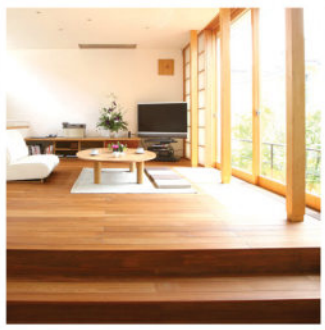
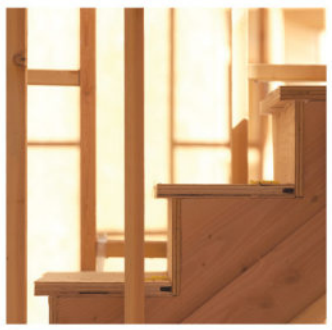
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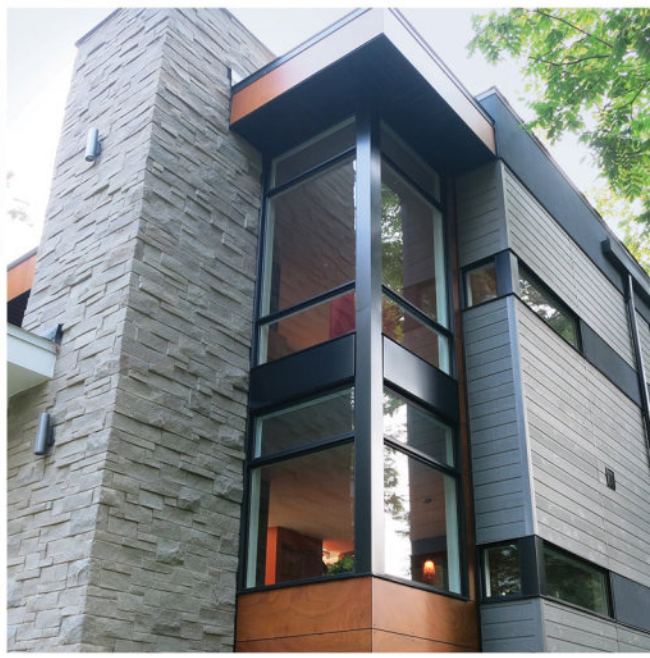












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PREFACE



Canadian Wood-Frame House Construction by Canada Mortgage and Housing Corporation (CMHC) has been a popular publication for builders, homeowners (current and prospective) and students of housing technology since its first edition appeared in 1967. It continues to be a widely used reference for numerous college and university courses and is one of many continuing efforts by CMHC to provide accessible, affordable and sustainable housing for Canadians.

HOW TO USE THIS BOOK

Canadian Wood-Frame House Construction is a concise description of Canadian wood-frame house construction and references several other publications that provide additional information. This book is not intended to be a complete reference on wood-frame house construction, but it is an introductory book for understanding and applying wood-frame house construction principles.

Though *Canadian Wood-Frame House Construction* is based on the requirements of the 2010 edition of the National Building Code (NBC), it is not a substitute for the NBC. Readers are encouraged to refer to the housing-related codes and standards in their jurisdictions for a complete set of requirements. The book also provides some recommendations that go beyond the requirements of the NBC.

The organization of *Canadian Wood-Frame House Construction* generally corresponds to the construction sequence for a typical house. In this updated version, information about the functions of the building envelope has been moved close to the front (see Chapter 5)

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to reflect the importance of this topic and the need to consider it early in the planning process.

The chapters are based on major aspects of wood-frame house construction and reflect typical practices, some of which vary across Canada. Readers are urged to consult local building departments, trades and suppliers for additional direction.

Ideally, users of this book should read the book from start to finish. However, if specific information is required, each chapter has been developed as a stand-alone reference.

In order to keep this book to a manageable size, a glossary of the numerous housing terms used in this book is not included. Readers should consult CMHC's *Glossary of Housing Terms*.

Please send any feedback and suggestions on new or improved content, which are highly valued, to:

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Canada Mortgage and Housing Corporation
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NEW FEATURES

This edition of *Canadian Wood-Frame House Construction* has been updated to reflect the residential requirements of the 2010 edition of the National Building Code of Canada (NBC), including new energy efficiency requirements in the 2012 Interim Changes to the 2010 NBC. Many other changes have been made to bring the book in line with current building science research, construction methods and construction materials.

CHOOSING THE SIZE AND SPACING

This edition also includes "Choosing the Size and Spacing" text boxes that provide examples for sizing the typical wood structural components of a house based on the tables in the Appendices. For situations not covered by the tables, consult a structural engineer.

SUSTAINABLE HOUSING INSIGHT

CMHC is committed to providing the Canadian housing industry with reliable information on appropriate housing technology that responds to people and the environment. In this edition, practical considerations derived from CMHC's sustainable housing initiatives have been included in "Sustainable Housing Insight" text boxes like this one. These include technologies, building methods and products that would make a house more sustainable or improve performance beyond industry standard practice.

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METRIC AND IMPERIAL DIMENSIONS

Canadian Wood-Frame House Construction provides both metric (SI) and imperial units. The National Building Code of Canada uses metric units and these govern whenever strict interpretations of Code requirements are required. Imperial units of measure (feet and inches) are still commonly used for wood-framing materials and house construction technology.

Imperial sizes for lumber are nominal sizes (the rough sawn sizes before planing and dimensional changes resulting from drying). For example, a wood member with a nominal size of 2 × 4 in. has a finished size of about 1½ × 3½ in. The metric dimensions for lumber are actual sizes (for example, 38 × 89 mm).

Every reasonable effort has been made to provide accurate conversions of metric dimensions to imperial equivalents; however, it remains the responsibility of designers and builders to comply with building code requirements. Some conversion factors are given in Table 1 (Appendix A).

Consult the local building department to determine the units measurement required for house plans.

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CHAPTER 1
Important General Information



Wood-frame construction has been the option chosen for millions of houses in North America and provides some of the world's most affordable and comfortable housing. From the days when early settlers used abundant forest resources for housing materials, wood-frame construction has since become a sophisticated technology supported by a wealth of research and is capable of meeting or exceeding all building science challenges.

ADVANTAGES OF WOOD-FRAME CONSTRUCTION

Wood-frame construction can incorporate dimension lumber, engineered wood products and structural wood panel sheathing into wall, floor and roof assemblies that are robust, economical and fast to build. Current wood-frame technology is the result of many years of development and improvement and extensive research by the National Research Council, Canada Mortgage and Housing Corporation, industry and others.

Like any other building system, wood-frame construction requires reasonable care in its design and construction to provide lasting shelter, comfort and safety. When well-designed and constructed, wood-frame construction is:

- fast and easy to build and renovate;
- durable;
- built from a renewable resource;
- a natural insulator that is easy to insulate to minimize heating and cooling costs;
- strong, light and flexible using basic tools and fasteners;
- easily tailored to the range of wind and snow loads found throughout Canada;
- easily reinforced to withstand extreme wind and earthquake loads;
- adaptable to all climates ranging from hot and humid to extremely cold climates; and
- able to meet or exceed code-established levels of fire safety and sound control.

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BUILDING DESIGN

Wood-frame housing may be built to various designs and specifications. Whether a standard design is used or a custom design is created, building code provisions and good design principles must be observed to provide a durable house; to maximize occupant health, comfort and safety; and to reduce a building's environmental footprint. Building design should provide easy access for people of diverse physical capabilities and adapt to occupants' changing needs. Obtain professional design assistance for special requirements such as barrier-free access for people with disabilities.

STRUCTURAL DESIGN

To agree with the National Building Code, the metric spacing of wood framing members is expressed as 'soft' conversions from the actual imperial dimensions. For example, spacing of 12, 16 and 24 inches on centre are converted to 300, 400 and 600 mm on centre, respectively. In order to suit the imperial sizes of common 1220 × 2440 mm (4 × 8 ft.) panel products, such as gypsum board, OSB and plywood, the actual spacing of framing members has been adjusted to approximately 305, 406 and 610 mm on centre, respectively.

The NBC contains provisions for bracing to resist lateral loads from earthquakes and high winds. The provisions are based on a three-level risk-based approach developed from environmental load data. There are no special requirements for areas where the risk is *low* to *moderate*. This means that normal sheathing, cladding and finishes provide adequate resistance. Most of the new requirements apply to areas of *high* risk, mainly the coastal area of British Columbia. For these areas, builders can incorporate adequate lateral load resistance without the need for further structural engineering design. The measures include providing "braced wall panels" in "braced wall bands" that are continuous horizontally and vertically throughout the building and that extend from the top of the supporting foundation, slab or subfloor to the underside of the floor or ceiling above. There is also the option of designing in accordance with NBC Part 4 or good engineering practice such as that provided in the Canadian Wood Council's *Engineering Guide for Wood-Frame Construction 2009*. Refer to Chapter 10 for more information.

In the few Canadian locations where risk is *extreme*, bracing to resist lateral load must be designed in accordance with NBC Part 4 or good engineering practice such as that provided in the *Engineering Guide for Wood-Frame Construction 2009*.

FIRE SAFETY

The NBC does not explicitly require fire-rated floor or wall assemblies in single-family houses. Wood-frame construction is considered to provide an acceptable level of fire safety, dependent to a degree on gypsum board finishes, which provide essential fire protection of structural components for a certain period of time. In addition, occupants are considered to be familiar with hazards and safety features of such buildings and to know how to safely exit the house.

Wood-frame construction can satisfy the fire safety provisions of the National Building Code. Fire safety is a combination of many factors, some of which can be minimized by building requirements, and others that can only be controlled by the occupants. Examples of building code fire safety measures include:

- limiting the area of unprotected openings (windows and doors) in buildings close to property lines to reduce the chance of a fire spreading from one house to another;
- requiring smoke alarms on every floor and in sleeping areas;

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- setting minimum door and exit route widths and requiring window egress routes from bedrooms to help occupants escape in the event of fire; and
- providing clearances around heating and cooking appliances to prevent fires from starting.

Occupants can minimize their exposure to fire risk by:

- maintaining smoke alarms in working order;
- ensuring all occupants are aware of escape routes and of the outdoor gathering point in the event of fire; and
- exercising care when using cooking and heating appliances.

The requirements for attached housing such as duplexes, houses with a secondary suite, townhouses and apartments are often more complex because a fire in one unit could spread to an adjacent unit without the occupants in the affected unit being aware of a problem.

Space between Houses

Fire spreads from one building to another principally by thermal radiation through windows and other unprotected openings. Many things contribute to radiation intensity, and several are more significant than cladding. At any given distance, radiation intensity will primarily depend on the total area of windows radiating heat.

The intensity varies inversely as the square of the distance from the source—if the distance is doubled, the radiation intensity will be only 25 per cent that of the original spacing. For this reason, the closer one building is to a property line or an assumed line between two buildings on the same property, the smaller the area of windows and other unprotected openings (such as non-fire-rated doors) is permitted.

The location of a house in relation to a property line can affect the area of openings (windows), the design and construction of overhangs, and the types of exterior cladding materials that are permitted. Restrictions generally apply for houses situated within 2 m (6 ft. 7 in.) of a property line. Consultation with local building officials is recommended before applying for a building permit.

SOUND CONTROL

Sound control between rooms of a house is provided by means of the materials used in the floor and wall assemblies and by reducing flanking paths so that noise is not transferred around assemblies. There are no code requirements for additional sound control measures in single-family houses because house occupants can take measures to reduce noise.

When a higher level of sound privacy is needed, acoustical insulation can be installed or other measures taken with respect to floors and partition walls.

Houses with a secondary suite are required to have a higher level of sound privacy because there could be two separate groups of occupants in one house. Walls and floors between adjacent dwellings must have sound-absorbing materials, resilient channels on one side, and 12.7 mm (½ in.) thick drywall on ceilings and both sides of walls.

If a house is to be built in an area with a high level of traffic or airport noise, an acoustic engineer should be consulted to devise a means to reduce external noise.

In multi-family buildings (such as semi-detached or row houses or apartments), sound control measures are required between all dwellings to improve occupant comfort.

For more information, refer to the *2010 National Building Code of Canada* published by the National Research Council of Canada.

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SECONDARY SUITES

A secondary suite is located in a house, townhouse or semi-detached houses (two side-by-side dwelling units) and used, for example, as a rental unit or to accommodate family members in an independent area of a house. A secondary suite, which may also be referred to as an accessory suite or secondary unit in some jurisdictions, may occupy more than one storey or be on the same level as or above/below the principal suite in the house.

Some special building requirements apply to secondary suites because the occupants' activities in one suite can affect the health and safety of those in the adjoining suite. These requirements are simpler and less costly than those pertaining to apartment buildings, for example, and strike a balance between practicality and cost, and the health and safety of the occupants. Consultation with local building officials is required before a secondary suite is built. Some of the considerations are as follows:

- A secondary suite is a living space and the ceiling height must be at least 1.95 m (6 ft. 5 in.) and not less than 1.85 m (6 ft. ¾ in.) under beams and ducting.
- Occupants of both the principal and the secondary suite must be provided with adequate escape routes for use in the event of fire. This means adequate stair, ramp and door widths and adequate handrails and guards must be provided.
- A continuous smoke-tight barrier consisting of not less than 12.7 mm (½ in.) gypsum board must be provided between the suites.
- Smoke alarms must be interconnected so that residents in one suite are alerted by a fire in the adjoining suite.
- Some additional protection against sound transmission between a dwelling unit and a secondary suite must be provided.
- Heating and ventilating ductwork can spread smoke and/or fire from one suite to another. For this reason, separate and independent forced-air furnaces and ductwork must be provided for the house and the suite, or, an alternate heating system such as hot water or electrical heating must be provided. If the house has a forced-air heating system, the easiest way of meeting this requirement is to heat the secondary suite electrically.

ROOM HEIGHT

Building codes establish minimum ceiling heights for living area rooms. In general, the minimum ceiling height is 2.1 m (6 ft. 11 in.). Unfinished basement areas must have ceilings at least 2.0 m (6 ft. 7 in.) high in any location that would be used for passage.

RADON

Radon is a colourless, odourless, radioactive gas that occurs naturally in the environment. Outdoors, its concentration is negligible, but it can accumulate in buildings to levels that pose a health risk. Radon can seep from the ground into buildings through cracks and unsealed penetrations in the floor and walls abutting the ground.

Although there are regions in Canada with high radon levels, all new residential buildings are now required to provide measures for radon mitigation because (a) there are no reliable maps showing where radon is present; (b) high radon concentrations can be found in one building and not in neighbouring buildings; and (c) it is very difficult to detect problematic

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radon concentrations during construction. Because mitigating high radon concentrations after construction could be expensive, taking measures during construction can increase safety and reduce the cost of future mitigation.

The basement can be protected against radon if an air barrier connecting the basement slab to the walls is installed to keep radon from entering the living space. A roughed-in, capped pipe extending under the floor slab should also be provided, as it could be used to ventilate the space below a basement floor later, if radon were to become a problem.

Unheated crawl spaces do not need to be protected against the ingress of radon because required ventilation can prevent radon accumulation. Rough-ins for a future radon extraction system are not needed for heated crawl spaces if they do not have a concrete floor slab and if they remain accessible. This way, a person could easily install a connection to the sub-air barrier space to be used for the radon extraction system.

The building owner can easily test the house for radon. The test equipment is relatively inexpensive, and test kits can be ordered over the Internet. If test results indicate an annual average concentration exceeding 200 Bq/m^3, it may be necessary to complete the subfloor depressurization system to reduce radon concentration. This requires that the roughed-in pipe be uncapped and connected to a ventilation system exhausting to the outside. The building should be retested for radon once the depressurization system has been completed and activated.

For further information on how to measure and remediate existing houses, refer to Health Canada's publications *Guide for Radon Measurements in Residential Dwellings (Homes)* and *Reducing Radon Levels in Existing Homes: A Canadian Guide for Professional Contractors.*

ENERGY EFFICIENCY IN HOUSING AND SMALL BUILDINGS

Once adopted by the provinces and territories, changes to NBC Part 9 will require that building envelopes, heating, ventilating and air conditioning systems and service-water heating systems meet or exceed minimum energy efficiency performance requirements. Where adopted, the new provisions will have an impact on the design and construction of houses, so builders should stay alert for building code amendments in their areas.

MATERIAL COMPATIBILITY

Many types of building materials are used in a house. Experience has shown that materials such as sealants and metals can adversely affect an adjacent material at times, resulting in premature degradation.

Many sealant products are suited to a wide range of applications, and there is no simple and universal product labelling system. Improper selection can lead to problems such as paint failure or damage to window frame finishes. Connecting different metals can cause galvanic corrosion, leading to premature failure.

Premature failure can also result from job site-imposed conditions or deadlines. For example, in the rush to apply paint in unheated conditions, a painter might ignore the temperature range recommended by the product manufacturer, resulting in a costly recall.

CONSTRUCTION SAFETY

Care should be taken during construction to avoid injuries, and the following require attention:

- *Site work*—Chainsaws and other mechanical equipment must be used with care, and appropriate safety equipment should be worn.

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- *Excavation*—Cave-ins are dangerous and common. Ensure that excavations are adequately back-sloped or shored to prevent slope failure.
- *Foundation*—Concrete formwork must be strong enough to resist the weight of the concrete while it is being poured.
- *Framing*—Care is required for the placement and temporary bracing of wall sections. Wood trusses are unstable until they have been braced.
- *Exterior finishes and roofing*—Since this involves working at heights well above ground, those doing this work must take proper care and wear fall protection devices.
- *Electrical and mechanical*—Wiring, gas piping and heating and electrical appliances must be installed by qualified personnel to ensure safety during construction and over the lifespan of the house.
- *General*—Follow the manufacturer's instructions for the use of all equipment and tools and obtain practice and experience. Use eye, breathing and hearing protection. Fall protection and the securing of ladders and scaffolding are important steps to ensuring safe construction.

PROTECTION AGAINST MOISTURE AND TERMITES

Wood-frame construction has a record of long-lasting performance. Like all materials, wood has advantages and disadvantages, and some precautions are needed to ensure long service life.

Wood will not decay in conditions where it is kept dry or, if wetted, has an opportunity to dry. Protection is ensured through good design and construction, proper material storage and handling, and the use of materials suited to service conditions.

Many of the chapters in this book cover, to some extent, the building materials and principles intended to reduce damage from moisture such as:

- *Chapter 3—Concrete:* Good concrete mix design, placement and curing is essential for preventing water leakage in foundations.
- *Chapter 5—Functions of the Building Envelope: Water, Air, Vapour and Heat Control:* The building envelope must prevent the movement of water and vapour.
- *Chapter 7—Footings, Foundations and Slabs:* Foundation dampproofing and, where high water tables occur, waterproofing are essential for keeping basements dry.

In addition, roofing, cladding, flashing, vapour barriers, air barriers, ventilated roof spaces, windows and doors all play a role in keeping building materials dry, and they must all work together as a system.

Separation from Wet Conditions

Wood can be used in exposed locations without having to be preservative-treated if it is kept off the ground and installed so that drying is possible between wettings. Here are some examples of separation:

- Foundation walls should be kept at least 200 mm (8 in.) from the ground where wood sidings or wood-base sidings are used.
- The ground level in a crawl space should be at least 300 mm (12 in.) below joists and beams.

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- Untreated wood supported on a concrete slab or footing (such as the sole plate in interior basement walls or basement columns) must be separated by a moisture barrier or the wood must be treated.
- Where the bottom of a beam is below ground level, it must be surrounded by an air space to prevent contact with concrete or treated to prevent decay. The space around the beam must be left open to allow air to circulate and must not be filled with insulation, vapour barriers or airtight materials.
- Where untreated framing members are less than 150 mm (6 in.) above the surface of the ground, the framing must be separated from the supporting base by a moisture barrier.

Preservative Treatment

In applications where wood cannot be kept dry, other measures such as the use of preservative-treated wood must be taken to provide reasonable service life.

Alkaline copper quaternary (ACQ) and copper azole (CA) are the most common preservatives used for residential wood products and are distinguished by the green colour of the finished product.

Borate, another chemical used to treat wood against termites and decay, is usually colourless and results in a much deeper penetration of the chemical into the wood than other methods. However, borate tends to leach out of wood that is exposed to rain, so it is approved only for uses where the wood is protected from direct exposure to moisture.

Corrosion-resistant fasteners such as those that are hot-dip galvanized or made of stainless steel should be used with treated wood. Regular nails or screws should not be used and electric galvanized fasteners should be avoided because the protective coating is too thin for long-term service.

If preservative-treated lumber must be cut on the job site, the cut ends should be coated with a brush-on preservative until it is no longer absorbed into the wood.

Wear gloves when handling treated wood and a mask when cutting it (as for the cutting of many materials). Treated wood should be discarded in accordance with local regulations and should never be burned.

Termites and Other Insects

In some areas, wood is subject to attack by termites, carpenter ants and powder post beetles. The map of known termite locations in Canada indicates that they are present only in a few localized areas in the southernmost parts of British Columbia, Alberta, Saskatchewan, Manitoba and Ontario.

In these areas, the clearance between structural wood elements and the ground must be at least 450 mm (18 in.) unless the wood is treated with a chemical that is toxic to termites (for example, ACQ and CA). In addition, foundation walls must extend at least 150 mm (6 in.) above the ground.

Structural supports must be visible for inspection and the detection of mud tubes that termites build to travel to a food source. Where the foundations are insulated or otherwise constructed in a way that could conceal termite activity, a metal or plastic barrier must be installed through the insulation above finished ground level to control termite passage.

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SUSTAINABLE HOUSING INSIGHT

Principles of Sustainable Housing

A growing awareness of the relationship between human health, the environment and the economy has given rise to the concept of sustainable housing in Canada. For the purpose of this publication, sustainable housing means implementing design, construction and operation principles that maximize occupant health and safety, minimize the consumption of resources and energy, have a minimal negative effect on the environment, and make housing durable and affordable. It is also important that house designs are compatible with local climate.

In some cases, Sustainable Housing Insights in this book reflect code requirements and in others, introduce concepts or recommendations that exceed code requirements. For example, the 2012 Interim Changes to the 2010 National Building Code have minimum requirements for insulation levels intended to make Canadian houses more energy efficient. However, it might be cost effective to provide higher levels of insulation and reduce heating and cooling costs over the service life of a house.

Sustainable housing is founded on five fundamental principles shown in Figure 1. These principles should be considered at the design stage when options can be easily assessed and revised. Examples of how this can be achieved are provided below.

Healthy Indoor Environment

- *Indoor air quality*—Reduce the level of contaminants built into the building (material selection), provide measures to prevent carbon monoxide or radon ingress, remove any contaminants at the source and provide adequate ventilation and humidity control.

1 Principles of sustainable housing



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Continued

- *Water quality*—Connect to a safe supply of potable water, or where this is not possible, provide appropriate home treatment to remove bacteria, chemical contaminants and unpleasant tastes or odours.
- *Light and sound*—Provide adequate natural light throughout the house and isolate internal and external noise sources.
- *Fire safety*—Provide sufficient doors to the outside and operable windows, which could serve as means of egress in the event of a fire or other danger.

Energy Efficiency

- *Building thermal performance*—Minimize the building volume by using a compact design, improve the building envelope by using better insulated and more airtight assemblies, and install high-performance windows and doors.
- *Energy for heating, cooling and ventilation*—Select appropriate energy sources and provide high-efficiency equipment having the appropriate capacity.
- *Renewable energy technologies*—Incorporate wind, solar, biomass (for example, pellet stoves) and geothermal energy sources to reduce reliance on fossil fuels and grid electricity.
- *Building orientation*—Orient the building and locate the windows to capture solar gains during cold months and to enhance natural (passive) ventilation and cooling of the house during hot months.
- *Electrical consumption and peak demand*—Provide controls to avoid or minimize electrical power consumption during peak periods, such as mornings and early evenings, and select efficient domestic appliances and lights.

Resource Efficiency

- Use renewable, recycled or reused materials where possible and avoid the use of materials that might have a damaging effect on the environment.
- *Management of construction waste*—Use materials carefully to reduce waste, reuse materials where possible and recycle waste materials.
- *Water*—Install water-efficient plumbing fixtures and appliances indoors and carefully plan landscaping and natural drainage to minimize water consumption outdoors. Consider using grey water or rainwater for irrigation.
- *Durability and longevity*—Construct a durable building structure, envelope and finishes that resist the effects of climate, use and abuse.

Environmental Responsibility

- *Manufacturing*—Select appropriate materials made from environmentally responsible manufacturing processes, and avoid the use of materials that might have a damaging effect on the environment.
- *Emissions and combustion by-products*—Select high-efficiency, low-emission equipment and appliances.
- *Wastewater and sewage*—Reduce wastewater through water conservation and the provision of appropriate treatment for private wastewater treatment systems.

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Continued

- *Community and site planning issues*—Design houses and developments and choose materials to minimize damage to the environment.
- *Hazardous materials: landfill and disposal*—Avoid the use of hazardous materials. When recycling is not feasible, dispose of materials in appropriate facilities.

Affordability

- *Cost*—Design housing with an affordable purchase price and low maintenance and operating costs. Affordability means finding the right balance between initial (construction) cost and ongoing maintenance and operational costs.
- *Adaptability*—Build housing that serves current needs and can easily be adapted for changing needs.
- *Suitability*—Build housing that meets the needs and expectations of homebuyers.

RELATED PUBLICATIONS

2010 National Building Code of Canada,
National Research Council of Canada

Collecting and Using Rainwater at Home: A Guide for Homeowners,
Canada Mortgage and Housing Corporation (product no. 67925)

Engineering Guide for Wood Frame Construction 2009,
Canadian Wood Council (reference no. EGWF-09-E)

Guide for Radon Measurements in Residential Dwellings (Homes),
Health Canada (catalogue no. H128-1/08-543E)

Household Guide to Water Efficiency,
Canada Mortgage and Housing Corporation (product no. 61924)

Reducing Radon Levels in Existing Homes: A Canadian Guide for Professional Contractors,
Health Canada (catalogue no. H128-1/11-653-1E)

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CHAPTER 2
Planning, Design and Construction



This chapter provides a summary of the planning, design and construction essentials for each aspect of wood-frame house construction described herein.

The book has been updated to incorporate the requirements of the 2010 National Building Code (NBC) and the 2012 Interim Changes to the 2010 NBC for energy efficiency. However, it is not meant to replace the NBC. Consultations with municipal building officials during the design, plan approval and construction stages are strongly recommended to ensure that problems are avoided.

Building codes generally describe the minimum measures required for building performance and safety. Some builders and consumers may wish to add features that exceed code requirements, such as additional insulation to reduce heating and cooling costs.

Recent changes to the NBC require that houses have a minimum level of energy efficiency that affects building envelope construction (Chapter 5), service water heating systems (Chapter 19), and heating, ventilation and air conditioning systems (Chapter 20).

APPROVALS, PERMITS AND INSPECTIONS

The system of approvals, permits and inspections for house construction can be quite complex. It is important to ensure that the property is zoned for the intended use before proceeding with house planning. Some properties may have development regulations, covenants or restrictions governing the size, location and exterior finishes of the house.

Requirements for drawings, permits and inspections vary across Canada, and special provisions may apply to suit local climatic and geological conditions. For example, the wet climates of both the east and west coasts require a drainage cavity in walls to resist rain penetration; varying snow loads across Canada result in the different structural capacities for roof members;

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and houses in areas subject to earthquake risk or high winds require additional strengthening. Most municipalities will require that the construction documents comply with the basic requirements of the applicable provincial or territorial building code, and some have additional requirements.

Drawings should be to scale and provide sufficient detail to enable a plans examiner to determine whether the proposed house is Code compliant. Building departments will indicate their preferred format for house drawings and the minimum information needed to obtain a building permit. Good drawings also enable suppliers and trades to furnish and install materials and equipment correctly. A competent designer should prepare a complete set of drawings and specifications.

The 2010 NBC includes prescriptive requirements and performance functional statements that form the basis for an objective-based code, which states the outcome that must be achieved and provides latitude for users to determine the solution. For example, while a prescriptive code might dictate how thick a concrete foundation wall must be, the performance requirements explain the need for the wall to resist forces and allow the user to submit an alternate design that will work at least as well as the prescribed wall. The performance requirements of the Code enable engineers, architects and other design professionals to propose alternative solutions to building officials.

2 Approval, permits and inspection processes for new houses

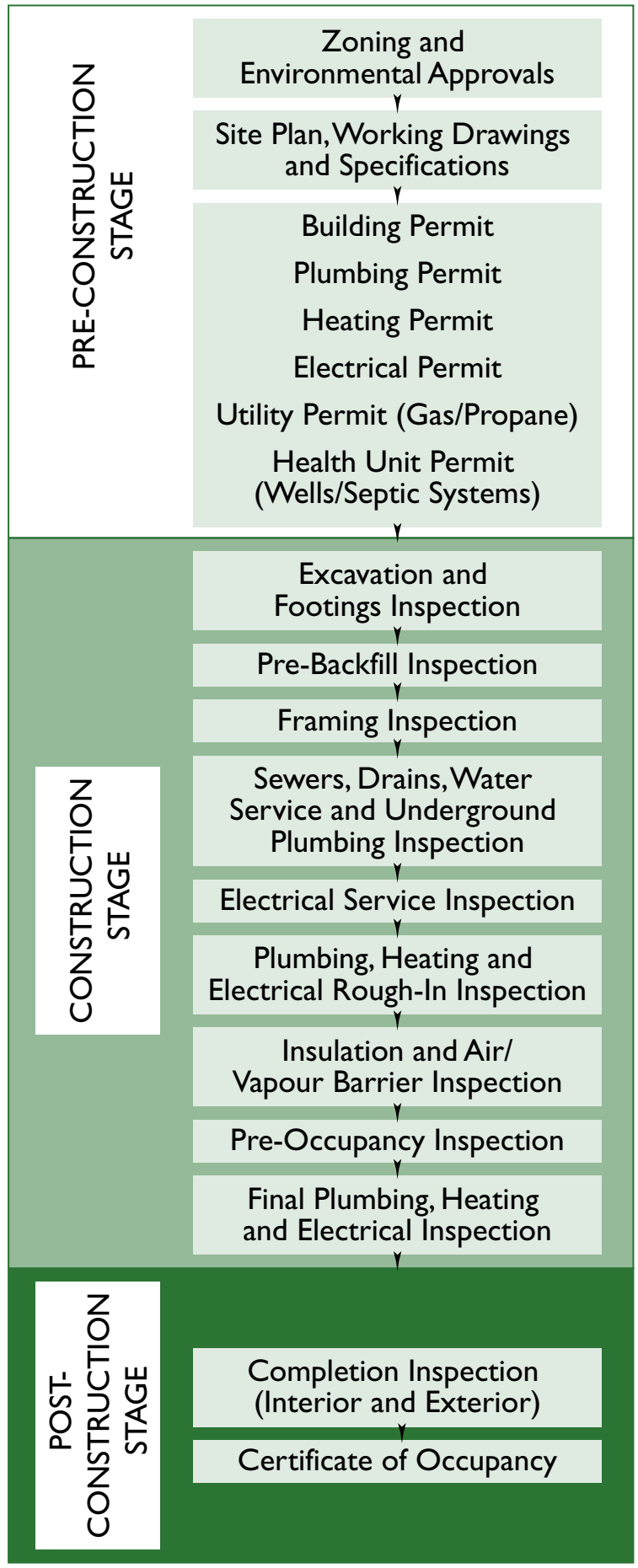


Figure 2 shows the process of approvals, permits and inspections that may apply to a new house. Municipalities may not inspect the work at every stage of construction; however, most will inspect when the foundations, framing, plumbing and electrical, insulation and exterior finishes are complete. In some areas, it may be necessary to observe additional registration and inspection

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requirements by warranty programs for new houses. Readers should consult their local building departments about requirements and procedures.

It is important to schedule inspections to avoid lengthy delays. Determine exactly what work must be completed and how much notice is required prior to calling for a particular inspection. Understand the local requirements and plan ahead so that administrative aspects and delays do not interfere with construction.

PLANNING AND DESIGN

A house is best designed for a specific building site. House size, the number and height of floors, the location and size of rooms and the type of heating system are planned early in the design process. These initial plans can be revised as more information is obtained and as the design becomes more detailed. The project cost should be checked as the design evolves to ensure that the desired features fit the budget.

This section provides a brief overview of the planning and design of a house and things that should be considered and perhaps adjusted as the design progresses. Frequent communication with the local building department will help to ensure the evolving design meets building code and local requirements.

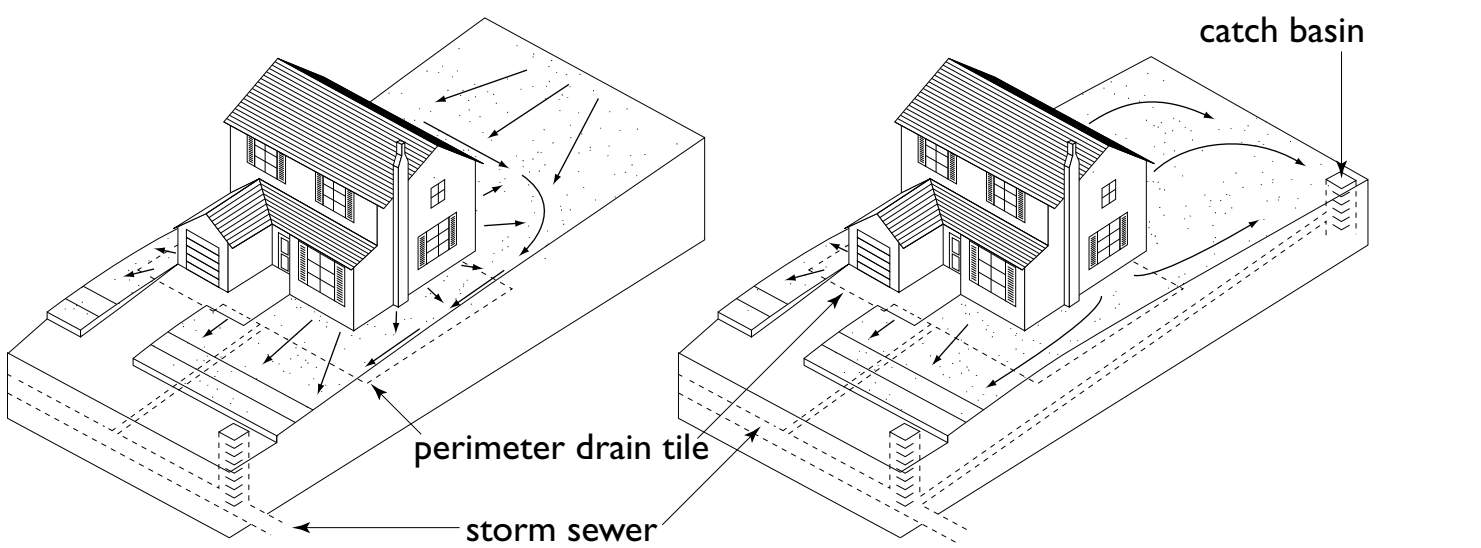
Drawings, Financing and Permits

- Plan for the time required to complete the design and drawings; and to estimate costs, arrange for financing and obtain a building permit.
- Arrange for access to the site and temporary power during this stage.

Site Planning

- Carefully plan to ensure the house is well situated in relation to property lines, road access, sunshine and shading, trees and other natural features.
- Establish the house elevation to accommodate storm and wastewater disposal and site drainage (Figure 3).
- Check with the building department for requirements for foundation drainage and basement plumbing.
- Avoid leading water from roofs and driveways into the foundation drainage system or onto neighbouring properties. Drain this water away from the house to a storm drain or, where none is provided, to a drainage ditch.
- Use gravity drainage for foundations, waste water and sewage wherever possible.

3 Site drainage



Surface drainage to the street **Surface drainage to the street and catch basin**

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Where a well and site disposal of wastewater are required, ensure adequate separation between them.

Consult Chapters 6 and 28 for more information on site planning.

Protection and Care of Materials on the Building Site

Materials stored on site must be protected. Failure to do so can result in waste or construction defects. When possible, material should be delivered to the site just before it is used.

The moisture content of framing lumber at the time of installation must not exceed 19 per cent. S-DRY lumber meets the 19 per cent moisture limit but can re-absorb water if it is left unprotected on the site. Store wood products in a dry, well-drained area. Lumber and sheathing materials should be stored 200 to 250 mm (8 to 10 in.) above the ground on flat supports. Keep the products covered until ready for use.

Vertical wood members exposed to the weather during construction can dry relatively quickly after wetting but horizontal components need more time to dry. After rain, wood members must be allowed to air dry before being enclosed. Allow sufficient time and ventilation for the materials inside wall cavities to dry to an acceptable level before installing the vapour barrier.

Asphalt shingles should be stored so that the bundles can lie flat without bending. Using curved or buckled shingles will result in an unattractive roof and a shortened service life.

If windows and doors are delivered before they can be installed, they should be protected from weather and damage.

Batt insulation and drywall are very susceptible to water damage and must be protected.

Hardwood flooring, interior trim and millwork should not be stored in the house until the building moisture resulting from concrete curing, drywall finishing and any rain that was admitted during construction has had time to dissipate.

Distribute heavy materials stored on framing members, such as gypsum wallboard or asphalt shingles, to avoid overloading.

Excavation, Footings and Foundation

A good foundation is essential for structural support and controlling ground water and forms part of the soil-gas control system (see Chapter 7 for more information).

- Determine the water conditions on the property, how water will be drained away from the foundation, and whether basement dampproofing will be adequate for the water conditions.
- Establish the foundation wall thickness based on the backfill height, the number of storeys to be supported and the height of the wall.
- Consider the space required for beams, ductwork and plumbing in determining the basement ceiling height.
- Consider using a higher basement ceiling height if it is likely the basement will be finished.
- Determine whether the basement insulation will be on the inside or outside of the foundation walls.
- Plan for the foundation to support a masonry chimney, if there will be one.
- Plan for pipes and services that pass through the foundation.
- Provide the required pipe stub connection for future radon removal, should radon prove to be a problem after the house is occupied.
- Determine the location of anchor bolts in the top of the foundation wall to secure the framing to the foundation.

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- Ensure the concrete has cured and the first floor framing is in place to provide lateral support before backfilling.

Framing

Wood-frame construction is comprised of main structural members (the framing) and sheathing (oriented strand board or plywood that provides stiffness). The combination of framing members and sheathing provides rigidity, space for insulation and a framework for supporting interior finishes and exterior components. See Chapters 8 to 11 for more information.

Floor Framing

- Use span tables to select the joist size for the lumber species and grade, joist spacing, span and loads. Where in-floor heating requires concrete topping, floor joists should be deeper or more closely spaced.
- Consider how plumbing and ductwork will be installed without disrupting the floor system.
- Use floor sheathing and sub-flooring appropriate for the joist spacing and the type of floor finish.

Wall Framing

- Wood panel wall sheathing provides significant resistance to lateral loads from high winds and earthquakes. In areas with a risk of high winds and earthquake loads, thicker sheathing, closer nailing patterns and the provision of "braced panels" may be required to strengthen walls.
- Select appropriate sheathing thickness and nailing patterns to provide adequate resistance to lateral loads.
- Select a wall arrangement that will accommodate the necessary amount of insulation for your climate zone.
- Provide wall framing deep enough for the required insulation and locate pipes or ducts in interior walls.

Roof Framing

- Design the roof system to support local snow and wind loads and the weight of the roofing materials that will be used.
- Consider designing the roof structure to support future solar thermal and photovoltaic panels. Consult an engineer to ensure that the roof design addresses loading and electrical requirements.
- Use raised-heel trusses or deep rafters so there is room for adequate ceiling insulation where the roof meets the wall.
- Provide adequate ventilation in the roof space to prevent moisture from accumulating in the attic.

Exterior Finishes

In addition to enhancing appearance, exterior finishes serve as a barrier to the elements. The cladding is the first plane of protection for water penetration control. Exterior finishes include a wide variety of cladding materials (wood siding, brick veneer, vinyl siding, cementitious siding) as well as flashing, trim boards and sealant. Windows and doors and the roof covering are also part of the exterior finishes. See Chapters 5, 12 and 13 for more information on exterior finishes.

Flashing

The purpose of flashing is to prevent water from entering the building envelope and to intercept any that passes the first plane of protection and direct it to the exterior. Flashing is usually required wherever there is a discontinuity on exterior surfaces (for example, above windows), where there is a change in cladding materials (for example, vinyl siding above brick cladding), and at roof valleys. Carefully plan the location of flashing to fit with roofing materials, brick joints, sheathing membranes, windows, skylights and doors. See Chapter 14 for more information.

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Attics, Roof Spaces and Roofing

Unconditioned attics must be separated from the conditioned environment by insulation, an air barrier system and a vapour barrier. They should be vented to remove any moisture that has entered from the conditioned interior environment or the exterior environment. The roof shape must effectively shed water and be covered with roofing materials and flashing that will prevent water from entering. See Chapter 12 for more information.

Windows, Doors and Skylights

Windows, doors and skylights separate the indoor and outdoor environments, provide security and natural light, and must also provide a degree of thermal insulation. See Chapter 15 for more information.

Windows and Skylights

- Choose windows and skylights to bring in light and fresh air, and to reduce winter heat loss (thereby minimizing heating costs) and summer solar heat gain (to keep cooling costs down).
- Manufactured windows are classified according to key performance attributes such as insulating value (thermal conductance or ER value) and their resistance to solar heat gain, water penetration and wind and air leakage.
- Windows near the ground must provide resistance to forced entry.
- Consider the location, type and mode of operation, and the size of the rough openings required for framing. Some types of windows are easier to open for children and people with disabilities.
- Carefully design how windows will be flashed and drained to prevent water from entering the interior space and the adjacent wall assemblies, and how they will be connected to the air barrier system.
- Windows are much less thermally efficient than insulated walls. Consider the area, arrangement and placement of windows carefully to balance views, ventilation and appearance with thermal efficiency.

Doors

- Exterior doors must meet most of the same performance requirements as windows for heat, air and moisture control. Doors should be located under overhang protection (roof eaves, recessed under floors above, or canopies), whenever possible.
- Choose doors that are insulated to reduce heat loss and that have durable seals and weatherstripping.
- Manufactured exterior doors, frames, locks, latches and hinges meet a standard for resistance to forced entry. Any site-built exterior doors must also resist forced entry.
- Consider installing wide or double doors if you have exceptionally large appliances or furniture (such as a piano), or to make a house accessible to wheelchairs.
- Doors for wheelchair access should have special thresholds of 12 mm (½ in.) or less in height.

Stairs

Stairs provide access for people, furniture and appliances; and must be wide enough and have sufficient headroom to provide safe passage. Falls on stairs are a major source of accidents, and risk is reduced by strict adherence to code requirements for the width, rise and run of stairs. See Chapter 17 for more information.

- Open stairs must be surrounded by guards and railings that meet code requirements for height and lateral load resistance. Guards must be high enough to keep adults from falling over them and balusters must be closely spaced to prevent children from falling through them.

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- Straight stairs make it easier to move large objects, and can be fitted with lifts when persons with disabilities need access to another floor level.
- Stairs can be built on site in rough form for use during construction, then finished when the house is nearing completion. Alternatively, a temporary stair or ladder can be used during construction and replaced with a finished stair when the house is complete. In the latter case, the stair design must account for the thickness of the floor finishes and the stair opening must provide extra room in which to manoeuvre the finished stair.

Moisture, Air Leakage, Vapour Diffusion and Heat Transfer Control

In modern wood-frame houses, continuous insulation is needed to provide energy efficiency and comfort. A continuous air barrier system will restrict air movement into and out of a house, help provide thermal comfort, reduce heat loss and avoid moisture condensation in the walls and ceilings that can cause damage. A vapour barrier prevents water vapour from migrating into the framing and insulation. A sheathing membrane is installed over the exterior sheathing to prevent inward migration of water that penetrates beyond the cladding. The membrane should also allow vapour that has migrated from the conditioned space to dissipate to the exterior. The functions performed by various materials in the building envelope are described in the following sections. See Chapter 5 for more information on this topic.

Water Penetration Control

- Cladding (wood siding, brick, vinyl siding, stone, stucco, etc.) forms a first plane of protection and is detailed to limit the amount of water that gets past it.
- The sheathing membrane is a second plane of protection that prevents water from entering the building envelope and allows water vapour to drain and diffuse out of a wall assembly.
- Several materials can be used as sheathing membrane including asphalt-impregnated paper (tar paper), spun-bonded polyolefin (housewrap) and self-adhering or liquid waterproof membranes.
- A rainscreen (a drained and vented air space acting as a capillary break between the cladding and sheathing membrane) is required in wet climates, to allow water that gets past the cladding to drain to the exterior and to allow the space to dry. A rainscreen design is recommended for all walls that will frequently be wet.

Air Leakage Control

- The air barrier system must be continuous around the entire surface that separates the conditioned (heated or cooled) environment from the unconditioned (outdoor) environment. Therefore, the components that make up this “environmental separator” (such as walls, windows, doors and membranes) must be sealed to each other to make the air barrier system airtight. Consideration must be given to how the connections are made, for example, around rim joists between floors during the design. The air barrier system must be capable of resisting wind loads.
- For house construction in Canada, the primary material used in the air barrier system is most often 0.15 mm (6 mil) polyethylene installed on the interior (warm side) of the insulation with all joints and penetrations taped or sealed. In this case, the polyethylene also serves as the vapour barrier. It resists wind loads by being supported by the insulation and the drywall.

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Vapour Diffusion Control

The vapour barrier should be relatively continuous but can be interrupted by penetrations such as floor joists. It does not need to be sealed unless it is also part of the air barrier system.

Heat Flow Control

- All assemblies that separate the conditioned environment from the unconditioned environment, including attached garages, must be insulated. This includes roofs, walls, foundations, windows and doors.
- The 2012 Interim Changes to the 2010 NBC regulate the "effective" insulation value for each assembly or component of the building envelope for six different Canadian climate zones. More than one type of insulation may be used to provide the effective insulation value. For example, batt insulation may be used between wall studs in combination with rigid insulation installed on the exterior.
- The effective insulation value is the combined insulation value of the studs, sheathing, drywall and the insulation itself. Framing members, ducts and pipes reduce the space available for insulation materials and reduce the insulating value of the assemblies; therefore, the effective value is usually lower than the "nominal" value (the value of the insulation itself).
- Different types of insulation are needed for different parts of the building. For example, only water-resistant insulation can be used on the exterior of the foundation below grade.

Plumbing, Electrical, Heating and Ventilation

Determine the type of domestic hot water heating systems to be used early in the design process, considering system efficiencies, local practice and the availability and cost of fuel and energy. High-efficiency appliances have replaced the mid-efficiency equipment used previously and are now required by the building code. Plan plumbing and ductwork in conjunction with floor framing to avoid conflicts. Avoid penetrating the air barrier system with plumbing, electrical or other components. When fixtures such as dryer vents, water pipes or electrical conduit must penetrate the air barrier system, take special care to seal around the penetrations. See Chapters 19 and 20 for more information.

Plumbing

- Plan for all pipes, conduits and drains that must be installed in the basement floor.
- For radon control, install an inverted 'T' shaped PVC pipe in a convenient location below the basement floor slab, with the vertical leg extending up through the slab and capped. A fan and exhaust duct can be attached at a later date to depressurize the gravel below the slab if radon gas is detected.
- If a sump pump is required, a sump pit must be incorporated into the basement floor. Locate the pit so that it can be sealed from the conditioned space to prevent soil gas and radon from entering the house.
- Consider how to finish the basement in the future and install roughed-in drains below the floor slab for a future toilet, shower, bathtub and/or sink. Install roughed-in piping in the wall or ceiling to the nearest vent.

Electrical

- Locate the electrical meter where it can be easily serviced by the electric utility provider and not detract from the appearance of the house. Consider burying a conduit from the hydro service to the meter to avoid having overhead wires. The electric service panel should be installed inside the house near the meter.

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- Choose the size of the electrical service so that it has sufficient capacity for future electrical needs, such as air conditioners, exterior lighting and electrical appliances.
- Consider burying a conduit from the electrical panel to special landscape features or structures where you might need power or lighting.
- Consider installing cable and telephone wiring to the unfinished basement should you opt to finish the basement in future.
- Consider providing electrical rough-ins for future solar thermal and photovoltaic panels.

Heating and Ventilation

- Plan where heating and ventilation ductwork will be located and how it might affect floor joists and wall insulation values.
- Use low-noise source exhaust fans.
- Consider the use of heat recovery ventilation as an energy efficient means of providing required ventilation.
- Consider installing additional heating ducts close to the floor in parts of an unfinished basement that might be finished in future.
- Consider installing an exhaust duct to an exterior wall cap for a future basement bathroom.

Interior Wall and Ceiling Finishes

Gypsum board (drywall) is the most common interior finish in Canadian houses. In addition to providing a smooth, paintable surface, gypsum board provides a degree of fire resistance to lightweight structural framing, allowing walls and floors to remain in place to provide some time for occupants to become aware of a fire and exit the building. Interior partitions also play a role in reducing sound transmission. Gypsum board also provides a degree of lateral resistance to wall assemblies. Painted gypsum board tightly fitted and sealed to other air barrier materials can also be part of the air barrier system. For more information, consult Chapters 21 and 23.

Floor Coverings

Floors are subject to wear and tear. Higher-quality finish flooring can often be cost effective because it will likely last longer than less expensive flooring. The sub-flooring must be adequate to support the finished flooring, especially ceramic tile. Planning the type of finished flooring to be used can minimize elevation differences (tripping hazards) between different flooring materials. See Chapter 22 for more information. Consider polished concrete as a finished floor, especially in areas where concrete can capture and radiate solar heat.

Decks, Porches and Balconies

Decks, porches and balconies are considered structures in the building code and when over 600 mm (24 in.) above ground, must be supported by frost-resistant foundations, be laterally braced, be designed to accommodate the weight of people and snow, and have stairs and railings that meet code requirements. If planning to build a deck, porch or balcony in the future, provide for later attachment to the house in a way that does not allow water to enter the wall cavity to which the structure is attached. Any roof over a deck must be designed to support the snow load. See Chapter 26 for more information.

Garages

Attached garages are popular and common in Canadian houses. Because of the risk of carbon monoxide getting into the house and the likely storage of paints, gasoline and other chemicals in the garage, it must be separated from the house by an effective air barrier system. If there is a connecting door, it must be tightly fitted

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and weatherstripped and provided with a closure. Ensure that the ventilation system for the house is isolated from the garage to prevent fumes from entering the living space. Even heated garages are considered by the building code to be unconditioned spaces (when the garage door is open) and therefore any wall or ceiling that separates the garage from living space must be insulated. See Chapter 27 for more information.

STAGES OF CONSTRUCTION

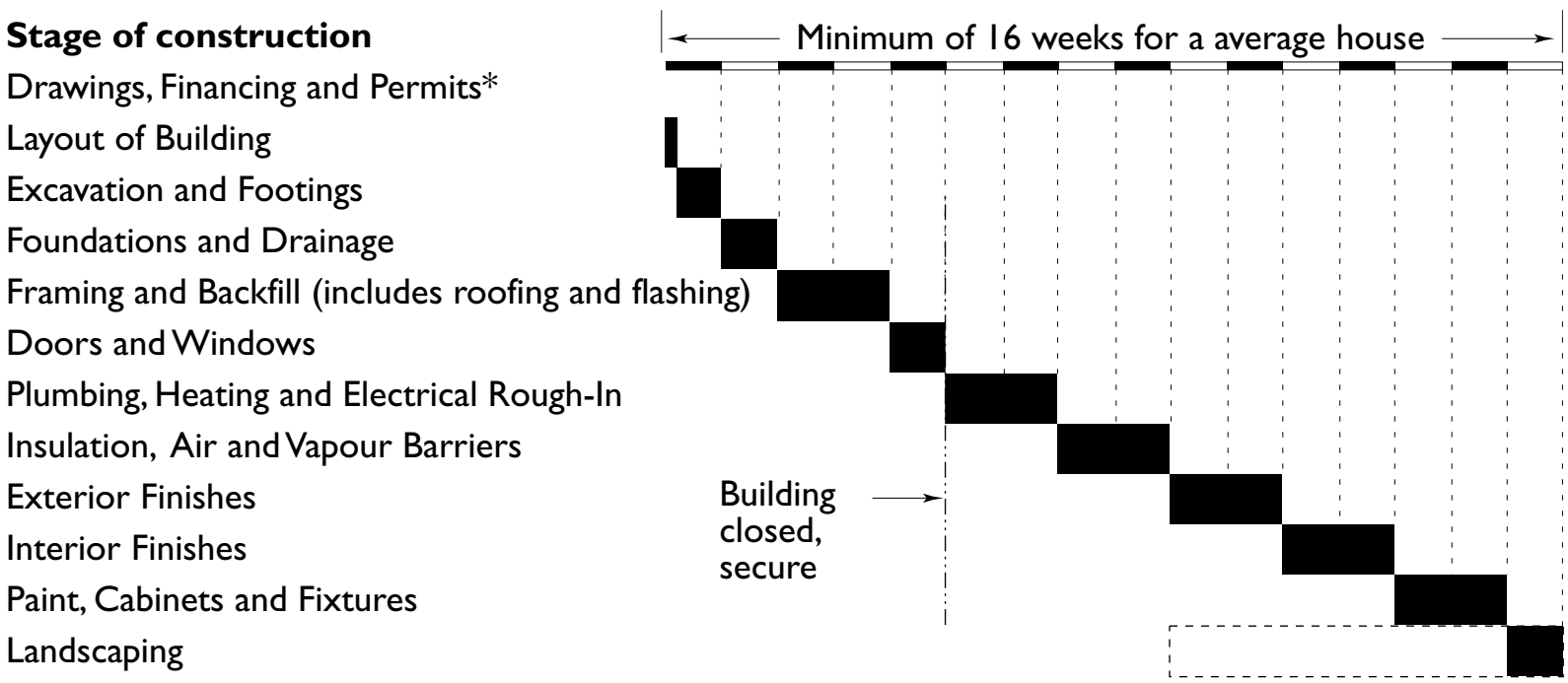
Due to the wide variety of house styles and sizes, house construction may differ, but certain basic principles apply. The description of the house construction process in this book is based on common wood-frame house construction techniques for a typical one-, two- or three-storey house. Special features such as sunrooms or swimming pools are not included in this description.

Canadian wood-frame house construction continues to evolve. The time required for construction has decreased due in large part to the introduction of panel products such as plywood, oriented strand board (OSB) and gypsum board; factory-built components, such as roof trusses, wood I-joists, windows and cabinets; and improved power tools.

Construction time depends on many factors, especially the size and complexity of the house. For average-sized houses, about 16 weeks are required from start to finish. For more complex houses, 18 or more weeks may be needed. This does not account for delays due to inclement weather, inspections, material shortages, custom-ordered items or the scarcity of tradespersons during busy construction periods. Prior to construction, delays may be incurred while obtaining financing and a building permit. While late spring, summer and early fall are the best times for construction in Canada, year-round activity is possible if precautions are taken to protect materials.

There are a number of stages in constructing a house that must be properly planned, coordinated and executed (Figure 4).

4 Sample single house construction schedule



* Drawings, financing and permits as well as any other aspects of the pre-construction stage will have a variable duration depending on site and house characteristics.

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Building Layout

The first construction step is to position the building on the property. The services of a land surveyor may be required to establish the distances from the foundation to property lines, locate the municipal services and establish the layout and the depth of the excavation.

Excavation and Footings

Excavation for the foundations may proceed once the building layout has been completed. This can often be completed in one day depending on the type of equipment used and site conditions. Another few days are needed to trench for and install services, form and place footings, remove footing formwork and lay out the foundation walls and columns. Placement of the granular layer and basement floor slab usually occurs later when the basement plumbing rough-in is completed. Storing topsoil and good quality excavated material suitable for backfilling can reduce the amount of imported fill and topsoil for landscaping.

Foundations, Drainage and Backfill

Foundations can be placed in one day by a skilled contractor and require at least one week for concrete to cure before formwork can be removed. Dampproofing, foundation drainage systems and backfill requires another day or two. Additional measures for foundation drainage such as waterproofing, sump pumps, ditching or dry wells may be required. Backfilling should not begin before the first floor framing has been anchored to the foundation and the first floor sub-floor has been installed because the floor framing helps to resist the soil pressure. Contact your building official to inspect the footings and foundation and municipal service connections.

Framing

About two weeks is needed to complete the framing and install roofing to provide weather protection during subsequent stages of construction. Built-in bathtubs and shower enclosures are usually installed at this time. Framing dimensions must be appropriate for these components. Once installed, they should be protected from damage until the house is finished. Chimney installation and the building of stairs or the installation of pre-manufactured stairs is usually considered part of the framing stage. Deck framing is usually performed while the landscaping is being done.

Doors and Windows

Installing doors and windows requires a few days to complete and includes the installation of sub-sill membrane, flashing, locks and other hardware. Jamb extensions are usually part of the finishing carpentry work, and exterior trim is usually installed by the trade installing the exterior finishes. The air sealing of gaps around window and door openings is usually performed as part of the insulation, vapour barrier and air barrier system work. Contact your building official to inspect the completed house framing, including windows, doors and skylights.

Plumbing, Heating, Electrical and Ventilation Rough-in

The water-heating piping is installed. Plumbing is installed to connect from the water service to the water heater and fixtures. The electrical panel is installed. Electrical wiring, smoke and carbon monoxide alarms, telephone and computer lines, and cable TV are roughed in. The furnace ductwork or piping are installed, along with ductwork for exhaust fans and mechanical ventilation equipment such as heat recovery ventilators (HRVs). This work takes about two

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weeks to complete. Contact your building official to inspect completed plumbing, electrical and mechanical systems.

Insulation, Air Barrier System and Vapour Barrier

Insulation, vapour barriers and air barrier systems may be installed at the same time as exterior finishes, provided the insulated assembly is protected against moisture damage such as that caused by wind-driven rain. This stage requires a few days to complete and requires careful fitting and sealing around mechanical penetrations, fixtures and electrical boxes. Contact your building official to inspect the completed insulation, vapour barrier and air barrier system.

Exterior Finishes

One to two weeks are needed to complete this stage. If an exterior air barrier material such as a sheathing membrane is being used, it is usually applied at the same time as the exterior finishes (however, it may also have been installed during the framing stage). Masonry, siding and stucco, soffit, fascia, eavestroughing, downspouts and the caulking and flashing of windows and doors are all part of the exterior finishes stage. Exterior trim and millwork, staining and painting may also be included during this stage.

Interior Finishes

This stage includes the installation of ceiling, wall and floor finishes, shelving and cabinets. Finishing carpentry for interior doors, frames and trim along with stair balusters and handrails is usually done immediately after the floor, wall and ceiling finishes have been prepared for painting and varnishing. The interior finishing stage normally requires about two weeks to complete.

Paint, Cabinets and Fixtures

Painting is performed at the beginning of this stage followed by the installation of items such as ceramic tile backsplashes. Next up for installation are electrical receptacles, light fixtures and smoke alarms and equipment such as furnaces, water heaters, mechanical ventilation systems, stoves and clothes dryers. The heating contractor will install all grilles and registers for forced-air systems and radiators for hydronic or electric baseboard systems. Ensure that all installations have been inspected and function properly and that operating instructions and warranties are provided. A final clean-up of the dwelling concludes the work. About two weeks are normally required to complete this stage of construction.

Landscaping

This final stage includes finished grading, driveways, steps, walkways, ground cover, shrubs and trees. Carpentry work associated with decks and fences, and plumbing work for items such as irrigation systems may also be done at this time. Approximately one week is needed for this final stage; however, the time will vary depending on the nature of the landscaping. Additional time is required for special features such as decks and pools. If a house is completed in the fall or winter, landscaping will be delayed until warm weather arrives.

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SUSTAINABLE HOUSING INSIGHT

- The house can be seen as a system in which the building, the environment and the occupants interact. All the components, systems, materials and assemblies of a house need to balance one another and work together to provide affordable shelter, health and safety for the occupants, consume as little energy as possible and have minimal impact on the environment.
- Sustainable houses incorporate materials that (a) do not adversely affect occupant health; (b) are highly insulated and airtight to reduce energy use; (c) are planned to use materials and space efficiently and can adapt to occupants' changing needs; (d) are adapted to the local climate and cause minimal damage to the environment; and (e) are designed to minimize capital and operating costs.
- Building with wet materials can lead to future moisture problems, mold and related indoor air quality problems.
- Construction is a necessary human endeavour and one that consumes large amounts of energy and resources. All stages of construction affect, to varying degrees, the five principles of sustainable housing: healthy indoor environment, energy efficiency, resource efficiency, environmental responsibility and affordability.
- Sustainable houses are designed to last for generations, and when they are no longer useful, they can be easily dismantled and recycled for other uses.
- Energy is required to extract raw materials for the production of construction products and to manufacture, transport and install them (their embodied energy). Careful storage and protection of materials reduces waste and therefore helps to reduce the effects of construction on the environment.
- Sustainable houses should provide only as much living volume as is needed.

RELATED PUBLICATIONS

About Your House: Canada's Housing Construction System,
Canada Mortgage and Housing Corporation (product no. 62966)

About Your House: Photovoltaics (PV) Systems,
Canada Mortgage and Housing Corporation (product no. 63890)

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CHAPTER 3
Concrete



Concrete, both non-reinforced and reinforced, is often used for footings, foundation walls, basement floor slabs and garage slabs-on-grade. Concrete for columns, fireplaces, chimneys and foundation walls must have a minimum strength of 15 MPa (2,200 psi). Basement floors must have a minimum strength of 20 MPa (3,000 psi). Garage and carport floors, exterior steps and driveways must have a minimum strength of 32 MPa (4,600 psi), and air-entrained concrete must be used for exterior applications.

Air entrainment is required to reduce degradation caused by de-icing salts and exposure to freezing temperatures. The tiny air bubbles also make concrete more workable and easier to place than plain concrete. Air entrainment for exterior applications must be between 5 and 8 per cent. In areas where soils are sulphate reactive, cement types 20, 40, 50 or equivalent must be used to protect the concrete.

Aggregates used in the manufacturing of concrete should not contain sulphides such as pyrite, pyrrhotite and marcasite as these compounds may oxidize and hydrate, leading to volume increases within the concrete material causing the concrete to crack and spall, or the release of sulphate which produces sulphate attack upon the cement paste.

Whether concrete is delivered from a plant or mixed on site, additional water should not be added at the construction site to make concrete easier to place. Additional water will lower strength, increase permeability and decrease freeze-thaw resistance. If more workability is required, the concrete supplier should be asked to adjust the mix, possibly by adding a plasticizer or other concrete admixture to improve workability and placement, while conforming to the appropriate concrete standards.

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For site-batched concrete and concrete for garage floors, a slump test may be used to gauge the consistency and the workability of the concrete. Slump is determined by filling a standard cone-shaped form with concrete and measuring the amount of settlement or slump that the concrete exhibits when the cone is removed.

READY-MIX CONCRETE

Ready-mix concrete is available in most urban areas. Manufactured in plants to established mix designs, the quality of ready-mix concrete can be tailored to meet strength, durability, and workability requirements of a particular application. Workability is attained by the ready-mix provider meeting the water-cement ratios set out in *CSA Standard A23.1-09: Concrete materials and methods of concrete construction.*

ON-SITE MIXING

When mixing must be done on site, the water and aggregate should be clean and free of organic material or other substances that might damage the concrete. The aggregates should also be well-graded, in other words, with the correct proportion and size of fine and course aggregates.

The air-entraining admixtures must be added according to manufacturer's recommendations—adding too much will decrease concrete strength. Air-entraining admixtures should be used only in concrete mixed in a motorized mixer.

On-site mixing can use premixed bags of cement and aggregate. In such cases, follow the manufacturer's instructions to obtain the desired strength and durability. If site-mixed concrete is to be proportioned on site, determine the correct ratios of fine and coarse aggregates, cement and water to produce a mixture that will work readily into angles and corners without causing free water to collect on the surface.

The concrete mixes in Table 2 (Appendix A) are considered acceptable for site-mixed concrete if the water to cement ratio is: 0.70 for walls, columns, fireplaces, chimneys, footings, foundation walls, and grade beams and piers; 0.65 for floors other than those in garages and carports; and 0.45 for garage and carport floors and exterior steps. Aggregate used in these mixes must not be larger than one-fifth the distance between vertical forms or one-third the thickness of the flatwork.

PLACING CONCRETE

Place concrete into forms continuously in horizontal lifts not exceeding 1.2 m (4 ft.) in depth. Do not allow concrete to fall into the forms from a height of more than 2.4 m (8 ft.) as this causes the concrete to segregate. For higher drops, use a pipe to deposit the concrete. Buggies, wheelbarrows, chutes or pumping can be used to move the concrete to locations not accessible to ready-mix trucks. The chutes should be metal or metal-lined with round bottoms and sloped with a rise-to-run inclination between 1:2 and 1:3.

Do not deposit the concrete in a pile. Spread and level it by raking or shovelling. Use vibrators to consolidate the concrete but not to move it horizontally. Compact the concrete uniformly by means of tamping hand tools (puddling sticks) or, preferably, by a vibrator.

If it is necessary to interrupt concrete placement, the surface of the concrete placed in the forms should be levelled. If partial setting has started by the time concrete placement is ready to resume, roughen and dampen the surface to

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provide good bonding between lifts. For a surface that has set, spread a bonding agent comprised of grout (1 part cement to 2 parts sand) about 12 mm (½ in.) thick over the roughened surface between the two lifts. Place the new lift immediately after the grout has been applied.

When mixing and placing concrete (in all temperature conditions), maintain its temperature between 10°C (50°F) and 25°C (77°F). Do not place concrete against frozen soil and always remove any ice and snow from the formwork.

CURING CONCRETE

Newly placed concrete must be cured for a set period of time to allow the concrete to achieve its potential strength, water tightness and durability, and to minimize cracking. To cure, concrete must be kept damp and within a limited temperature range. Wall forms should be left in place for at least three days to retain moisture for proper curing, and longer if possible. After the forms have been removed, the curing should continue at least another day if the concrete temperature is kept above 21°C (70°F), and for another three days if the concrete temperature is kept between 10°C (50°F) and 21°C (70°F).

Maintain moist conditions by placing a soaker hose around the top of the wall and allowing water to run down the wall. When water curing is not practical, spray-on curing compounds that inhibit evaporation can be used. If a dampproofing compound is applied to the wall, curing can progress without the need for spraying.

In hot weather, concrete should be protected from rapid drying. Wood forms should be sprinkled with water while they are in place to deter concrete drying.

In freezing weather, freshly placed concrete footings should be protected with a thick layer of straw or other insulating material. For walls, it may be necessary to insulate the forms or to erect an enclosure and use space heating appliances.

Cure concrete slab-on-grade by spraying with water, covering with burlap kept continuously moist, polyethylene sheeting or other means to prevent moisture loss.

Allowing concrete to cure properly is an important step in the construction process. Attention to this step will help avoid costly problems.

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SUSTAINABLE HOUSING INSIGHT

Environmental Responsibility and Affordability

- Consider using concrete with high fly-ash content to improve workability and reduce the amount of cement and aggregate needed in the mix.
- The cement in concrete is made by cooking limestone at a very high temperature, which means it takes a lot of energy to manufacture. To reduce environmental impact and material costs:
  - Estimate concrete quantities carefully when ordering.
  - Ensure formwork is adequate to retain the concrete after placement to avoid swelled or failed forms that may result in wastage.
  - Use concrete with the required strength for the application and allow it to cure so that it develops its full potential strength and can have a long, satisfactory service life.
  - For sloped sites, use a stepped foundation to reduce the quantity of wall and footing concrete.
  - Consider using fabric-type forms for footings to reduce formwork and protect footings from rising damp.

RELATED PUBLICATIONS

CSA Standard A23.1-09/A23.2-09: Concrete materials and methods of concrete construction/Test methods and standard practices for concrete,
Canadian Standards Association

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CHAPTER 4
Lumber and Other Wood Products



Many types of wood components can be used in wood-frame construction. The framing forms the structural shell that encloses and divides spaces, to which finishes are applied.

Lumber is commonly referred to by its nominal dimensions (size before planing and drying), which are larger than its actual, finished dimensions. For example nominal 2 by 4 in. lumber is actually about 1½ by 3½ in. Timber is lumber 114 mm or more (5 in. nominal) thick in its smaller dimension. Table 7 (Appendix A) shows the grades, common grade mixes, principal uses and grade categories for the various sizes of dimension lumber. There are also decking, board and finish lumber groupings.

Metric sizes of softwood lumber are expressed in millimetres of actual thickness and width after surfacing. The concept of "nominal size" is not used with metric dimensions; therefore, metric lumber dimensions are actual sizes. Table 8 (Appendix A) relates the current metric dimensions to the imperial equivalents (actual and nominal).

GRADE MARKS

Lumber used for construction in Canada is grade-stamped to show that it conforms to the National Lumber Grades Authority (NLGA) grading rules for Canadian lumber. The grading and grade marking of lumber must also conform to *CSA Standard O141-05 (R2009): Softwood Lumber*. A grade stamp indicates the grading agency, the species or species combination designation, the grade, the moisture content at the time of manufacture and the mill number. Facsimiles of Canadian grade marks are shown in Table 9 (Appendix A).

"S-GRN" in the grade mark signifies that the lumber was surfaced at a moisture content higher than 19 per cent to a size that would allow for natural shrinkage during seasoning. "S-DRY" in the mark indicates the lumber was surfaced at a moisture content not exceeding 19 per cent. KD (kiln-dried) indicates that lumber has been dried in a kiln to a moisture content of 19 per cent or less. The moisture content of framing lumber at the time of

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installation is not to exceed 19 per cent. This means S-GRN lumber must dry before installation. The best way to limit moisture in new construction is to use S-DRY lumber.

LUMBER GRADES

Each piece of construction lumber is examined and assigned a grade depending on its physical characteristics such as the size and location of knots and the slope of the grain. The assigned grade is an estimate of its strength.

Softwood lumber species having similar strength properties may be combined into a single-species combination and marketed under a group designation. The most common group is spruce-pine-fir (SPF). The Canadian commercial species combinations and their characteristics are shown in Table 10 (Appendix A).

Select Structural grade is used where high-strength, stiffness and good appearance are required. No. 1 grade may contain some percentage of Select Structural material, but permitted knots are slightly larger. Tests have shown that No. 1 and No. 2 grades of lumber have the same strength and therefore, No. 2 and better is a typical grade category for most general construction uses.

There are two types of machine-graded lumber: machine-stress-rated (MSR) lumber; and machine-evaluated lumber (MEL). Both MSR and MEL are produced using non-destructive stiffness measuring machines.

The grade stamp on MSR and MEL indicates strength properties. MSR and MEL are most often used in applications where strength is crucial, such as for manufacturing wood trusses.

Stud grade is 38 to 89 mm (2 to 4 in. nominal) thick and 38 to 140 mm (2 to 6 in. nominal) deep lumber used for wall studs.

Finger-jointed structural lumber manufactured to the requirements of NLGA SPS 1 is interchangeable with non-finger-jointed lumber of the same species, grade and length, and can be used for joists, rafters and other applications. Finger-jointed stud lumber manufactured to the requirements of NLGA SPS 3 can only be used as vertical, end-loaded members in compression (such as wall studs).

Construction and Standard grades are used for structural purposes. Construction grade lumber has strength properties similar to No. 3 grade, and Standard grade is lower. Utility and Economy grades are not used for structural purposes.

The National Building Code lists the minimum grades for various uses of lumber in wood-frame construction. Tables giving maximum allowable spans for visually graded lumber and for MSR lumber, when used as joists and rafters, are available from the Canadian Wood Council.

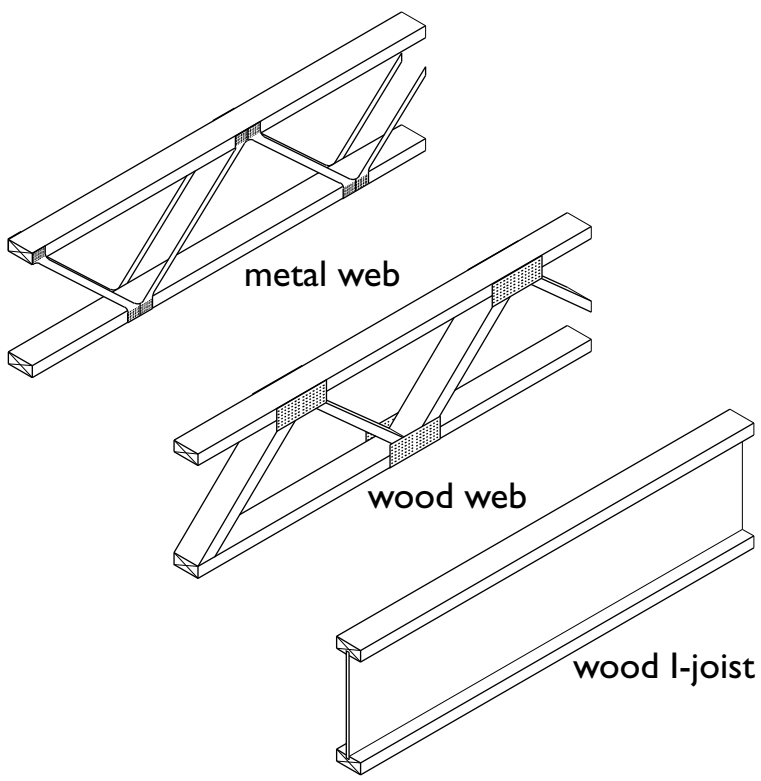
ENGINEERED WOOD PRODUCTS

Several types of engineered wood products (EWPs) are routinely used in wood-frame house construction. These products can provide equivalent or superior strength compared with dimension lumber and are typically manufactured using less wood fibre and available in long lengths. They include: wood I-joists, glulam, plywood, oriented strand board (OSB), laminated veneer lumber (LVL) and others. Dimension lumber and other wood products are often combined in the manufacture of EWPs

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using glue or mechanical fasteners (for example, prefabricated trusses). See Figure 5. Wood I-joists consist of lumber or LVL flanges and OSB webs.

5 Examples of engineered wood products



All these products provide design flexibility by virtue of their longer span capabilities and higher strength compared to dimension lumber.

Structural composite lumber (SCL) includes laminated veneer lumber (LVL), parallel-strand lumber (PSL), laminated strand lumber (LSL) and oriented strand lumber (OSL).

Laminated veneer lumber consists of thin veneer panels laid parallel to the longitudinal direction, coated with a waterproof adhesive, and bonded by heat and pressure. Available in a wide variety of sizes and strengths, LVL may be cut into desired lengths for use as beams, columns, headers (lintels), joists and as flanges for wood I-joists.

Parallel-strand lumber is manufactured using thin veneer panels cut into narrow strips and then bonded together using a process similar to LVL. Members are available in a variety of widths, depths and lengths, and are primarily used as beams, columns and headers.

Laminated strand lumber and **oriented strand lumber** are manufactured using wood strands combined with an adhesive and are oriented and formed into a large mat and pressed. LSL and OSL are commonly used as beams, headers and studs.

SHEET OR PANEL PRODUCTS

Panel products such as plywood and oriented strand board (OSB) are used in wood-frame construction to add rigidity to roof, wall and floor framing, and to provide a uniform surface for the application of roofing, cladding and floor finish materials.

Plywood is made of thin layers or plies of wood glued together with the grain direction of adjacent plies perpendicular to each other. Common thicknesses range from 6.0 to 18.5 mm (¼ to ¾ in.). Like dimension lumber, plywood is graded for particular uses. Douglas fir plywood (DFP) and Canadian softwood plywood (CSP) are the most common types of sheathing plywood. All sheathing-grade plywood is made with exterior-grade glue. Overlaid plywood is plywood that is sealed with paper and resin and used for concrete formwork.

Oriented strand board (OSB) is a structural panel made from wood strands mechanically oriented in layers, with the outer layers running parallel to the long dimension of the sheet, and the inner layers having a random alignment. OSB is made with exterior-grade glue and is structurally equivalent to plywood. It is primarily used for roof or wall sheathing, sub-flooring, siding and the webs of wood I-joists.

Waferboard is made of wood wafers that, unlike OSB, are not oriented. It has been replaced by OSB and its availability in Canada is very limited.

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Fibreboard is made of wood fibres bonded together under pressure. It is available both plain and asphalt-impregnated, which is used primarily for wall sheathing. Medium-density fibreboard is often used for interior mouldings, trims and casings.

Particleboard is composed of fine wood particles held together with phenolic glue and pressed into panels usually 1.22 × 2.44 m (4 × 8 ft.) or 1.523 × 1.523 m (5 × 5 ft.) in size. It is generally used as floor underlay or interior finishing such as shelving and other cabinetry. It is also used as a substrate for plastic laminate counter tops.

Hardboard is made of wood fibre, like fibreboard, but is denser and harder. It is used for furniture and cabinetry products. Hardboard siding is prefinished and is an alternative to wood, vinyl or aluminum.

SUSTAINABLE HOUSING INSIGHT

Healthy Indoor Environment

- Glued wood products made for structural uses such as for floor joists or sheathing (plywood and OSB) must be made from water-resistant adhesives so that wetting during storage and construction will not weaken them. Such adhesives have very low volatile organic compound (VOC) emission rates.
- Glued wood products made for interior uses such as particleboard and other wood products often used for furniture and cabinetry use more economical glues that have higher emission rates. Sealing the faces and edges of a panel with a laminate drastically reduces emissions. Low-emission boards are available.

Energy Efficiency

- Though a fairly good insulator, wood is not as effective as non-structural materials made specifically for thermal insulation. The wood structural members have a lower insulating value than the surrounding insulation. These "thermal bridges" conduct heat towards the cold and reduce the overall insulating value of a wall, roof or floor assembly. NBC insulation requirements are based on effective RSI-values, which take into account the lower insulation value of studs and other thermal bridges.
- Wood framing provides space for insulation, which can result in highly insulated structural components that take up very little space. Where higher insulation levels are required, consider using wood-framing materials such as "I" joists that allow more space for insulation, yet use minimal amounts of dimensional wood.

Resource Efficiency

- The use of engineered wood products such as wood I-joists is common because of their span and performance capabilities and their efficient use of wood fibre. Finger-jointed lumber makes use of short lengths of lumber.
- Advanced framing, or optimum value engineering, uses design restrictions to reduce the amount of wood framing in a building. This can lead to a 15–20 per cent reduction in the quantity of wood used.

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Continued

Environmental Responsibility

- Attention is needed to reduce wood waste. Order carefully, use off-cuts, and choose framing spacings that minimize usage.

Affordability

- Part of the cost of wood products is the energy used to dry and transport them to the site. Careful planning, proper storage and handling, and good construction practices will minimize waste and cost.

RELATED PUBLICATIONS

Wood Products,
Canadian Wood Council (web content available at www.cwc.ca)

CSA Standard O141-05 (R2009): Softwood Lumber,
Canadian Standards Association

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CHAPTER 5
Functions of the Building Envelope: Water, Air, Vapour and Heat Control



This chapter contains information about important functions that impact all parts of the building envelope and influence the design of construction elements covered in Chapters 7 to 15. They are introduced early in this book to help ensure the design of the building envelope is considered from the outset and at each stage of house design.

The building envelope is the outer "skin" of the building that acts as a barrier or separator between the exterior and interior environments of a building. It is comprised of the foundation walls and basement floor, the above-grade exterior walls, attic, ceiling and roof, as well as openings including windows, doors, skylights and mechanical and electrical penetrations.

Every building envelope is a *system* and many inter-related issues affect its performance and durability. The designer and the builder must carefully consider the interaction between the interior and exterior environments as well as the materials and components that comprise the building envelope to provide a durable, long-lasting building.

Important: The building envelope performs several functions (such as structural support, fire protection and noise control), which are discussed in later chapters. This chapter focuses on the building envelope's functions as an environmental separator: the control of water, air, vapour and heat, because these physical processes have a crucial effect on building performance:

- they affect comfort, durability and cost of operation;
- they require careful planning and construction; and
- if inadequately controlled, they can lead to problems that are difficult or expensive to correct.

The durability of the building envelope of wood-frame structures is directly affected by four inter-related physical processes of moisture, air, vapour and heat moving through the various

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assemblies. These processes act on the building envelope in different ways and with different intensities. The assemblies and materials that comprise the building envelope are selected and arranged to effectively control these four processes:

- **Water penetration control** prevents water from entering the interior space or building envelope assemblies and causing premature deterioration of materials. This is the most important function because water potentially causes the most rapid and destructive deterioration of the building envelope.
- **Air leakage control** through the materials, interfaces and joints of the building envelope provides occupant comfort, minimizes heating and cooling energy use; and limits the potential for condensation. Uncontrolled air leakage allows moisture to move through the building envelope, which can also result in severe deterioration of the building envelope assemblies.
- **Vapour diffusion control** through the materials that comprise the building envelope limits the potential for condensation. Water vapour diffusion through the building envelope is a very slow and uniform physical process. As a result, the accumulation of condensation-related moisture occurs slowly and is less likely to lead to damage.
- **Heat flow control** through the materials that comprise the building envelope provides occupant comfort, minimizes heating and cooling energy use; and limits the potential for condensation.

The designer must choose appropriate assemblies of materials and develop appropriate interface and penetration details to address all of these control functions. The following sections describe how design and construction of wood-frame houses can control water penetration, air leakage, vapour diffusion and heat loss.

WATER PENETRATION CONTROL

The building envelope for a wood-frame house controls exterior precipitation (usually water from rain, snow and ice melt) by deflecting moisture away from a wall, draining any moisture that penetrates into the building envelope back to the exterior, and allowing any accumulated moisture to dry over time. See Chapters 12 to 15 for specific construction details.

All walls are required to have a primary and a secondary line of defence against rain penetration. The first plane of protection is typically the cladding (for example, siding, masonry or stucco). It includes accessories such as trim or caps that are part of the cladding system. The second plane of protection ordinarily consists of a sheathing membrane or insulating sheathing, flashing, sealants and other materials, and is intended to:

- intercept any water that has penetrated the first plane; and
- drain those relatively small quantities of incidental water to the exterior.

Both the first and second planes of protection must provide adequate protection of the wall assembly where penetrations have been made for windows, doors, ventilation ducts, piping, wiring and electrical outlets; and at the interface with other wall assemblies. These penetrations and interfaces at openings are where most wall assemblies develop problems over their lifetime.

Deflection: components and features of the building envelope (such as overhangs) that limit the exposure of assemblies and details to water running along surfaces of the building envelope and divert it from the assembly (shingle lapping materials and drip edges and flashings).

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Drainage: surfaces (such as the back side of cladding, or the sheathing membrane) within assemblies that redirect any water that enters the envelope downwards and out to the exterior.

Drying: features that encourage vapour diffusion and air movement to transport water vapour, and evaporate moisture from surfaces. These features include vapour permeable materials (which allow water to diffuse to the surface of materials), and in some cases, vented or ventilated air cavities located on the interior side of the cladding.

The following sections describe the water penetration control aspects of some common building envelope assemblies: basement floors, below- or above-grade walls and roofs.

Basement Floors

Basement floors are usually constructed on dry sites or have sufficient drainage such that water penetration control is not a primary concern. Polyethylene sheet dampproofing is normally placed over granular material before the concrete slab is poured to reduce the amount of moisture entering the basement from below the slab. When bulk water penetration is a concern, a waterproof membrane is applied over a slab at least 75 mm (3 in.) thick, and a second slab at least 75 mm (3 in.) thick is poured over the membrane. The waterproof membrane must be connected to the wall membrane to form a complete seal.

Walls Below Grade

Dampproofing (usually a bituminous coating) acts as the primary barrier (the first plane of protection) against water penetration from the exterior side of the foundation wall. The concrete foundation wall can be considered a second plane of protection. The use of a drainage composite product can also provide improved drainage at the exterior surface of the wall. Neither of these planes of protection will address water penetration control at joints or cracks in the concrete. So if the site is wet with some probability of hydrostatic pressure occurring, additional measures must be taken to provide adequate water penetration control (such as using a waterproof membrane, and crack and control joint waterproofing details). See Chapter 7 for more information.

Walls Above Grade

Cladding such as wood siding, stucco or brick veneer provides a first plane of protection against precipitation ingress in above-grade wall assemblies. In geographic locations where the probability of wetting due to precipitation is high and the drying potential of the walls is low, a capillary break (an air space) must be provided between the first and second plane of protection in exterior walls. This configuration is commonly called a rainscreen. The need for a rainscreen is determined by the Moisture Index (MI) for a particular geographic location. MI values are provided for many locations in Canada as part of the climatic data tabulated in building codes.

The capillary break, or air space, allows precipitation that penetrates past the cladding to readily drain on the backside of the cladding, or alternately on the sheathing membrane, which provides a second plane of protection against precipitation ingress. The air space also allows materials to dry by means of evaporation and exchange of air.

Capillary breaks can be provided by:

- a 10 mm (7⁄16 in.) gap between the sheathing membrane and the cladding (usually furring strips are used) so that water droplets do not infiltrate between the cladding and the sheathing and can drain back to the exterior;
- a mesh material not less than 10 mm (7⁄16 in.) thick and at least 80 per cent open;
- common horizontal metal and vinyl siding, without contoured insulated backing, that is loosely fastened to the sheathing and is designed with a 10 mm (7⁄16 in.) space at the bottom of each horizontal strip; or

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- the air space in masonry cavity walls allowing moisture to drain to the exterior.

In order to be effective, a capillary break must be provided over the full height and width of a wall, except where openings (such as windows and doors), service penetrations (such as pipes, ducts and electrical outlets) or flashings are present. Where furring is used to provide the gap, it must not cover more than 20 per cent of the wall area. A screen should be installed at the bottom of the capillary break or air space at foundations, windows and doors to prevent insects from getting in. The top of the capillary break should not vent into the attic space as this can lead to condensation on surfaces in the attic. Although blocking at the top of the capillary break restricts ventilation, it does not impede drainage, which is the more important aspect of water penetration control for rainscreen construction.

In conventional wood-frame construction, sheathing membranes are applied over the OSB or plywood sheathing in horizontal strips, shingle-lapped at the joints and stapled. When rigid or semi-rigid insulation is applied over the exterior of wall sheathing, the sheathing membrane may be applied over the outside face of the insulation (when the outboard insulation type must be protected from wetting) and fastened through to the frame wall. Alternatively, the sheathing membrane may be applied over the wall sheathing and on the inside face of the insulation (when the outboard insulation type does not need to be protected from wetting). Some rigid insulation products such as extruded polystyrene are also relatively vapour impermeable. If used, care must be taken in the selection of cladding material and detailing to ensure that no significant amounts of water reach the interface between the extruded polystyrene insulation and the vapour permeable sheathing membrane. This risk may dictate the use of insulation products with high vapour permeability and low water retention, such as mineral fibre.

The sheathing membrane should be installed so that it intercepts any moisture that gets behind the cladding (the first plane of protection) and directs it outward over flashings, at openings, at changes in cladding materials and at the base of walls. The sheathing membrane must be permeable enough to permit water vapour to diffuse from a wall assembly to the exterior. One layer of sheathing membrane is generally used and may be applied horizontally or vertically with 100 mm (4 in.) or greater laps at the joints. A second layer may be required for added moisture protection.

Common breather-type sheathing membranes on walls are asphalt-saturated felt, building paper and spun-bonded polyolefin (housewrap). Vapour permeable liquid membranes and self-adhered sheet products are also used for sheathing membranes. Some sheathing membrane materials (such as spun-bonded polyolefin) can also be utilized as part of the air barrier system, where they are required to be structurally supported. Self-adhered vapour permeable sheet membranes are desirable in these situations because the adhesion helps to provide the necessary structural support.

Where wall sheathing is not used, two layers of sheathing membrane are needed unless large panel siding such as plywood is used. Apply both layers vertically with 100 mm (4 in.) or greater laps at the studs. Staple both layers to the framing members, the top layer with staples spaced 150 mm (6 in.) or less along the edges of the sheet to hold it securely in place. See Chapter 10 for more information.

Roofs

On pitched roofs with slopes where the rise and run are equal to or greater than 1:6, asphalt-saturated sheathing paper is applied over the roof sheathing to provide a secondary plane of protection to water that may penetrate beyond the primary plane of protection—the shingles, tiles or metal roofing.

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Pitched roofs with slopes less than 1:6 require a waterproof membrane, usually consisting of one or more layers of bituminous membrane with joints shingle-lapped and welded, self-adhering "peel-and-stick"membrane, reinforced liquid applied membranes, or an EPDM (ethylene propylene diene monomer) rubber membrane. The lower pitch of these roofs does not shed or drain water as readily as a steeper pitch, and therefore requires a more robust and completely waterproof membrane.

AIR LEAKAGE CONTROL

Water vapour can be driven through the building envelope by air movement (which can be controlled by an air barrier system) and vapour diffusion (which can be controlled by the use of low-vapour-permeable materials placed at appropriate locations relative to the insulating materials). This section describes how the air barrier in the building envelope controls air movement. Vapour diffusion is discussed in the "Vapour Diffusion Control".

Wood-frame houses should be constructed as airtight as possible. In addition to protecting the building envelope, airtightness promotes energy efficiency, eliminates thermal comfort issues related to drafts, allows for better control of natural and mechanical ventilation, reduces the transmission of outdoor noise and controls odours. Air leakage through the building envelope can also result in water vapour condensing on cold surfaces, and this moisture can lead to deterioration of materials within the building envelope if allowed to accumulate for sufficient time. Airtightness is cumulative—good workmanship in the construction of each element of the entire building envelope is essential to its proper performance.

Air leakage through the building envelope occurs as a result of differences in air pressure from inside to outside the building caused by the operation of fans or the action of wind. When the air pressure is greater inside than outside, air will flow outwards through any holes or cracks in the building envelope, carrying with it any water vapour it contains. This is called "exfiltration." The reverse, called "infiltration," is true when the air pressure outside is greater than inside, and air will flow in through holes and cracks.

Air Barrier System

The NBC stipulates that the building envelope must be designed and constructed with a continuous air barrier system comprised of air barrier assemblies to control air leakage into or out of the conditioned space. Air leakage control requires a continuous air barrier system carried through the basement floor and walls, above-grade exterior walls and ceilings adjacent to roofs. Air leakage control within building envelope assemblies can be accomplished by incorporating materials with low air permeability, which are fairly common in house construction. However, joints and penetrations must also be sealed to stop air leakage, and the air barrier must be supported to prevent deformation or tearing. Polyethylene sheets are commonly used as an air barrier in wood-frame construction and are relatively easy to secure, seal and support on wood framing.

In addition to polyethylene sheets, other materials such as spun-bonded polyolefin, gypsum board, sealants, gaskets, spray-applied foam, rigid insulation, concrete, plywood or OSB sheathing, metal and glass can be used as part of the air barrier. All joints, connections and penetrations must be sealed using tapes, gaskets, foams, sealants and membranes in order for the building envelope to be airtight.

Location of the Air Barrier System

Because air movement through holes and cracks in the building envelope plays a much greater role in transporting water vapour than vapour

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diffusion through materials (in the order of 30 times more), the air barrier system is more important than the vapour barrier in preventing moisture from moving through the building envelope.

The air barrier system can be located anywhere in the assembly. However, in Canadian wood-frame house construction, a combined air barrier and vapour barrier is often provided by 0.15 mm (6 mil) sheet polyethylene under the gypsum board wall and ceiling finish that is sealed at joints, penetrations and interruptions, such as windows and floor junctions. When combined in this manner, the air and vapour barrier must be located on the warm side of the insulation to minimize the possibility of condensation in a wall or roof cavity due to vapour diffusion.

There may be reason for separating the air barrier system from the vapour barrier. For example, it may be beneficial to locate an air barrier on the exterior side when insulation is added outside the wall framing.

However, when an air barrier membrane is placed outside the insulation (for example, housewrap), it must be permeable to vapour in order for the assembly to dry towards the exterior. This is explained in more detail in the "Vapour Diffusion Control" section.

Polyethylene is commonly used for the air barrier in roofs and attics. It is usually attached to the roof framing on the warm side of the attic insulation and to the wall air barrier. For the polyethylene to perform as an air barrier, it must be structurally supported. In typical house construction, this is accomplished by having the sealed polyethylene layer supported on one side by drywall and on the other by framing and insulation.

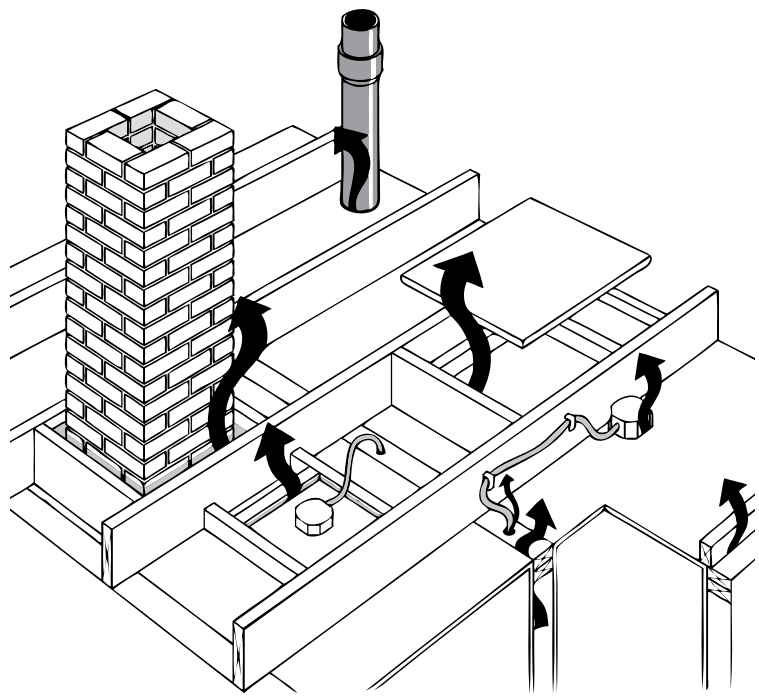
The concrete basement wall can form part of the air barrier system and should be sealed to the concrete floor and to the air barrier for the upper floors. If radon or soil gases are present, they can be controlled by sealing the concrete floor to the walls, and by sealing at drains, cracks and penetrations.

Air Barrier Details

Many places in the building envelope such as rim joists, tops and ends of partition walls, openings, services, vent stacks, chimneys, unusual framing details and electrical, plumbing and mechanical penetrations are prone to air leakage (Figure 6) and must be carefully sealed in a durable manner (that is for the life of the building). Durability is important because the air barrier is seldom accessible for maintenance or repairs once the building envelope construction has been completed.

6 Examples of air leakage locations

Typical air leakage paths into an attic through ceiling penetrations



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It is important to reiterate that the air barriers described for the following areas of a house must be connected and sealed in order to provide a continuous air barrier system.

Basement Floors

A concrete floor or polyethylene sheet can serve an air barrier. The floor air barrier must be sealed to the air barrier in the below-grade walls. This can be done by caulking the joint between the floor and basement walls.

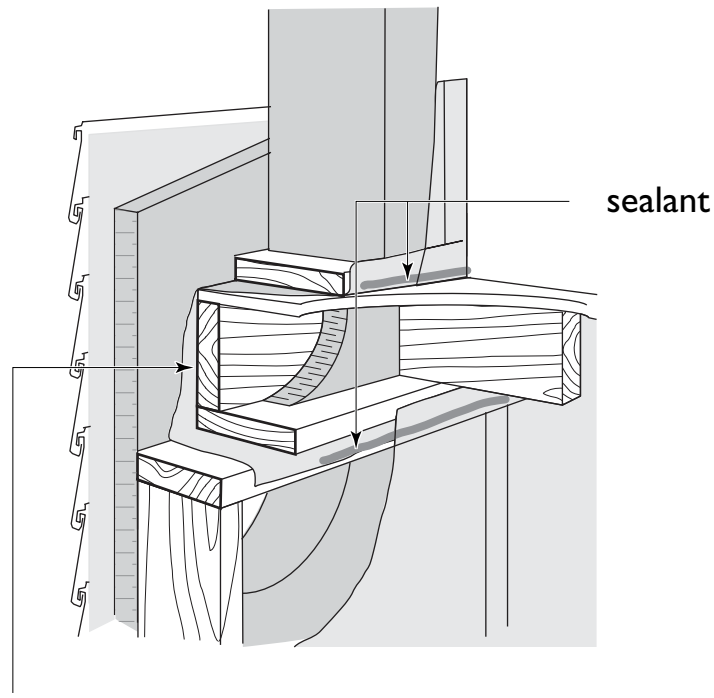
Walls Below Grade

Concrete walls or polyethylene sheet can serve as an air barrier. The below-grade wall air barrier must be sealed to those of both the basement floor and the walls above grade; and should be caulked or sealed to the air barrier at the floor framing (for example, by wrapping the joist header with spun-bonded polyolefin as described in the next section) to make the air barrier continuous. If the basement walls are insulated on the interior, it is important to restrict the movement of air to the face of the concrete foundation wall because it will be cold, significantly increasing the potential for condensation. This can best be accomplished by placing rigid insulation directly onto the concrete and sealing insulation board joints.

Walls Above Grade

When the air barrier is on the interior of the wall framing, it can be easily sealed to the polyethylene attached to the underside of the roof framing. However, it is difficult to install a polyethylene air barrier where the floor joists meet an exterior wall because the joists interrupt the continuity of the air barrier. It is good practice to wrap vapour-permeable (and air-impermeable) spun-bonded polyolefin (housewrap) from the inside of the lower wall, around the outside of the rim joist, to the inside of the wall above (Figure 7). The housewrap is then sealed to the polyethylene air barriers on the inside of the walls above and below. Because it is vapour-permeable, the housewrap will not impede vapour flow at the rim joist. Similarly, the junction between foundation walls and sill plates, the sill plate and joist headers and the rim joists and the subfloor material must be made airtight by installing sealants and gaskets between adjoining elements, or by wrapping the outside of the header with a sheet material capable of making the header airtight.

7 Carrying the air barrier around a rim joist at a floor intersection



If the plane of airtightness is located on the interior of the building envelope, the electrical wiring, outlets and switches and recessed light fixtures penetrating through the plane

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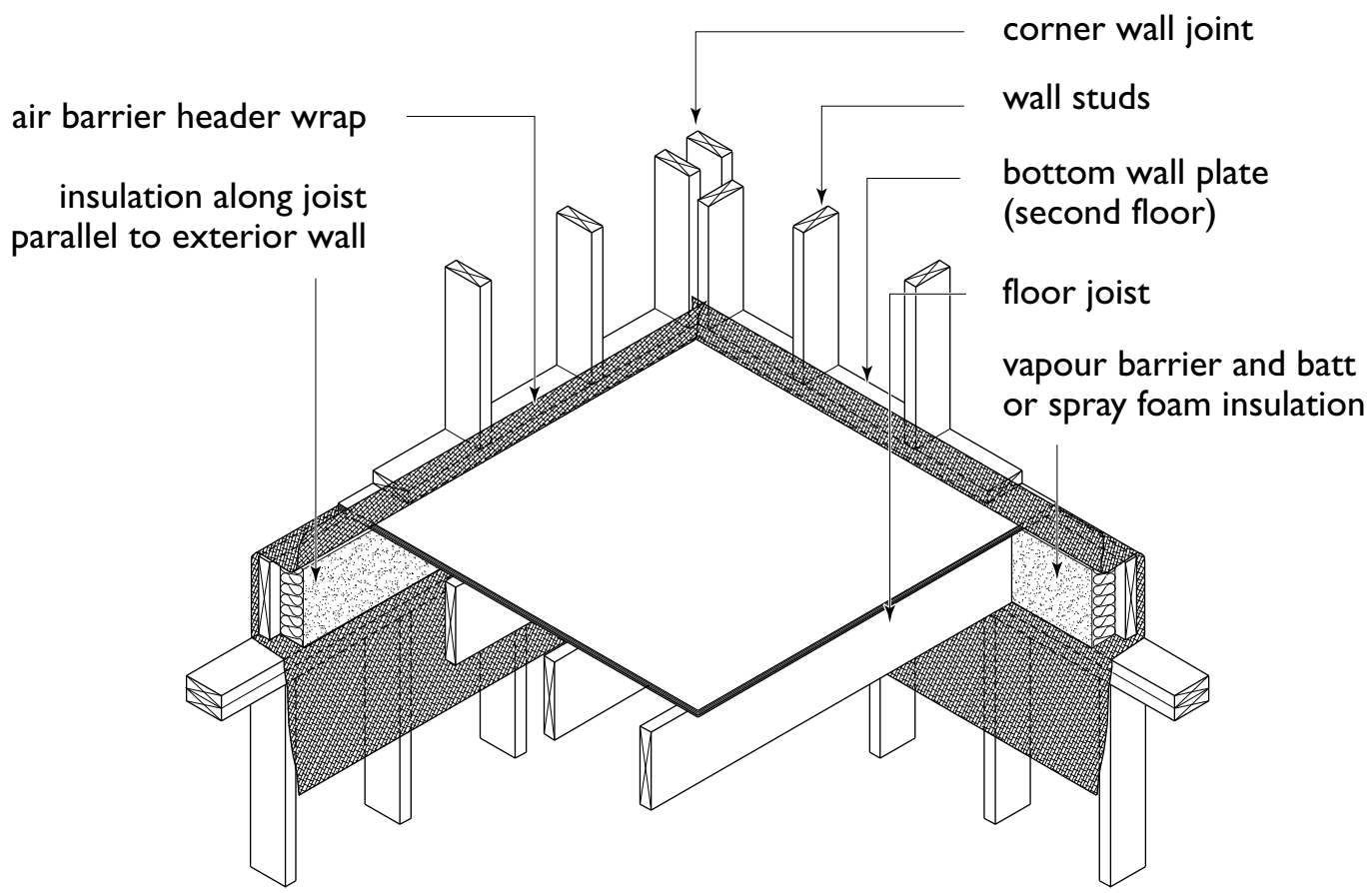
of airtightness must be constructed airtight. Airtight electrical boxes are recommended for fixtures, outlets and switches located in the building envelope. When polyethylene serves as an interior air barrier component, it should be lapped over and sealed to the electrical boxes. Alternatively, wrap electrical boxes with 0.15 mm (6 mil) polyethylene, then lap over the polyethylene on the wall and tape or caulk the polyethylene wrapper to it. The lap should be at least 100 mm (4 in.) and occur over a framing member. All wires should be caulked where they enter the box to prevent air leakage. It is preferable to avoid locating electrical outlets on exterior walls when possible.

A vapour barrier is required for insulation installed between the ends of floor joists in the rim joist space but does not need to be carefully sealed to the joists and floor sheathing unless it also forms part of the air barrier. It is more difficult to achieve an effective air barrier at this location because the materials must be cut and fitted between the joists (Figure 8). Sprayed closed-cell foam is commonly used in this location because it fills the space tightly and acts as both insulation and air barrier.

When also serving as an air barrier, the edges of the polyethylene covering the fitted insulation should be caulked to the framing, in order to seal the joints and prevent exfiltration. Rigid insulation is suitable in this location, and some semi-rigid or soft insulation materials that come with a reinforced aluminum backing can also be used effectively.

Make the interfaces between windows, doors and skylights and wall/ceiling assemblies airtight by sealing all junctions between the

8 Placement of air barrier over joist headers

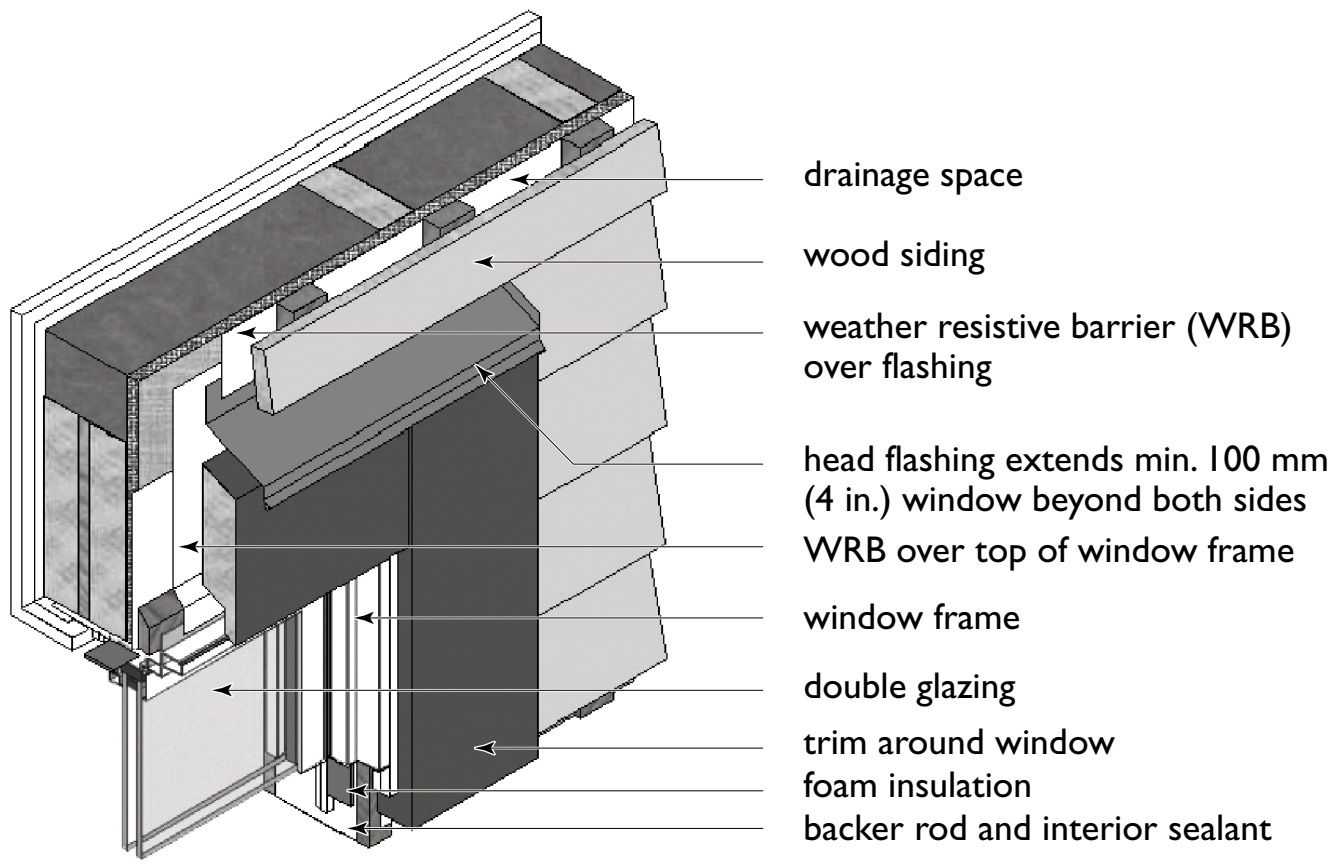


Note: Polyethylene is not to be used as a header wrap.

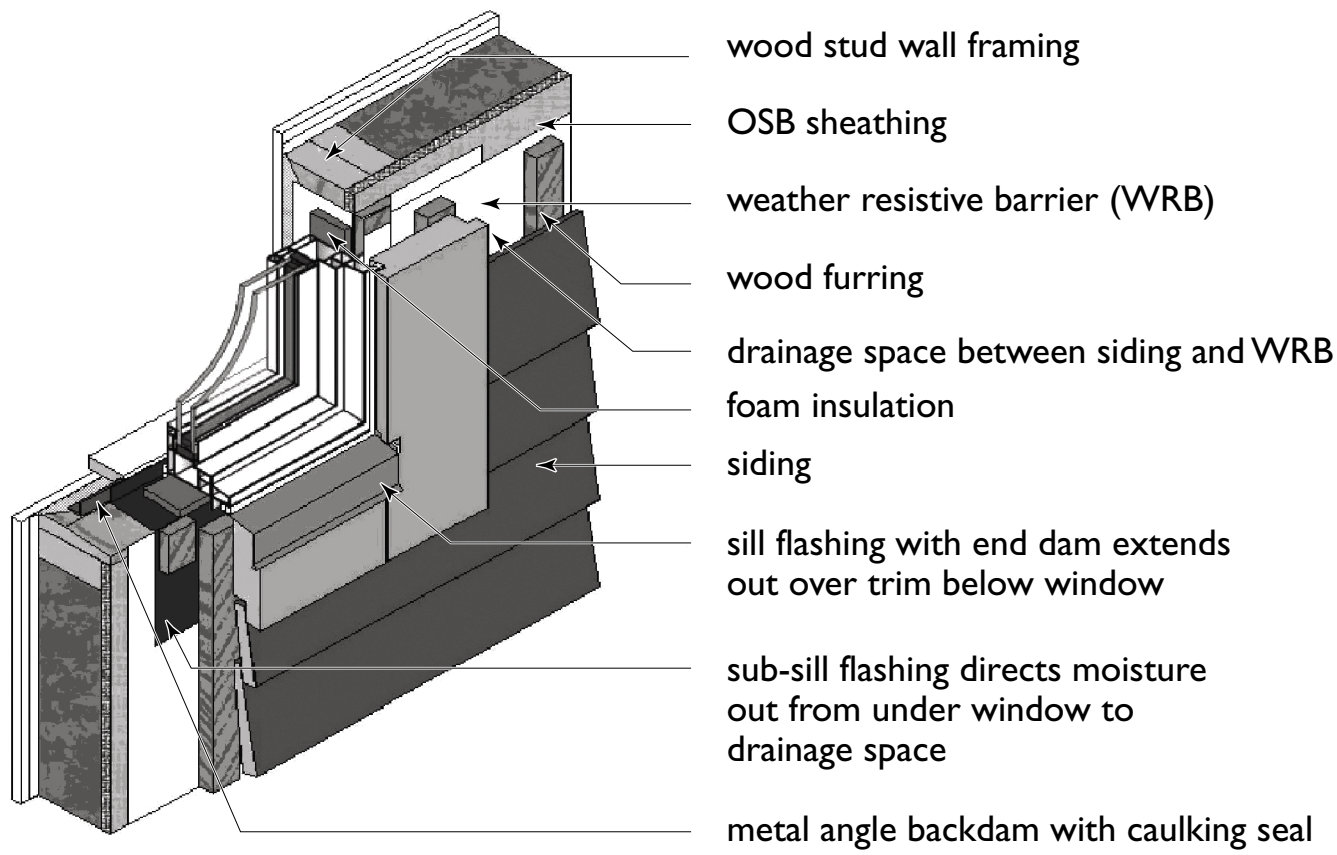
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polyethylene air barrier and the window, door, or skylight frame (Figures 9 and 10). Overhangs and cantilevered floors over unheated spaces or the exterior and ducts, chimney flue and pipe penetrations must also be made airtight.

9 Air barrier and moisture management details at window head



10 Air barrier and moisture management details at window sill

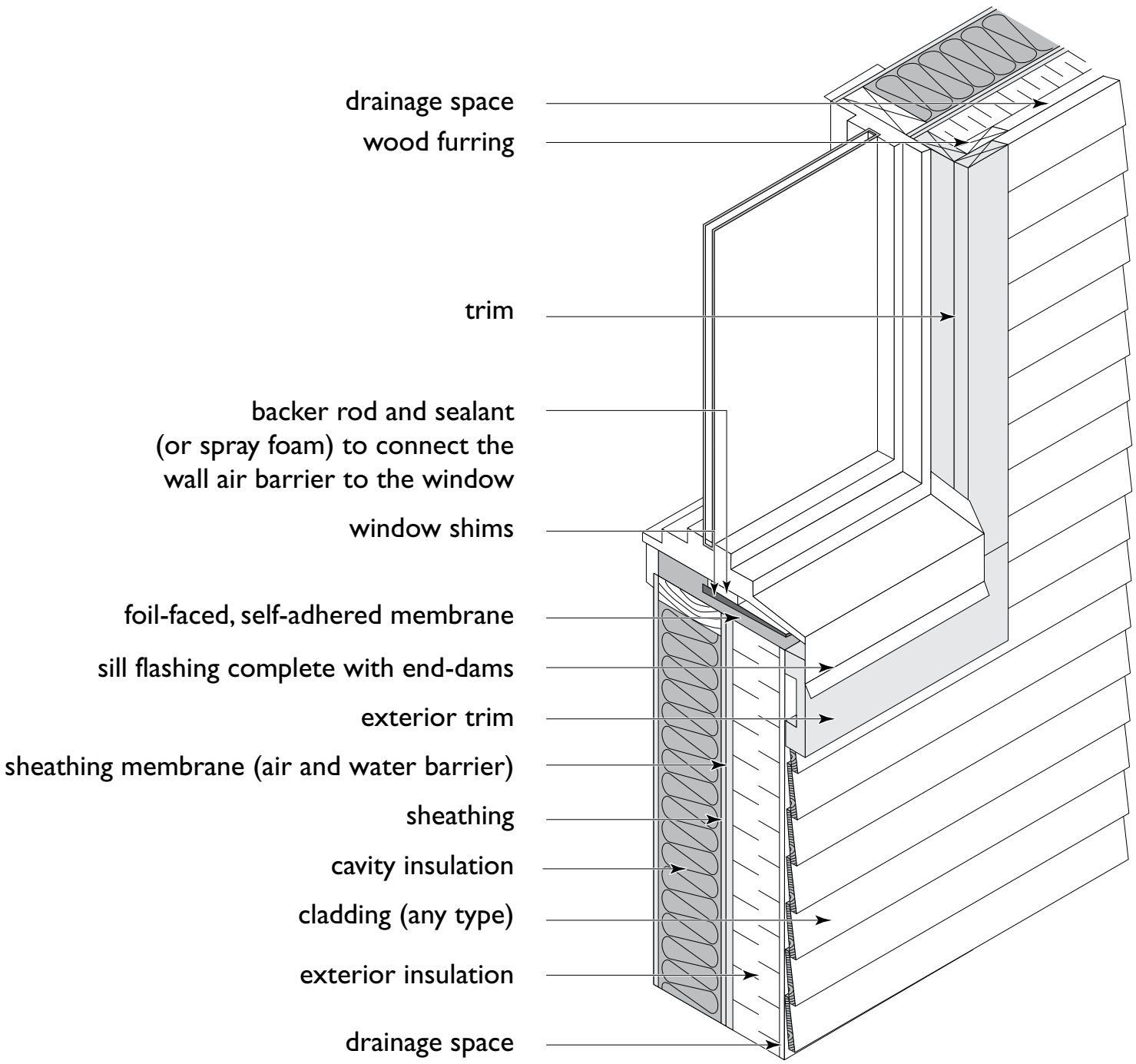


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Windows can be installed in line with either the exterior or the interior surface, or in the middle of the rough opening, as shown in Figure 11, in walls, including highly insulated wall assemblies that may be dimensionally thicker than conventional walls because of added insulation. Installing the window in line with the interior wall will help to reduce the potential for condensation on the glass as it is in a warmer location but may require deep sill flashings and window trims on the exterior. This reduces window exposure to wind-driven rain but relies more on flashings to deflect water. Installing the window in the middle of the wall, as shown, requires less exterior flashing and trim, and provides space for an interior window sill.

Garage doors that separate heated garages from unheated space or the exterior must be weatherstripped. Fireplaces must be equipped with doors or enclosures to restrict air movement in the chimney when the fireplace is not in use. These improvements are not air barriers, but should help to reduce air leakage.

11 Window in highly insulated wall

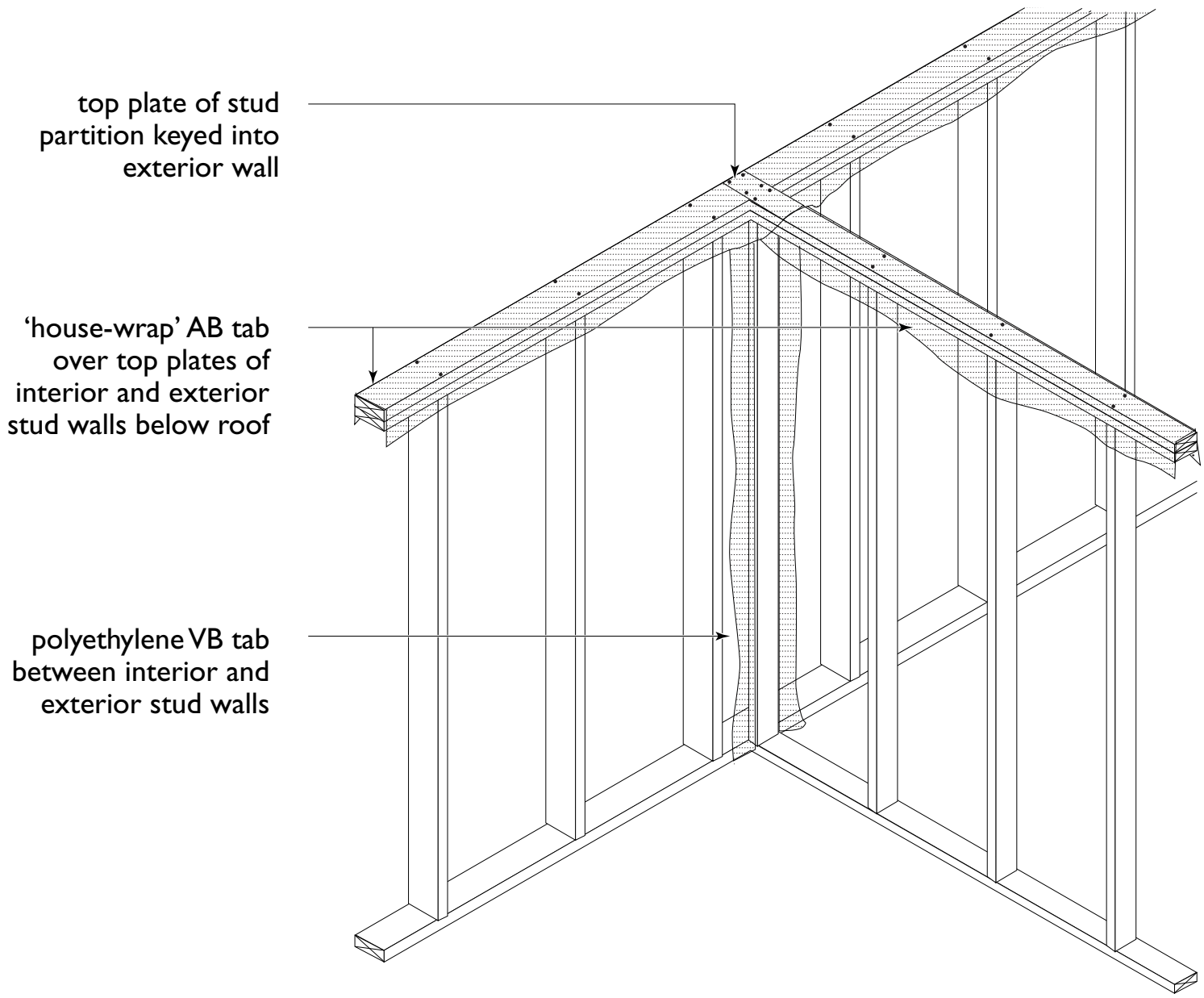


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Roofs

It is common to install the ceiling air barrier before the interior partitions are built, because it is easier to make an airtight connection between the wall top plates and unconditioned spaces (such as attics). Alternatively, when the interior partitions are built before the ceiling air barrier is installed, the top and ends of the interior partitions should be covered with strips of polyethylene or polyolefin at least 450 mm (18 in.) wide (Figure 12), which are subsequently lapped and sealed to the wall and ceiling air barrier materials.

12 Polyethylene strips at end of partition and over wall top plates to provide continuity of the air barrier



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The strips can be installed between the two top plates to avoid damage during construction (Figure 13).

The air barrier can be lapped under and taped to the strip of polyethylene at the top of the wall. This is sealed to the polyethylene attached to the underside of the roof framing to ensure that the air barrier system is continuous at the junction between the walls and roof.

To reduce air leakage through the attic hatch, install a compressible gasket between the opening portion and the frame and latches to keep the hatch closed.

VAPOUR DIFFUSION CONTROL

Water vapour can migrate through building envelope assemblies by penetrating through materials by 'diffusion'. Many activities such as cooking, dishwashing, laundering and bathing release considerable amounts of water vapour into the air and increase its humidity. As water vapour diffuses through assemblies, it can condense on cold surfaces such as the inside face of the exterior sheathing and cause deterioration.

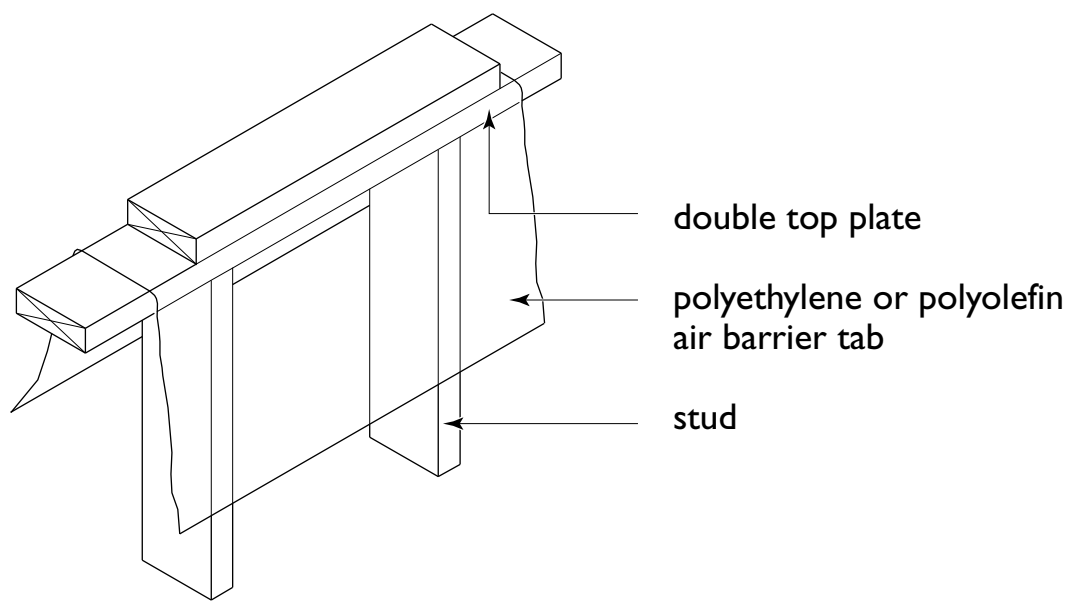
Vapour Barrier

In the winter, the air inside the house may contain more water vapour than the outside air. This causes a difference in vapour pressure and creates a driving force that can lead to water vapour diffusing through materials into the building envelope. Many building materials are permeable to the passage of water vapour, but those classified as vapour barriers, such as polyethylene sheet, have very low permeability and are very resistant to diffusion.

Location of the Vapour Barrier

To prevent condensation from forming within building envelope assemblies, materials that act as vapour barriers (vapour retarders), including certain types of insulation, must be located within the assembly so that moisture moving from the inside to the outside does not condense and accumulate within the assembly. This means that vapour barriers should be located on the warm side of insulating materials (Figure 14). An exception to this rule is permitted for walls where no more than one third of the total thermal resistance or RSI-value (R-value) is located on the interior side of the vapour barrier.

13 Installation of polyethylene sheet strips in interior wall framing



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This is common in double-wall construction that maintains a sufficiently warm temperature at the vapour barrier to prevent condensation from vapour diffusion in most Canadian climate zones.

Polyethylene film is the most common vapour barrier used in Canadian houses. Other materials serve as vapour barriers such as metal foil, polystyrene insulation, sprayed polyurethane foam, polyisocyanurate insulation, metal and glass.

A vapour barrier must be continuous but *does not* need to be sealed. (An air barrier needs to be continuous and *must be* sealed). As a result, sheet polyethylene can only serve as both vapour barrier and air barrier if it is sealed to form a continuous airtight assembly around the perimeter of the house.

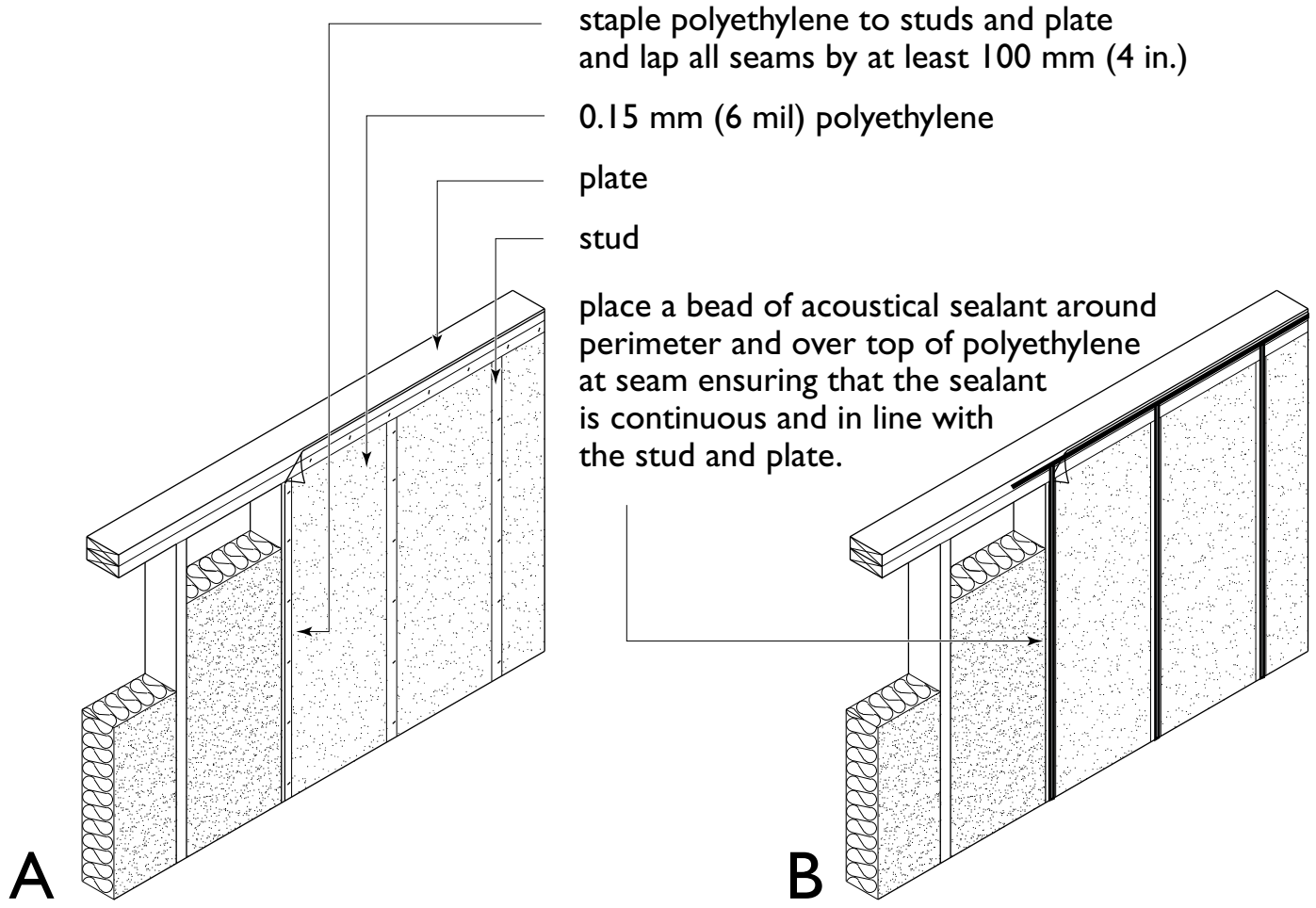
Basement Floors

Dampproofing and air barrier protection against radon leakage into conditioned spaces is usually provided by a sealed polyethylene barrier under the basement slab. This arrangement also constitutes a vapour barrier.

Walls Below Grade

Dampproofing on the exterior wall is required to keep moisture out (see "Water Penetration Control: Walls Below Grade"). If insulation is located on the exterior (see Figure 15), a vapour barrier is not required. If there is insulation on the interior wall (see Figure 16), an interior dampproofing membrane may be required, if moisture-sensitive materials (for example, framing and batt insulation) are situated close to the concrete foundation walls. In this case,

14 Combined air barrier/vapour barrier



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a vapour barrier is required to prevent vapour from entering the space between the wall finish and the concrete wall. The vapour barrier is typically sheet polyethylene.

Walls Above Grade

For wood-frame residential construction, the most common vapour barrier for above-grade walls is sheet polyethylene. Vapour barrier paint on gypsum board or plaster can also be used. Spaces between floor joists at floor/wall junctions also require a vapour barrier. The most common are sheet polyethylene as shown in Figure 16 or rigid insulation. The vapour barrier must be tightly fitted into these spaces, but does not need to be sealed.

Roofs

Sheet polyethylene is usually used as a vapour barrier in ceilings separating conditioned space from attic space.

HEAT FLOW CONTROL

The National Building Code has requirements for minimum insulating values in building assemblies. The building envelope must be designed to ensure adequate performance of the insulation by preventing the decrease of the effective thermal resistance due to air leakage, convective loop heat flow, thermal bridging or moisture. The required levels of insulation are determined by the number of heating-degree days (NBC Appendix C) where the building is located.

Insulation

The effectiveness of a building assembly such as a wall or ceiling in resisting the flow of heat is measured as its thermal resistance or RSI-value in metric units (R-value in imperial units). Although materials used for structure, cladding and finishes have some resistance to the flow of heat, insulation materials are required to provide sufficient levels of thermal resistance. Insulating materials have *nominal thermal resistance* values determined by laboratory testing. Construction assemblies have *effective thermal resistance* values, which usually are lower than nominal values because they take into account thermal bridging through materials caused by framing members and fasteners that have less insulating value than the insulation material itself.

Wherever one component of a building envelope meets another part and the planes of insulation do not physically join, the insulation must be overlapped for a distance of at least four times the distance separating the insulation. For example, where above-grade walls with insulation on the exterior meet a foundation wall with insulation on the interior, the insulation is separated by the thickness of the foundation wall. In this situation, interior insulation must overlap the exterior insulation by four times the thickness of the foundation wall.

Types of Insulation

Insulation is manufactured from a variety of materials and in various forms. The most common types of insulation used in wood-frame housing are described below.

Batt Insulation

Batt insulation is made from fibres of glass, mineral or steel-mill slag spun together with a binding agent. The product comes in lengths and widths to fit standard framing spaces and in a range of thicknesses that provide different RSI-values (R-values). Most batt insulation is called “friction fit” because it is made slightly wider than the standard framing space and held in place by friction. Batts should not be compressed to fit a smaller space because this reduces the insulation value.

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Loose-Fill Insulation

Loose-fill insulation is made of materials such as cellulose fibre and mineral wool fibre and is installed by pouring or blowing it into spaces between the framing. In attics, the loose fill extends above the top of the ceiling joists to raise the insulating level and reduce thermal bridging caused by the framing members. Loose fill insulation in walls must be installed behind a membrane that permits visual inspection to ensure there are no gaps or voids before the interior finish is applied.

Rigid Insulation

Rigid insulation is manufactured in sheets or boards using materials such as polyisocyanurate and expanded or extruded foamed plastic and is usually applied to flat surfaces such as walls. Extruded polystyrene has low moisture permeability and can be used in damp conditions such as on below-grade walls.

Semi-rigid Insulation

Semi-rigid insulation boards are made of glass or mineral fibres and usually applied to flat surfaces such as walls. They are more flexible than rigid insulation products and not as easily damaged by impact or bending. Some semi-rigid insulation has good drainage properties and can be used on below-grade walls.

Foamed-in-place Insulation

Specially formulated polyurethane and isocyanurate insulations can be installed by spraying or injecting under pressure. The liquid sets into a rigid mass within minutes of installation. Some products develop heat or expand during the curing process. Ensure that the products being installed are approved for use in houses, and have a qualified contractor perform the installation under well-ventilated conditions.

Amount of Insulation

The NBC (9.36) has requirements for minimum effective levels of thermal insulation for houses. Compliance can be assured by following prescriptive requirements, or by demonstrating that the calculated performance meets or exceeds the performance of a reference house. For buildings other than housing and small buildings, the insulation requirements are contained in the National Energy Code for Buildings.

The prescribed amount of insulation is based on climate severity as determined by heating degree-days (HDDs). The HDD value is the cumulative sum of the differences between 18°C (64°F) and the mean temperature for every hour of every day in the year when the mean temperature is below 18°C (64°F) (NBC Appendix C).

As shown in Tables 11 to 13 (Appendix A), the NBC prescribes minimum insulation values for each part of the building envelope depending on climate zone. Compliance can also be demonstrated by modeling the proposed house and showing that it uses no more energy than a similar “reference” house that meets the prescribed minimum requirements in the building code.

All walls, floors and ceilings that separate heated space from unheated space or the outside air must be insulated to at least the levels required in the NBC for those locations, unless the house is intended for seasonal use only. Trade-offs are permitted between some building assemblies. For example, the thermal resistance of a wall could be less than the minimum required if additional insulation is provided elsewhere, so that the overall insulation value is maintained on an area-weighted average basis.

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When a house has a heat recovery ventilator (HRV) and complies with minimum air-tightness requirements, the insulating values can be reduced in most cases. Refer to the NBC for insulation requirements for building assemblies when HRVs are installed.

The NBC requires the building envelope to have a minimum effective thermal resistance but allows some minor penetrations such as pipes, ducts, equipment with through-the-wall venting, packaged terminal air-conditioners or heat pumps, shelf angles, anchors and ties and associated fasteners, and minor structural members, as permitted thermal bridging elements. Unheated and unventilated enclosed spaces, such as porches and garages, are not required to be insulated.

Major structural penetrations through the building envelope such as floor and roof decks, balcony slabs, beams, columns and ornamentation or appendages must be taken into account in determining effective thermal resistance when the sum of their areas is greater than 2 per cent of the penetrated gross wall area.

Except for a balcony or canopy, any ornament that penetrates an exterior wall or insulated roof or ceiling and breaks the continuity of the insulation must be insulated (a) on both of its sides inward or outward from the building envelope for a distance equal to 4 times the thickness of the penetrated wall insulation; and (b) to an effective thermal resistance no less than that required for the exterior wall.

Mechanical ducts, chases and electrical system components such as pipes, conduits, cabinets, panels or recessed heaters located in the building envelope must have an effective thermal resistance not less than that of abutting assemblies. Expansion or construction joints, or joints between walls and doors or fenestration, must be insulated to provide thermal continuity across the joints.

Wall assemblies inclined less than 60° from horizontal are considered to be roof assemblies, and roof assemblies inclined 60° or more from horizontal are considered to be wall assemblies for the purposes of determining the effective thermal resistance. In calculating the effective thermal resistance of roof assemblies, all related structural framing must be taken into account.

It is relatively easy and economical to insulate wood-frame construction by filling the spaces between the framing members with interior insulation, which usually costs less than insulation intended for exterior use. Typically, insulated wood frame walls use 38 × 140 mm (2 × 6 in.) studs with wood sheathing and batt insulation. However, in colder Canadian climate zones, additional insulation is required either in the exterior or interior side of the framing members (see Table 11 Effective thermal resistance of assemblies in buildings with a heat recovery ventilator in Appendix A).

Methods of insulating these different areas are explained in the following sections. The figures show a number of possible methods of insulating building elements, but there are other acceptable methods.

Basement Floors

Insulation is generally not required under basement floors that do not contain heating elements. RSI 2.32 (R13) insulation must be placed under heated floor slabs in climate zones up to 4999 HDD, and RSI 2.85 (R17) is required in colder climates. Extruded polystyrene is commonly used under basement floors because it is resistant to damage from water and is strong enough to support most floor loads.

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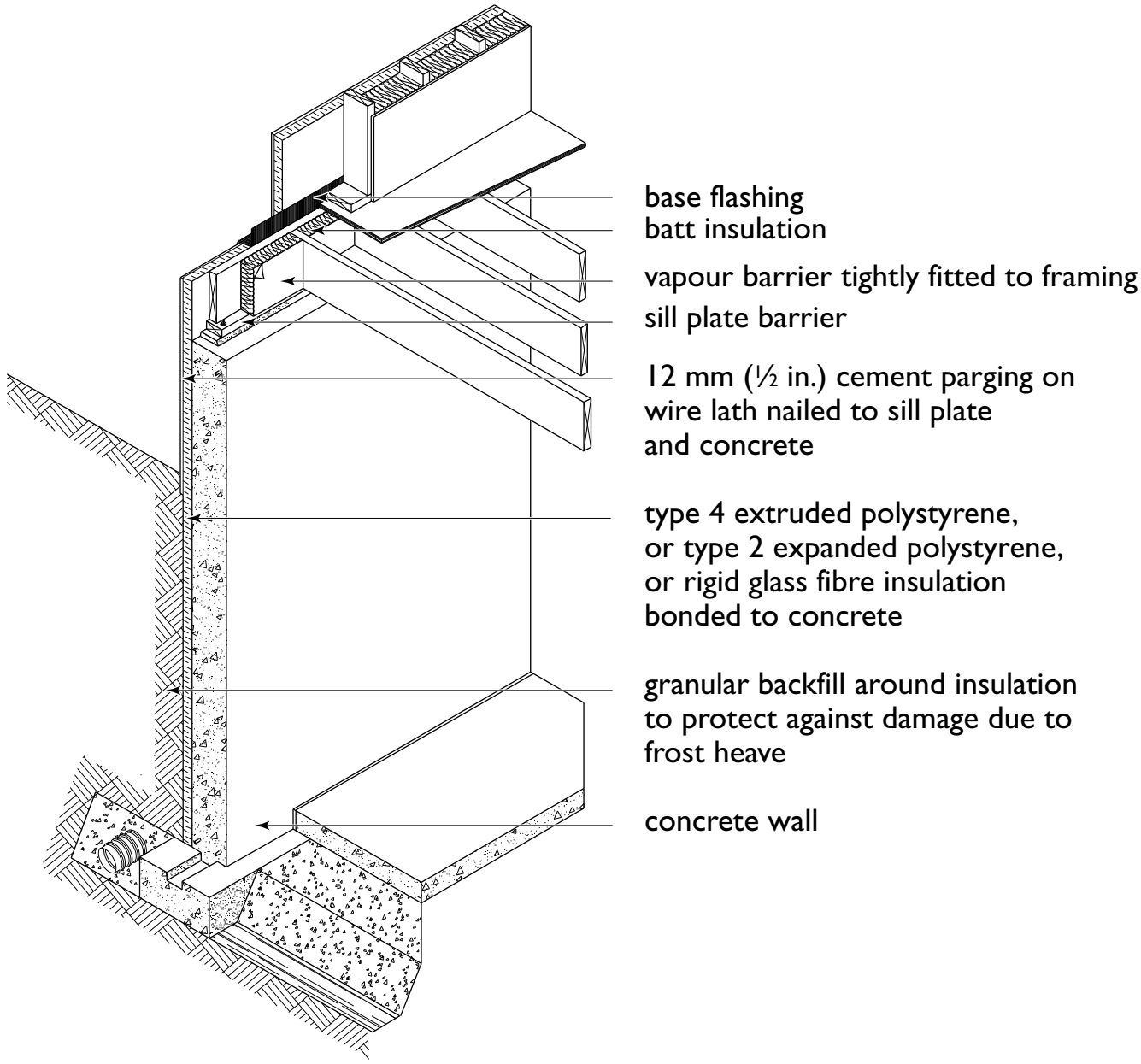
Walls Below Grade

Exterior Insulation

When foundation walls enclosing conditioned space are insulated on the exterior, the insulation must extend at least to the bottom of the floor of the conditioned space. If the top of a footing is less than 0.6 m (2 ft.) below the exterior ground level, wall insulation must extend down to the top of the footing and the same level of insulation must be placed on the top or bottom surface of the floor and extend at least 1 m (3 ft. 3 in.) from the perimeter. A floor-on-ground with imbedded heating ducts, cables or pipes must have insulation placed under its entire bottom surface. All floors-on-ground enclosing conditioned spaces must be insulated around their perimeters to reduce heat loss from the slab to the foundation wall, or wall insulation must be placed on the outside of the foundation wall and extend down to the level of the bottom of the floor.

When insulation is applied on the outer surface of a wall or a slab perimeter, it must be a type not susceptible to water damage such as expanded or extruded polystyrene. It may also be a type designed to drain water, such as high-density, rigid glass fibre or mineral fibre insulation. The portion of the insulation above grade must be protected by 12 mm (½ in.) cement parging on wire lath applied to the exposed face and edge, cement board or preservative-treated plywood (Figure 15).

15 Concrete wall with rigid insulation on outer face



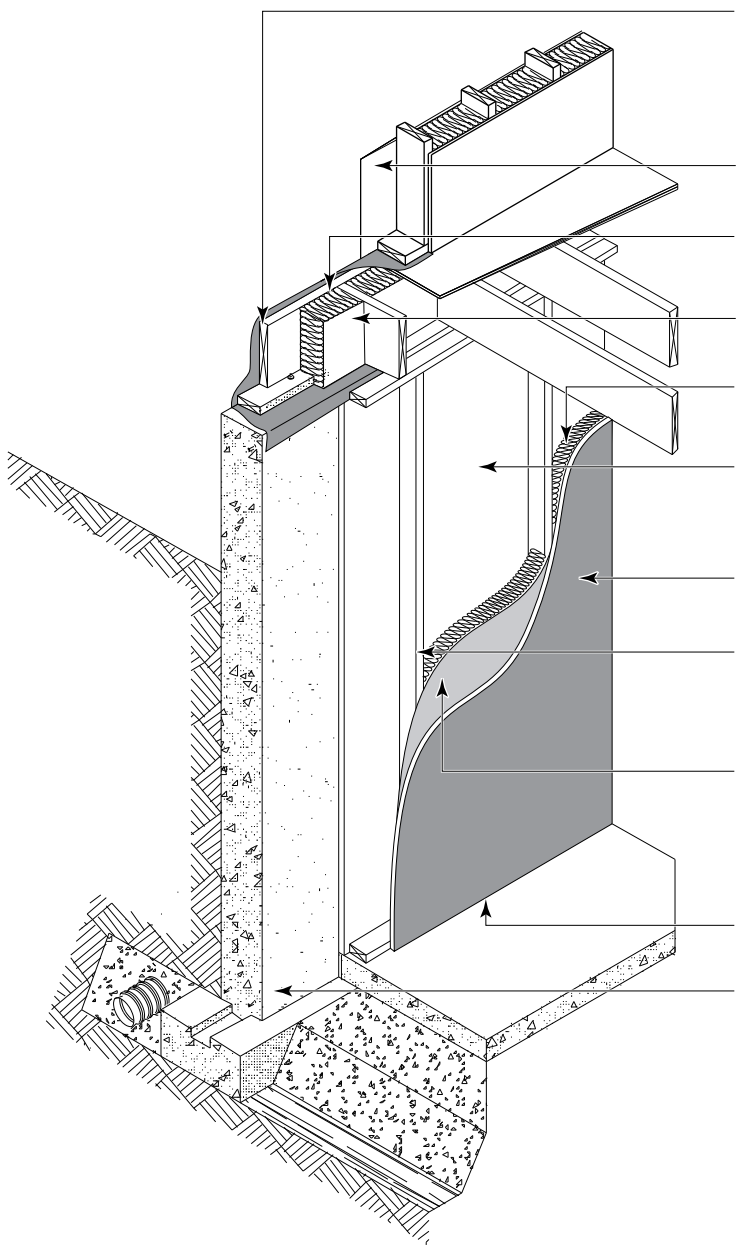
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Interior Insulation

Foundation walls may be insulated on their interior surfaces. Framing materials should be separated from a concrete wall by dampproofing materials. Polyethylene should not be used for this purpose with new concrete walls because it does not allow the drying of moisture escaping from the concrete. Building paper protects the framing and insulation from moisture damage by conducting the moisture to the bottom of the wall. Alternatively, expanded or extruded polystyrene insulation may be installed against the concrete foundation wall prior to the framing, batt insulation and vapour barrier (Figure 16). If adhered to the concrete and sealed around the board perimeters, it can effectively isolate the cold interior concrete surface from interior air and reduce the potential for condensation.

Rigid insulation should be bonded to the wall with cement grout or synthetic adhesive applied in bands forming a grid pattern. This pattern of bonding is recommended to limit warm moist air movement behind the insulation since this can cause condensation and moisture accumulation between the wall and the insulation.

16 Concrete wall insulated with rigid insulation and batts



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For fire safety reasons, polystyrene insulation on the inside of house must be covered by an acceptable finish, such as drywall.

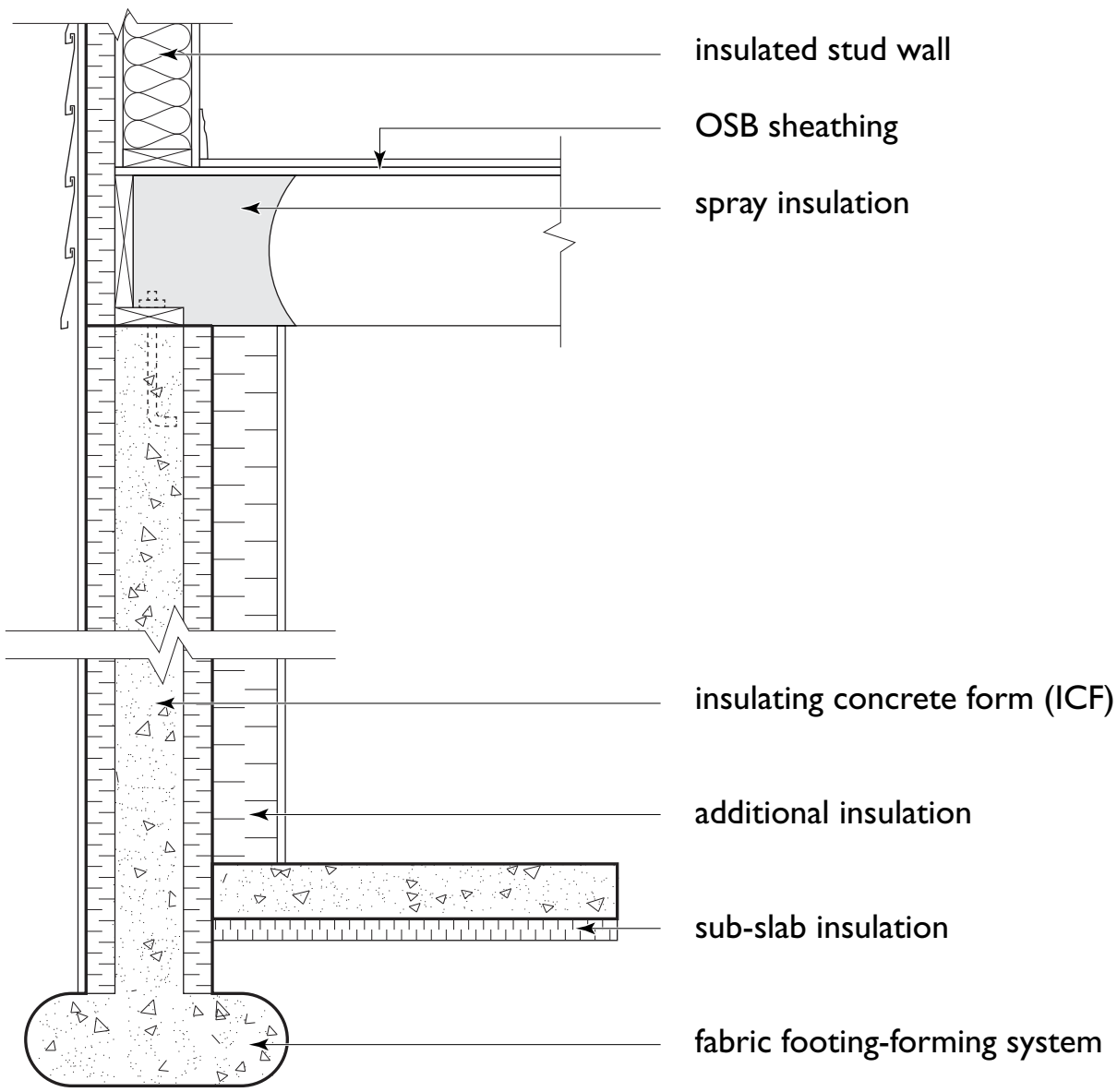
Preserved Wood Foundations

Insulation is normally placed between the studs in preserved wood foundations. The stud cavity should be filled to prevent air pockets and the possibility of convection loops within the cavity, as they would cause heat loss.

Insulating Concrete Form Foundations

Insulating concrete form (ICF) walls are concrete walls cast in polystyrene forms that remain in place after the concrete has cured (Figure 17). Most ICF walls are "flat" ICF walls, which means that the concrete is of uniform thickness over the width and height of the wall. The NBC requires that any exposed polystyrene be protected by a fire-retardant material, such as gypsum board.

17 Insulated concrete form foundation wall

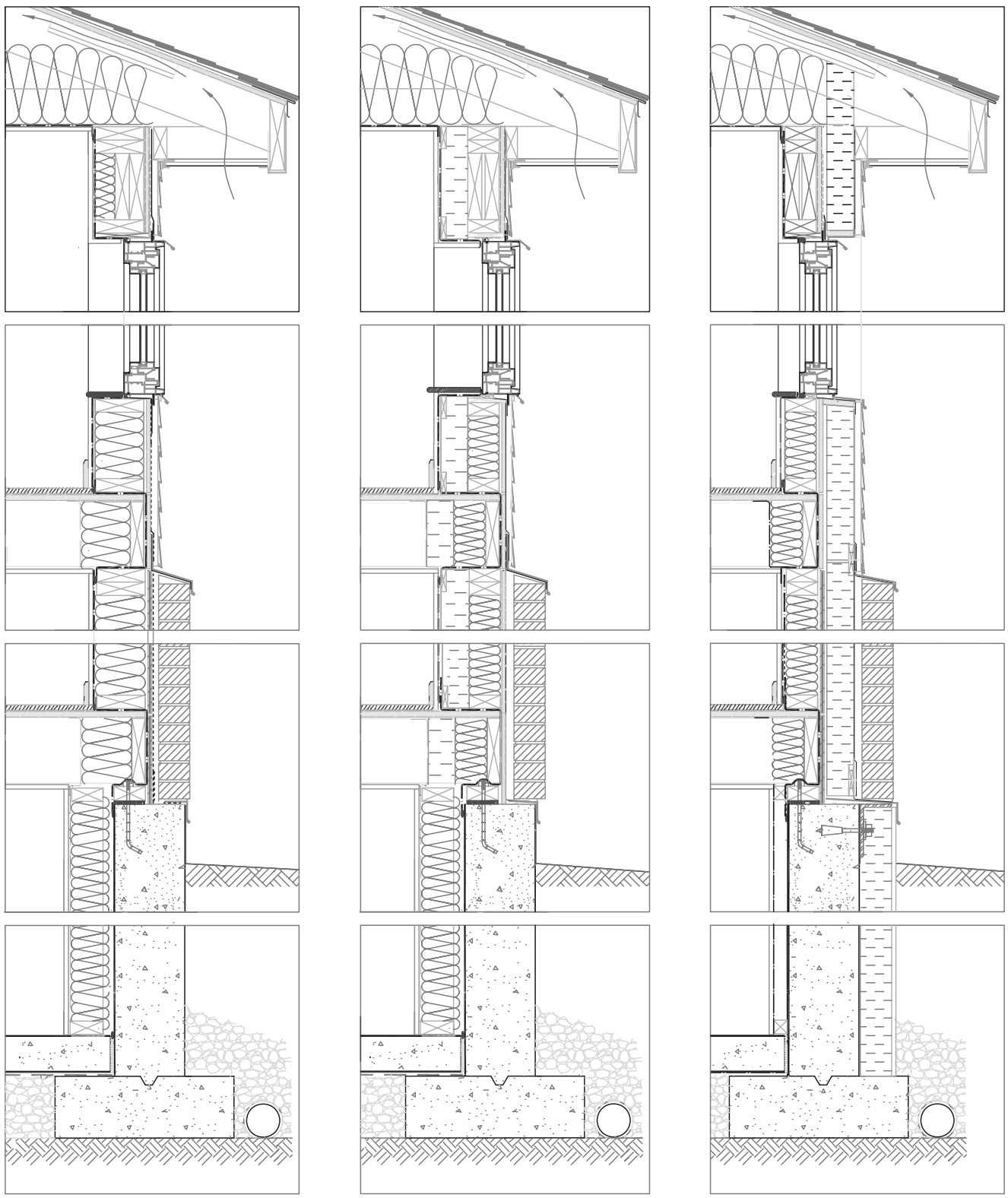


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Walls Above Grade

Figure 18 shows three different approaches for insulating within and beyond the stud space and foundation wall. In warmer climate zones, the required level of thermal resistance can be achieved using batt insulation in the stud space (Figure 18a). In climate zones where required effective insulating values cannot be provided within the framing space alone or where higher insulation levels are desired, additional insulation must be provided on either the inside or the outside of the framing (Figure 18: b and c).

18 Location of thermal insulation



2 Story stud insulation

(a) Insulation within framing space

2 Story inside insulation

(b) Insulation inboard of framing space

2 Story outside insulation

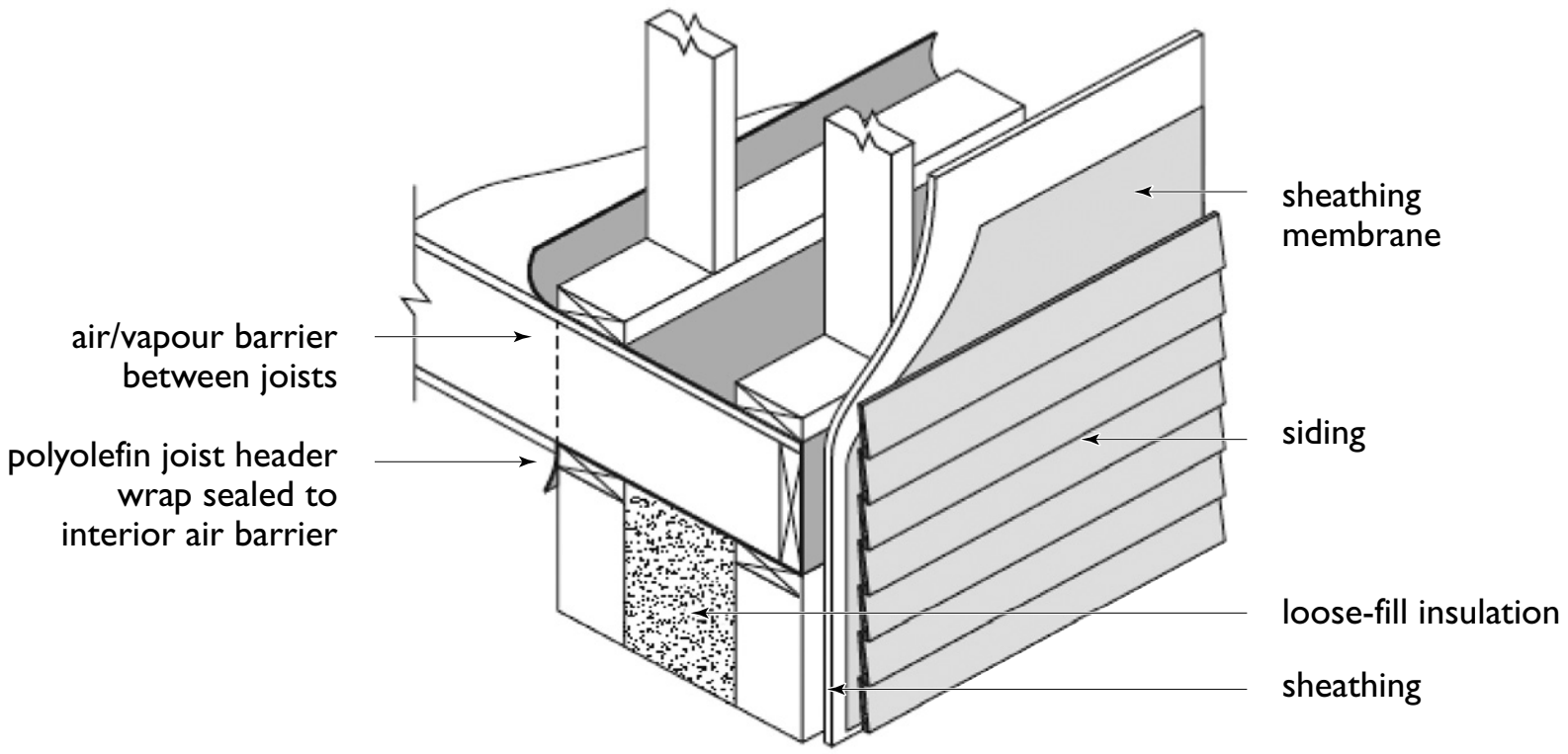
(c) Insulation outboard of framing space

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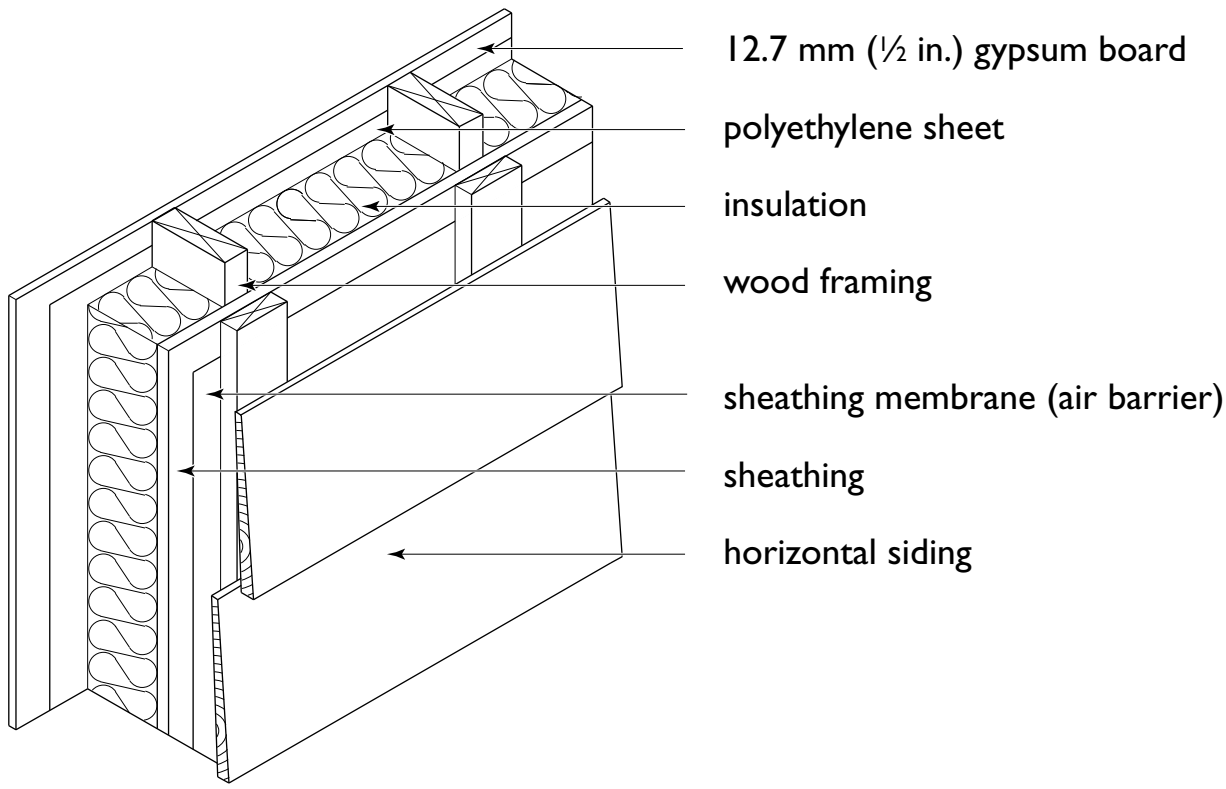
Double wall framing can be used to provide more space for insulation (see Figure 19). The interior stud wall should be kept apart from the exterior load-bearing stud wall to allow for continuous insulation and prevent thermal bridges. The interior and exterior wall sections can be connected with OSB or plywood spacers and erected as a single unit, or erected separately. Polyethylene film or mesh is attached to the interior stud face to contain loose fill insulation, when it is used to fill the stud cavity.

Figure 20 shows an example of a wall with insulation contained in the framing space.

19 Double-wall framing construction



20 Typical 38 × 140 mm (2 × 6 in.) wall

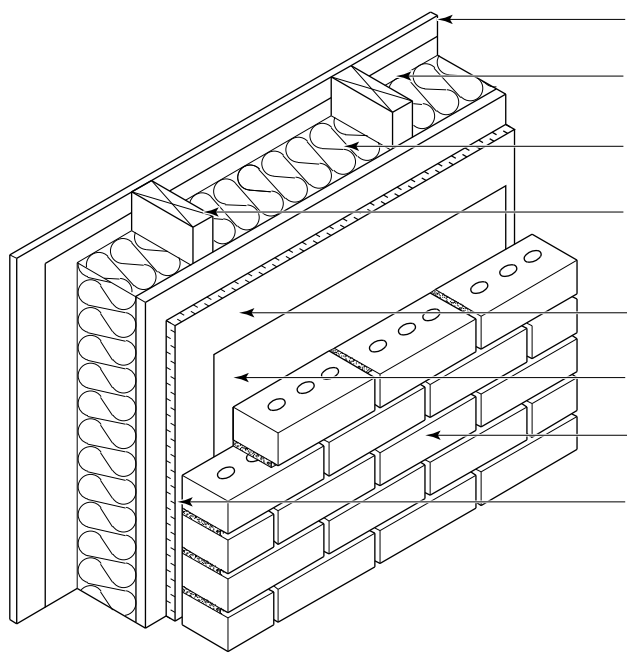


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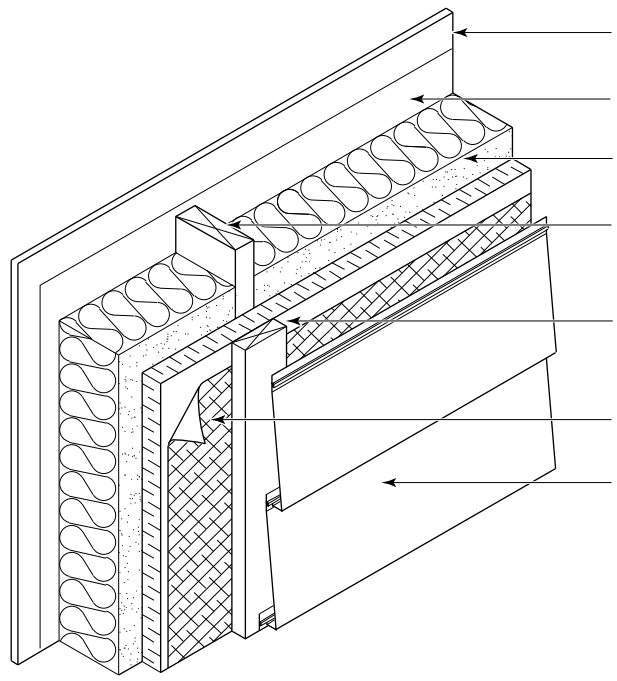
Figures 21 and 22 show examples of walls insulated within the framing members and have insulation outboard of the framing.

Some types of semi-rigid insulation come with a spun-bonded polyolefin sheet attached to one surface. This material is vapour permeable but air impermeable, and may serve as an air barrier if the joints between the sheets are taped and if the air barrier system is continuous and sealed at doors, windows and other penetrations. If the air barrier is provided on the interior of the building envelope, the exterior rigid insulation does not need to be sealed unless it is also part of the second plane of protection resisting water ingress.

21 Brick veneer cladding with insulation in the framing space and outboard



22 Siding with insulation in the framing space and outboard



Note: Bracing required in walls at corners.

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Electrical and mechanical features such as boxes, pipes and ducts should not be installed in exterior walls. Where this cannot be avoided, the NBC allows slightly reduced insulation levels at these locations provided the plane of insulation is continuous. Air barrier continuity at these penetrations is still important.

Small spaces at intersections in corners and around openings must contain insulation that is not compressed.

Walls between dwelling units and garages must be insulated to the same level as exterior walls, whether the garage is heated or not, because garages may be left open for extended periods of time.

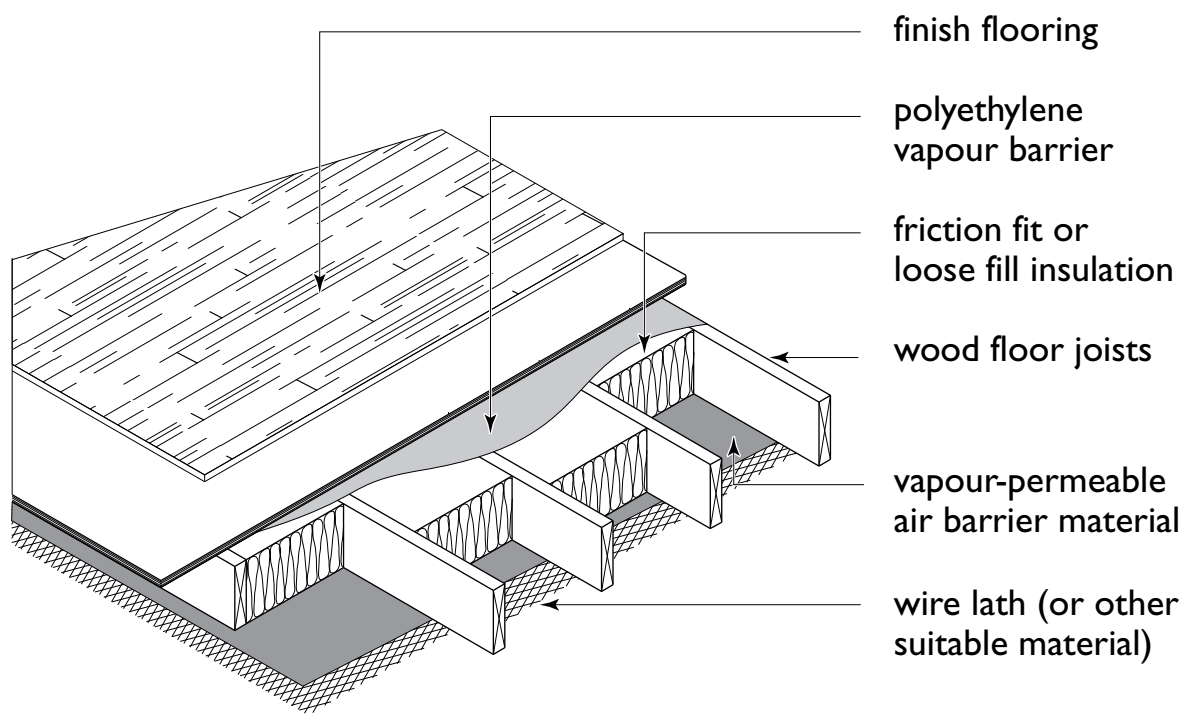
Floors over Unconditioned Spaces

Floors over unheated crawl spaces or over garages must be insulated. It is common to fill the space between the floor sheathing and a gypsum board ceiling under the floor with insulation.

Where there is no finished ceiling on the underside of the floor, the insulation must be supported (to prevent the insulation from falling through). For friction-fit batts or rigid insulation (Figure 23), attach wire lath, "chicken wire", wood furring or a vapour permeable sheet material to the bottom of the joists. For loose fill-type insulation, provide solid support with a vapour-permeable material (to avoid creating a vapour barrier on the cold side of the insulation).

Fit insulation around cross-bridging or blocking between joists and insulate small spaces such as those between blocked double joists or joist spaces below a wall. The NBC requires that a vapour barrier be installed on the warm side of the insulation, which is usually the upper side in a floor over an unconditioned space. A plywood or OSB subfloor with tight-fitting or sealed joints can serve as the vapour barrier.

23 Floor over unheated crawl space insulated with friction-fit batts



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To provide the required insulating value, additional insulation may have to be installed below the insulated framing space. Install wood framing perpendicular to and underneath the floor framing. Fill the framing cavity with insulation, which will cover the underside of the floor framing and thus prevent thermal bridging.

Roofs and Ceilings

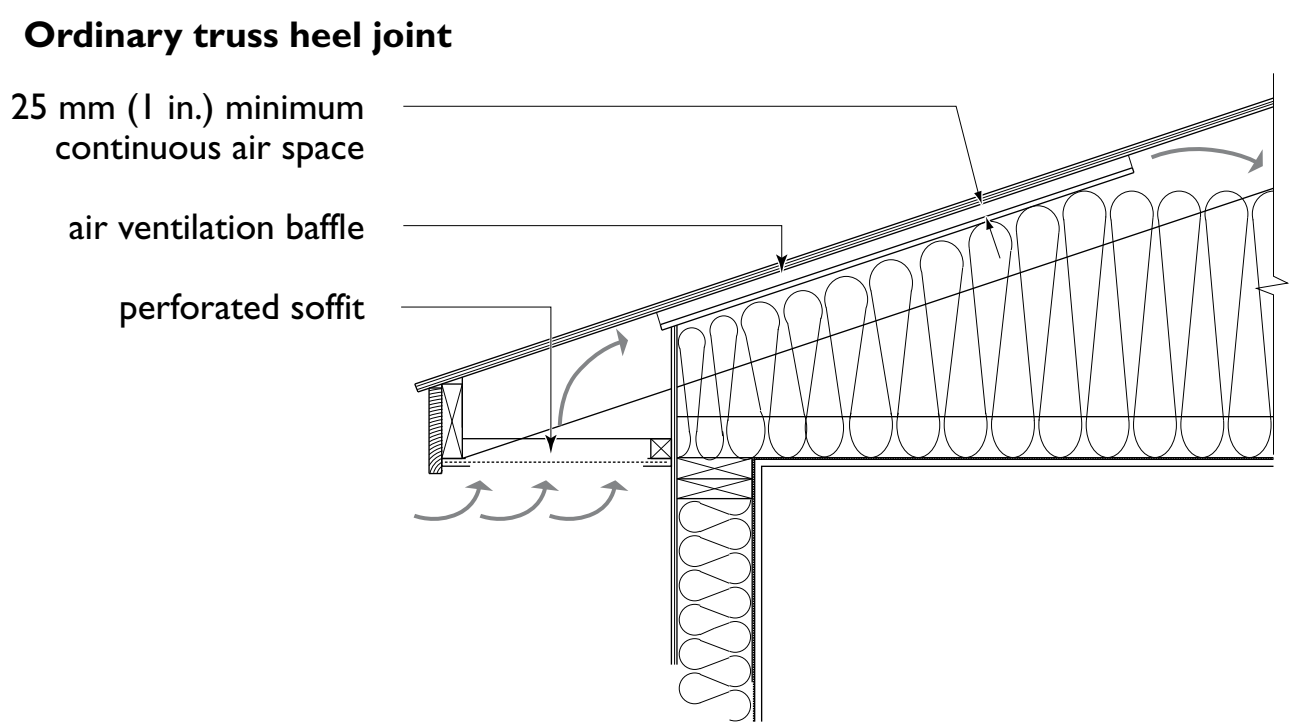
Truss or Rafter-Type Roof Ceilings

Before the 1970s, conventional roof trusses were usually about 150 mm (6 in.) deep where they rested on exterior walls, which didn't leave much space for attic insulation. Since the oil crisis of the 1970s, roof trusses have a "raised heel" design at the plane of the exterior wall, which makes them 250 mm (10 in.) deep or more at this location and provides more space for insulation. The NBC requires that the level of insulation where the roof meets an exterior wall must be equal to or greater than the insulation level in the wall.

Thick batts are made for insulating roofs in widths equal to the full centre-to-centre distance of standard roof framing. The lower portion is slightly compressed when installed between the framing, but the upper portion retains its width and covers the tops of the framing, thus reducing thermal bridging (heat loss) through the framing.

Loose fill insulation can also be used to cover the framing. Use insulation baffles to prevent loose fill insulation from spilling onto eave vents (Figure 24) and from being displaced by wind entering the vents. Where loose fill insulation is installed in a roof space over a sloped ceiling, the slope of the surface must not exceed 4.5:12 for mineral fibre or cellulose fibre insulation, and 2.5:12 for other types of loose fill insulation.

24 Eave details to avoid blocking ventilation

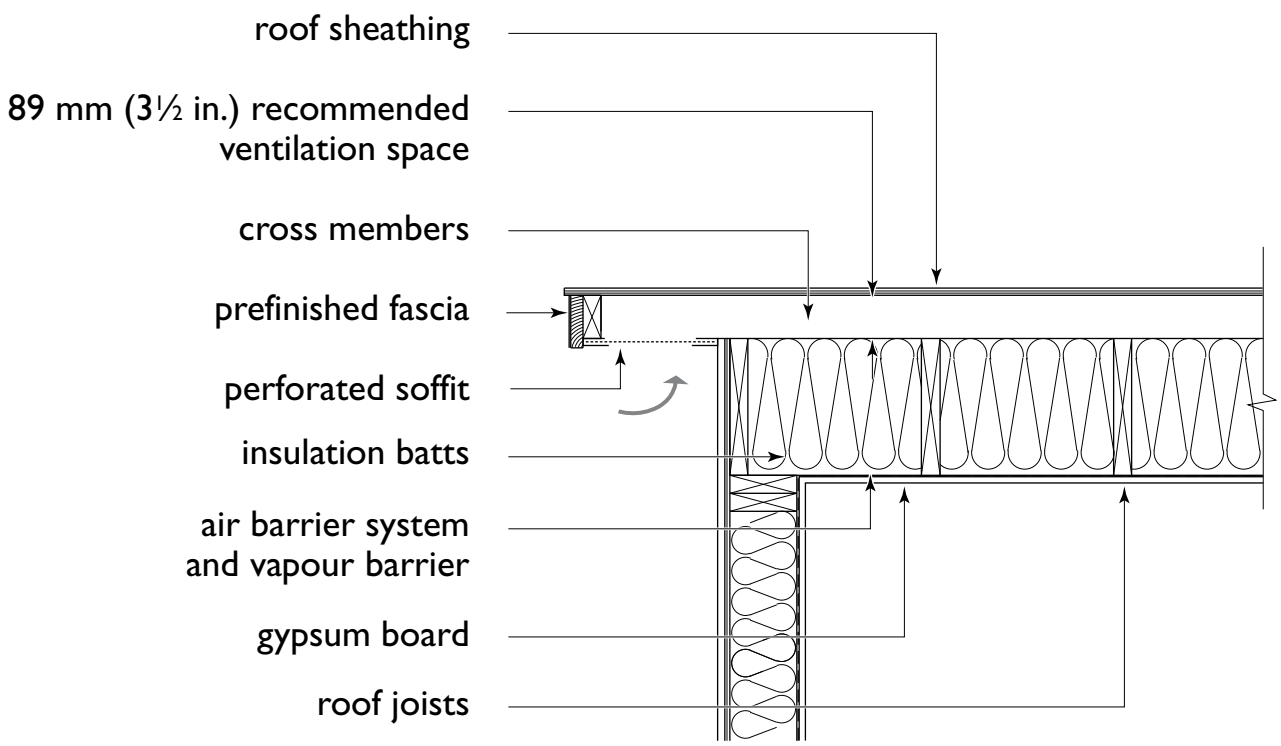


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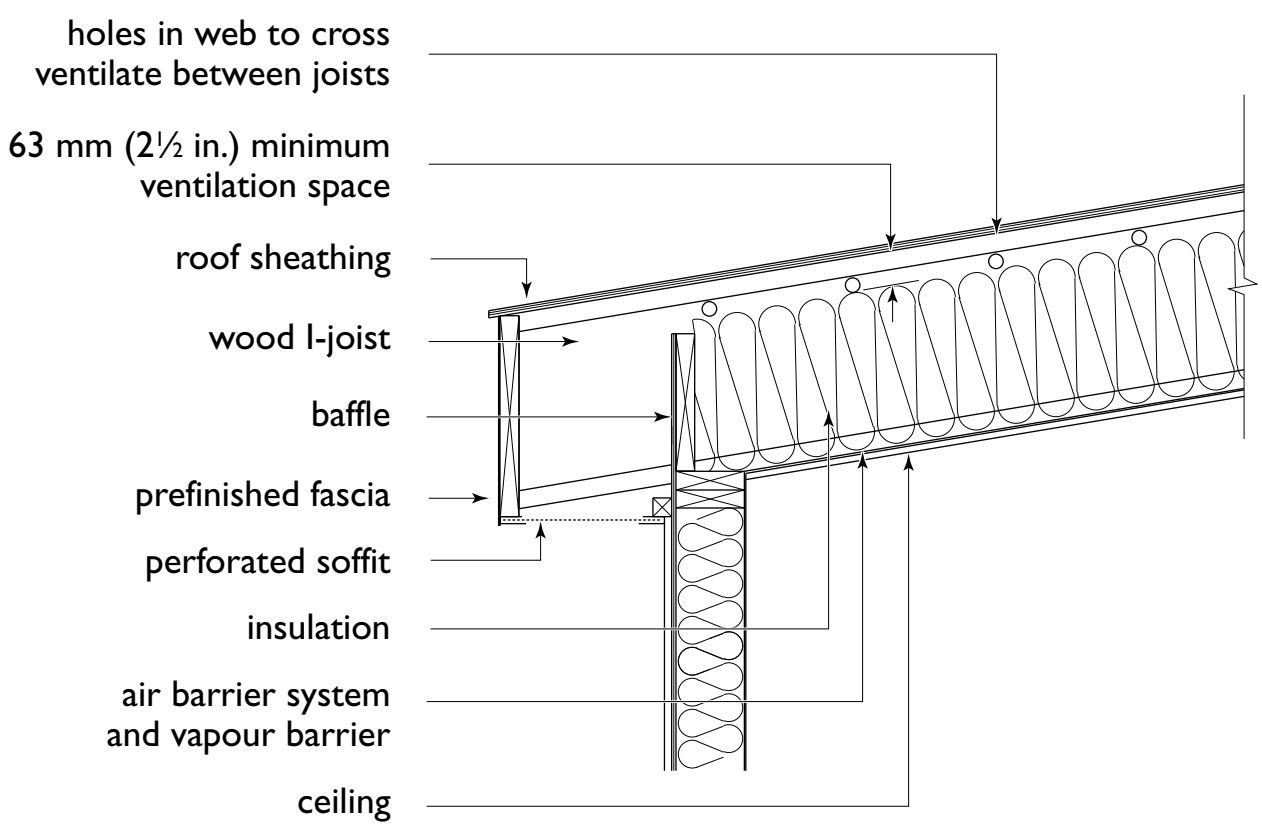
Joist-Type Roof Ceilings

When roofing is attached directly to the top of ceiling joists as is the case for cathedral or sloped ceilings, the space above the insulation must be vented to prevent the accumulation of moisture, or the space must be filled with insulation (such as sprayed closed-cell foam) that prevents air vapour from condensing within the insulation or on other surfaces in the roof (Figures 25 and 26).

25 Insulating joist-type roof ceiling between the ceiling and sheathing



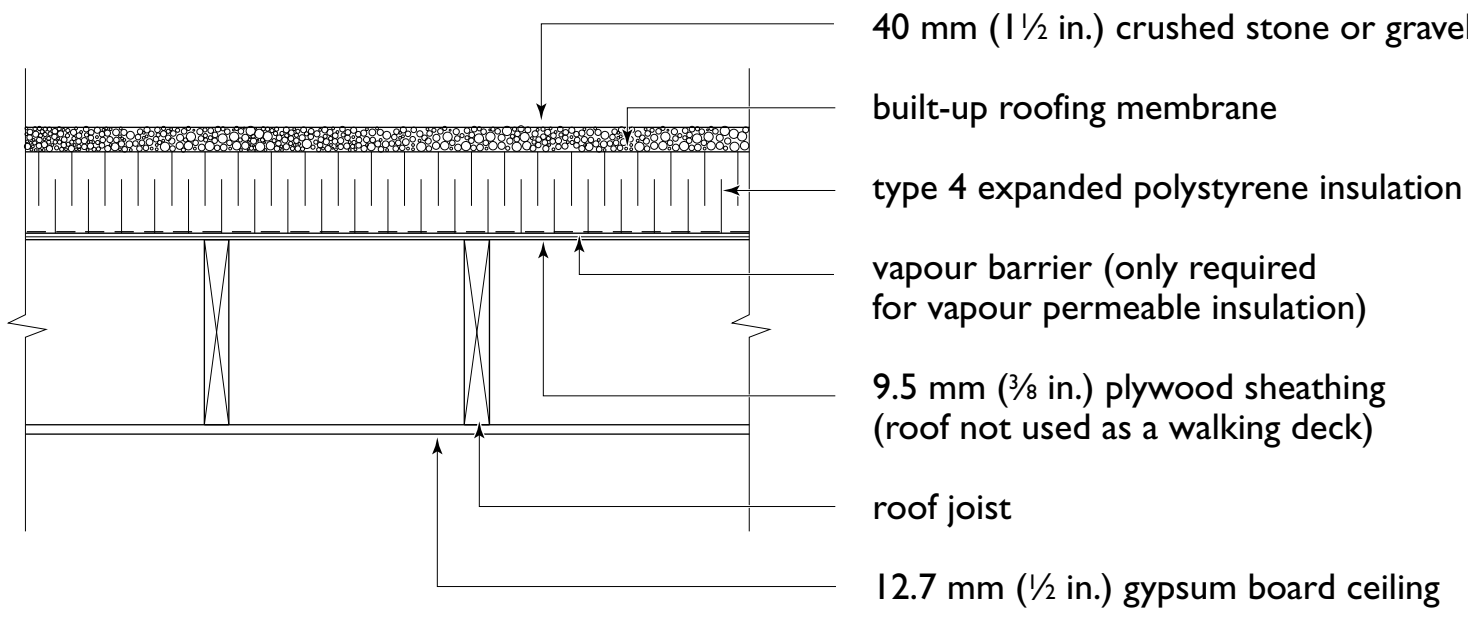
26 Alternative method of insulating joist-type roof ceiling between the ceiling and sheathing



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Another approach is to place the insulation above the sheathing, as is commonly done with low-slope roofs (Figure 27). Insulation exposed to the weather must be impermeable to moisture. Polystyrene insulation is commonly used on the outside of roof sheathing and protected by the roofing membrane.

27 Insulation of a flat joist-type roof ceiling above the sheathing



SUSTAINABLE HOUSING INSIGHT

Healthy Indoor Environment

- Batt and loose fill insulations release airborne particles. As a result, masks and gloves should be worn when handling or disturbing these materials.
- Polystyrene and polyisocyanurate insulation must be protected against exposure to fire.
- Controlling the movement and condensation of water vapour with a vapour barrier and sufficient insulation reduces the likelihood of mold problems.
- Reducing air leakage with an air barrier system also reduces the likelihood of moisture condensing in the walls or roof and causing decay and mold growth.
- Controlled mechanical ventilation can provide better quality air to the house than uncontrolled ventilation through air leakage.

Energy Efficiency

- Reducing air leakage and using high levels of insulation save heating and cooling energy.
- Consider providing insulation levels higher than those required by the building code to increase the overall energy efficiency of the house.

Resource Efficiency

- Where possible, use insulation materials made from industrial by-products or recycled waste such as most glass, mineral fibre and cellulose insulations.

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Continued

Affordability

- The payback period for the cost of installing additional insulation may likely become shorter with the passage of time should energy costs rise.
- Vapour and air leakage control is crucial for prolonging service life and avoiding expensive repairs to building assemblies.

RELATED PUBLICATIONS

2010 National Building Code of Canada (Part 9.36 and Appendix C),
National Research Council of Canada

2011 National Energy Code for Buildings,
National Research Council of Canada

Building Enclosure Design Guide, Homeowners Protection Office (HPO),
British Columbia

Building Envelope Guide for Houses, Homeowners Protection Office (HPO),
British Columbia

Canadian Home Builders' Association Builders' Manual,
Canadian Home Builders' Association

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CHAPTER 6
Location and Excavation



MARKING THE EXCAVATION AREA

Check with the municipality or township for minimum setback and side yard requirements before deciding the exact location of the house on the site. The proximity of the house to a property line can also affect such things as the size of window openings, soffits and exterior cladding so that the house does not pose a fire risk to a neighbouring house.

Always check with local utility companies prior to digging to ensure that the excavation will not interfere with buried services. Inadvertently cutting telephone, gas or power lines can prove costly and result in injury. After the site is cleared, mark the perimeter of the house using the exact location of the corners of the lot as a reference. The latter are usually determined by a certified surveyor, marked by small wooden stakes accurately located at each corner, with nails driven into their tops indicating the outside line of the foundation walls.

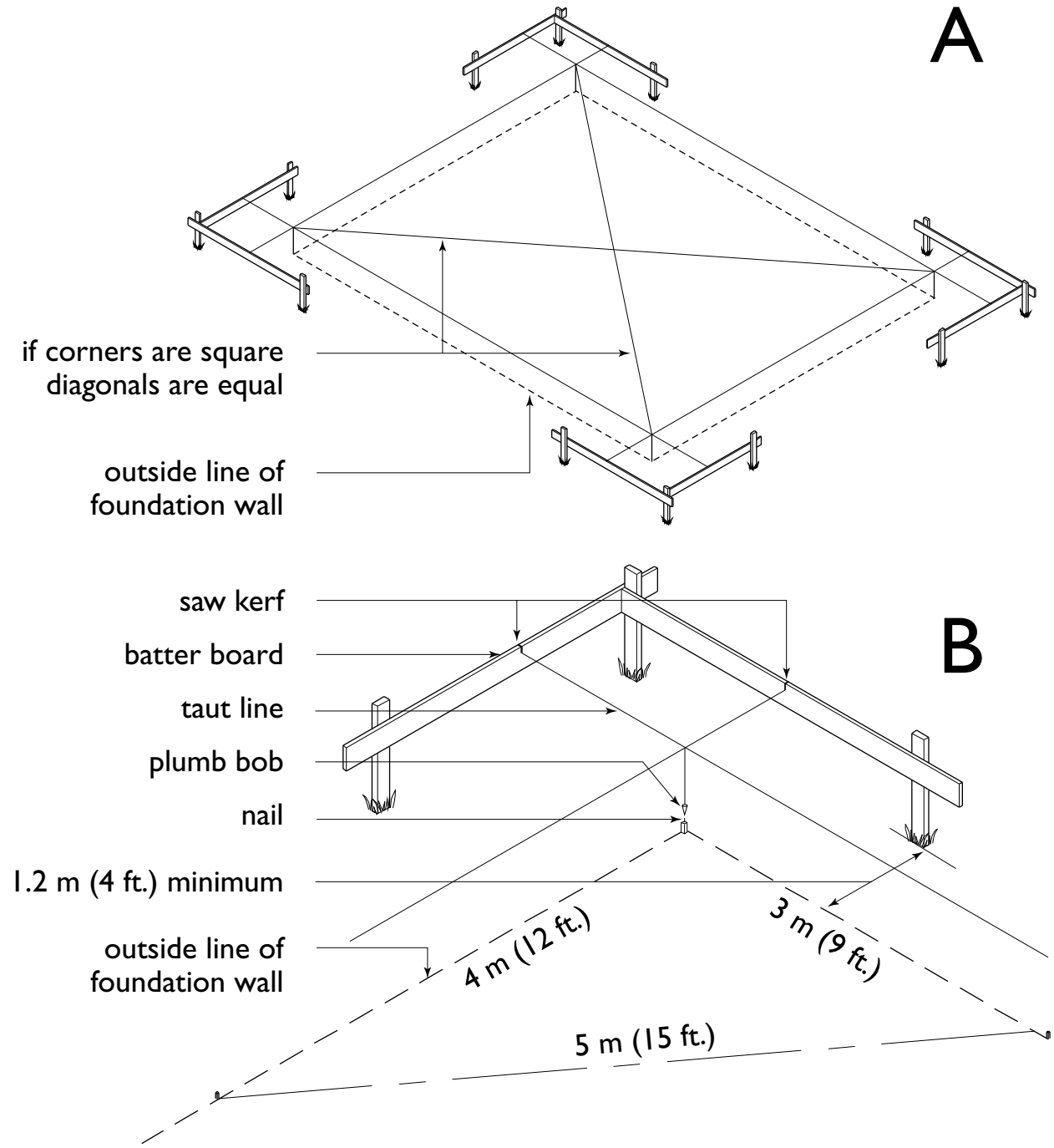
Additional markings are needed because these stakes will eventually be lost during excavation. Offset markings may be located by extending the lines of the foundation walls from the established corners, and fixing these offset markings either with stakes or marks on surrounding permanent objects. These markings are used after excavation to erect batter boards (Figure 28).

The area to be excavated is staked out, usually 600 to 700 mm (24 to 28 in.) wider than the corners of the house. This extra width is needed for easy handling and erection of the formwork, placement of the drain pipe, application of dampproofing and placement of the exterior insulation, if this is intended. Fluorescent paint may be applied to the ground to mark the perimeter of the excavation.

Excavations more than 1.2 m (4 ft.) deep must have a back slope to ensure the safety of those working near the edge of the excavation.

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28 Establishing the lines of a house



EXCAVATION SIZE AND DEPTH

Before excavating begins, topsoil should be stripped and stored for reuse. Some excavated material suitable for backfill may be stored on site and surplus material removed from the site. The depth of the excavation is established during the planning stage, depending on the access to the street, sewer and water services, the profile of the lot, the level of finished grade around the perimeter of the house and the elevation of adjoining properties.

The basement headroom and the elevation of the floor above grade also affect the depth of the excavation. Basement headroom for finished basements must be at least 2 m (6 ft. 7 in.) to the underside of beams or joists. If the basement is to be used as a living space, however, the headroom must be at least 2.1 m (6 ft. 11 in.), the same minimum height as the other finished floor areas. The elevation of the first floor should allow for a minimum distance from finished grade to the beginning of exterior finishing (normally starting at the top of the foundation)

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of 150 mm (6 in.) for masonry and metal siding, and 200 mm (8 in.) for wood siding, plywood, hardboard and stucco (Figure 29). This is intended to minimize damage to framing and cladding from melting snow and rainwater deflected from the ground and to protect the wood from insects and pests.

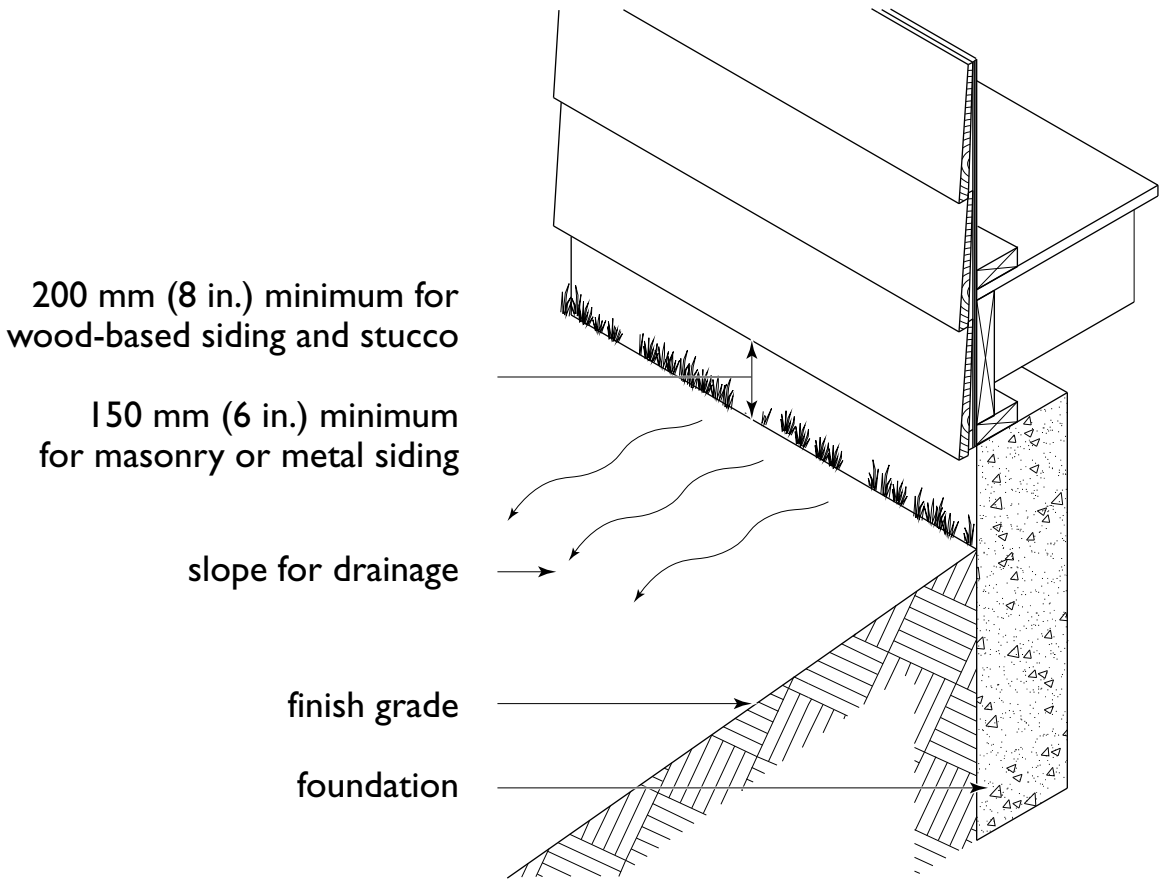
Poor soil conditions may require the excavation to be deepened until suitable soil is encountered. The foundation depth can also be affected by the water table or bedrock elevation. Ensure that excavation does not affect the foundations of adjacent buildings. Contact your local building department when these situations are encountered.

Ensure the excavation is deep enough to accommodate the granular base under the basement floor slab. This depth is usually sufficient for accommodating the thickness of the footings. If a site is well drained and only a dampproofing membrane is used without the granular base underneath, the main excavation need only extend to the elevation of the top surface of the footings. When this is done, the footings are formed by trenching. Adequate space must be provided for the drainage pipe outside the footing.

Insulate the excavation in the winter to prevent frost penetration. Building on frozen soils can cause problems that are difficult and costly to remedy.

The rough grade around the house should be kept at least 100 mm (4 in.) below the line established for the finished grade to allow for subsequent placing of topsoil or paving material.

29 Finish grade sloped for drainage



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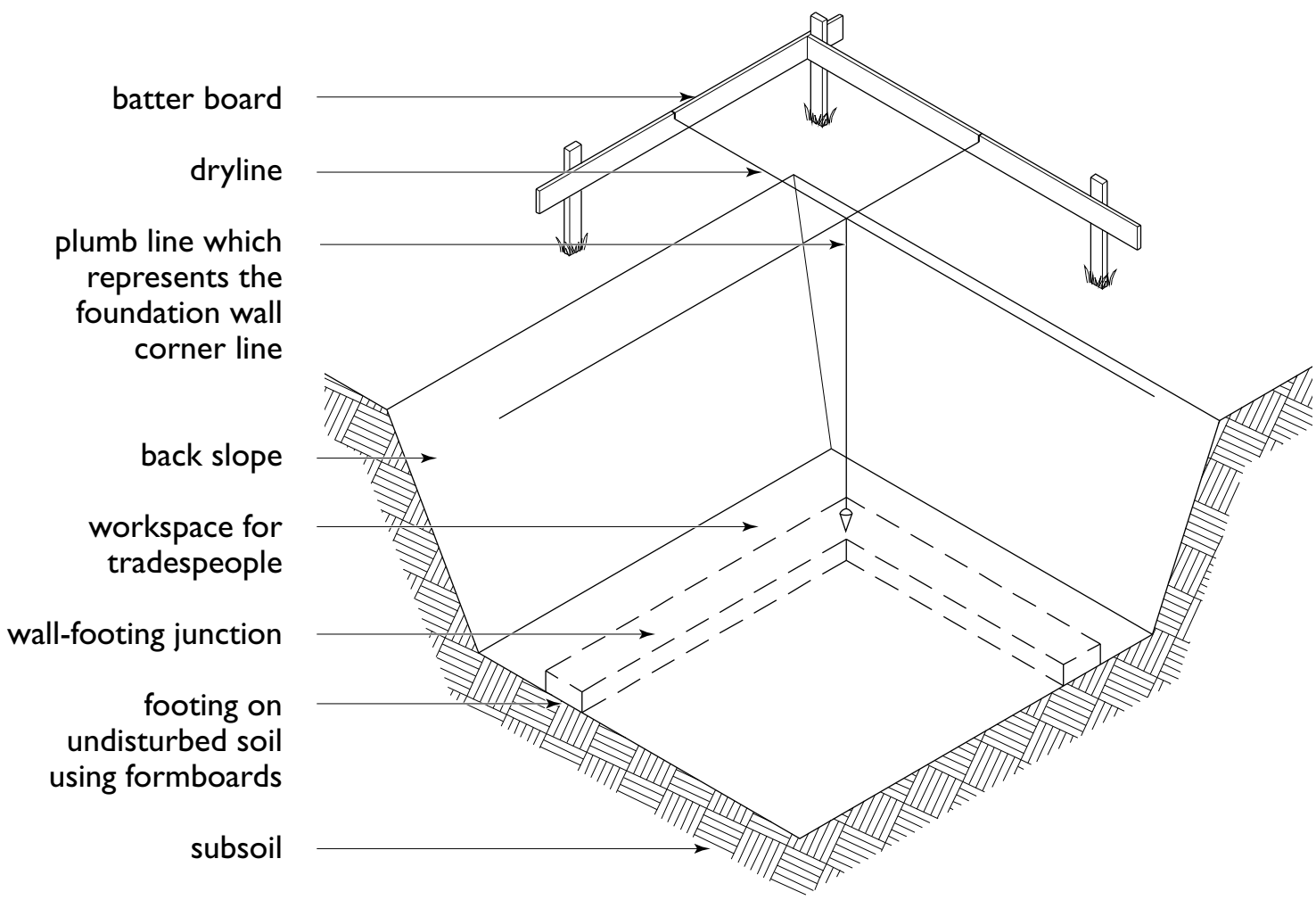
PLACEMENT OF THE HOUSE

After the excavation has been completed, the next step is to establish the lines and elevation for the footings and foundation walls. Figure 30 shows a convenient arrangement of batter boards for this purpose.

Using the previously established location of the foundation walls, place three stakes of suitable length at each corner at least 1.2 m (4 ft.) beyond the lines of the excavation. Nail horizontal boards as shown in Figure 30 so that the tops of all the boards are level and at the same elevation. Wire or stout string is stretched across the tops of opposite boards at two corners and adjusted exactly to follow the line of the outside edge of the foundation wall. Cut saw kerfs 6 to 8 mm (¼ to ⅜ in.) deep or install nails where the lines touch the boards to mark the position of the lines so that they can be replaced if needed.

Two methods are commonly used to determine whether the building corners are square. The first is to measure the diagonals. If the diagonals between building corners are equal, the building corners are square (Figure 28). Another method known as triangulation calls for measurements along one side of the corner a distance in multiples of 300 mm (12 in.) and along the adjacent side the same number in multiples of 400 mm (16 in.). The diagonal, or hypotenuse, will have an equal number of multiples of 500 mm (20 in.) when the corner is square (Figure 28).

30 Method of setting batter boards and establishing corners for excavation



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SUSTAINABLE HOUSING INSIGHT

The location of a house on a building lot must meet local zoning requirements for height, size and setbacks from property lines. The lot must also have access to the street and, if necessary, provide space for parking. Once these criteria have been met, there may be opportunities to situate the house to take advantage of some sustainable housing principles.

Healthy Indoor Environment

- Schedule noisy activities during normal work hours to avoid disturbance.
- Design surface drainage so that it is conducted away from the foundation to swales, ditches and sewers.
- Build waterproof foundations and floor slabs in locations with high water tables.

Energy Efficiency

- House orientation affects solar heat gain through windows, which can lower winter heating costs and increase summer cooling costs. Consider locating large windows facing south, with shading devices to maximize winter solar gain and minimize summer heating. In addition, consider locating smaller windows facing north to reduce winter heat loss.
- Unshaded south-facing roofs and walls are potential sites for collecting solar energy (with solar panels for example).

Resource Efficiency

- Set foundation elevations so that excavated fill can be used for rough site-grading. The builder should choose the proper elevation to avoid having to dispose of surplus fill or to import new fill.

Environmental Responsibility

- Protect existing trees and landscaping where possible. Protect drainage ditches and sewers from silt, soil or chemical contamination resulting from construction activities.
- Remove, protect and re-use topsoil and clean fill.
- Maintain natural runoff patterns. Avoid having surface water flowing onto neighbouring properties.
- Design site grading to convey storm water to areas where it may infiltrate the soil and replenish groundwater.
- Keep excavations clear of chemical contaminants, refuse or degradable matter such as branches, stumps and roots.

Affordability

- Establish the footing elevation to minimize rock excavation and facilitate connection to water and sewer service or on-site systems.
- Avoid excessive foundation height or changes in direction and elevation that would increase the cost of the foundation.
- Set the elevation so that exterior stairs are not needed. In addition to reducing cost, a level-entry makes a home more adaptable to persons with limited mobility.

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RELATED PUBLICATIONS

2010 National Building Code of Canada,
National Research Council of Canada

About Your House: Photovoltaic (PV) Systems,
Canada Mortgage and Housing Corporation (product no. 63890)

Glossary of Housing Terms,
Canada Mortgage and Housing Corporation (product no. 60939)

Landscape Guide for Canadian Homes,
Canada Mortgage and Housing Corporation (product no. 63523)

Collecting and Using Rainwater at Home: A Guide for Homeowners,
Canada Mortgage and Housing Corporation (product no. 67925)

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CHAPTER 7
Footings, Foundations and Slabs



FOOTINGS

Footings receive house loads through foundation walls or columns and transmit these loads to the soil. The type and size of footings must be suitable for soil conditions and be located below the frost level. Alternatively, they must be placed on material that is not susceptible to frost action or otherwise protected by exterior insulation. Insulation may be used to protect shallow foundations from frost, but this requires a professional design. Because water must be present for frost to occur, frost action can be further minimized by providing good drainage around the foundation to direct water away from the building.

Footings should rest on undisturbed soil, rock or compacted granular material. The latter must not contain pyritic shale, a material found in the St. Lawrence lowlands and prone to swelling.

Table 3 (Appendix A) shows the minimum depths for several soil conditions. A foundation built on fill should extend down to undisturbed earth or be designed to suit the ability of the fill to support the building loads.

Wall Footings

The size of wall footings should comply with building code requirements. Table 4 (Appendix A) shows minimum concrete sizes for average, stable soil and the number of stories supported. If the distance to the water table from the bearing surface is less than the width of the footings, the footing sizes in Table 4 must be doubled.

Footings should project beyond each side of the wall by at least 100 mm (4 in.), and the thickness of unreinforced footings should be no less than their projection beyond the wall.

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Footings must never be less than 100 mm (4 in.) thick (Figure 31). If the soil has low load-bearing capacity, wider reinforced footings may be required. Local building officials can provide advice on local conditions affecting footings.

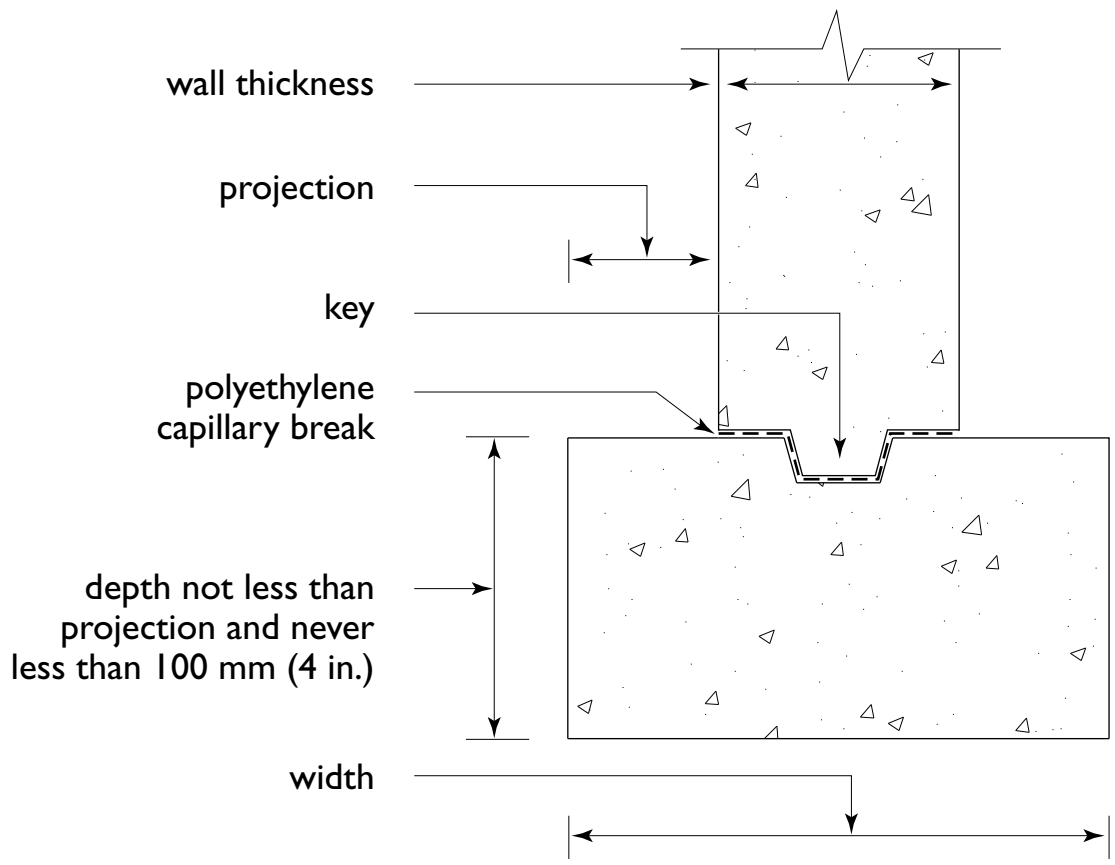
Forming a key on the top of the footings (Figure 31) is a good practice that helps the foundation wall resist earth pressure at the bottom of the wall. It is good practice to place a polyethylene sheet over the footing for the width of the foundation wall. This will act as a capillary break, preventing moisture in the footing from wicking up into the foundation wall. The polyethylene can also be connected to the air barrier system in the basement floor and walls.

If the footing excavation is uneven and too deep in places, compacted granular material, not excavated material, should be used to level the excavation. Pipe trenches directly under wall footings should be encased with concrete.

Wood Footings

Continuous preserved wood footings are often used instead of concrete footings for preserved wood foundations. Wood footings and the required granular drainage layer act together to distribute loads from the structure to undisturbed soil. The sizes of interior and exterior footings are provided in the Canadian Wood Council publication entitled *Permanent Wood Foundations*.

31 Size of footings



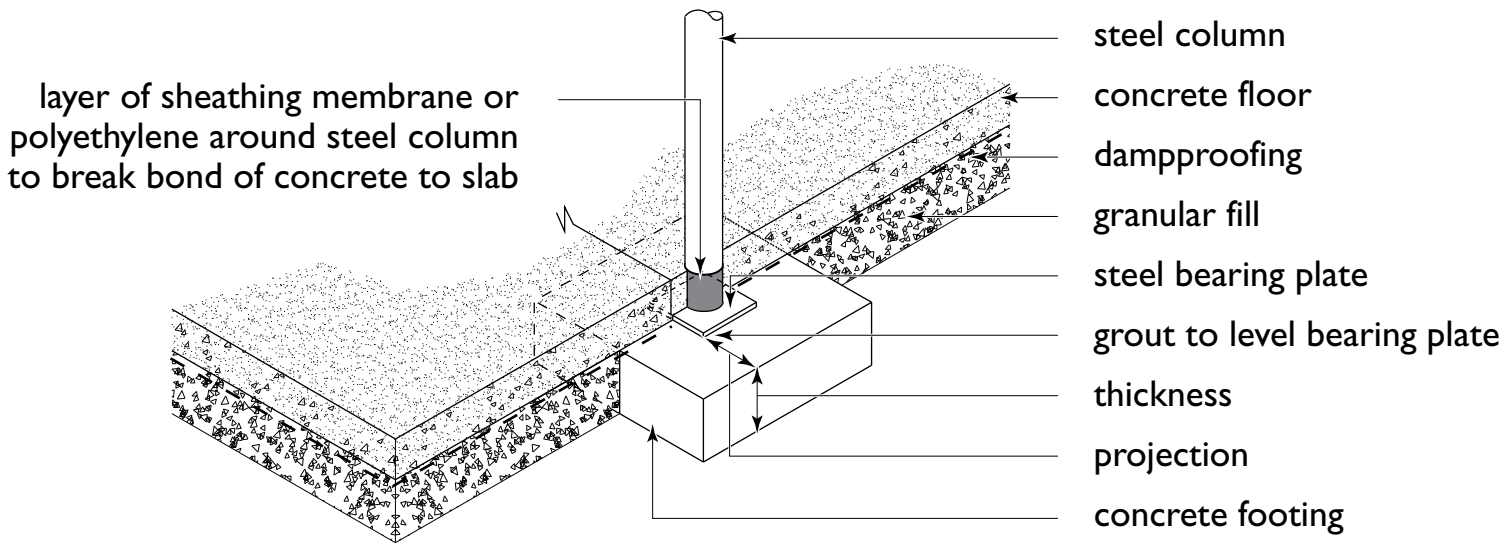
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Column Footings

Locate footings for posts or columns (Figures 32 and 33) so that the members they will support are centred. Footings vary in size depending on the allowable soil pressure and the load they support. On average stable soil, common sizes are 0.4 m^2 (4.3 sq. ft.)—about 640 × 640 mm (25 × 25 in.)—for one-storey houses and 0.75 m^2 (8 sq. ft.)—870 × 870 mm (34 × 34 in.)—for two-storey houses. The thickness of column footings without reinforcement must be at least 100 mm (4 in.) and must never be less than the column footing's projection measured from the edge of the column base plate to the edge of the footing. Footings for fireplaces and chimneys are usually placed at the same time as other footings.

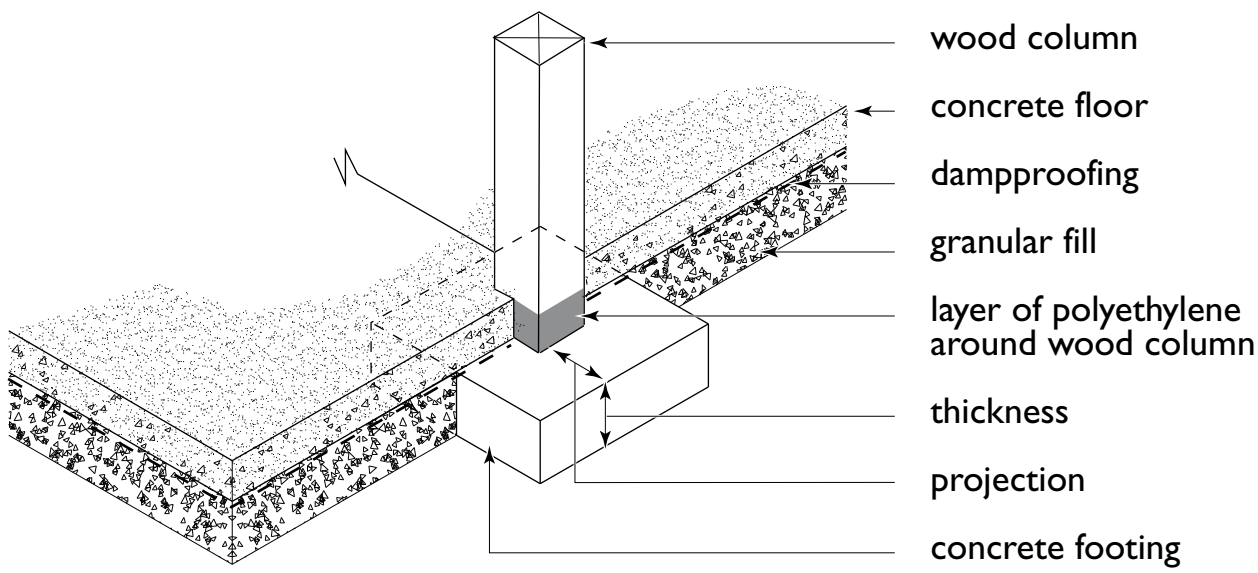
Fabric form footings are an innovative way to cast and form concrete footings using non-woven polypropylene, woven polyethylene or other similar materials, with the fabric supplied in a bag format to form pads for columns or a continuous

32 Steel column supported on steel bearing plate resting on footings



The thickness of the footing must not be less than the projection and never less than 100 mm (4 in.).

33 Wood column supported on concrete footings



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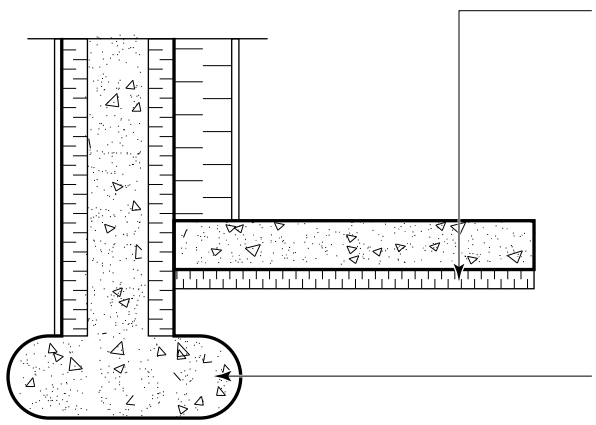
format to form strip footings. The fabric is laid on the ground and, when filled with concrete, conforms to the uneven ground surfaces. The fabric is left in place preventing rapid drying of the concrete and eliminating the need to strip away the formwork. When integrated into foundation forms such as ICF formwork shown in Figure 34, concrete footings and foundation walls can be cast in one continuous concrete pour.

Stepped Footings

Stepped footings may be required on sloping sites or where there is an unstable soil pocket under a footing. They may also be required in split-level houses and walk-out basements. Unless placed on rock, the bottom of each run level of the footing should be placed on undisturbed soil or compacted granular fill. The vertical part of the step should be placed at the same time as the footing.

The vertical connection between footings at the step should be concrete at least 150 mm (6 in.) thick and the same width as the footings (Figure 35). On steep slopes, more than one step may be required. Except in rock, the vertical distance between steps should not exceed 600 mm (24 in.), and the horizontal distance between steps should not be less than 600 mm (24 in.).

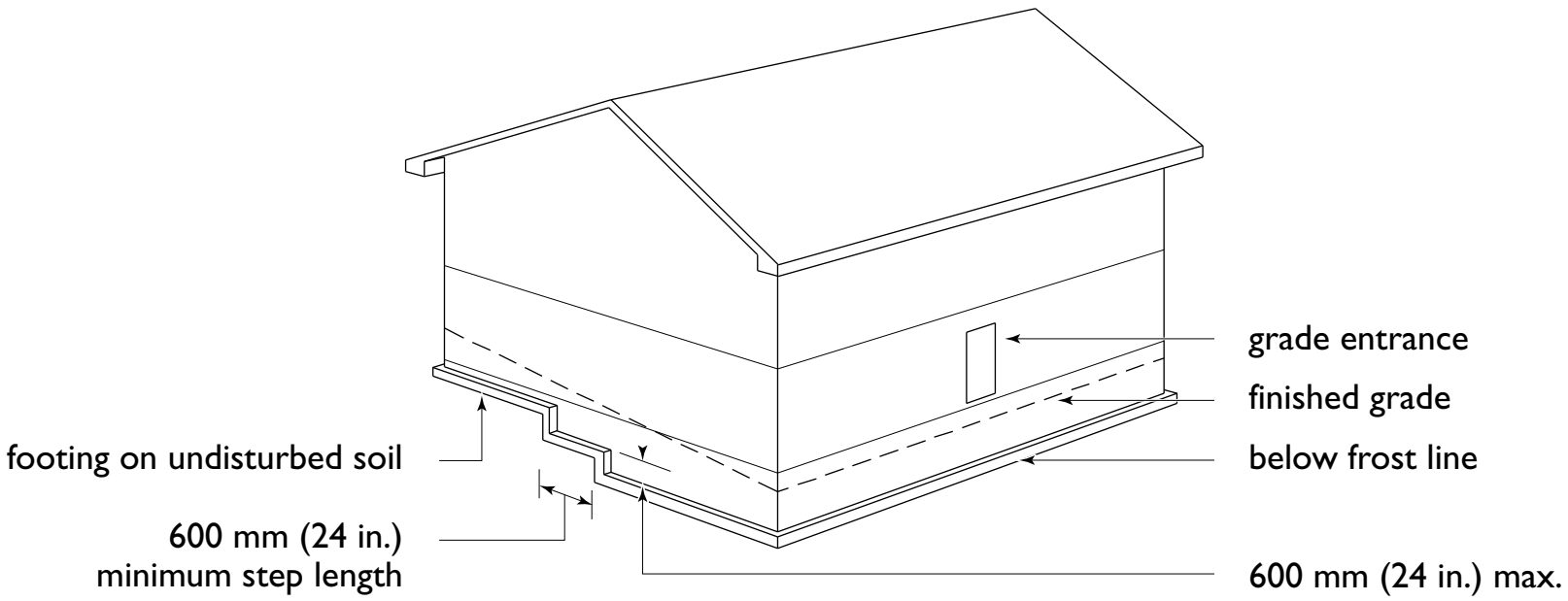
34 Fabric form footing and ICF foundation wall



Sub-slab insulation extruded polystyrene foam board
- provides RSI 3.5 (R20) insulation minimizing heat loss through floor slab
- made using non-ozone-depleting expanding agent

Footing utilizing fabric forming system
- easy leveling
- prevents concrete water from entering water table
- produces a stronger footing
- single concrete pour for walls and footing
- eliminates ground water entry

35 Stepped footings



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For sand or gravel, a vertical distance between steps of no more than 400 mm (16 in.) is recommended. For very steep slopes, or where these limitations cannot be maintained, special footings may be required.

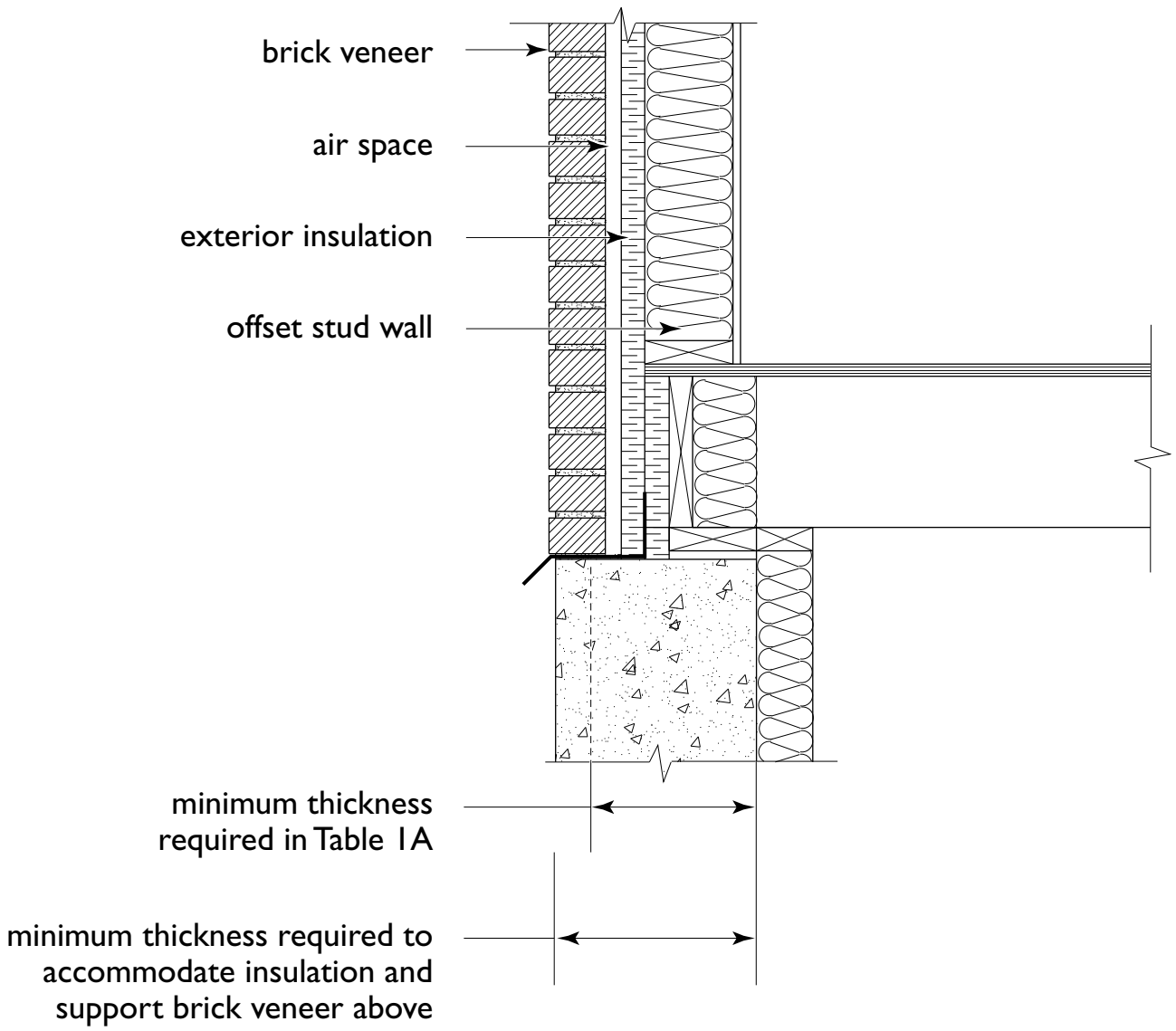
FOUNDATIONS

A foundation wall transfers the floor, wall, roof and other building loads (including snow and occupant loads) down to the footings. The four most common types of foundations are cast-in-place concrete, concrete blocks, insulating concrete forms (ICF) and preserved wood. Precast concrete may also be used.

The required wall thickness of concrete and concrete block walls varies from 150 to 300 mm (6 to 12 in.) depending on their height and depth below grade and the lateral support provided by the floor-framing system. Table 5 (Appendix A) shows minimum foundation wall thicknesses for solid concrete and concrete masonry units in stable soils. Wall thicknesses may have to be increased to support brick veneer and exterior insulation, as shown in Figure 36.

In unstable soils, foundation walls should be built to proven local practices or be designed by an engineer.

36 Adjusting foundation thickness to accommodate insulation and masonry veneer



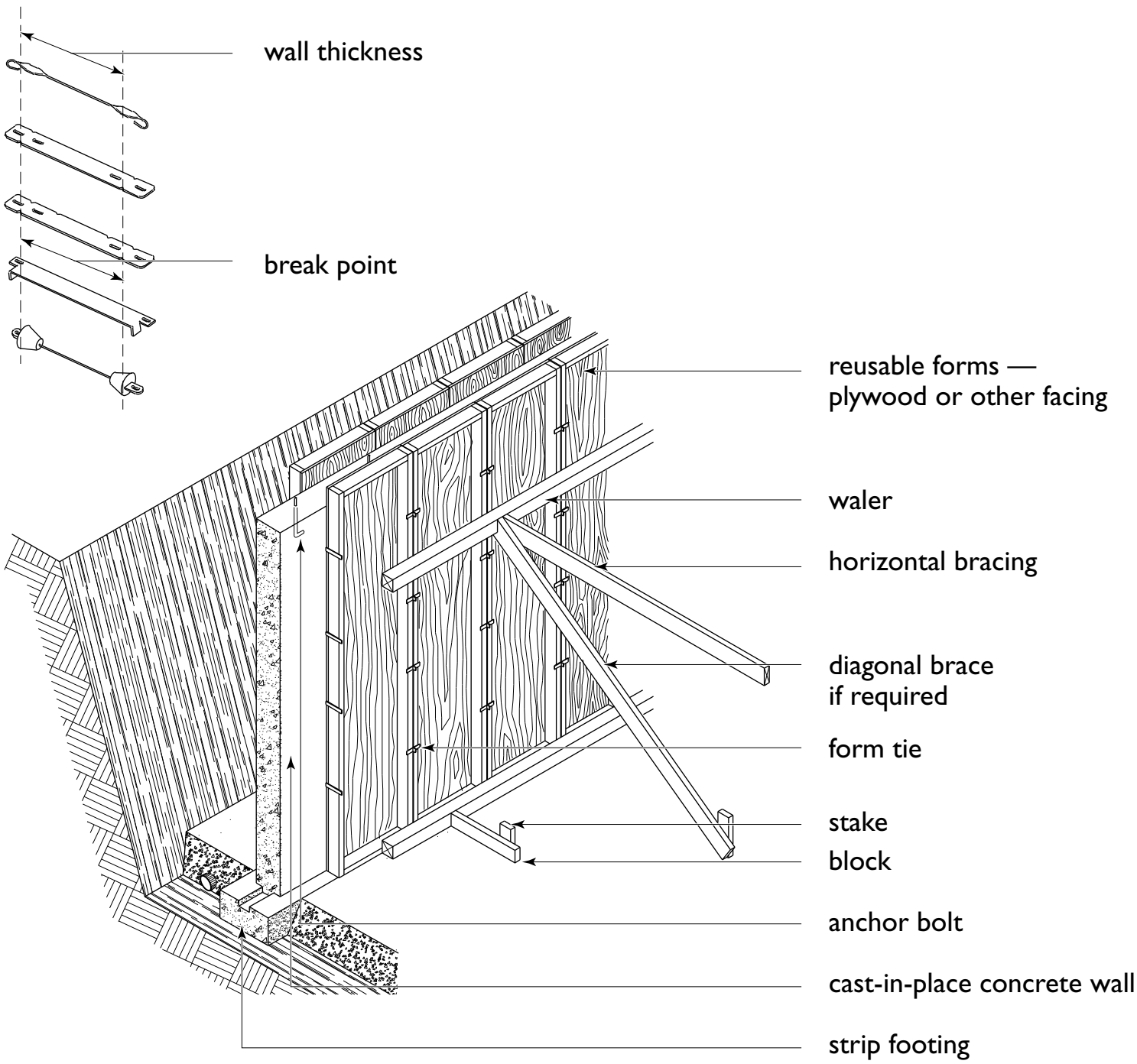
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Formwork for Foundations

Formwork for concrete walls must be tight, well-braced and tied to withstand the pressure of the concrete. Reusable forms are made of plywood or steel. Steel form ties are used to hold the two sides of the formwork together and to serve as spreaders to maintain the necessary width between the formwork (Figure 37). The ends of the ties are usually broken off after the concrete has cured and the holes are patched. Where wire ties are used, wood spacer blocks, whose length equals the finished thickness of the wall, are placed between the faces of the form and removed as the concrete reaches their level. Wire ties hold the forms firmly against the spacer blocks.

Formwork can also be made with lumber (tongue-and-groove or shiplap), supporting members and form ties. It can be built in sections and erected on site. Where the forms are higher than the top of the concrete pour, mark the desired elevation on the forms with chalk lines, pour strips or nails to indicate the desired concrete elevation.

37 Concrete formwork and combination form ties

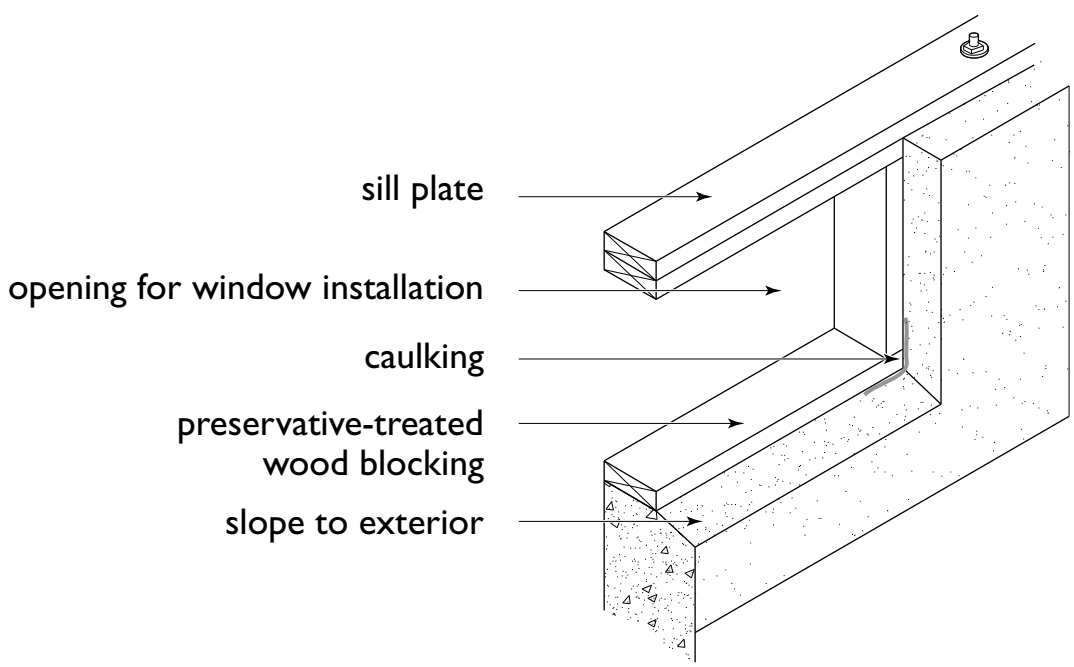


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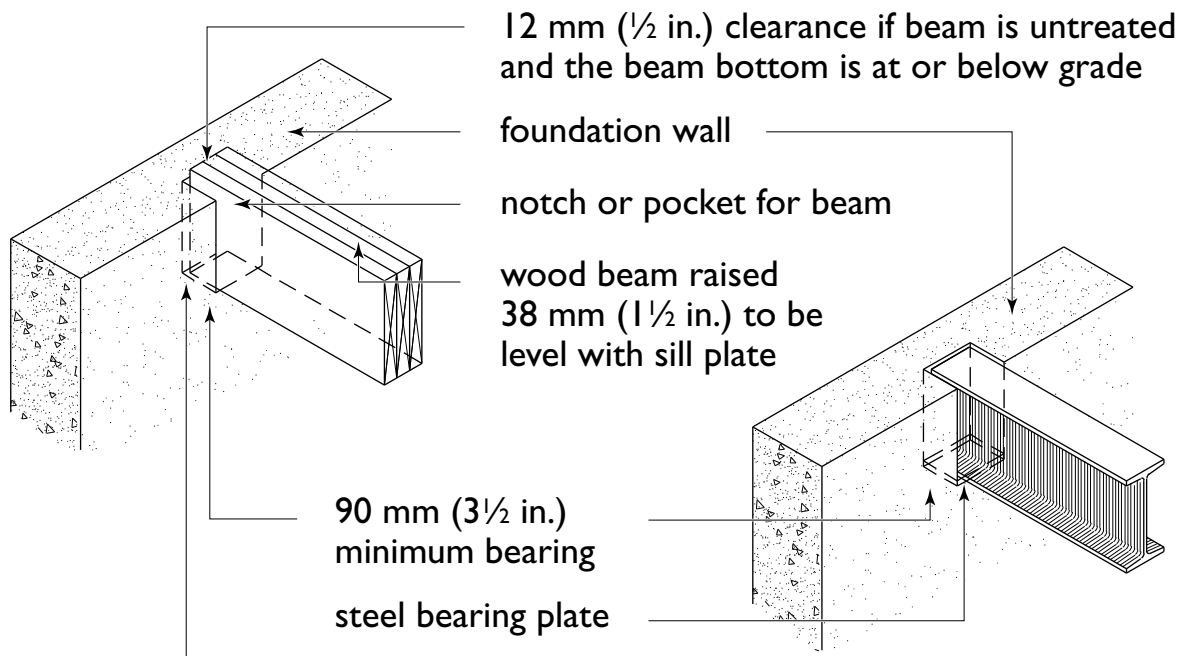
The rough framing for basement windows, doors and other openings, as show in Figure 38, may be installed at the time the foundation wall formwork is erected. Measure and check the diagonals of the frames to ensure that the frames are square. The framing should be properly braced to keep the forms vertical and in place until the concrete has set.

Boxes that will form notches for the ends of floor beams would also be inserted into the foundation formwork prior to pouring the concrete (Figure 39). Treat wood beams abutting concrete below grade with preservative to prevent decay, or leave at least 12 mm (½ in.) of clearance at the sides and ends of the beam for air circulation.

38 Framing for a basement window



39 Notches or beam pockets in foundation walls



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Forms should not be removed until the concrete has acquired sufficient strength to support loads imposed during early construction. At least three days are required, but a week is preferable, particularly in cold weather.

After the forms have been removed, seal all holes and recesses from the form ties with cement mortar prior to the application of dampproofing or waterproofing material.

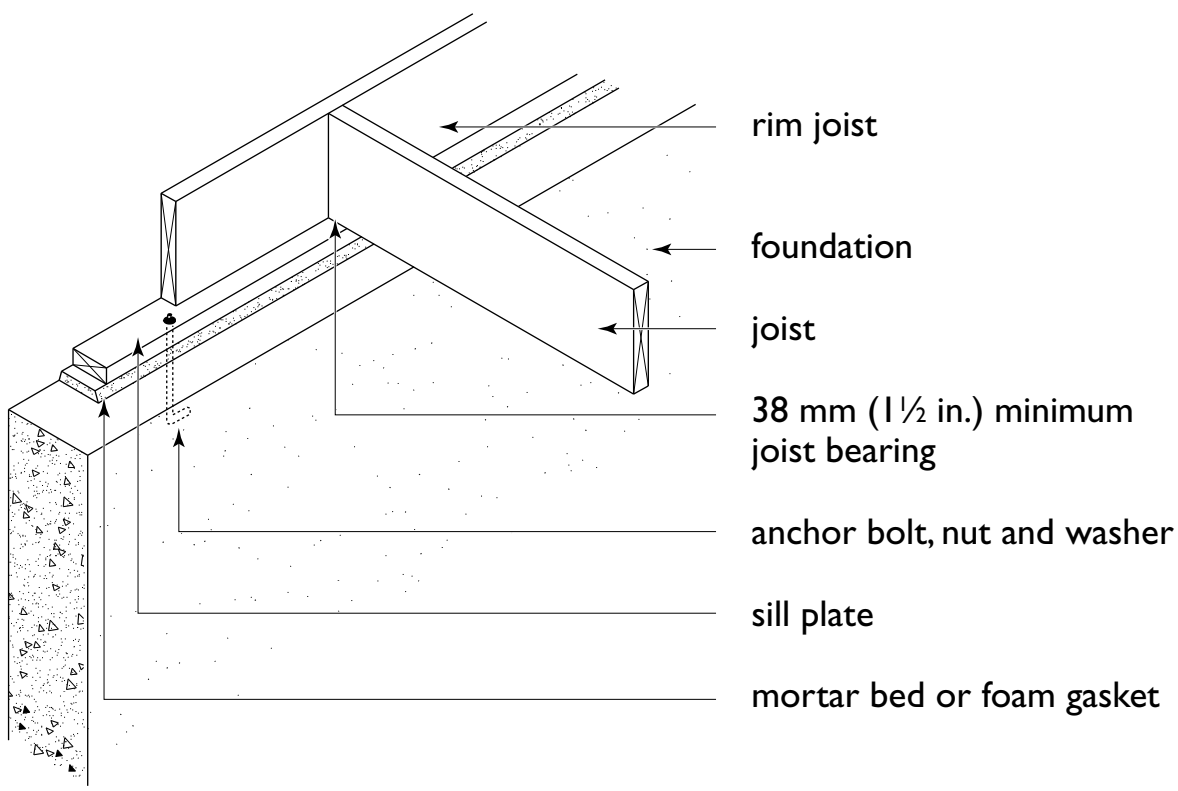
Cast-in-place Foundation Walls

Place concrete continuously without interruption. Tamp or vibrate the concrete to remove air pockets and to work the material around and beneath window frames and other blocking.

Anchor bolts for sill plates should be placed while the concrete is in an unhardened condition. Such bolts are at least 12.7 mm (½ in.) in diameter, spaced no more than 2.4 m (8 ft.) apart (Figure 40) and embedded at least 100 mm (4 in.) into the foundation wall. The ends should be deformed or bent to provide secure anchoring. The bolts themselves should be free of oil, and the concrete should be cured before the bolts are tightened.

Wood-frame buildings with two or more floors situated in areas of high exposure to wind or earthquake require additional anchorage, specifically 12.7 mm (½ in.) bolts spaced not more than 1.7 m (5 ft. 6 in.) on centre or 15.9 mm (⅝ in.) bolts spaced not more than 2.4 m (8 ft.) on centre. In both cases, the first anchor bolt must be located within 0.5 m (1 ft. 8 in.) of the end of the foundation and there must be at least two anchors per braced wall panel. Engineering design is required for the anchorage in areas with *extreme* earthquake or wind loads.

40 Method of anchoring floor system to concrete walls, showing anchor bolt for wood sill



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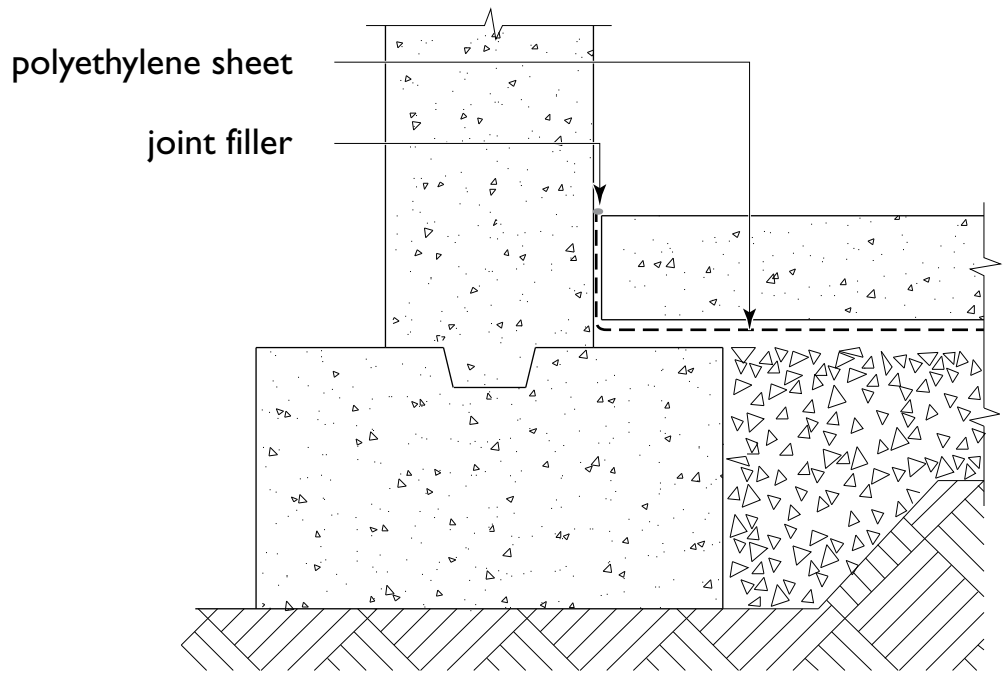
Floor-Wall Intersections

A good seal is necessary between foundation walls and floor slabs to prevent radon gas from entering the basement (Figure 41). The polyethylene moisture barrier underneath the slab should extend at least 100 mm (4 in.) up the inside of the foundation walls and be sealed to the foundation.

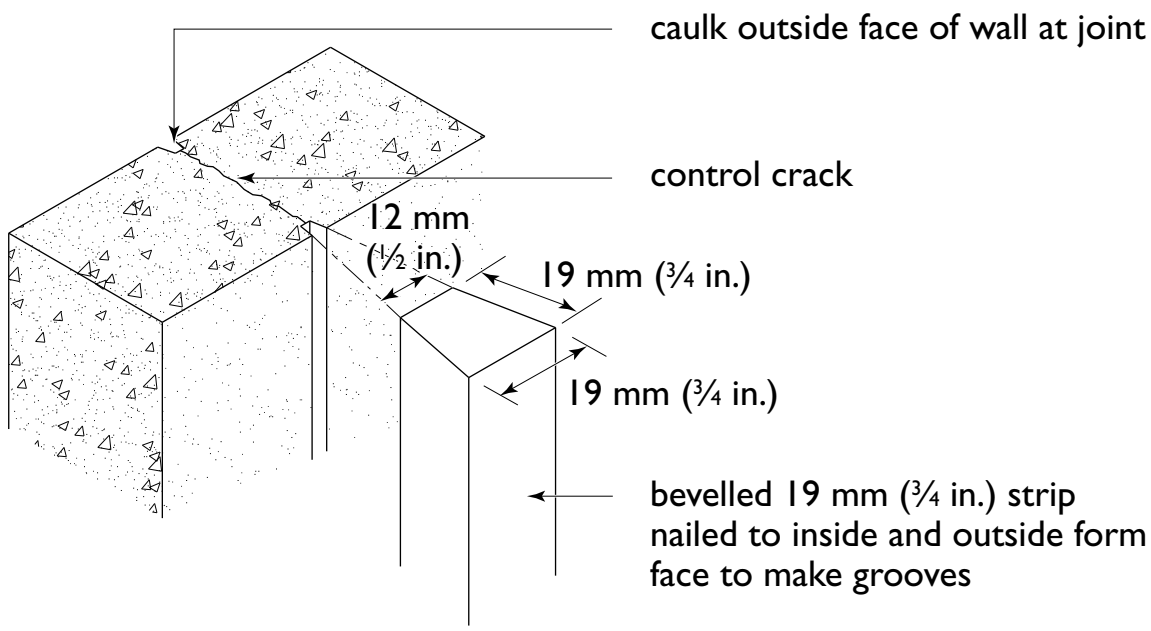
Control Joints

Cracking in concrete slabs and walls can be minimized by using steel reinforcing rods or control joints (Figure 42) formed by nailing bevelled wood strips to the inside of both interior and exterior wall forms. Their purpose is to create a weakness in the wall that will predetermine the location of shrinkage cracks.

41 Typical floor slab/wall isolation joint



42 Control joint in basement wall



Note: The combined thickness of inner and outer strips should equal approximately one-fifth of the wall thickness. This example is for an 200 mm (8 in.) thick foundation wall.

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Control joints are necessary in walls longer than 25 m (82 ft.) and at intervals not greater than 15 m (49 ft.). Locate control joints first at natural planes of weakness such as window and door edges. Control joints are not mandatory but recommended for short walls. After removal of the wall forms, the groove in the exterior face of the wall should be caulked with a good-quality joint sealer. The dampproofing material, applied after the caulking operation, must be compatible with the sealant.

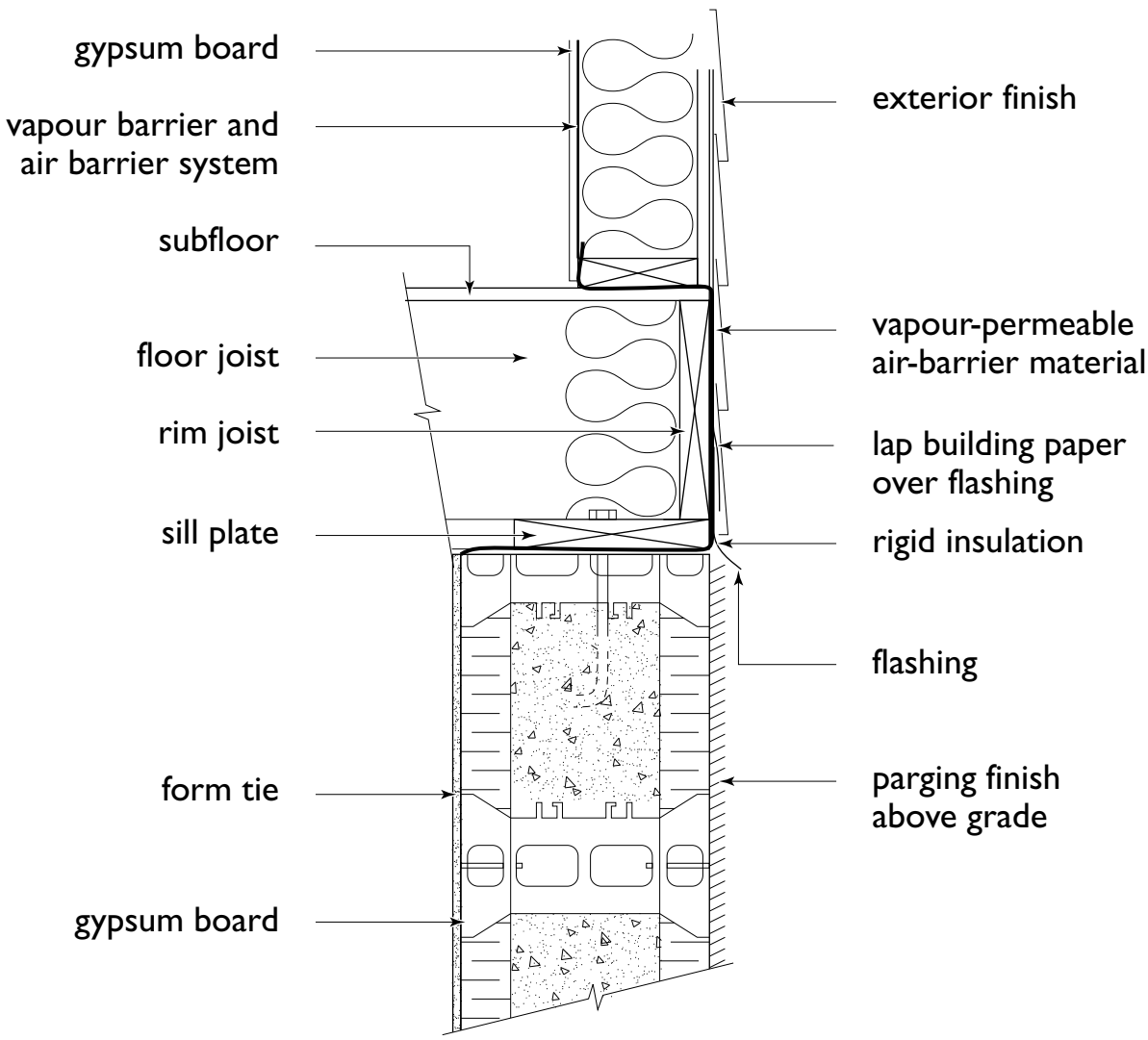
Insulating Concrete Form Foundations

Insulating concrete form (ICF) foundations are made up of two polystyrene faces held apart by permanent plastic or metal spacers and are being used increasingly in Canada.

When concrete is poured into the space between the polystyrene faces, they provide both permanent formwork and insulation for the concrete wall. The polystyrene eliminates the need for form stripping and promotes curing.

For housing applications—foundations not supporting more than two floors with a maximum floor-to-ceiling height of 3 m (10 ft.)—typical concrete thicknesses range from 140 to 240 mm (5½ to 9½ in.). The reinforcing required is dependent on the wall thickness and the height of the backfill supported by the wall. The connection of the ICF foundation wall to the wood-frame floor (Figure 43) is similar to that of the cast-in-place concrete wall without polystyrene forms. Where an ICF foundation supports a masonry wall, the top of the ICF may be flared and reinforced to accommodate the masonry.

43 Insulating concrete form foundation



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ICF foundation walls can be designed by an engineer or built according to simplified, prescriptive requirements that apply to flat ICF walls—solid ICF walls where the concrete is of uniform thickness over the height and width of the wall. In addition, several manufacturers of ICFs have obtained evaluation reports from the Canadian Construction Materials Centre or another evaluation agency or testing lab describing the specific system, its usage and limitations and performance.

Flat ICF foundation walls are required to have one 10M—9.5 mm (⅜ in.)—reinforcing bar placed within 300 mm (12 in.) of the top and other horizontal bars spaced not more than 600 mm (24 in.). The bars must be located in the middle third of the wall and have at least 30 mm (1³⁄₁₆ in.) of concrete cover from the face of the concrete. Vertical reinforcing is also required, with size and spacing determined by wall thickness and height. Reinforcing is also required around large openings.

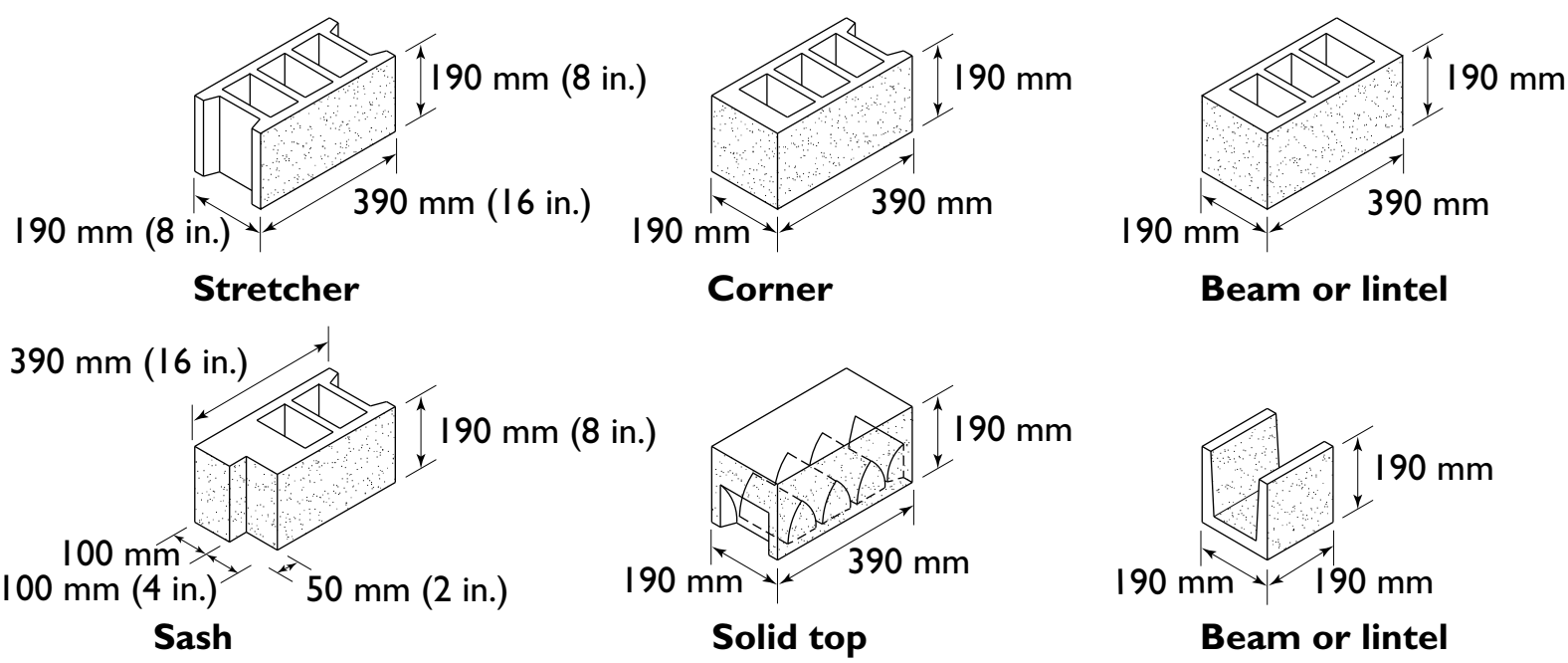
Concrete Block Foundation Walls

Concrete blocks are available in various sizes and shapes, but the most common ones are modular sizes 200 mm (8 in.) high, 400 mm (16 in.) long, and 150, 200, 250 or 300 mm (6, 8, 10 or 12 in.) wide. The actual size is 9.5 mm (⅜ in.) less than the modular size to allow for the mortar joint.

Block courses (rows) start at the footings and are laid up with 9.5 to 12 mm (⅜ to ½ in.) mortar joints. No joint should exceed 20 mm (¾ in.). Tool all joints smooth to resist water seepage. Use full bed and head joints in the bottom course. Succeeding courses may be laid with mortar applied to the contact surfaces of the block. For a higher wall, it may be necessary to add steel reinforcement to a concrete block foundation wall. Pilasters are column-like projections that normally protrude into the basement space. They are sometimes required to strengthen a wall or support a beam, in which case they need to be placed to a set height, usually lower than the top of the foundation.

Use special concrete blocks, such as universal, pier or sash blocks to frame the sides of openings for basement doors and windows. Sash blocks (Figure 44) have a keyed face or recess into which the frames are connected, thus providing rigidity and helping to control air infiltration. Use proper sill and lintel details to achieve the same effect.

44 Concrete blocks for foundation construction



Note: All dimensions are nominal dimensions.

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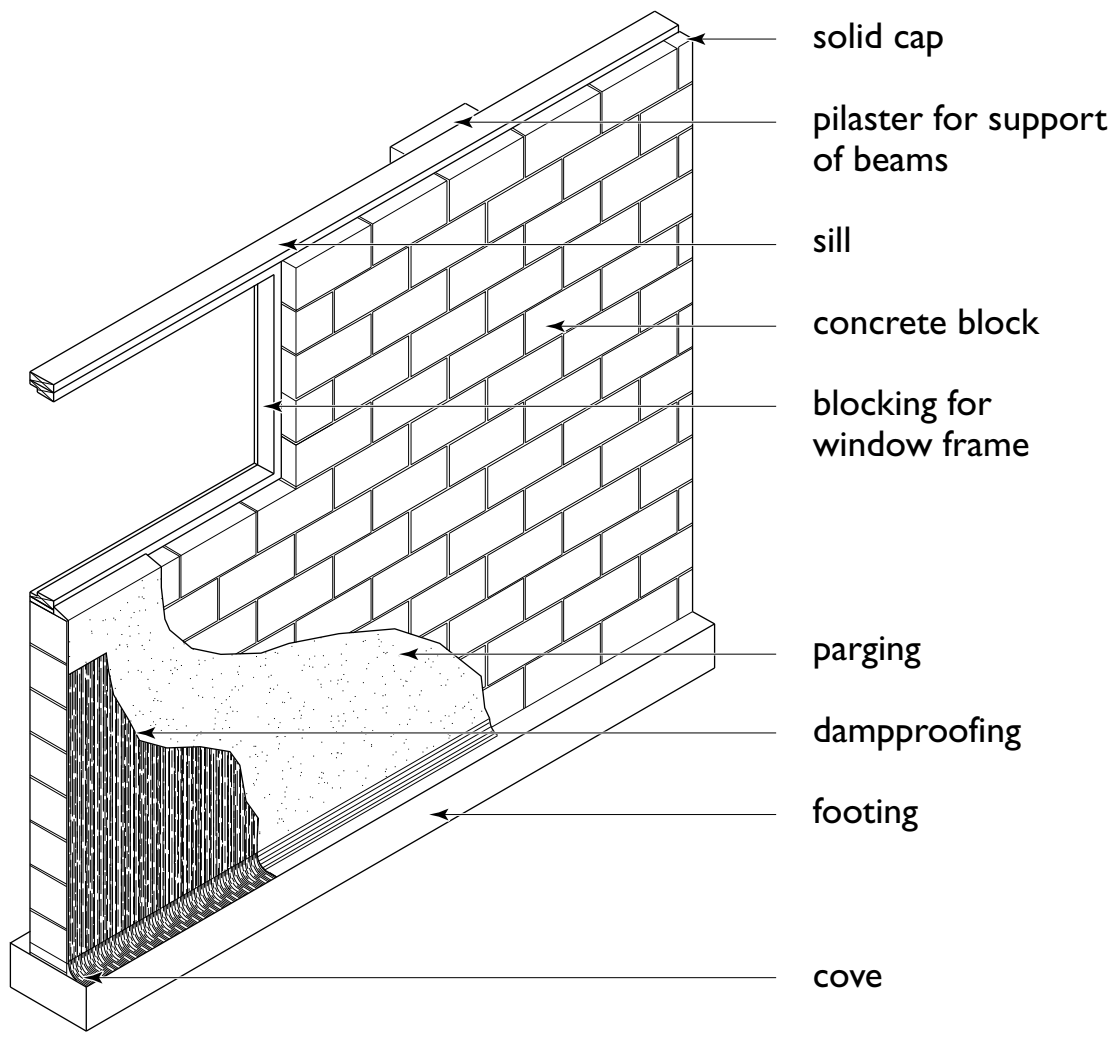
Cap block walls with either 50 mm (2 in.) of solid masonry or concrete, or with a mortar filling in the top block course. Where termites are not a problem, a preservative-treated wood plank 38 mm (2 in. nominal) thick and the same width as the wall may be used. Separate the block courses at grade to prevent convection currents in the cores of hollow masonry walls by filling the upper course with mortar, or using a solid masonry unit.

Siding must overlap the foundation wall by at least 12 mm (½ in.) so that rainwater cannot enter the top of the foundation. Cap pilasters supporting beams with 200 mm (8 in.) of solid masonry.

Protect freshly laid block walls from below-freezing temperatures to prevent low adhesion, low strength and joint failures. Mortar mix proportions should conform to those shown in Table 6 (Appendix A).

Parge the outside face of concrete block walls with at least 6 mm (¼ in.) of Portland cement plaster, forming a cove on the outside perimeter joint between the footings and the wall (Figure 45). Dampproof the wall by applying at least one heavy coat of bituminous material over the parging up to the proposed ground level. For added protection where large quantities of water accumulate in the soil, waterproof the wall by mopping on two layers

45 Concrete block wall



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of bitumen-saturated membrane and cover it with a heavy coating of bituminous material. This covering will help prevent leaks if minor cracks develop in the blocks or joints between the blocks.

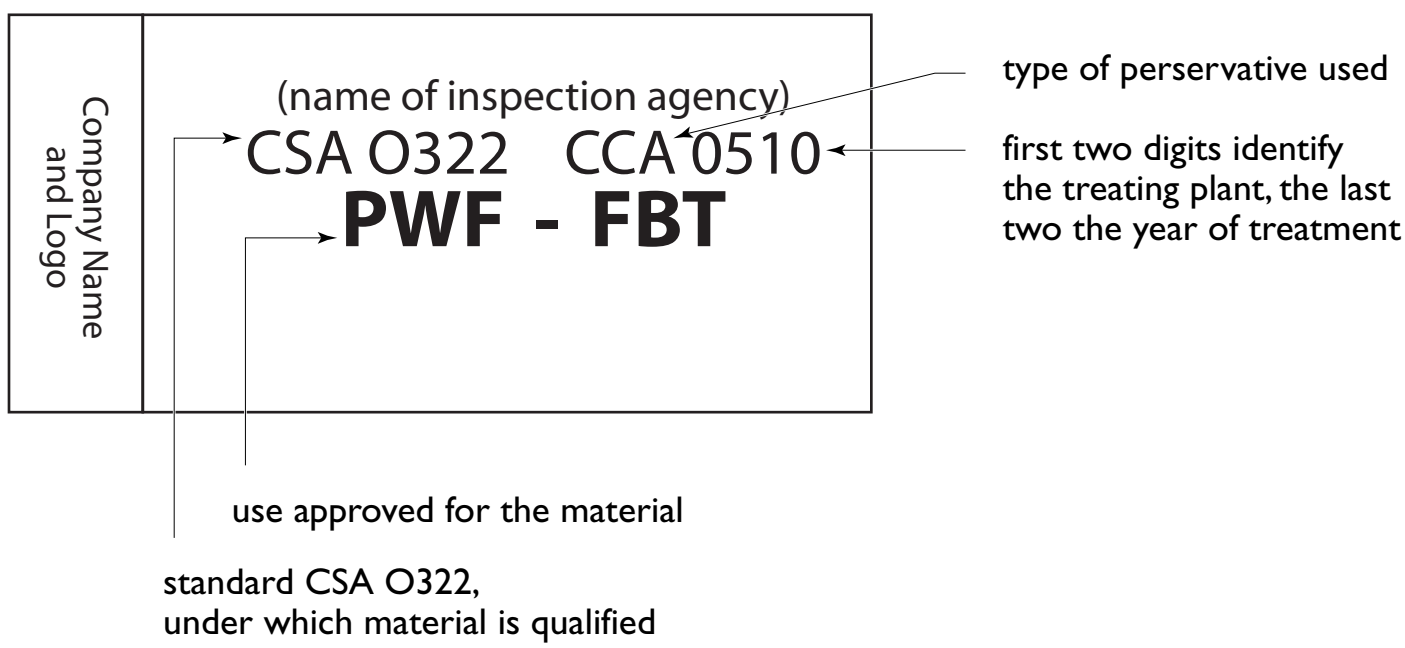
Preserved Wood Foundations

Preserved wood foundations are constructed according to typical framing methods. Some additional bracing requirements must be met and special fasteners used. The foundations consist of a pressure-treated wood footing plate resting on a granular drainage layer, with pressure-treated bottom and top plates, studs and blocking and pressure-treated plywood sheathing covered with a polyethylene sheet for dampproofing. The space between the studs may be filled with insulation and the interior finished to provide a warm living space either partly or entirely below ground level. A polyethylene sheet ground cover is required under preserved wood foundation floors. In addition, place a polyethylene strip between the bottom plate and the footing to keep the plate dry and to prevent moisture from getting into the wall cavity.

All wood framing and plywood used in a preserved wood foundation system must be pressure treated with chemical preservatives in accordance with *Canadian Standards Association (CSA) Standard O80 Series 08: Wood Preservation*. The chemicals permanently impregnate the wood cells to levels of penetration and concentration that make the wood highly resistant to attack by decay organisms and insects such as termites. The dried wood is odourless and is only slightly coloured. Lumber and plywood are identified by a certification mark showing that the material has been treated by a plant certified according to *CSA Standard O322-02 (R2007)* (Figure 46).

Wood foundations can be built with a conventional concrete slab floor, a wood floor on sleepers resting on a granular drainage layer, or a suspended wood floor (Figure 47). The required size, species and grade of studs and thickness of plywood depends on stud spacing and backfill height and the number of storeys supported.

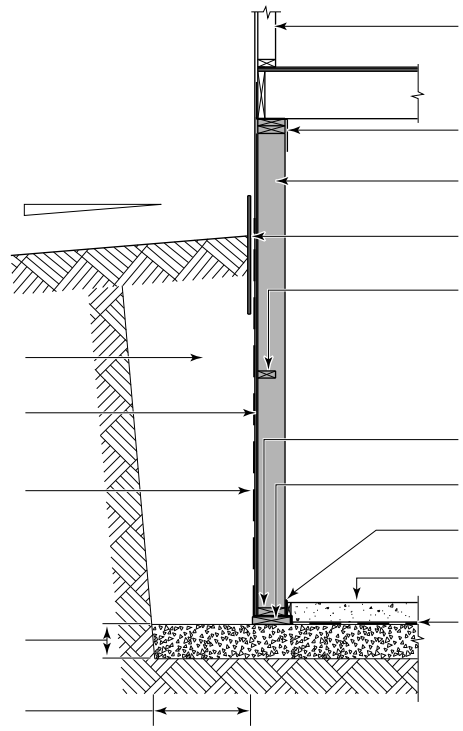
46 Certification mark for preserved wood foundation wood and plywood



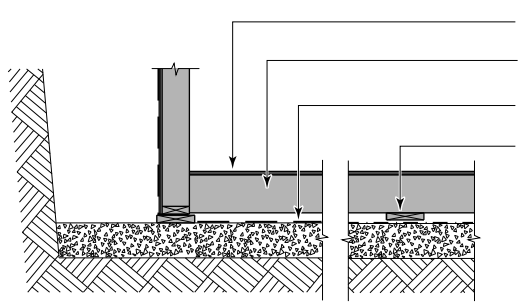
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47 Preservative-treated wood foundations

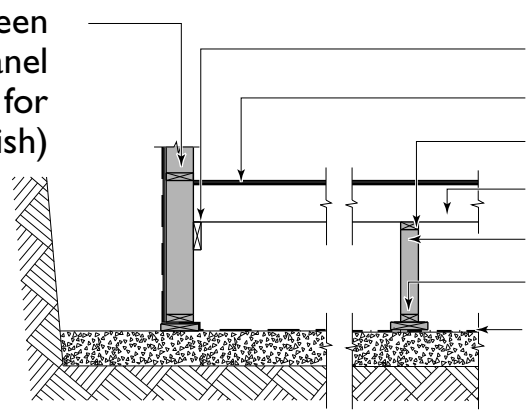
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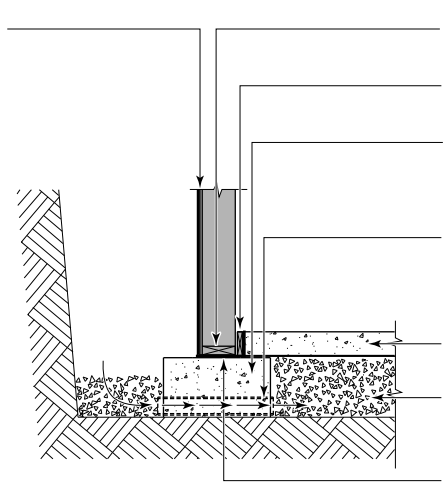
B



C



D



Note: Shaded areas indicate those members that are preservative treated.

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SLABS

Concrete slabs are used for basement floors and for houses or portions of houses constructed at grade. In small buildings, they are generally supported by the ground below and not by perimeter foundations.

Basement Floor Slabs

Basement floor slabs are usually installed after a building has been closed-in, sewer and water lines installed and the basement floor drain put in place. These slabs should be at least 75 mm (3 in.) thick and slope toward the floor drain or sump pit.

There should be at least one drain (or sump pit) located near the laundry area, if one is provided in the basement. Curing concrete gives off moisture that can seriously affect finish flooring, drywall or millwork. Therefore, the basement should be ventilated to allow moisture to escape before finish flooring or millwork is installed.

Floor slabs separating conditioned space from the ground must be constructed with an air barrier system to prevent radon or other soil gases from entering. An effective air barrier system for floors-on-ground is provided by:

- minimizing concrete cracks;
- providing a barrier material under the floor. In most cases, this will be accomplished by placing 0.15 mm (6 mil) polyethylene under the floor; and,
- sealing voids, joints and penetrations.

The usual construction sequence for a concrete floor slab is as follows:

1. Complete the installation of sewer lines and other subsurface work before the slab is placed. Compact backfill in trenches.
2. Place at least 100 mm (4 in.) of crushed rock or coarse gravel under the floor slab to restrict the passage of moisture by capillary action from the ground to the slab and to facilitate soil gas remediation if necessary.
3. Consider installing rigid polystyrene insulation over the gravel base in cold climates, when the basement may contain habitable space, or when the basement floor slab will be heated.
4. Apply the layer of 0.15 mm (6 mil) polyethylene sheet below the slab to dampproof the floor and provide a barrier to soil gas, including radon, and seal it to the foundation wall at the perimeter. Where the water table is high, waterproofing the slab will be necessary.
5. To allow for slight movement due to shrinkage of the slab during drying and settling of the sub-base, provide a pre-moulded joint filler or double layer of sheathing paper, or extend the under-slab polyethylene (Figure 41) between the floor slab and wall or column. Seal the joint filler, sheathing paper or polyethylene to the polyethylene air barrier/dampproofing membrane on the wall to keep radon from entering the living space.
6. Place and consolidate the concrete, then strike it off with a straightedge to the proper elevation. This can be determined by measuring down from the bottom of properly levelled floor joists. In order to eliminate local high or low areas and to embed large aggregate particles, the surface is then immediately smoothed using a large darby or bull-type float or by other appropriate means. Tools used for air-entrained concrete should have a magnesium surface. Take care not to overwork the concrete, because this will result in a less durable surface.

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7. After the water sheen has disappeared and as soon as the concrete can support foot traffic without indentations occurring, edging, jointing and floating operations can begin. Performing any of these operations while bleed water is present will cause serious dusting or scaling.

8. Proper control jointing or grooving may be necessary to avoid minor random cracking in the slab. Control joints should be placed on line with interior columns and at changes in width of the floor slab (Figure 48). The maximum spacing of control joints should be between 4.5 and 6.0 m (15 and 20 ft.) in either direction. Joints may be formed in the freshly placed concrete by cutting grooves by hand with a jointing tool as soon as the concrete is firm enough. The depth of joints should be about one-quarter the thickness of the floor slab.

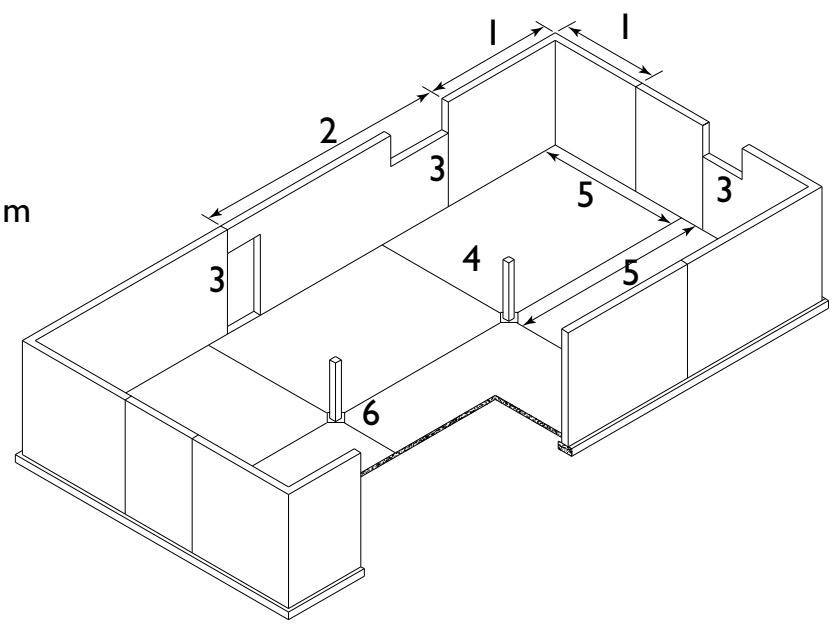
9. As soon as the floor surface has been finished, curing should begin. It should continue for at least five days at air temperatures of 21°C (70°F) or higher, or for seven days at temperatures of 10 to 21°C (50 to 70°F). Curing may be carried out by ponding water on top of the slab (by temporarily plugging all floor drains), or by covering with burlap kept continuously wet. If this is not practical, liquid, membrane-forming curing compound may be spread on the concrete surface. Use curing compounds that are compatible with tile adhesives if the floor finish is to be tiled.

The 2010 NBC provides specific protection against future radon ingress into conditioned spaces in housing by requiring compliance with one of the following two methods:

- The first method requires a gas-permeable layer between the ground and the air barrier that allows for depressurization of the space below the soil gas barrier. This layer could be coarse sand or a dimpled membrane or another product that allows the collection and extraction of gas. An inlet needs to be provided that allows for effective depressurization of the gas-permeable layer. An outlet must be provided that permits

48 Location of control joints

1. control joints within 3 m (10 ft.) of corners
2. spacing of joints 6 m (20 ft.) maximum
3. joints incorporate side of opening
4. control joint in floor slab
5. floor slab joint spacing of 6 m (20 ft.) maximum
6. control joint around column footings (see note)



Note: The diamond-shaped joints (6) may be omitted if column footings are below floor level and the column is wrapped with two layers of sheathing membrane or joint filler to break the bond.

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connection to depressurization equipment sealed to maintain the integrity of the air barrier system. The outlet should be clearly labelled to indicate that it is intended for the removal of radon from below the floor-on-ground. An example of this method would be a sump chamber that is sealed to the air barrier, which can be connected and used to exhaust air from beneath a floor-on-ground.

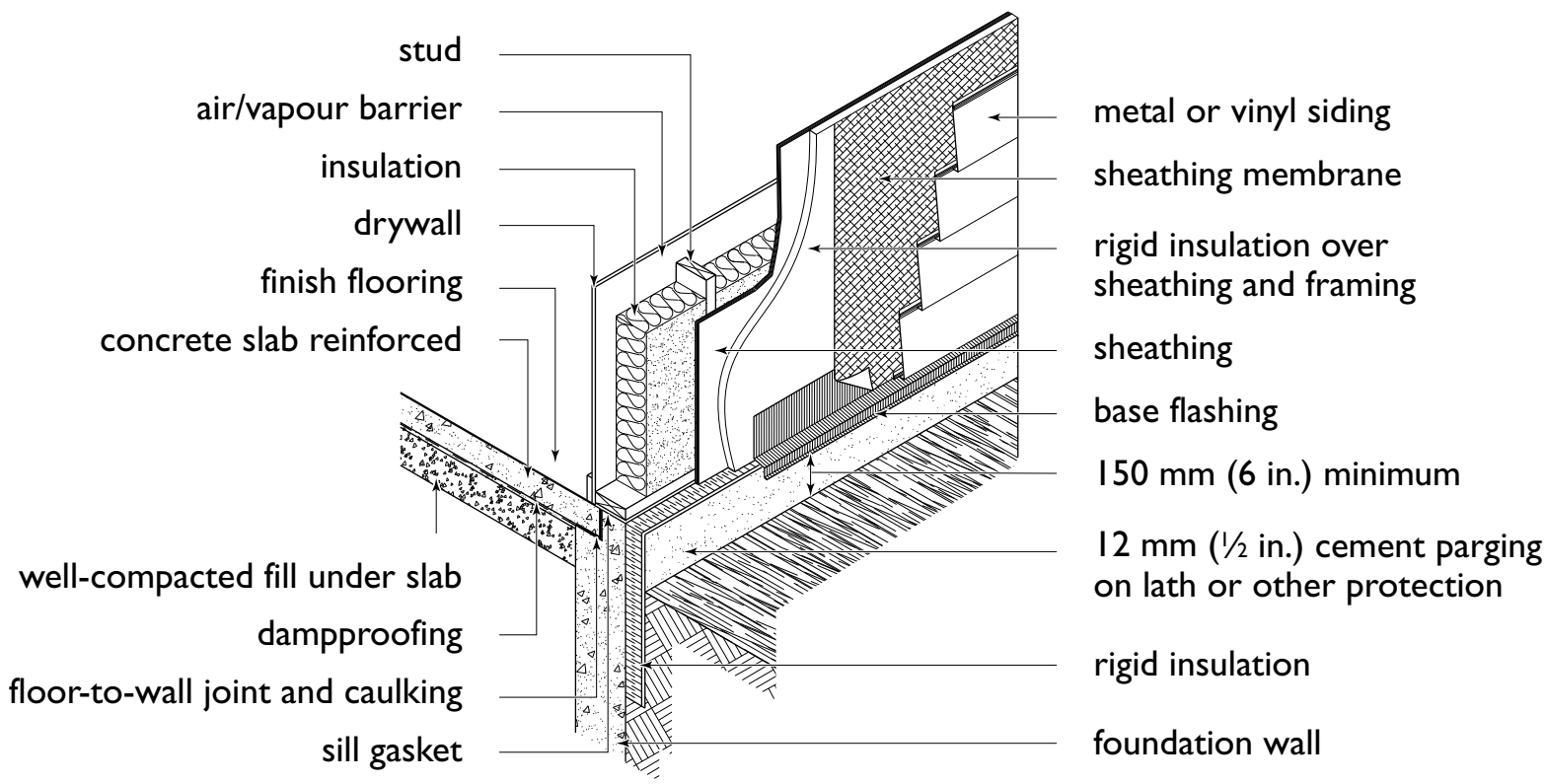
- The second method is more specific and requires a 100 mm (4 in.) layer of clean, granular material under the floor-on-ground and a pipe at least 100 mm (4 in.) in diameter through the floor. The lower end of the pipe extends into the required granular layer. The top of the pipe must be fitted with an airtight cap. If there is a desire to locate the pipe rough-in close to an exterior wall or into the service area of a basement, a normal plumbing pipe can be used to connect the vertical pipe to the center of the sub-floor. If the sub-floor space is interrupted by internal footings, it is important to ensure that the collection system is capable of depressurizing all areas.

Slabs-on-ground

Because slabs-on-ground have requirements similar to those pertaining to basement floor slabs, the steps and precautions described for the latter apply here as well. An important difference is the need to establish the finish floor level at a sufficient height above the natural grade so that the finished grade will provide good drainage away from the house (Figure 49). The top of the slab must be at least 150 mm (6 in.) above finished grade.

Remove all debris, stumps and organic matter from the area below the slab and fill voids with compacted granular material to provide a smooth surface free of soft pockets.

49 Independent concrete floor slab and foundation wall



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Install water-resistant rigid insulation around the perimeter of the slab and protect it from physical or ultraviolet damage with parging or a board finish. To resist cracking, reinforce the slab with 9.5 mm (⅜ in.) thick steel reinforcing bars spaced 600 mm (24 in.) on centre in both directions. (The steel bars have a metric product designation of 10M.) Alternatively, welded wire mesh can be used that forms a grid of 152 mm (6 in.) squares in which the thickness of the steel is 3.4 mm (0.15 in.). [The metric product designation of this grid is 152 × 152 mm (MW 9.1 × 9.1.)]

A mechanical float finish provides a smooth finished surface.

The requirements for footings and foundations for houses with slabs-on-ground are similar to those for crawl spaces and constructed in the same manner. A structural slab, which supports loads from vehicles or the walls above, must be designed by an engineer.

FOUNDATION DAMPPROOFING

Dampproofing is necessary for all foundations that contain habitable space to restrict the movement of soil moisture into the wall. Dampproofing materials include bitumen, polyethylene or other sheet material. In poorly-drained soils or soils with a high water table, waterproofing will be required.

Dampproof concrete and unit masonry walls below grade with a heavy coat of bituminous material applied on the exterior surface from the footings to the finished grade line. Such a coating is usually sufficient to make the wall resistant to surface water moving down to the footing drainage system. Mineral fibre insulation or drainage layers are recommended to drain water away from the foundation walls.

Insulating concrete form (ICF) foundations must also be dampproofed and the material used must be compatible with the foam formwork/insulation.

When backfilling walls, avoid causing damage to the dampproofing, waterproofing, insulation or drainage layer.

Dampproofing is also required on the interior of concrete or unit masonry walls that come into contact with interior wood framing supporting insulation or interior finishes. When installed between the foundation wall and interior framing, the dampproofing prevents moisture in the foundation wall from coming into contact with the wood framing. It usually consists of building paper applied on the inside of the wall, and must extend from the basement floor and terminate at the exterior finish grade level.

WATERPROOFING

Waterproofing is needed where there is a likelihood of hydrostatic water pressure and requires the services of a qualified professional to identify which measures are to be taken to deal with the water and the forces imposed on the foundation. Waterproofed foundations need not be dampproofed. For walls, waterproofing consists of an impermeable membrane, such as two layers of bitumen-saturated felt. The layers of felt are attached to the wall and each other and covered with liquid bitumen. Waterproofing materials for ICF foundations must be compatible with the foam formwork/insulation.

Floor slabs must also be waterproofed where hydrostatic pressure could be an issue. The waterproofing materials must consist of a membrane sandwiched between two layers of concrete, each layer not less than 75 mm (3 in.) thick. The floor membrane must be sealed to the wall membrane. In many cases,

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foundations subjected to hydrostatic pressure are also equipped with a means of relieving the water pressure to prevent structural damage.

FOUNDATION DRAINAGE

Foundation drainage is required unless it can be shown that natural, free-draining soil makes it unnecessary. Foundation drainage normally consists of a drain pipe installed around the perimeter of the basement and usually a wall drainage layer. A layer of granular material can be used in lieu of a perimeter drain for foundations such as preserved wood foundations, where the granular layer slopes to a sump.

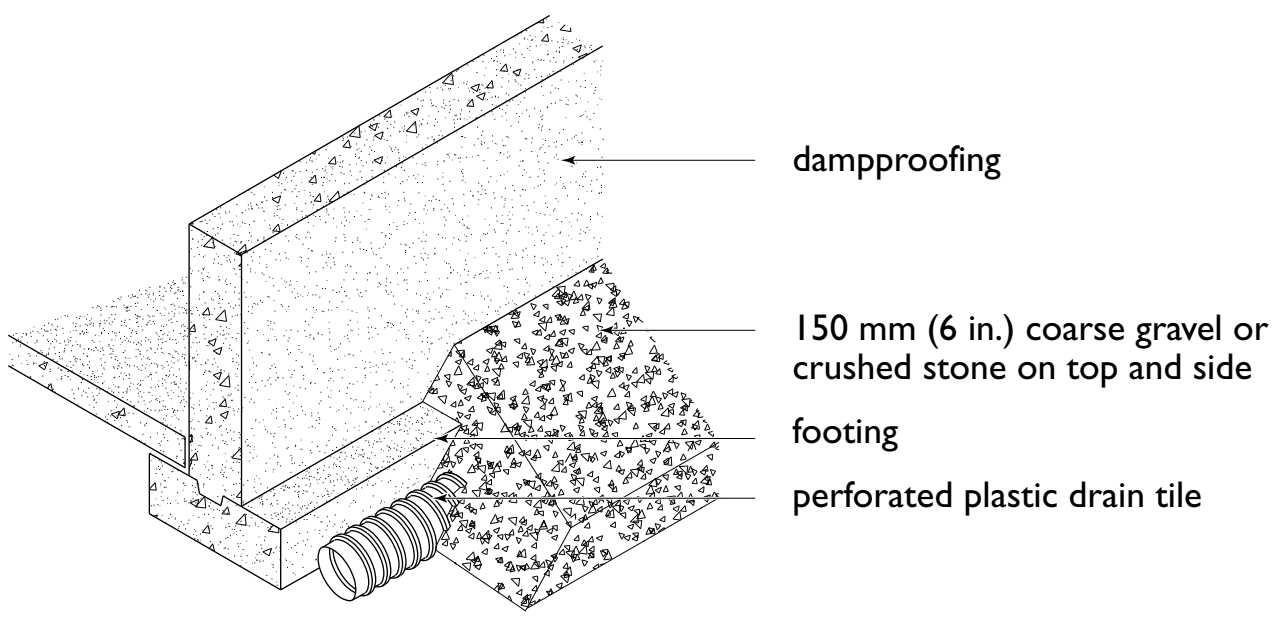
Adequate drainage is essential to prevent the infiltration of water into the basement. Drain pipe should be laid on solid undisturbed soil around the footings, with the top of the pipe below the level of the basement floor or crawl space, and with a slight slope to the outlet. Cover the pipe with a minimum of 150 mm (6 in.) of coarse, clean gravel or crushed rock (Figure 50). The pipe should be wrapped with a filter fabric "sock" to prevent fine particles in the backfill from clogging the drain. Backfill must not contain pyritic shale or materials finer than 4 mm (5⁄32 in.).

Connect the drain pipe with a tight joint to a storm sewer or other satisfactory outlet. A sump may be necessary in some cases.

On wet sites, special drainage features such as lateral drain pipes under the floor slab may be needed to avoid hydrostatic pressures on basement walls and slab. Note that foundation drainage is not intended to deal with high water tables. Foundations located on sites with high water tables must be designed by an engineer.

For a preserved wood foundation, a granular layer must be employed in combination with a sump. The granular layer must be at least 125 mm (5 in.) thick under the footings and extend at least 300 mm (12 in.) beyond the edge of the footings (Figure 47). Slope the bottom of the excavation so that it drains to the sump, which must be drained by gravity to a sewer, ditch or dry well, or evacuated by pumping.

50 Drain pipe at foundation wall



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The granular layer technique is applicable to any type of foundation that includes a sump.

Drainage layers may be applied to the outside of the basement wall to direct any infiltrating rainwater that comes into contact with the foundation wall down to the drain pipe or granular layer and away from the wall. Consult the local building department to determine whether drainage layers or membranes are required.

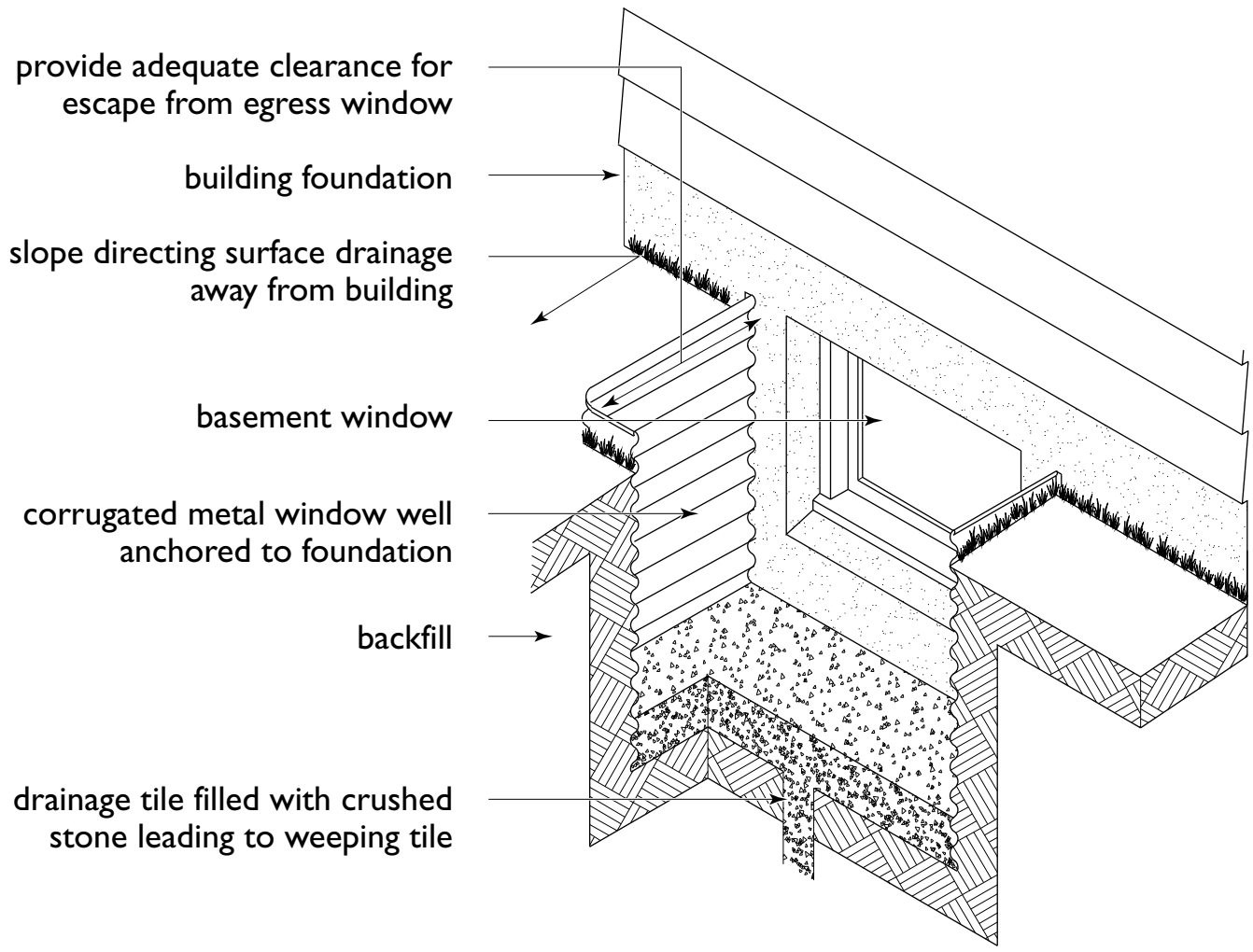
Wall drainage layers normally consist of 19 mm (¾ in.) or thicker mineral-fibre insulation with a density of at least 57 kg/m^3 (3.6 lb./cu. ft.) or other commercially available wall drainage materials. Alternatively, free-draining granular material may be used as backfill. It is important that the drainage layer direct water to the drain pipe, avoiding any ponding at the base of the foundation wall. The granular fill surrounding the drain pipe should also cover the drainage layer at the base of the wall.

Basement windows that extend below ground level require window wells (Figure 51) to direct water away from them. Corrugated steel frames are commonly used for this purpose.

When the backfill is not a granular material, the bottom of the window well should be drained by a pipe or hole 150 mm (6 in) in diameter installed through the backfill material to the drain pipe and filled with crushed stone.

Where a bedroom window with sliders, casement or inward-opening awning opens into a window well, it must have a clearance of at least 760 mm (30 in.) in front of the

51 Window well at basement wall



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window to allow for escape in the event of emergency. Additional clearance is required for outward-opening awning windows.

BACKFILLING

Place backfill after the first floor joists and subfloor are in place because they provide lateral support for the foundation walls. This applies to concrete, ICF, masonry and preserved wood foundation walls. Table 5 (Appendix A) shows the maximum height from basement floor to finished grade for both laterally supported and laterally unsupported foundation walls.

Backfill material within 600 mm (24 in.) of the foundation should be free-draining granular material (not subject to ice lensing). It should be free of large rocks, clay clumps, construction waste and pyritic shales. These materials can cause pressure points on the foundation wall, damage dampproofing or waterproofing membranes, and impair proper drainage around the foundation.

Unequal backfill loading against foundation walls can cause movement or cracking. Therefore, deposit backfill material uniformly around the perimeter in small lifts. Compact each lift before the next one is placed. Ensure that externally mounted insulation, drainage material, dampproofing or waterproofing membranes are not damaged.

FOUNDATION INSULATION

Foundation (basement) walls are required to be insulated if they enclose conditioned space. Basement floors with radiant heating must be insulated underneath. The levels of insulation required are determined by the climate zone in which the house is built. See Chapter 5 for more detailed information.

Foundations can be insulated on the interior or the exterior of the building. Foundation walls enclosing conditioned space should be insulated along their full height. To reduce the possibility of trapped moisture, it is recommended that concrete foundation walls insulated on the interior be left exposed for several months so that they lose excess moisture before the insulation is applied. When batt insulation supported by wood framing is used, interior dampproofing material must be used to separate the framing from the concrete walls. With framing in place, it is relatively economical to add drywall to create a finished wall. When spray-foam or polystyrene insulation is installed on the interior of basement walls, it must be covered by a barrier such as drywall to protect it in the event of fire.

Basement walls can also be insulated on the exterior. Some exterior insulation products also serve as a wall drainage layer. The portion of the insulation that extends above grade must be covered by a protective material.

FOOTINGS AND FOUNDATIONS FOR CRAWL SPACES

Crawl spaces are enclosed spaces between the underside of a floor assembly and the ground below, where the clearance is less than the minimum 2 m (6 ft. 6 in.) required for a basement and less than 25 per cent of their area above ground is open to the outdoors. Crawl spaces are often used to give access to ducts, pipes, cables and other utilities and can be heated (conditioned) or unheated (unconditioned). If a crawl space is unheated, it is essential to have an effective air barrier between the conditioned and unconditioned space.

As for other types of foundations, footings for crawl spaces must be placed at a depth below grade determined by soil conditions and frost penetration (see Table 3 in Appendix A). Footing sizes are generally the same as those used to support basement walls. Crawl space

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walls may be built of concrete, ICFs, concrete masonry units or preserved wood. Since the inside grade is seldom much lower than the outside grade, the thickness of the foundation walls may be less than those enclosing a basement. Crawl space insulation, which can be installed either at the perimeter of the foundation or in the floor framing under the living space, is discussed in Chapter 5.

Crawl Space Ventilation and Ground Cover

Crawl space walls below the level of the outside finished grade must be dampproofed. Install drain pipe around the footings and connect it to a sewer, ditch or dry well. Slope crawl space floors and access trenches toward the floor drain. For unheated crawl spaces, install a ground cover of concrete, asphalt or 0.15 mm (6 mil) polyethylene or Type S roll roofing over the ground surface with the joints lapped at least 100 mm (4 in.). For heated crawl spaces, install a 0.15 mm (6 mil) polyethylene sheet with joints lapped at least 300 mm (12 in.), sealed and weighted down, or, covered with at least 50 mm (2 in.) of concrete. The ground cover prevents ground moisture from entering the crawl space area. The crawl space must be conditioned like the remainder of the house, or ventilated (see Chapter 20), in which case the floor above must be insulated and be provided an adequate air barrier system and vapour barrier.

FOUNDATIONS FOR DECKS AND CONCRETE STEPS

Frost action can cause supports for exterior decks, balconies and stairs to shift. Movement can cause structural damage and may allow water to drain towards the house. For this reason, balconies with roofs, concrete steps with more than three risers, and decks more than 600 mm (2 ft.) above the ground require their supports to be founded on rock, on coarse-grained soil with good drainage, or, for other types of soils, the supports must extend below the frost line (Figure 175 in Chapter 26).

GARAGE FOUNDATIONS

Foundations for garages are usually concrete or masonry. Concrete slab-on-ground or preserved wood foundations are also options. The minimum depth below grade for a garage foundation attached to a house should not be less than that shown in Table 3 (Appendix A).

If fill is required below the floor, use compacted granular material to avoid settlement after the floor is placed and loads applied. The concrete floor should be at least 75 mm (3 in.) thick. Provide an airtight curb or partition at least 50 mm (2 in.) high at the edges of the slab adjacent to interior space, and slope the garage floor to the outdoors.

Place and cure concrete garage floors the same way as basement floor slabs. Provide control joints so that the concrete segments are similar in size. For a single car garage, one control joint dividing the floor into two roughly square segments should be sufficient.

The foundation walls should not be less than 150 mm (6 in.) thick and should extend at least 150 mm (6 in.) above grade.

Sill plates should be anchored to the foundation wall or slab with anchor bolts spaced not more than 2.4 m (8 ft.) apart and with at least two bolts in each sill piece. Extra anchors may be required at the side of the main door and in areas with high earthquake or wind exposure.

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SUSTAINABLE HOUSING INSIGHT

Healthy Indoor Environment

- Basements are places where radon and other soil gases can enter. It is therefore essential that basement floors and slabs and any penetrations such as sump pits and floor drains be airtight. Builders are now required to provide a stub for a sub-floor radon collection system that can be connected and vented outside should radon or soil gases prove to be a problem.
- Damp basements can be conducive to mold. Dry basements provide a healthier environment for people and better conditions for storage. Provide foundation dampproofing, perimeter drainage and insulation on the foundation wall to reduce or eliminate condensation on interior surfaces. A capillary break between the footings and the walls is recommended.
- Consider shallow basements in properties with high water tables to reduce the risk of water entering the foundation. Shallow basements can have large windows for better natural illumination and ventilation and to enhance safety for those having to exit below-grade living spaces.

Energy Efficiency

- The NBC requires that basement walls and some basement floors be insulated to a level determined by the number of heating degree days where a house is built.

Resource Efficiency

- Consider using fabric forms for concrete footings.
- Re-use formwork boards for rough framing and blocking.

RELATED PUBLICATIONS

CAN/CSA Standard O80 Series-08: Wood Preservation,
Canadian Standards Association

CAN/CAS Standard S406-92 (R2008): Construction of Preserved Wood Foundations,
Canadian Standards Association

CSA Standard O322-02 (R2007): Procedure for Certification of Pressure-Treated Wood Materials for Use in Preserved Wood Foundations,
Canadian Standards Association

Permanent Wood Foundations,
Canadian Wood Council (product No. PWPD-06-E)

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CHAPTER 8
Framing the House



Wood-frame construction combines repetitive framing elements such as wall studs, floor joists and roof trusses with floor, wall and roof sheathing to produce rigid building assemblies capable of resisting wind, earthquake, snow, occupant and construction loads. For housing applications, the repetitive framing members are spaced no more than 600 mm (24 in.) apart, the span of structural members must not exceed 12.2 m (40 ft.), and the design load due to occupants and contents must not exceed 2.4 kPa (50 psf). The repetitive framing members may be dimension lumber or engineered wood products such as trusses or wood I-joists.

The structural shell consists of the foundation, floors, walls and roof (see Appendix B). If a house has load-bearing interior walls, they must be erected at the same time as the exterior walls. The shell must be framed and sheathed to provide rigidity. Temporary bracing and cross-bracing may also be required to allow construction to proceed safely.

The framing method and depth and spacing of members affect insulation levels and must be considered carefully. Refer to Chapter 5 for more information.

This book shows metric dimensions followed by an approximate imperial equivalent (in brackets). Not all dimensions are exact. Although a 2 × 4 in. framing member is shown in its exact 38 × 89 mm dimensions, the metric dimensions for the spacing between the framing members are soft conversions from 12 in. to 300 mm (rather than 305 mm), 16 in. to 400 mm (rather than 406 mm) and 24 in. to 600 mm (rather than 610 mm), which is consistent with the values in the National Building Code. It is common practice in house construction to install joists, studs, and rafters in increments of 12, 16 and 24 inches, which are whole number fractions of the dimensions of panel products (gypsum board, plywood and OSB) that are supported on the framing. The soft converted metric values are provided for the reader's convenience. It is

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assumed that the spacing between framing members will conform to the actual metric dimensions of 305, 406 and 610 mm.

PLATFORM FRAMING

Platform construction is the most common method for framing a house. The floor platform is built first and the walls for each story are added above each floor. Prefabricated walls can be assembled on the floor platform, or walls can be built horizontally on top of the floor and then be tilted into place without using heavy lifting equipment. The bottom and top plates, which are an integral part of the wall framing, provide fire blocks at the floor and ceiling and also nailing support for wall sheathing and interior finish.

BALLOON FRAMING

Balloon framing was common up to the early part of the 20th century and is now used only occasionally. Unlike platform framing, the studs used for exterior and some interior walls are continuous, passing beyond the floors to the top plates that support the roof framing. Floors are supported by ribbon boards inset into the wall studs.

Unlike platform construction that provides fire blocking at each wall-floor junction, fire blocks must be specifically added to balloon frame construction to prevent fire from spreading from one floor to the next through the wall cavity. Because there are fewer horizontal members (rim joists and wall plates), there is less vertical shrinkage with balloon framing compared to platform framing.

In some two-storey houses, the intermediate load-bearing wall in an otherwise platform-framed house is balloon-framed to provide convenient passage for heating ducts and pipes.

ADVANCED FRAMING TECHNIQUES

Consider using advanced framing techniques (AFT), also referred to as optimum value engineering, to reduce the amount of wood framing used in construction by eliminating wood where it is structurally unnecessary, reduce the amount of site-generated construction waste, improve the thermal resistance of the building envelope and reduce construction costs. AFT requires careful coordination of the location of roof, floor and wall framing members. Advanced framing situates trusses, rafters or roof joists and floor framing members directly over load-bearing studs so that a single top plate can be used. With AFT, cripples and jack studs underneath lintels may be eliminated especially when the location of door and window openings in the exterior wall is coordinated with modular stud spacing and use window sizes that fit between the studs, and replaced with metal hangers, where larger openings are located in exterior loadbearing walls. For non-loadbearing exterior walls, cripples and jack studs may be removed as they serve no structural purpose and occupy space that could otherwise be filled with insulation.

STRUCTURAL STRENGTH

The combination of dimension lumber or engineered wood and wood panel sheathing gives wall, floor and roof assemblies the strength to resist vertical loads (snow, occupants and contents) and horizontal loads (wind and earthquake). Partitions, closets and finishes such as gypsum board (drywall) also add rigidity.

Where additional strength is required because of a high risk of exposure to earthquake or wind, the floors, walls and roofs can be made stronger by using thicker sheathing panels and by placing the fasteners closer together.

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In addition, the floors, walls and roofs of wood-frame buildings are meant to act as a structural unit. This is why the floor must be bolted to the concrete foundation. Additional connections are also required between the roof or floors and walls and between the walls and the foundations to provide a continuous and complete load path, especially in *high* exposure category areas for wind or earthquake.

RESISTANCE TO LATERAL LOADS DUE TO WIND AND EARTHQUAKE

Different areas of Canada are subject to varying risks of forces from winds and earthquakes. As a result, all buildings must be built to resist these lateral loads. The NBC Appendix C, *Climatic and Earthquake Information for Building Design in Canada*, provides wind pressures and earthquake factors used to determine exposure to wind and seismic (earthquake) loads for buildings. NBC 9.23 provides requirements for resisting lateral loads for low-rise buildings. The requirements are based on three levels of risk: *low to moderate; high*; and *extreme*.

Low to Moderate Exposure Category

Buildings in the *low to moderate* exposure category provide resistance to wind and earthquake loads if they are of traditional wood-frame construction comprised of exterior sheathing, panel-type cladding or gypsum board finish. If two or more of these options are chosen, lateral load resistance will be increased. Of the 680 locations identified in NBC Appendix C, 671 and 630 locations fall into this category for wind and earthquake exposure respectively. This means that for most locations in Canada, bracing requirements can be met by using standard wood-framing materials and fastening methods. One can also opt to design according to NBC Part 4 or follow good engineering practices such as those in the *Engineering Guide for Wood Frame Construction 2009* published by the Canadian Wood Council.

High Exposure Category

Buildings in the *high* exposure category require additional features to provide the required resistance to lateral loads. Nineteen locations identified in NBC Appendix C fall into this category for wind and 33 for earthquake exposure. For wind, affected locations are in Newfoundland, Quebec, Alberta, Nunavut and the Northwest Territories. Most of the locations affected by earthquake risk are in the coastal region of British Columbia and four in the Lower St. Lawrence region of Quebec.

The NBC includes prescriptive solutions that call for the use of strong portions of walls called *braced wall panels*. Requirements for location, spacing, dimensions, fasteners and construction materials must be met, and these solutions are subject to limitations based on building height and whether the construction is comprised of heavy materials such as concrete roof tiles or concrete topping on floors. In addition, buildings in the high exposure category must also address concerns such as foundation anchorage, sheathing thickness, and sheathing and drywall fastener lengths and spacings. Lumber sheathing, if used, must be installed diagonally on both walls and roofs. Obtaining an engineered design is also an option.

Extreme Exposure Category

Buildings in the *extreme* exposure category must be engineered. Only one of all the locations identified in NBC Appendix C falls into this category for wind, but three locations do in terms of earthquake exposure.

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SUSTAINABLE HOUSING INSIGHT

Construction is resource-intensive and any measures that reduce the quantity of resources needed will make construction more sustainable. The four Rs—Review, Reduce, Reuse and Recycle—apply to all building materials but are particularly applicable to the large proportion of wood products used in wood-frame house construction.

Resource Efficiency

Review

- Plan house layouts and room sizes for efficient use of space and to avoid excessive building area and heated volume.
- Plan room dimensions so that standard material sizes are used wherever possible.
- Consider using code-acceptable practices that use less framing materials such as advanced framing techniques (also called optimum value engineering).

Reduce

- Estimate quantities carefully to minimize leftover materials and waste.
- Store and protect materials properly to avoid damage and the need to discard and replace.
- Look for ways to reduce framing materials, such as by constructing walls with wider stud spacing and by using fewer studs at corners, where permitted.

Reuse

- Reuse cut-offs for short framing members and as blocking, strapping and bracing.
- Reuse materials and equipment when they have the same properties as new ones and are satisfactory for the intended use. For example, bricks can be reused as long as they are clean and free of mortar. Reuse lumber where possible. For example, use footing formwork lumber for bracing or strapping.

Recycle

- Sort and securely store materials for recycling.

RELATED PUBLICATIONS

2010 National Building Code of Canada (Section 9.23, Part 4 and Appendix C),
National Research Council of Canada

Engineering Guide for Wood Frame Construction 2009,
Canadian Wood Council (publication no. EGWF-09-E)

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CHAPTER 9
Floor Framing



The first floor framing consists of sill plates bolted to the foundation walls, with rim (header) joists and floor joists toe-nailed to the sill plates. Headers, trimmers and beams are used to carry loads around floor openings. Main support beams or load-bearing walls in the basement are usually required as intermediate supports for the floor. Other floors are similar except that the rim joists and floor joists rest on a wall top plate instead of the sill plate.

SILL PLATES AND ANCHORS

The sill plate should be levelled carefully. If the top of the foundation is level, the sill plate may be laid directly on caulking placed on the top of the concrete or over a closed-cell foam gasket or other air-impermeable material of the same width as the sill plate. If the top of the foundation is uneven or not level, the sill plate may be laid in a full bed of mortar. All sill plates must be anchored to the foundation wall with anchor bolts at least 12.7 mm (½ in.) in diameter spaced not more than 2.4 m (8 ft.) on centre or other approved anchors. Buildings with two or more floors located in areas where the exposure category to earthquake or wind is high are required to have stronger anchorage.

COLUMNS AND BEAMS

Wood or steel columns are usually used in the basement to support beams, which, in turn, support the inner portion of the first-floor joists as well as loads from upper floors transferred through walls, floors and posts.

Cylindrical structural-steel columns (called “teleposts”) with adjustable lengths and bearing plates at both ends are commonly used to support beams. The top plate should be as wide as the beam it supports and either be bolted to the flange where a steel beam is used or nailed where a wood beam is used.

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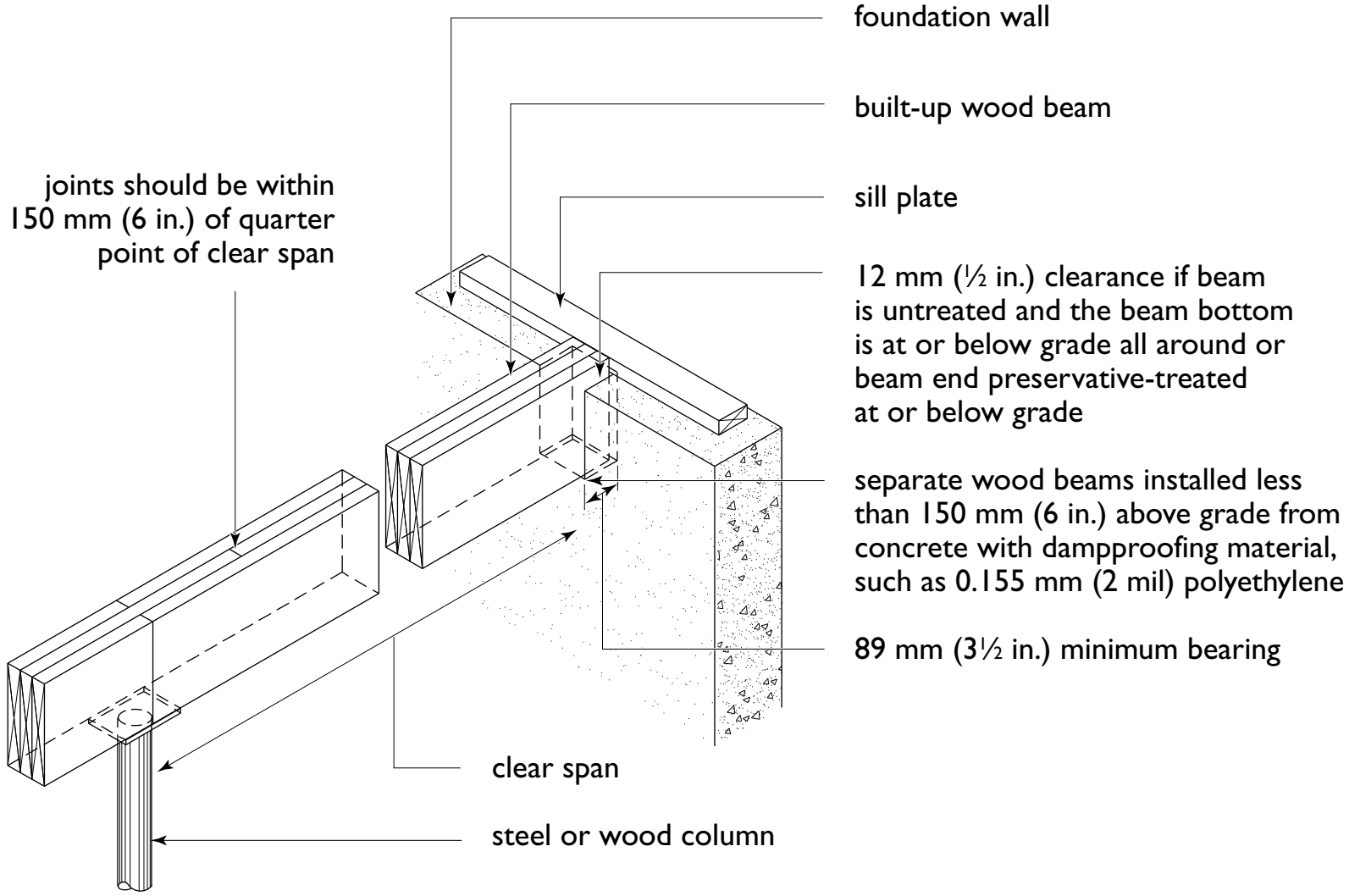
Wood columns at least 140 × 140 mm (6 × 6 in. nominal) may be solid or built-up from 38 mm (2 in. nominal) lumber. Use at least 76 mm (3 in.) nails spaced at 300 mm (12 in.) on centre to fasten the built-up members together. A wood column should be the same width as the beam it supports and be cut square to ensure even bearing at the top and bottom. Fasten the column to the beam at the top and install dampproofing material such as 0.15 mm (6 mil) polyethylene or Type S roll roofing to separate it from the concrete at the bottom.

Columns are usually spaced 2.4 to 3.0 m (8 to 10 ft.) apart, depending on the loading and strength of the beam they support. The footings for basement columns must be sized to suit the column spacing, the span of the supported joists, the number of floors supported and the soil-bearing pressure.

Either wood or steel beams may be used in house construction. For steel beams, the wide-flange (W) profile is most commonly used (Table 18 in Appendix A).

Wood beams can be solid or built-up. Built-up wood beams (Figure 52) are usually made of three or more pieces of 38 mm (2 in. nominal) lumber set on edge and fastened together from each side with 89 mm (3½ in.) nails. Space the nails not more than 450 mm (18 in.) apart in each row, with the end nails located

52 Built-up wood beam



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100 to 150 mm (4 to 6 in.) from the end of each piece. Locate butt joints in each member over a supporting post or within about 150 mm (6 in.) of the quarter points in the span. (See Tables 15 to 17 Appendix A) Joints are not permitted in either the end spans or in not more than half the members at any one location. Bolts at least 12.7 mm (½ in.) in diameter and spaced not less than 1.2 m (4 ft.) apart can also be used to laminate a wood beam.

Alternatives to built-up wood beams and columns include steel or glue-laminated timber (glulam) (Table 19 in Appendix A) laminated veneer lumber (LVL) beams, and parallel strand lumber (PSL).

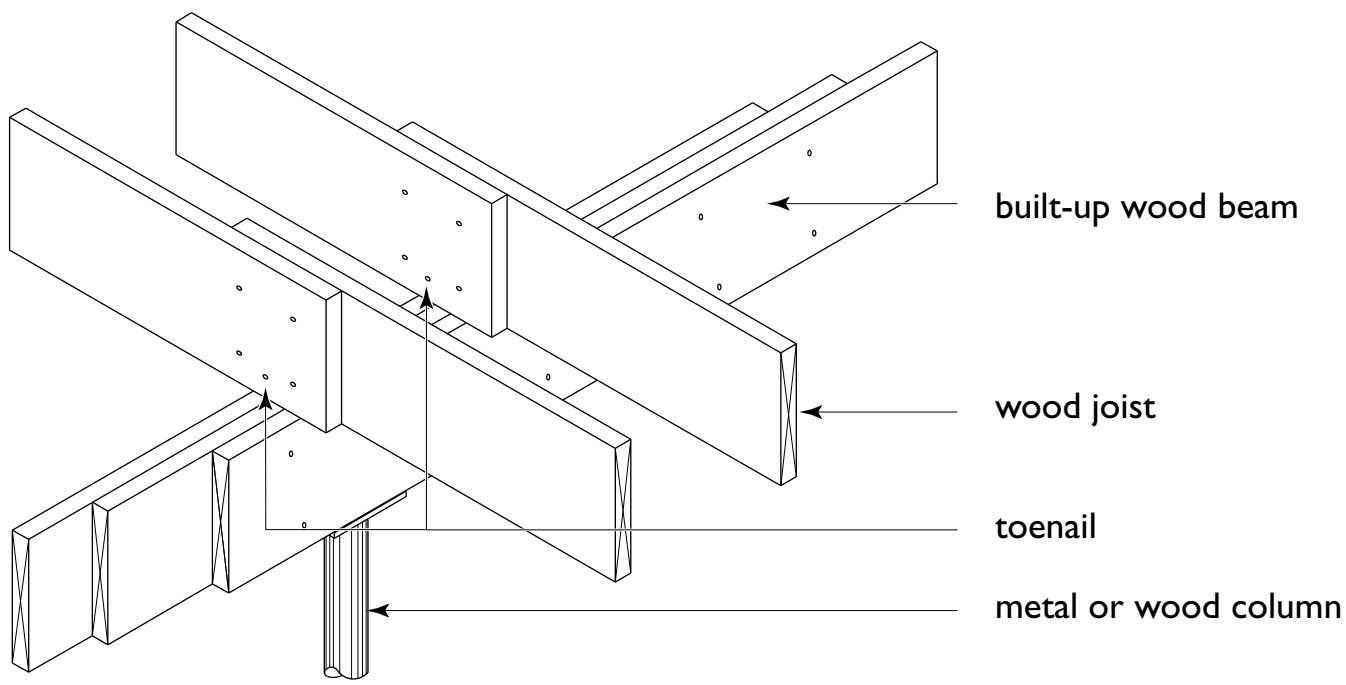
Ends of beams must bear at least 89 mm (3½ in.) on concrete or masonry walls or columns. To prevent deterioration, the ends of wood beams, located at or below grade and framed into masonry or concrete walls, must be treated to prevent decay or have a 12 mm (½ in.) air space at the ends and sides. Untreated wood beams should also be separated from the concrete with an impermeable membrane if they are 150 mm (6 in.) or less above grade.

BEAM AND JOIST INSTALLATION

Joists can rest on top of the beam (Figure 53), in which case the top of the beam is level with the top of the sill plate (Figure 52). This method is used where the basement has adequate headroom below the beam. The joists should lap above the beam and the maximum recommended length of lap is 300 mm (12 in.).

Where more clearance under a wood beam is desired, the beam may be installed flush with the joists, which are then supported by joist hangers or other structural connectors attached to the beam. Joists can also be supported on ledger strips attached to wood beams

53 Joists supported on top of wood beam



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(Figure 54). Nail a 38 × 64 mm (2 × 3 in. nominal) ledger strip to the beam with two 82 mm (3¼ in.) nails for each joist supported on the beam. The ends of the joists may be spliced as shown in Figure 54.

Joists framed into the side of a steel beam may be supported on the bottom flange or on a 38 × 38 mm (2 × 2 in. nominal) ledger strip bolted to the web with 6.3 mm (¼ in.) bolts spaced 600 mm (24 in.) on centre. Splice the joists (Figure 55) and provide at least a 12 mm (½ in.) space between the beam and the splice to allow for joist shrinkage.

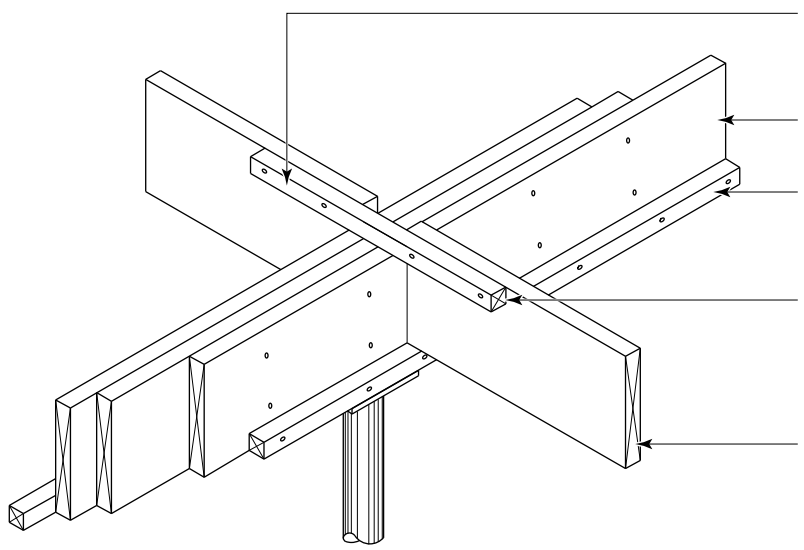
FOUNDATION WALL-FLOOR CONNECTION

There are two methods of wall and joist connection used in platform framing: the sill-plate method and the joist-embedded method.

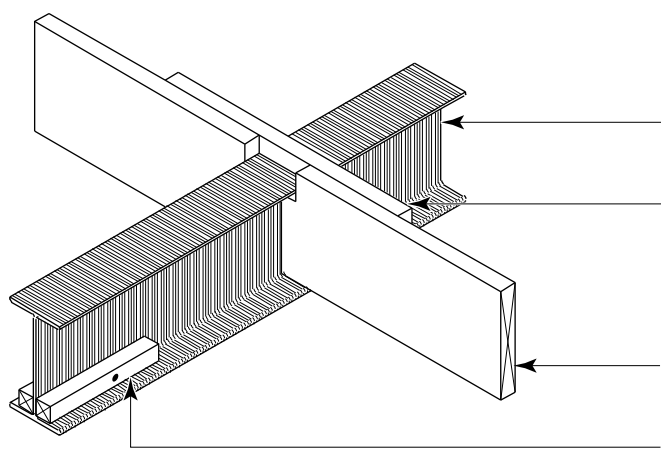
Sill-Plate Method

The sill-plate method is the most common form of connection and can be used with either concrete or concrete block foundation walls. It consists of a wood sill plate anchored to the

54 Joists supported on ledger strips nailed to beam



55 Joists framed into a steel beam

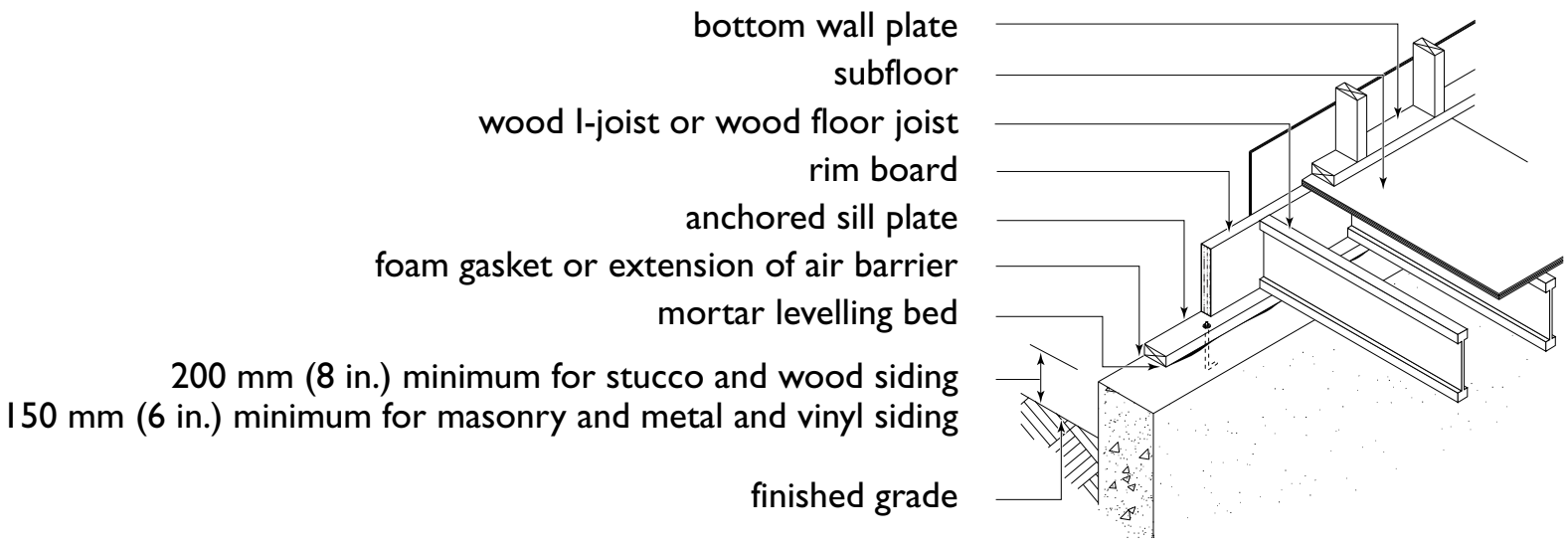


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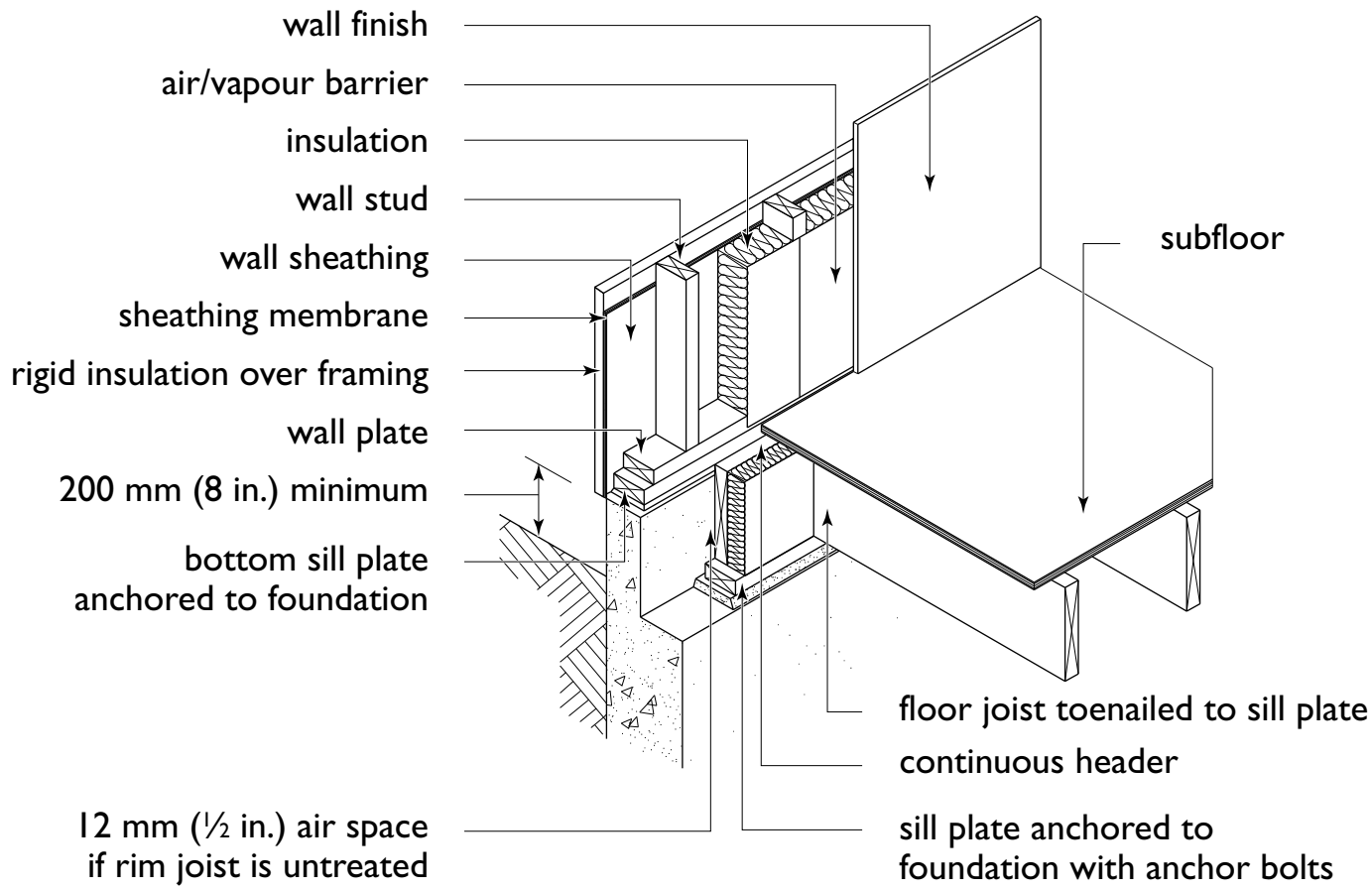
foundation wall (Figure 56) for the support and fastening of the joists and a rim joist attached to the ends of the joists. The sill plate is usually supported on the top of the foundation wall, in which case the bottom of the sill plate should be at least 150 mm (6 in.) above the finished grade, or else it must be separated from the concrete by 0.05 mm (2 mil) polyethylene or Type S roll roofing, or the wood framing must be preservative-treated. A foam gasket should be placed between the concrete and the sill plate to reduce or eliminate air leakage at this juncture.

Where it is desirable to lower the elevation of the main floor in relation to the top of the foundation, the top of concrete foundation walls may be reduced to 90 mm (3½ in.) in thickness (Figure 57). If siding or stucco is used as an

56 Sill-plate method used in platform construction



57 Floor joists supported on a ledge formed in the foundation wall



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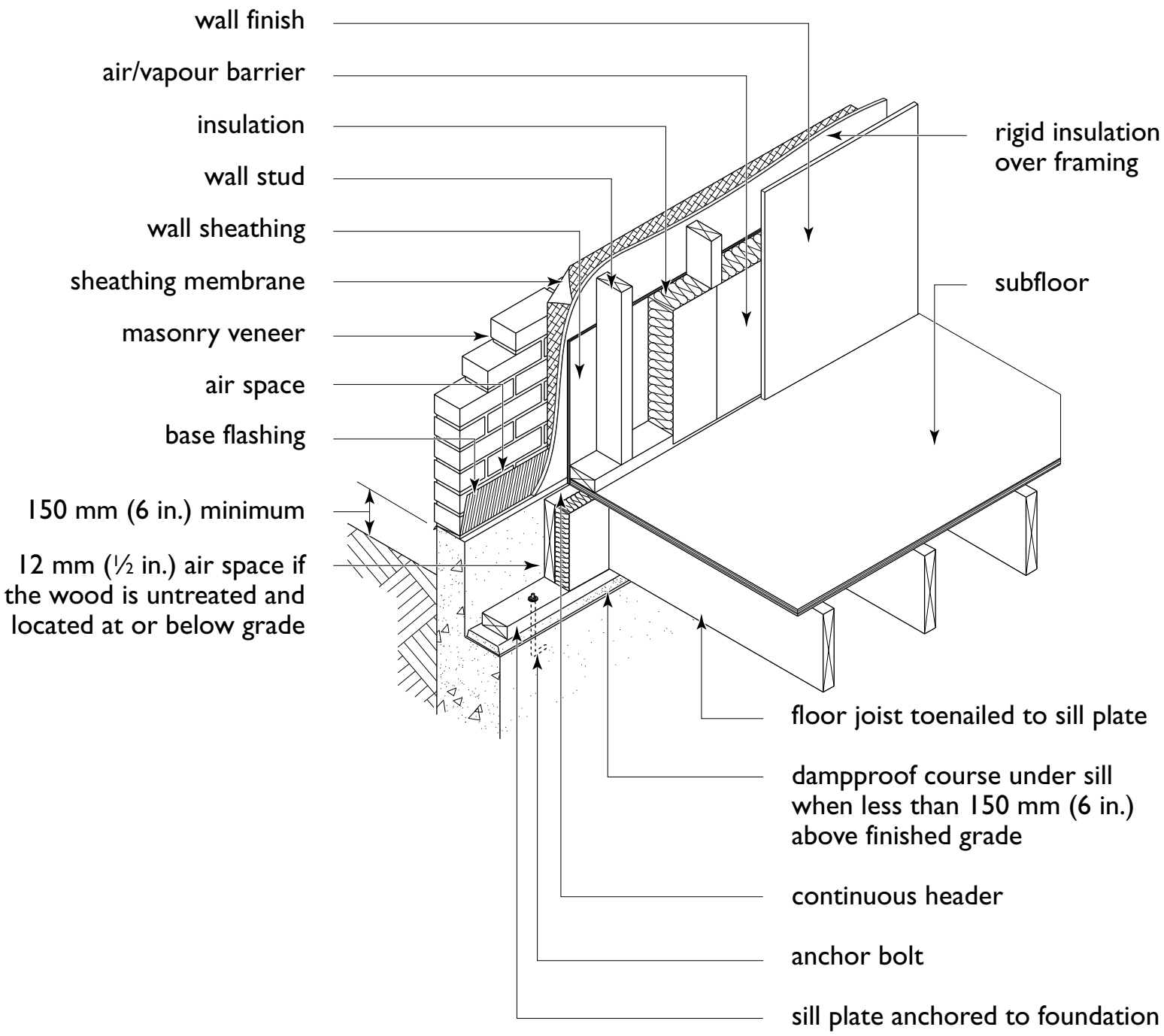
exterior finish, a sill plate anchored to the top of the wall supports the wall framing, and a separate sill plate located on a ledge formed in the wall supports the floor joists.

Where brick veneer is used, the top of the foundation wall supports the brick, and the floor framing supports the wall framing (Figure 58). If the thickness of the wall is reduced, the height of the reduced section cannot exceed 350 mm (14 in.).

Joist-Embedded Method

The joist-embedded method is used rarely, and only with cast-in-place concrete foundation walls. Beams, joists and headers are positioned before the concrete is placed. Support the floor framing temporarily on the inside concrete form and use wedges to level the framing. Place filler pieces between the floor joists and along the end walls to retain the fluid concrete between the joists.

58 Floor joists supported on ledge formed in foundation wall



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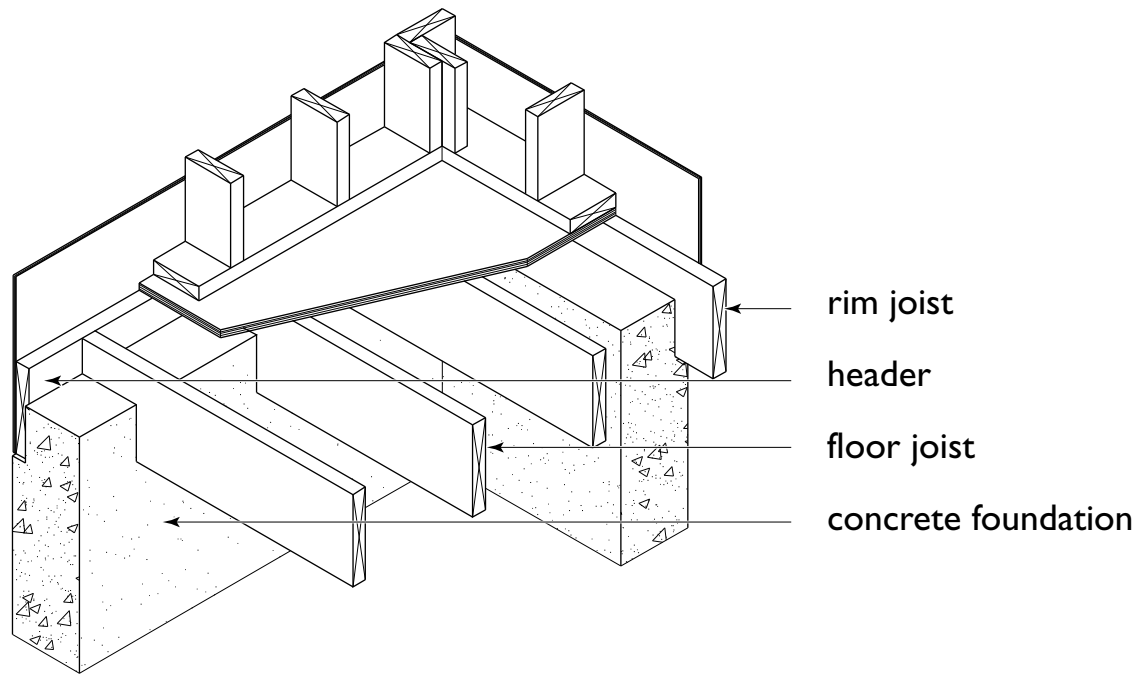
Set the filler pieces flush with the inner face of the foundation wall (Figure 59). Joist headers and end rim joists serve as outside forms for the concrete. Beam ends must be treated to prevent decay when the bottoms of the members are located at or below grade. Place the concrete so that at least two-thirds of the depth of each joist is embedded in the concrete, thus providing suitable anchorage for the floor-framing members.

Remove the filler pieces and the wall forms when the concrete has set. This method can also be used for a brick veneer finish (Figure 60).

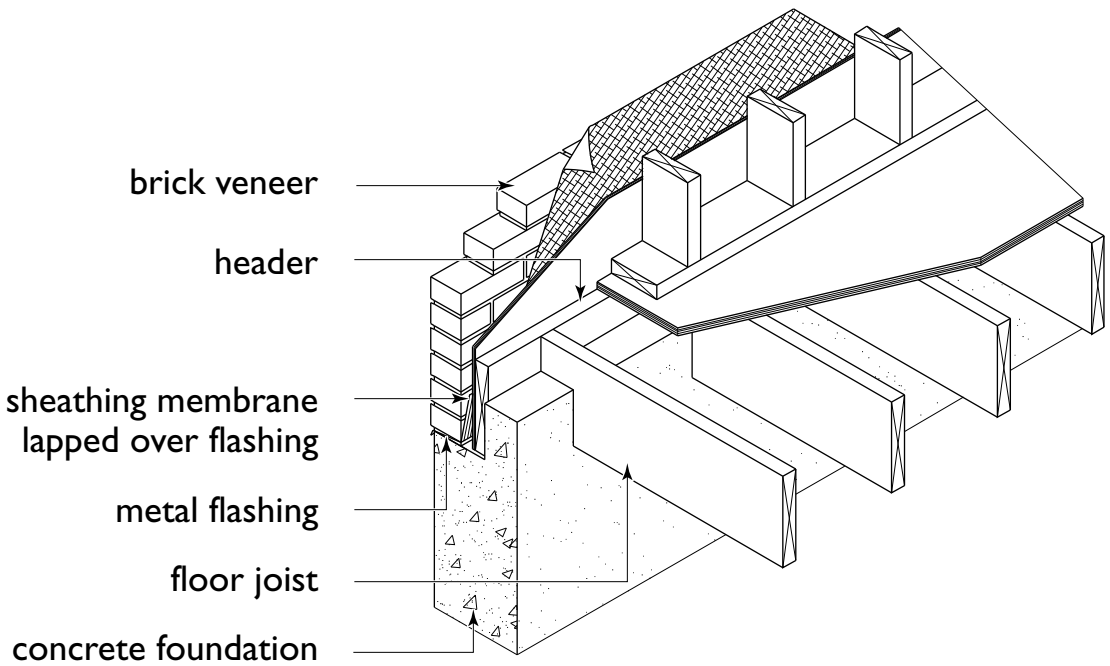
FLOOR JOISTS

Joists are selected to meet strength, deflection and vibration requirements on which the joist selection tables are based (Tables 20 and 21 in Appendix A). The spans in the tables are

59 Floor joists embedded in the top of the foundation wall



60 Masonry support using joist-embedded method of floor framing



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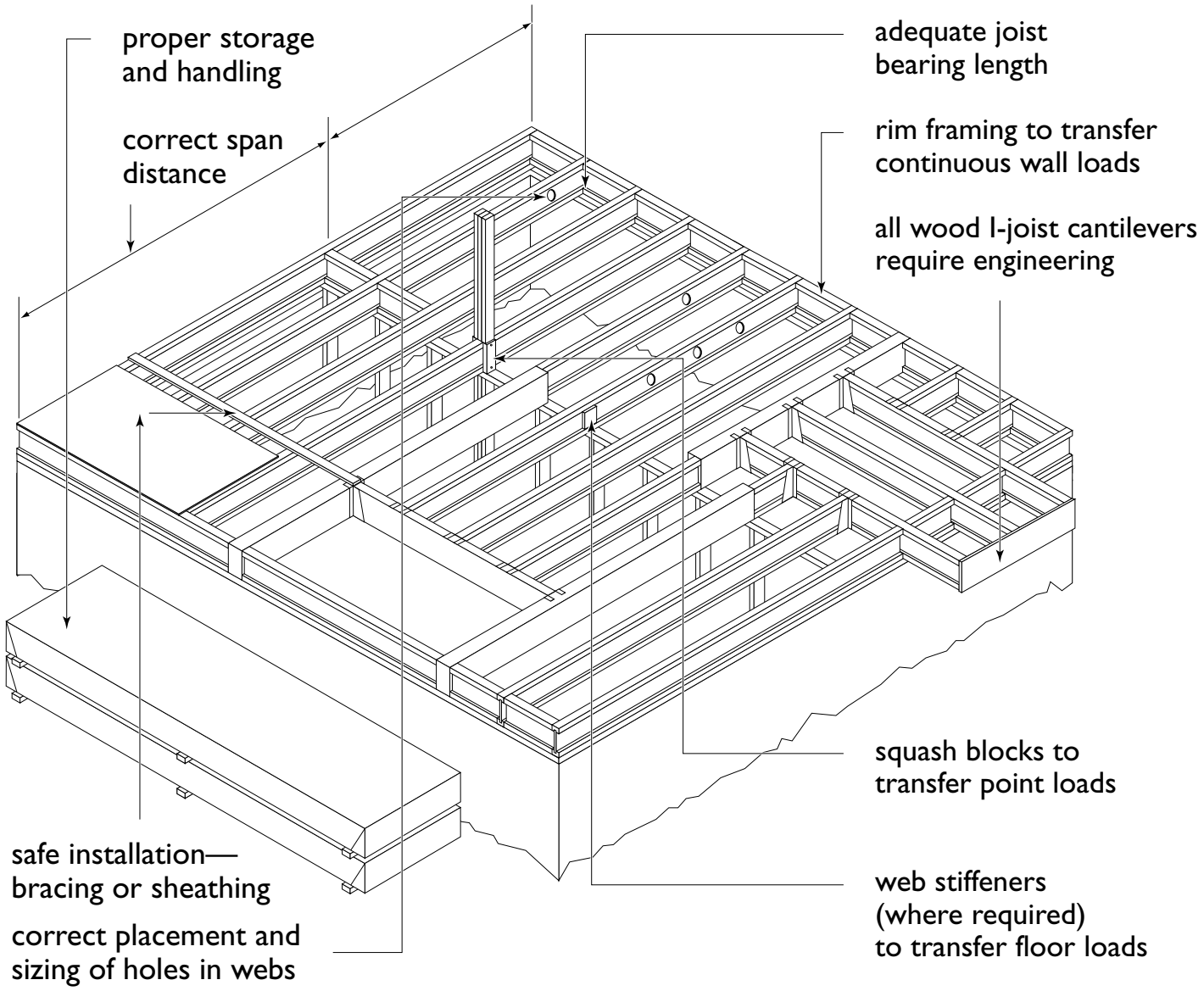
measured between the inside edges of the joist supports and have been calculated for standard Canadian lumber sizes. Strength requirements ensure the floor joist system is strong enough to support the anticipated loads. Deflection requirements ensure that the deformation of the floor under heavy load is within acceptable limits and will not lead to defects, such as cracking of the ceiling below the floor. Vibration requirements ensure that the floor is adequately stiff so that, for example, foot traffic will not cause dishes in cabinets to rattle.

Dimension lumber floor joists are usually 38 mm (2 in. nominal) thick and either 140, 184, 235 or 286 mm (6, 8, 10 or 12 in. nominal) deep depending on the loading, span, spacing between joists, and species and grade of lumber.

Alternatives to dimension lumber floor joists include laminated veneer lumber (LVL) joists, parallel chord trusses and wood I-joists. Wood I-joists have become common residential floor framing materials because they can span longer distances and they shrink less because they are made from dry materials. Typical residential wood I-joists are 241 mm (9½ in.) and 302 mm (11⅞ in.) deep. Wood I-joists have special installation details (Figure 61) that differ from those for dimension lumber joists.

Because of their thin webs, wood I-joists are less capable than lumber joists of supporting vertical loads (for example, from load-bearing walls above). For this reason, special blocking techniques are used to transfer vertical loads around and through the wood I-joists

61 Principles for wood I-joist installation



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(Figure 62). All manufacturers provide technical information that describes these requirements, and their directions must be followed.

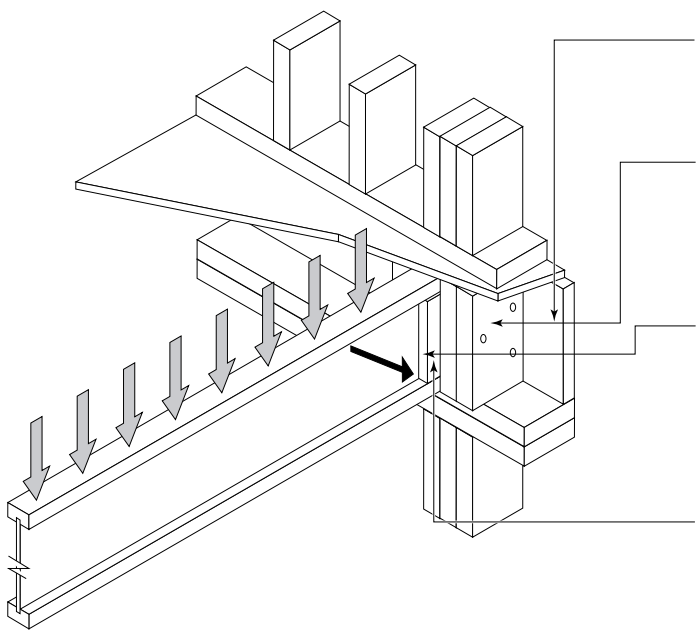
Where a sill plate is used, joists are installed after the sill plates have been levelled, caulked and anchored to the foundation wall. The joists are located and spaced according to the design.

Joist spacing of 400 mm (16 in.) on centre is the most common. For heavy loads or when floor depth is limited, joists spaced 300 mm (12 in.) may be acceptable. Conversely, if floor depth is not a limitation, deeper joists at 600 mm (24 in.) spacing may prove more economical.

A joist with a bow edgewise should be placed with the crown on top—it will tend to straighten when the subfloor and floor loads are applied.

A rim joist is end-nailed or toe-nailed to each joist. The joists, including the end joist parallel to the exterior walls, are toe-nailed to the sill plate (Figure 63). The inner portions of the joists

62 Load transfer requirements for wood I-joists



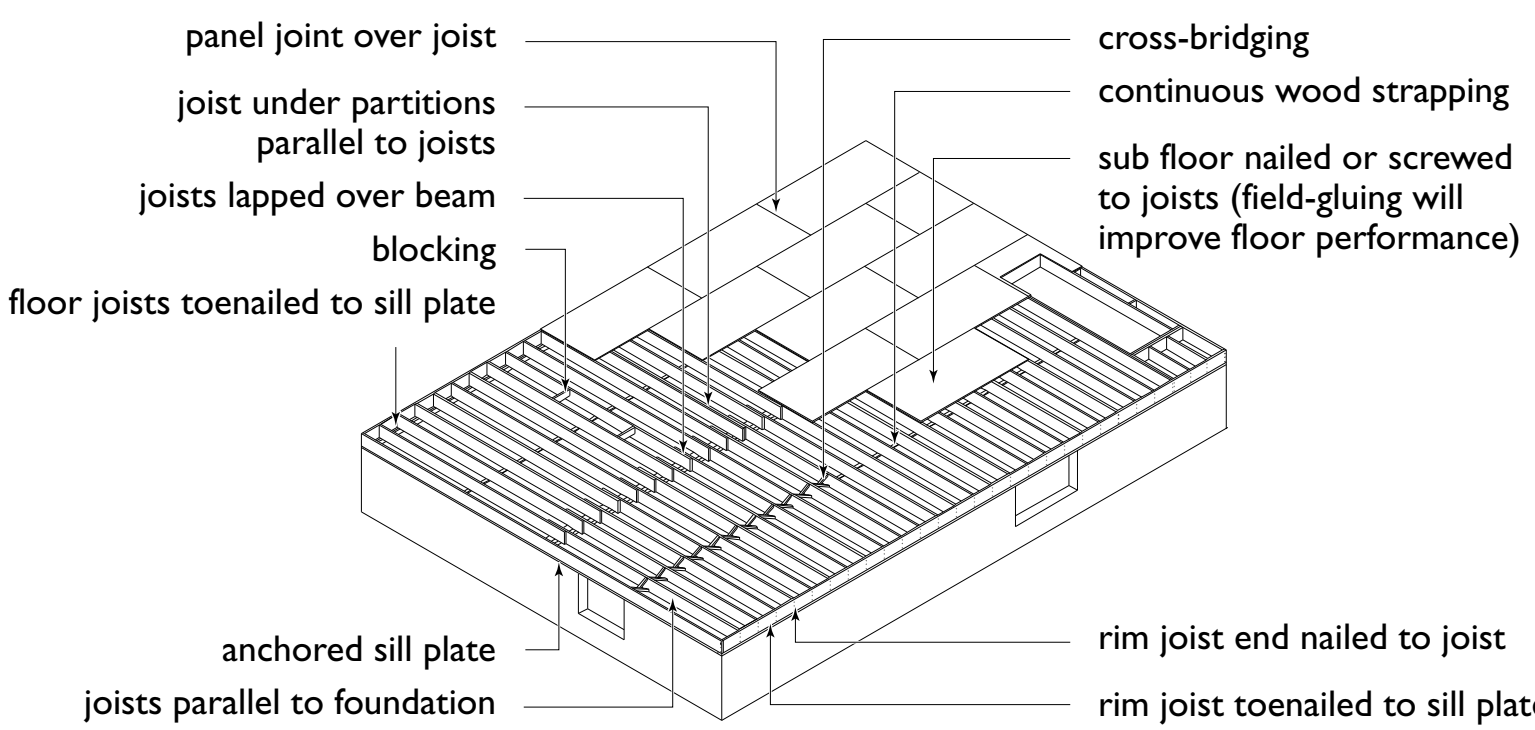
Rim framing transfers exterior wall loads around the I-joists to the wall below

Blocking transfers point loads and interior wall loads around I-joists to the wall or beam below

Squash blocks are used to transfer point loads from columns or framing around doors and windows from one floor to the next without loading the I-joists.

Web stiffeners may be required if the load on the joist exceeds the design capacity of the joist without web stiffeners.

63 Floor framing



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are supported on top of load-bearing walls or intermediate beams (Figure 53), or framed into the side of the beam (Figure 54).

When a load-bearing wall runs parallel to the joists, it must be supported by a beam or load-bearing wall in the basement. Floor designs often require a load-bearing wall located at right angles to the floor joists, but offset from the joist support. Load-bearing interior walls at right angles to floor joists should be located not more than 900 mm (36 in.) from the joist support when the wall does not support a floor, and not more than 600 mm (24 in.) from the joist support when the wall supports one or more floors, unless the joist size is designed to support such concentrated loads.

Non-load-bearing partitions parallel to the joists should bear on joists or on blocking between the joists. The blocking should be 38 × 89 mm (2 × 4 in. nominal) lumber spaced 1.2 m (4 ft.) or less on centre.

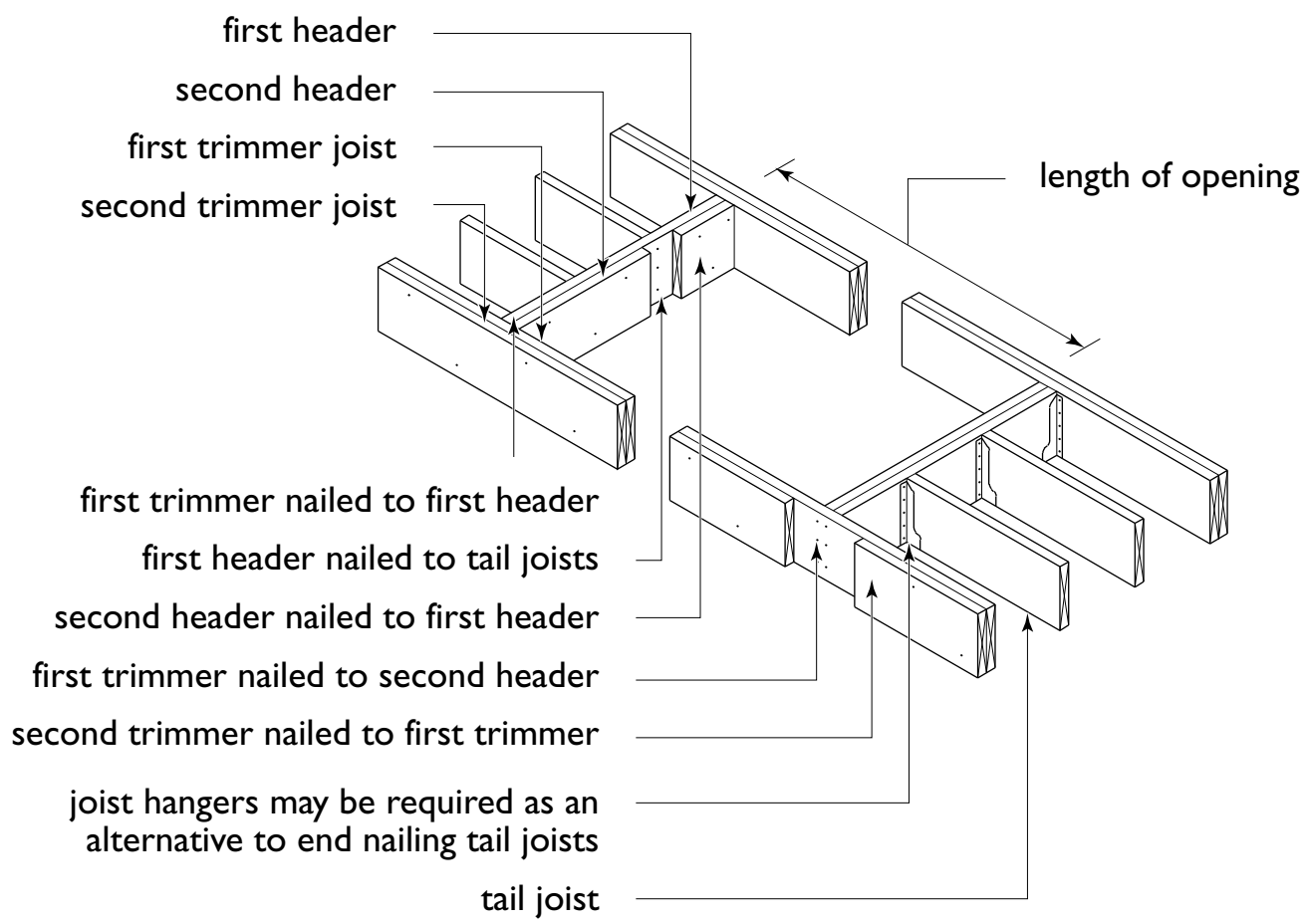
When framing for large openings such as stairwells or fireplaces, the trimmer joists must be doubled if they support header joists (joists into which other joists are framed) more than 800 mm (32 in.) long. Header joists longer than 1.2 m (4 ft.) must also be doubled. Where unusually large openings occur, trimmer joists that support header joists more than 2 m (6 ft. 6 in.) long and header joists that are more than 3.2 m (10 ft. 6 in.) long must be designed according to accepted engineering practice.

Nailing and assembly methods generally used in the framing of floor openings are shown in Figure 64.

Joist hangers are often used to support long joist headers and tail joists.

Joist twisting can be reduced and load sharing between joists improved by cross bridging, blocking, strapping or a ceiling finish fastened to the underside of the joists. Where a ceiling

64 Framing for floor openings where double headers and double trimmers are used



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finish is not used, restraint should be provided at intermediate locations between the supports and at distances not greater than 2.1 m (6 ft. 10 in.).

Intermediate restraint may be provided by the following methods: 19 × 64 mm (1 × 3 in. nominal) or 38 × 38 mm (2 × 2 in. nominal) cross-bridging; or continuous 19 × 64 mm (1 × 3 in. nominal) wood strapping nailed to the bottoms of the joists or both cross-bridging and strapping. Continuous wood strapping is not required when a ceiling finish is provided.

Floor Performance

The floor joist span tables incorporate vibration criteria. The tables recognize that some floor constructions are more "bouncy" or "springy" than others. Therefore, by adding blocking or increasing subfloor thickness, floors will be less springy or bouncy and floor joist spans may be increased. Alternatively, engineered wood products such as laminated veneer lumber joists, wood I-joists and parallel-chord trusses may be used, but vibration criteria must be also be considered for these engineered products.

SUBFLOOR

Plywood, OSB or tongue-and-grooved lumber no wider than 184 mm (8 in. nominal) is typically used for subflooring. Minimum thicknesses for subflooring are shown in Table 22 (Appendix A).

Plywood and OSB are often used as subflooring under wood-strip flooring or as a combination subfloor and underlay for resilient flooring or ceramic tile. When used as a combination subfloor and underlay, the side joints must be supported on blocking at least 38 × 38 mm (2 × 2 in. nominal) fitted between the joists unless the panels have tongue-and-groove edges.

Install subfloors with the direction of the panels or planks at right angles to the floor joists and with the end joints staggered and nailed along the edges at 150 mm (6 in.) on centre and 300 mm (12 in.) at intermediate supports. Use ringed underlay nails, which are designed to resist withdrawal and "nail popping," or approved staples where the panels provide a combination subfloor and underlay. See Table 23 (Appendix A) for sheathing and subflooring fastening requirements.

Floor stiffness can be increased and floor squeaks minimized by applying elastomeric glue between the floor joists and the subfloor. The subfloor, adhesive and joists act together as a strengthened floor frame, thus reducing deflection between adjacent joists.

All subfloor panels that do not have tongue and groove joints should be covered with an underlay where a vinyl floor covering or ceramic tile is used. An underlay is not required where the edges of the subflooring are supported.

All plywood and OSB panels used for subflooring should be the exterior type (manufactured with waterproof adhesives).

For a lumber subfloor, 19 mm (1 in. nominal) thick boards are generally used. This thickness can be reduced to 17 mm (11⁄16 in.) where joists are spaced at no more than 400 mm (16 in.) on centre. Apply the boards so that the end joints occur over the joists and stagger end joints throughout the floor. Boards may be applied at right angles to the joists or diagonally at an angle of 45°. When the subflooring is laid at right angles to the joists, place strip flooring at right angles to the subflooring unless an underlay is used. Diagonal subflooring permits strip flooring to be laid either parallel to or across the joists. Nail the boards with at least two 51 mm (2 in.) nails at each support. Lumber subflooring must be covered with a panel-type underlay when the floor is finished with resilient flooring.

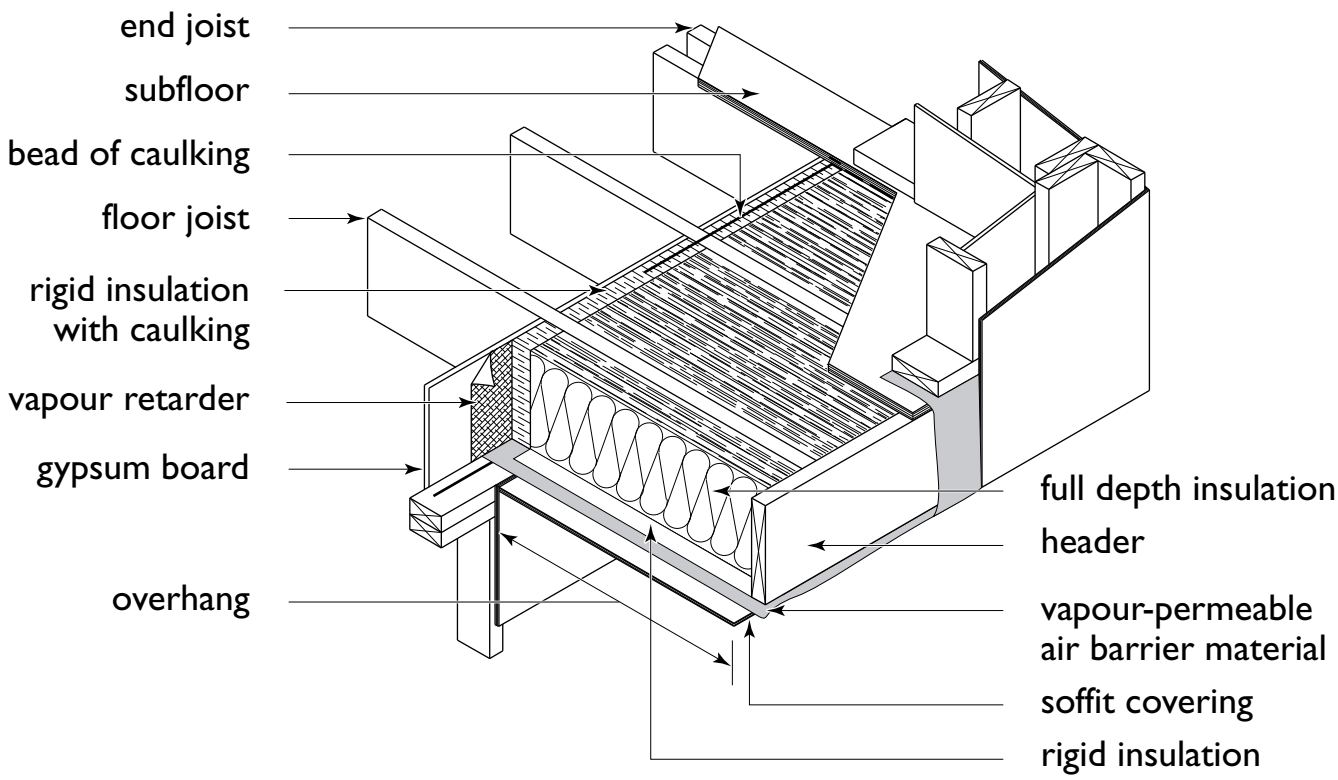
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FLOOR FRAMING AT PROJECTIONS

Floor joists sometimes project beyond the foundation or framed wall to provide support for a bay window or additional floor space in the upper rooms. The cantilevered portion of the floor framing should not exceed 400 mm (16 in.) for 38 × 184 mm (2 × 8 in.) joists and 600 mm (24 in.) for larger joists (Figure 65). In either case, this projection should not carry loads from additional floors. If the cantilevered floor joists are to carry additional loads, they must be specifically designed for the appropriate loads according to accepted engineering practice. Extend the subflooring flush with the outer framing members.

Install insulation carefully on top of the soffit finish under the cantilevered floor and up the inside face of the joist header and end joists. Consider using spray foam insulation. Place the vapour barrier on the warm side of the insulation and install an air barrier to prevent air leakage through the cantilevered floor assembly.

65 Floor framing at projections



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CHOOSING THE SIZES OF BUILT-UP WOOD BEAMS

Problem

Select two built-up beams that meet the following conditions.

Conditions

- One-storey, brick veneer house
- Beam supporting main floor only
- Supported joist length is 3.6 m (12 ft.)
- Beam span is 4 m (13 ft.)
- Species group and grade specified is SPF No. 2 and better

Selection

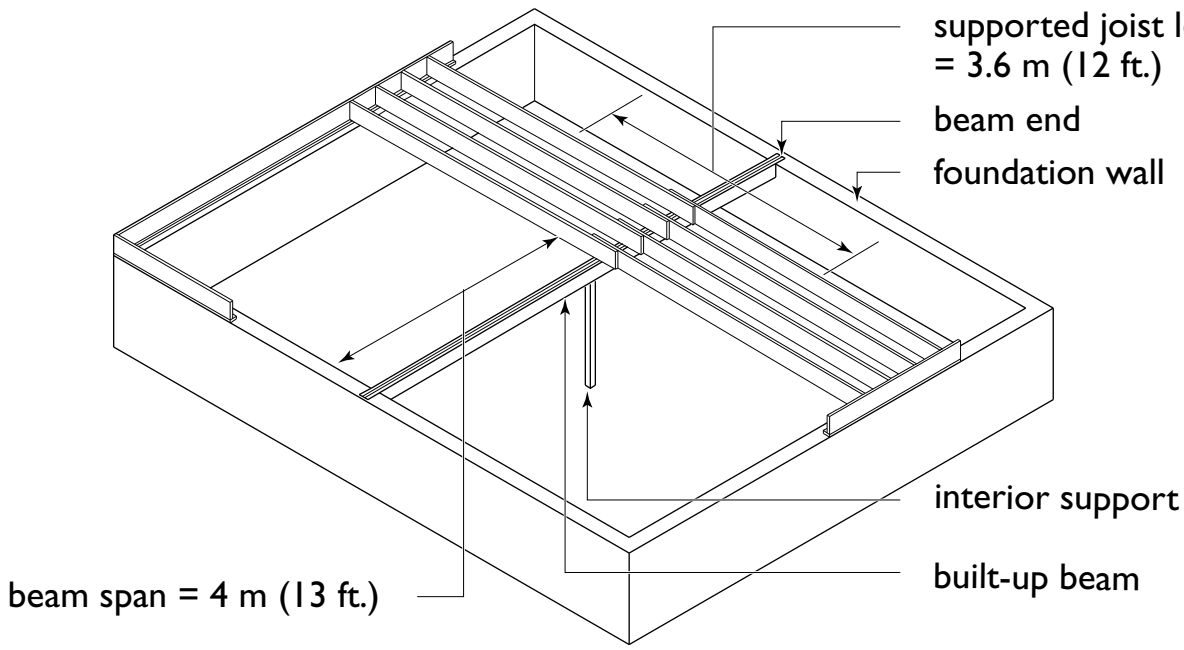
Use Table 15 (Appendix A).

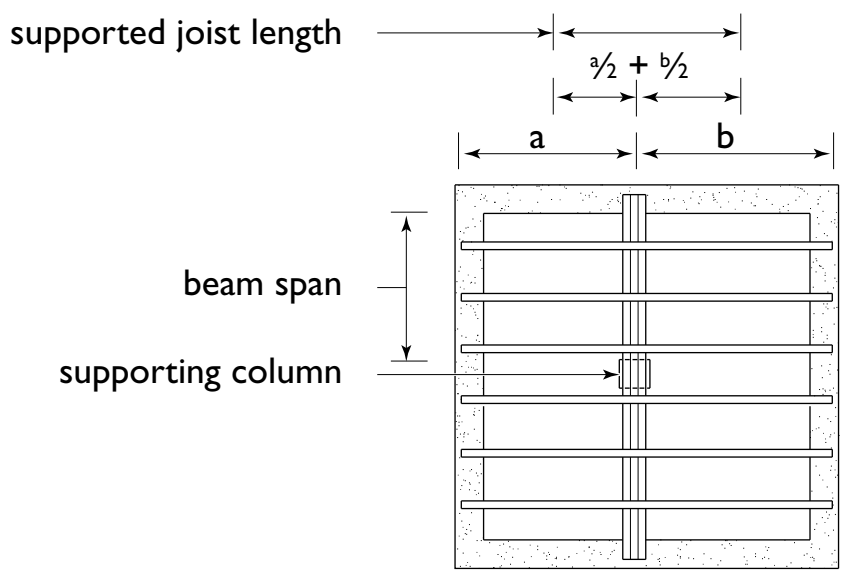
Acceptable beams for this application include:

5 – 38 × 235 mm (5 – 2 × 10 in.) or

4 – 38 × 286 mm (4 – 2 × 12 in.)

66 Basement beam and first floor joist framing





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CHOOSING THE SIZES AND SPACING OF FLOOR JOISTS

Problem

Select a floor joist that is acceptable for the following conditions.

Conditions

- Joists are supporting the living room floor
- Joist span is 3.75 m (12 ft. 3 in.)
- Bridging will be installed
- Basement ceiling will not be finished
- Species group and grade specified are SPF No. 2 and better
- Subfloor is 15.9 mm (⅝ in.) plywood nailed in place
- Also note that drywall or gypsum board ceiling finish can be considered as strapping. For this example, floor joists can be considered braced with bridging and strapping.

Selection

Use Table 20 (Appendix A).

Acceptable floor joist sizes for this application include:

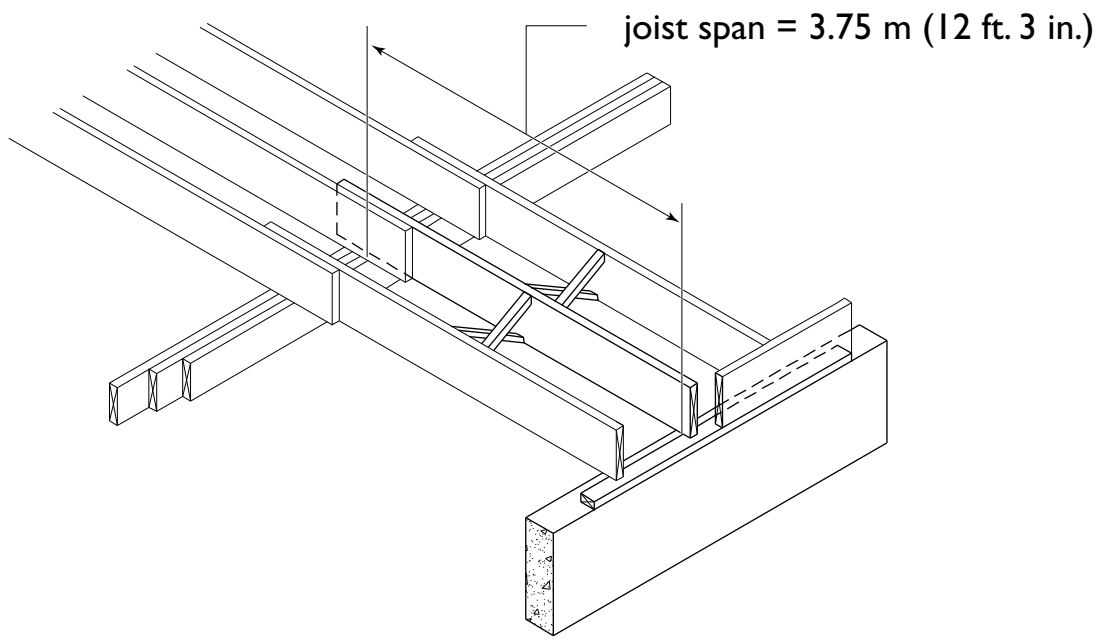
38 × 184 mm at 300 mm
(2 × 8 in. at 12 in.) on centre or

38 × 235 mm at 600 mm
(2 × 10 in. at 24 in.) on centre

Note 1: Any spacing less than 600 mm (24 in.) on centre for the 38 × 235 mm (2 × 10 in.) is acceptable.

Note 2: In accordance with the National Building Code, the metric spacing of wood framing members is expressed as a "soft" conversion from the actual imperial dimensions. For example, spacing of 12, 16 and 24 inches on centre is converted to 300, 400 and 600 mm. on centre, respectively. In order to suit the imperial sizes of common 1 220 × 2 440 mm (4 × 8 ft.) panel products, such as gypsum board, OSB and plywood, the actual spacing of framing members is commonly adjusted to 305, 406 and 610 mm on centre, respectively.

67 Floor joists bearing on beam and foundation wall



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SUSTAINABLE HOUSING INSIGHT

Resource Efficiency

- The use of engineered wood products such as wood I-joists is common because of their span and performance capabilities and their efficient use of wood fibre.
- Advanced framing techniques (also called optimum value engineering) can reduce the amount of wood framing materials by 15–20 per cent, compared with conventional framing.
- Consider using engineered wood beams, such as LVL and PSL. Engineered wood products may use lesser-quality wood fibre and adhesives to provide strength and rigidity, and usually weigh less and are easier to install.

RELATED PUBLICATIONS

Canadian Span Book 2009,
Canadian Wood Council (publication no. SB00-09-E)

Engineering Guide for Wood Frame Construction 2009,
Canadian Wood Council (publication no. EGWF-09-E)

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CHAPTER 10
Wall Framing



Wall framing includes studs, wall plates and lintels that resist lateral loads and vertical loads from the upper floors, ceiling and roof. All framing lumber should be grade-stamped and have a moisture content not exceeding 19 per cent. See Table 24 (Appendix A) for nailing requirements.

Exterior wall studs are the vertical members to which the wall sheathing and cladding are attached. They are supported on a bottom plate and, in turn, support the top plate(s). Studs usually consist of 38 × 89 mm (2 × 4 in. nominal) or 38 × 140 mm (2 × 6 in. nominal) lumber and are commonly spaced 400 mm (16 in.) on centre. This spacing may be changed to 300 or 600 mm (12 or 24 in.), depending on the load and the limitations imposed by the type and thickness of the wall covering used (Table 25 in Appendix A).

Insulation is usually installed in the stud spaces. If the stud space is not deep enough to contain the required level of insulation, wider studs, double walls, or rigid or semi-rigid insulation outside the stud space may be used. In all cases, the vapour control requirements presented in Chapter 5 must be observed.

Additional rigid or semi-rigid insulation or batts installed between 38 × 38 mm (2 × 2 in.) horizontal furring strips can be attached to the inside of the studs, or rigid or semi-rigid insulation sheathing fastened to the outside of the studs. Wider 38 × 140 mm (2 × 6 in. nominal) or 38 × 184 (2 × 8 in.) studs can also be used to provide space for more batt insulation.

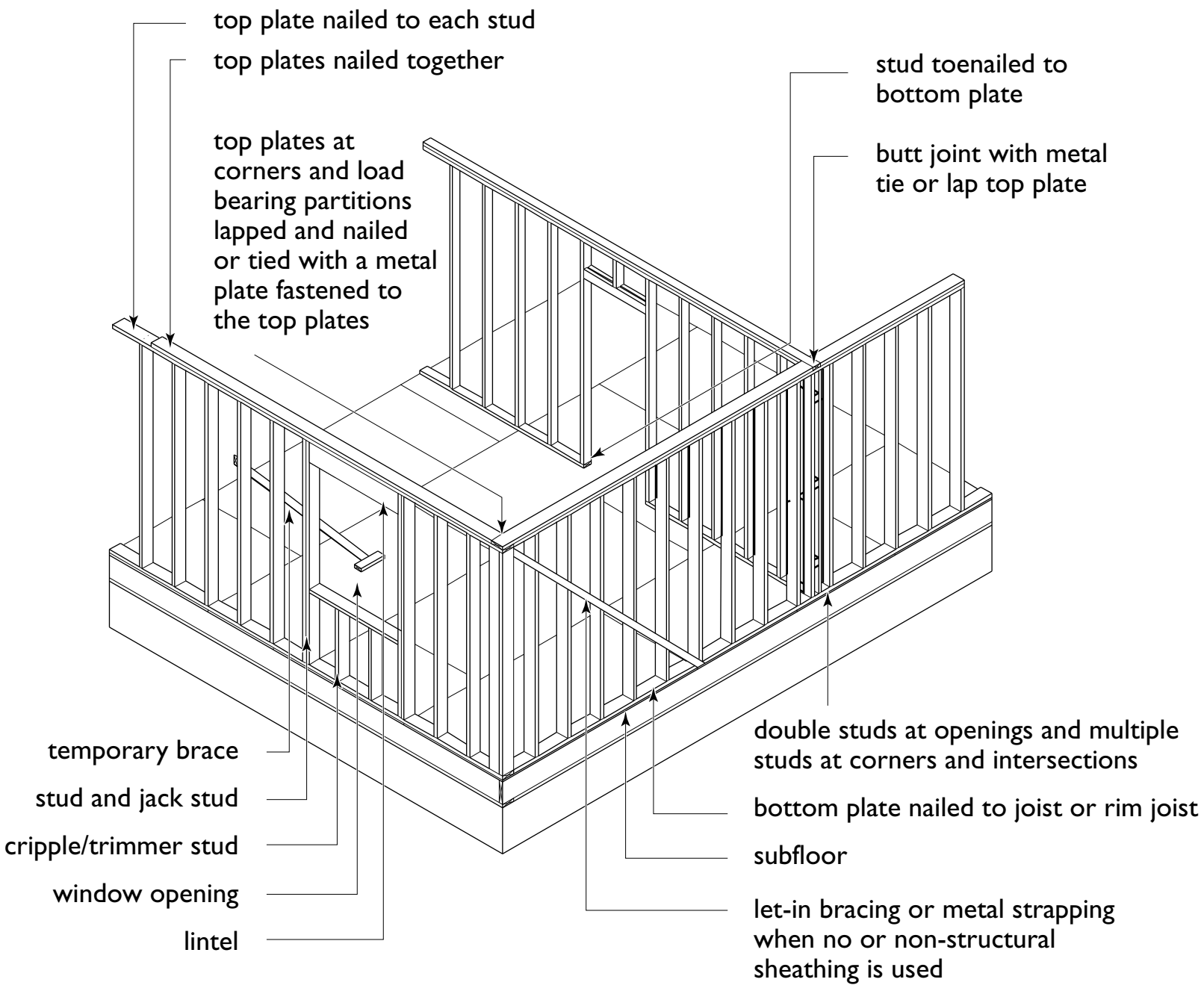
The studs are attached to horizontal top and bottom 38 mm (2 in. nominal) wall plates that are the same width as the studs. If a concrete topping is used on a floor, it is recommended

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that a double bottom plate be used so that there is a nailing surface at the bottom for affixing wallboard and finishes. Where the drywall is contributing to the strength of a braced wall panel, the second bottom wall plate is needed for attachment purposes. For load-bearing walls, unless the roof rafters or trusses are positioned within 50 mm (2 in.) over the wall studs, the top plate must be doubled. This second top plate usually laps the first plate at the corners and partition intersections and, when nailed in place, provides an additional tie to the framed walls. Where the second top plate does not lap the plate immediately underneath at corner and partition intersections, they may be held together with 0.91 mm (0.036 in.) galvanized steel plates at least 75 mm (3 in.) wide and 150 mm (6 in.) long, nailed with at least three 63 mm (2½ in.) nails to each wall.

Lintels are the horizontal members placed over window, door and other openings to carry loads to the studs on either side of the opening (Figure 68). They are usually constructed of at

68 Wall framing used with platform construction



Note: Where the lintel exceeds 3 m (10 ft.), the jack stud needs to be doubled on both sides of the opening.

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least two pieces of 38 mm (2 in. nominal) lumber, nailed together to form a single unit. Rigid insulation is commonly used as a spacer between the members to make the lintel the same thickness as the wall framing. The depth of a lintel is determined by the width of the opening and vertical loads supported. (See Tables 26 and 27 in Appendix A) For openings less than 3 m (10 ft.) wide, provide a full stud on each side of openings (Figure 68) and a jack stud on each side to support the lintel. For openings wider than 3 m (10 ft.), provide double jack studs on both sides in addition to the full studs.

PLATFORM FRAMING

This is a common framing method where each floor serves a work platform for building and erecting the walls for the next storey. End-nail the top and bottom plates to each stud with two nails at least 82 mm (3¼ in.) long. Apply wall sheathing to the framing prior to erection to eliminate the need for scaffolding for this operation. Some types of sheathing such as plywood and OSB will resist lateral loads and keep walls square. Others such as rigid glass-fibre, asphalt-coated fibreboard, polystyrene or polyurethane board will not, and walls need to be reinforced with diagonal wood or metal bracing let into the studs (Figure 68).

Once a wall section is ready, rotate it into the vertical position, add temporary braces and nail the bottom plates to the subfloor and floor framing members (Figure 68). The braces should have their larger dimension on the vertical and allow the vertical position of the wall to be adjusted so that it is plumb.

Once the wall sections are aligned and plumb, they are nailed together at the corners and intersections. When polyethylene is used for the air barrier system, a strip of the material should be placed between the interior walls and the exterior walls, and above the first top plate of interior walls before the second top plate is applied for later attachment and sealing to the rest of the air barrier (see Figures 12 and 13 in Chapter 5).

Interior partitions supporting floor, ceiling or roof loads are called load-bearing walls; others are called non-load-bearing or simply partitions. Interior load-bearing walls are framed in the same way as exterior walls. Studs are usually 38 × 89 mm (2 × 4 in. nominal) lumber spaced at 400 mm (16 in.) on centre. This spacing may be changed to 300 mm (12 in.) or 600 mm (24 in.) depending on the loads supported and the type and thickness of the wall finish used (Table 25 in Appendix A)

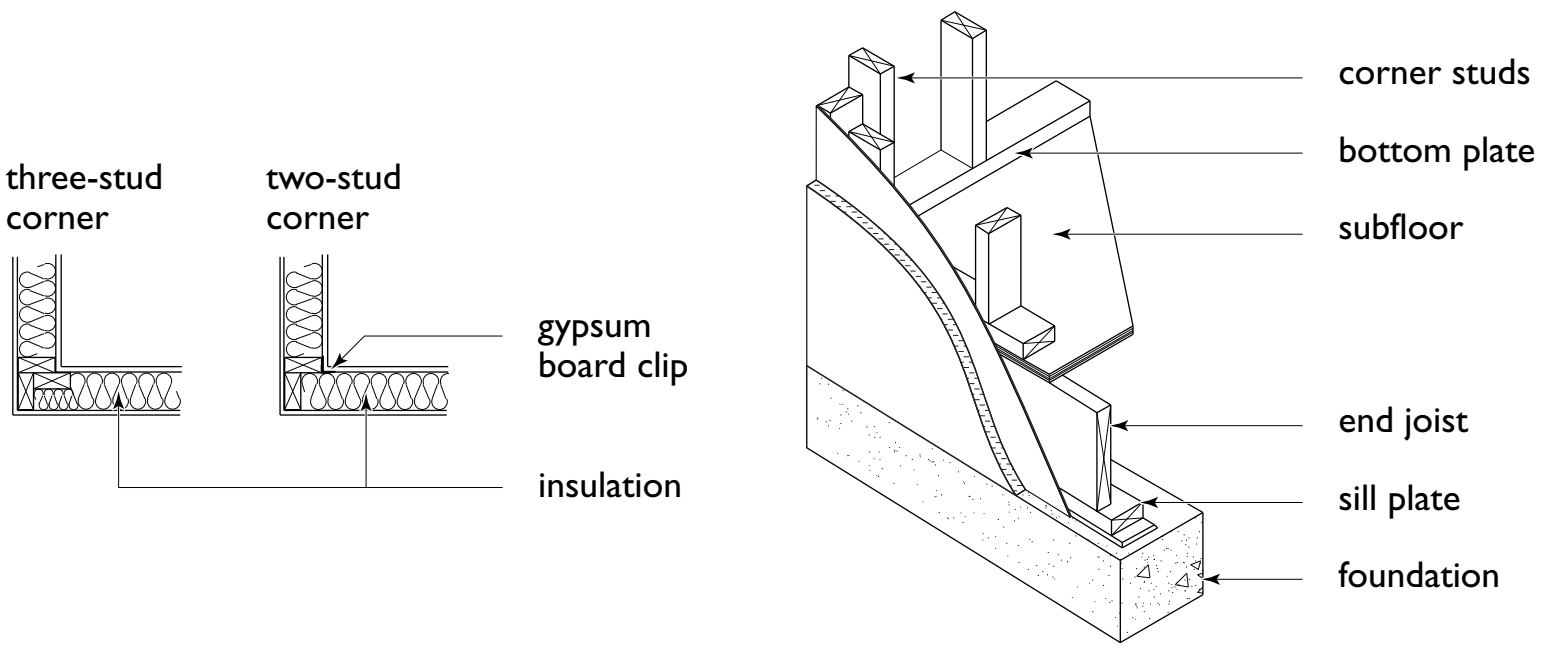
Partitions can be built with 38 × 64 mm (2 × 3 in. nominal) or 38 × 89 mm (2 × 4 in. nominal) studs spaced at 400 or 600 mm (16 or 24 in.) on centre depending on the type and thickness of the wall finish used. Where a partition does not contain a swinging door, 38 × 89 mm (2 × 4 in. nominal) studs at 400 mm (16 in.) on centre are sometimes used with the wide face of the stud parallel to the wall. This is sometimes done for partitions enclosing closets to save space.

Since there is no vertical load to be supported by partitions, single studs may be used at door openings. The top of the opening may be bridged with a single piece of 38 mm (2 in. nominal) lumber the same width as the studs. These members provide a nailing support for wall finishes, door frames and trim.

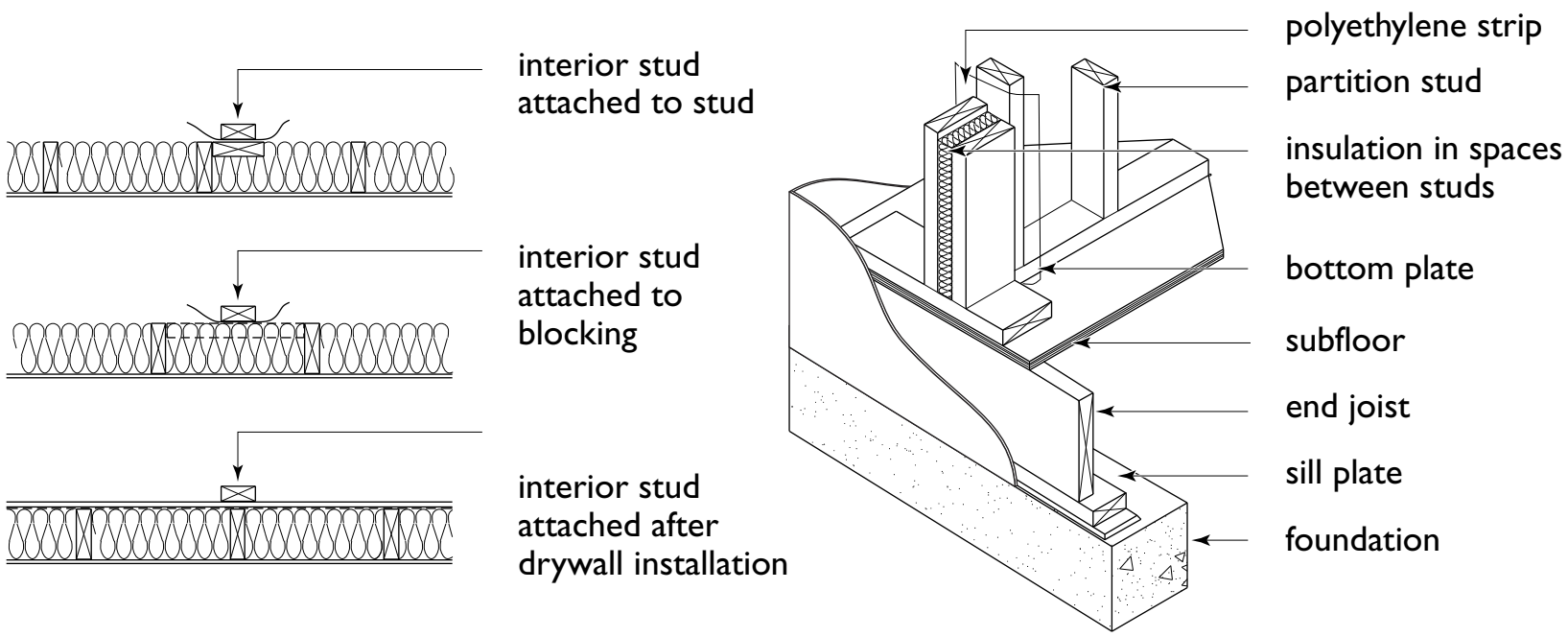
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A multiple-stud post made up of at least three studs, or the equivalent, is generally used at exterior corners and intersections to provide a good tie between adjoining walls and nailing support for the interior finish and exterior sheathing (Figures 69 and 70). Corners and intersections, however, must be framed with at least two studs.

69 Multiple stud arrangements at an exterior corner



70 Multiple stud arrangements at the intersection of an interior partition with an exterior wall



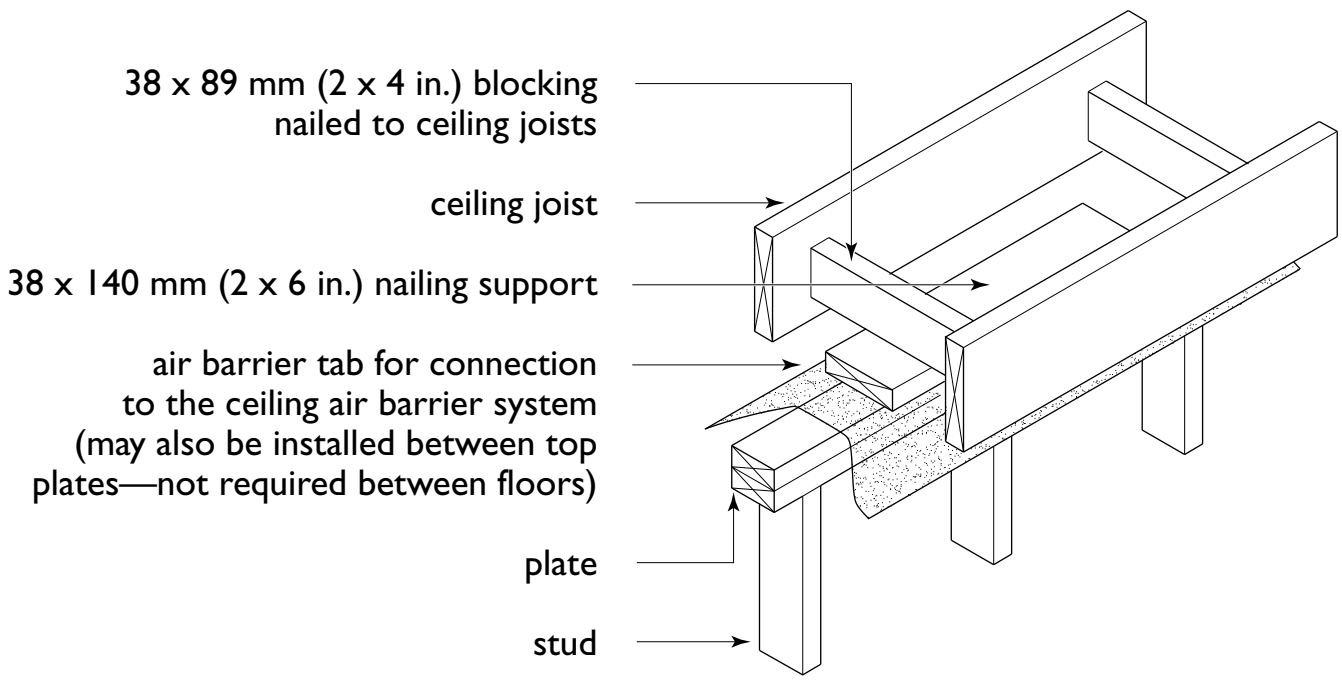
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Nailing support is required for the edges of the ceiling finish at the junction of the wall and ceiling where partitions run parallel to the ceiling joists (Figures 71 and 72).

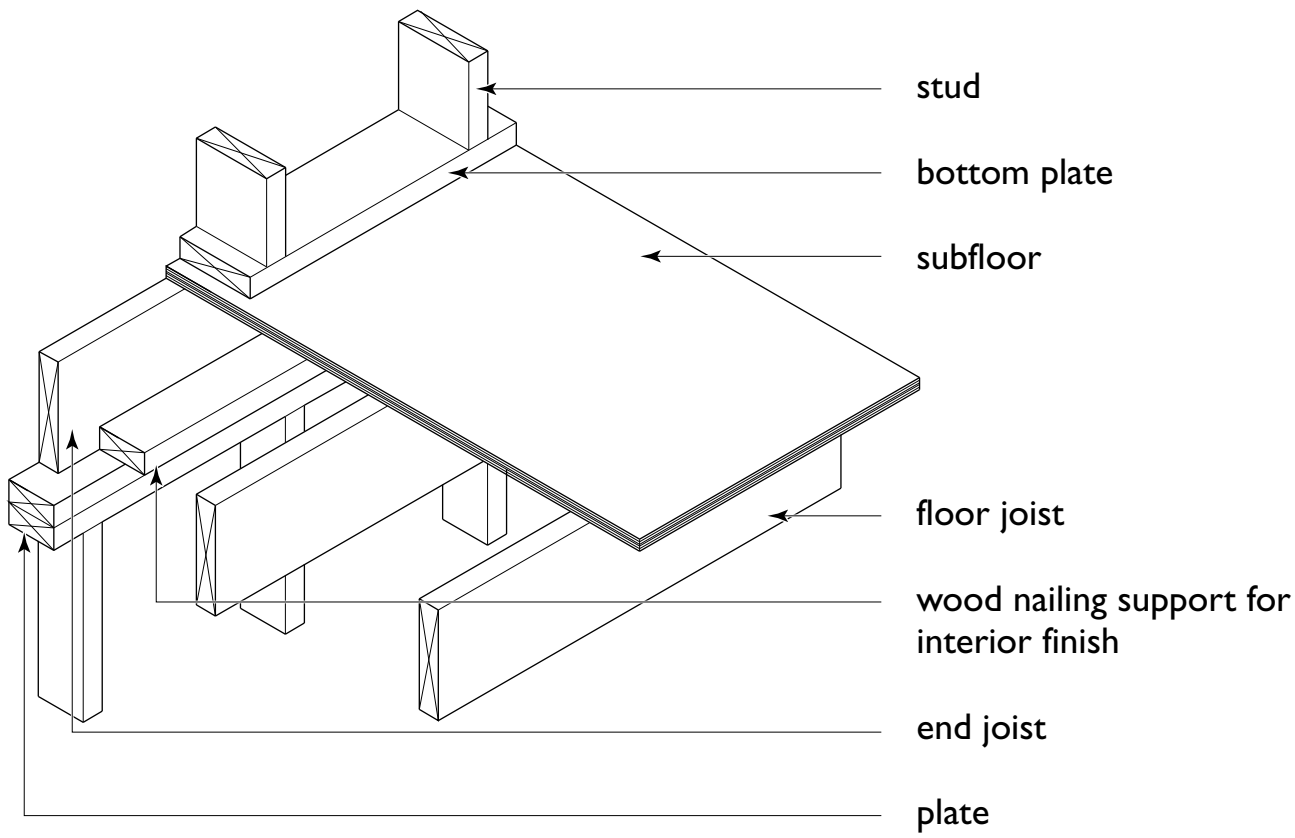
BRACED WALL PANELS

To provide lateral resistance in areas with high wind or earthquake exposure, builders have the option of using strong wall segments called

71 Support for ceiling finish where ceiling joists run parallel to a partition



72 End-wall framing and nailing support for interior finish for platform construction



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braced wall panels. A braced wall panel is a portion of a wood-frame wall where the bracing, sheathing, cladding or interior finish is designed and installed to provide the required lateral resistance. These requirements are intended to ensure all sides of a building are robust. If for instance, there is a desire to have a large area of windows on one side of a house, strong wall portions are required to compensate for the window openings.

Braced wall panels must be located within braced wall bands, which are 1.2 m (4 ft.) wide spaces that extend from one floor to another (Figure 73).

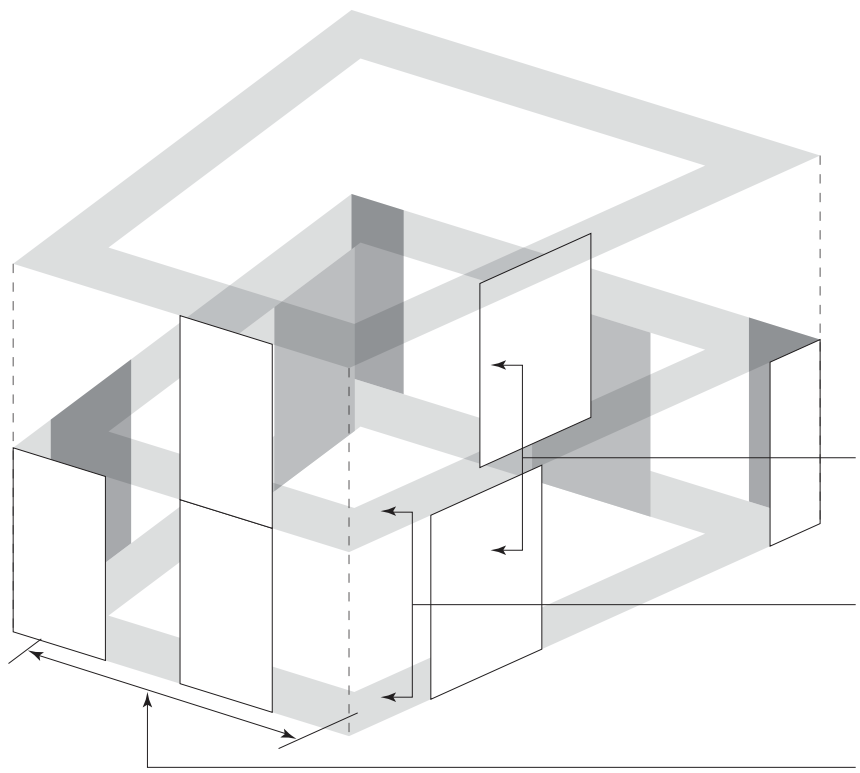
There is a limit to the number of stories that can be designed using the prescriptive solutions (braced wall panels), and the requirements dictate the location, configuration, spacing and dimensions for braced wall panels. The number of storeys permitted is reduced if heavy construction materials such as tile roofs or concrete toppings on floors are used.

For basements or crawl spaces, perimeter concrete or masonry walls provide significant lateral resistance as compared with above-ground frame walls. For this reason, interior braced wall bands can be terminated at the floor above the basement or crawl space, provided the remaining braced wall bands are spaced not more than 15 m (49 ft.) on centre or form a perimeter braced wall band.

Many traditional house designs have incorporated enclosed porches where the enclosure is light construction and mostly glazed, and modern house designs sometimes incorporate solariums that are constructed outside the main structure of the building. Neither of these designs has exterior wall area that could be constructed as braced wall panels. For this reason, an exception can be made to permit the construction of these spaces provided:

- they do not extend too far from the main structure of the building;
- they do not support a floor; and

73 Braced wall bands and panels



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- the roof provides lateral resistance by being either:
  - contiguous with the roof of the rest of the building with framing members not more than 400 mm (16 in.) on centre, or
  - constructed with roof framing not more than 400 mm (16 in.) on centre fastened to the framing of the main structure.

Braced wall bands and braced wall panels on the front wall of an attached garage significantly change current construction, and the width would have to be increased to accommodate both garage doors and braced wall panels. Because people do not generally spend a lot of time in garages or accessory buildings and do not sleep in these buildings or spaces, less stringent requirements apply to these structures, provided they do not support more than one floor above the garage, have limited depth and have a certain percentage of the back and side walls constructed of braced wall panels.

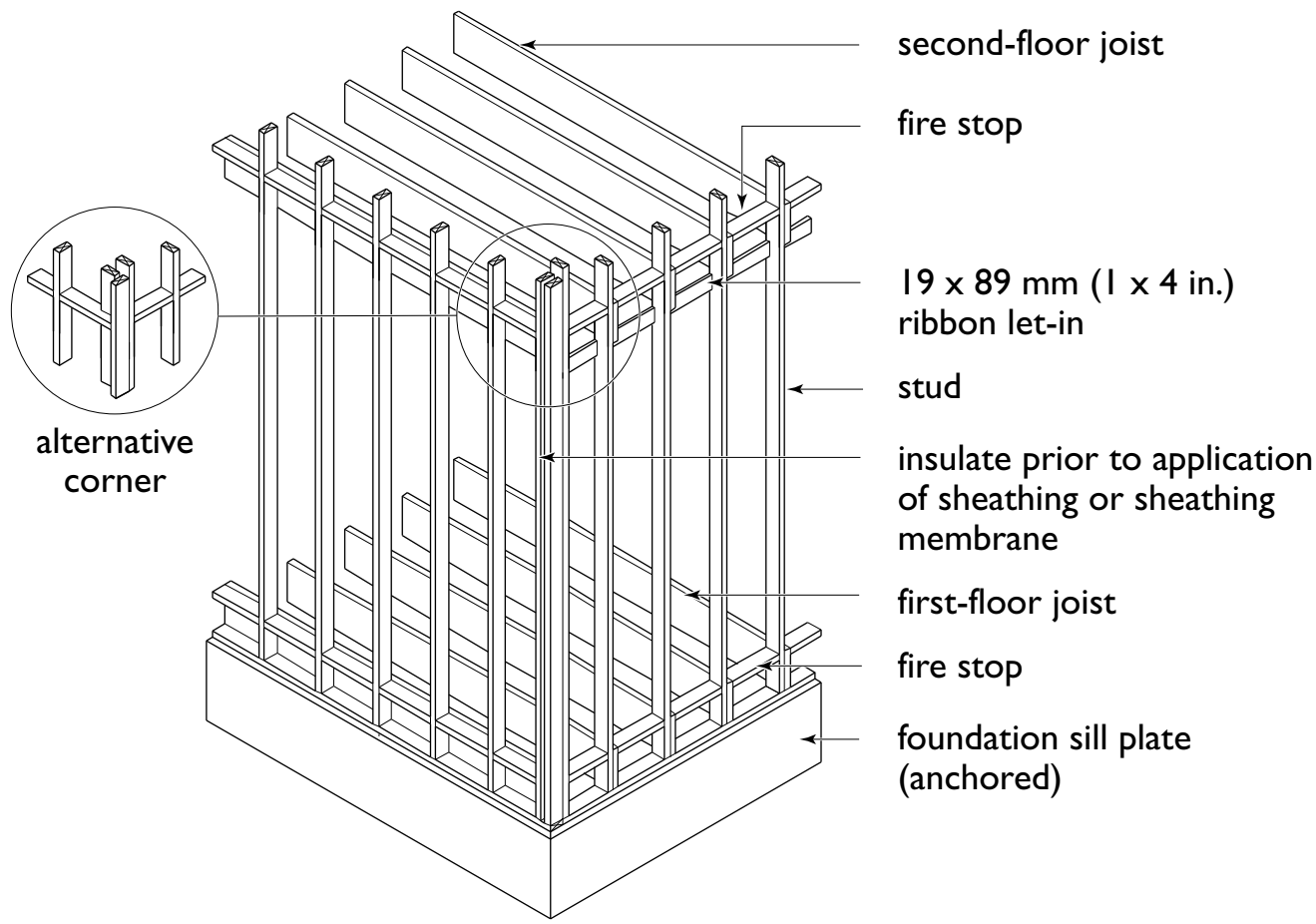
The requirements for walls in detached garages and in accessory buildings serving a single dwelling unit are also less stringent, provided these walls are not supporting a floor.

BALLOON FRAMING

For balloon-framed construction, both the studs and first-floor joists rest on the foundation sill plate (Figure 74) and an intermediate beam or bearing wall. Studs are toe-nailed to these supports with at least four 63 mm (2½ in.) nails; the joists in turn are nailed to the studs with at least two 76 mm (3 in.) nails. When lumber subfloor is laid diagonally, blocking is required between the joists at the wall lines to support the ends of the boards.

Upper-floor joists bear on a ribbon board not less than 19 × 89 mm (1 × 4 in. nominal) that has been let into the studs, and the joists are nailed to the studs. The end joists parallel to the exterior walls on all floors are also nailed to the studs.

74 Wall framing using balloon construction method



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As the spaces between the studs are not interrupted by wall plates (as they would be in platform framing), fire blocks are required at floor and ceiling levels to eliminate continuous concealed spaces in the wall. Lumber blocking 38 mm (1½ in.) thick is commonly used for this purpose. Fire blocking is not required where a wall space is filled with insulation.

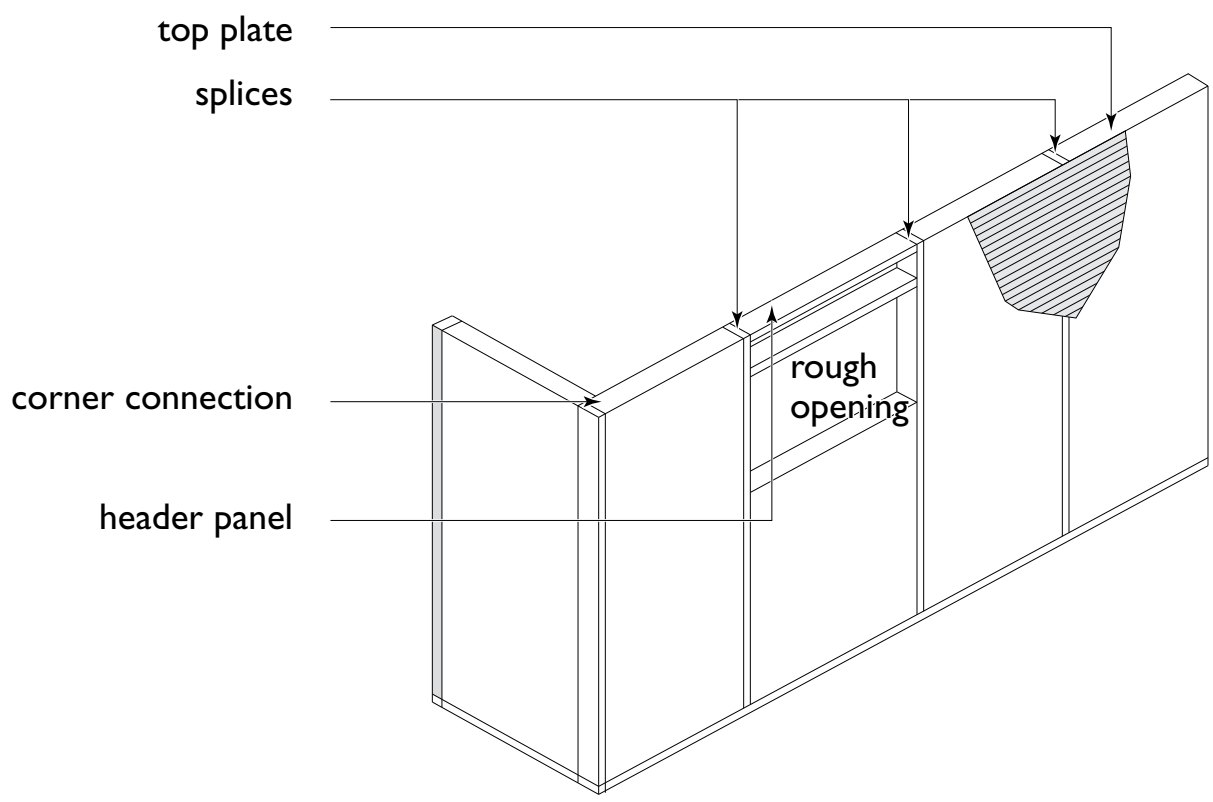
HIGHLY INSULATED WALLS

Consider building exterior walls with higher insulation levels than those required by the building code to reduce heating and cooling energy consumption and improve comfort (see Figure 19 in Chapter 5). Double-frame walls have been used successfully in cold climates and where the owners want highly energy-efficient construction. Rigid insulation applied over the exterior of the wall framing will increase the thermal resistance of the walls and reduce thermal bridging caused by the framing. Thermal bridging occurs when thermally conductive materials such as wood framing conduct heat through the building envelope, thereby bypassing the insulation in the framing cavity, and can considerably reduce the thermal resistance of a wall assembly.

STRUCTURAL INSULATED PANELS (SIPS)

Structural insulated panels consisting of an outer and inner layer of plywood or OSB bonded to a polystyrene insulation core provide both structural rigidity and high insulation levels. As most studs in the wall assembly have been eliminated, SIPs have negligible thermal bridging. The joints between SIP panels should be "tongue and groove" and sealed with caulking to prevent air leakage (Figure 75).

75 Structural insulated panel system (SIPS)



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CHOOSING THE SIZE AND SPACING OF WALL STUDS FOR PLATFORM FRAMING

Problem

Select the first floor wall studs that are able to support the superimposed loads as follows.

Conditions

First floor interior wall studs support a second storey and an attic that is not served by a staircase (that is, without storage).
All studs are 2.36 m (7 ft. 9 in.) long.

Selection

Use Table 25 (Appendix A).

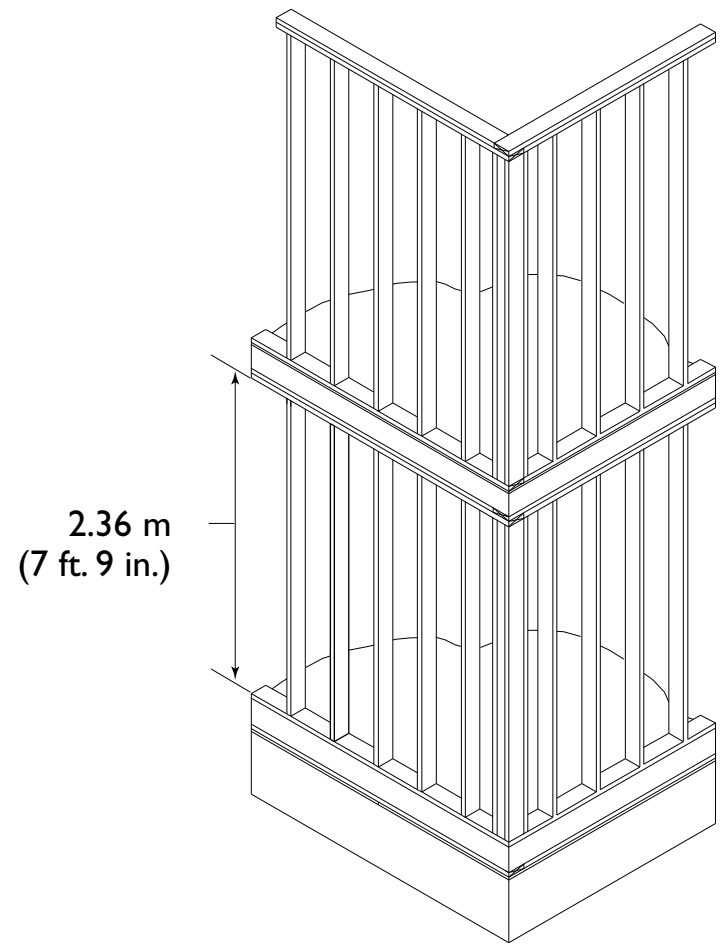
Acceptable wall stud sizes for this application include:

38 × 64 mm (2 × 3 in.) spaced at 400 mm (16 in.) on centre, or

38 × 89 mm (2 × 4 in.) spaced at 600 mm (24 in.) on centre

Note: In accordance with the National Building Code, the metric spacing of wood framing members is expressed as a "soft" conversion from the actual imperial dimensions. For example, spacing of 12, 16 and 24 inches on centre is converted to 300, 400 and 600 mm on centre, respectively. In order to suit the imperial sizes of common 1 220 × 2 440 mm (4 × 8 ft.) panel products, such as gypsum board, OSB and plywood, the actual spacing of framing members is commonly adjusted to 305, 406 and 610 mm on centre respectively.

76 Platform framing



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SUSTAINABLE HOUSING INSIGHT

Energy Efficiency

- Wood-frame construction provides space for insulation between the framing members. The dimensions of the framing may be increased or framing may be doubled to provide space for higher insulation levels.

Resource Efficiency

- Minimize the amount of waste from wall framing through proper planning and practices.
- Use dry lumber and store it properly to reduce damage.
- Use studs pre-cut to the required length for a standard wall height.
- For non-standard height walls, select lumber lengths that minimize the length of off-cuts.
- Space studs at 466 mm (19.2 in.) or 600 mm (24 in.) on centre when possible.
- Sort end cuts for reuse for blocking, bracing, etc.
- Lay out walls to maximize the use of full panels of plywood, OSB and rigid insulation.
- Reuse temporary braces as plates for the walls on the next floor.

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CHAPTER 11
Ceiling and Roof Framing



A roof must have a water-shedding surface air and vapour barriers to prevent moisture accumulation in the roof assembly, thermal insulation and ventilation to remove moisture that has escaped from the conditioned space. In Canada, most houses are framed with prefabricated wood trusses and have an unheated, ventilated attic space. Cathedral ceilings and flat roofs do not have attic spaces, but there must still be a vented space above the insulation to remove moisture.

Steeper roofs tend to shed water better than flat or low-slope roofs. The slope of a roof is expressed as a rise-to-run ratio with the vertical component, or rise, always shown first. There are two conventions for expressing the slope of a roof: imperial and ratio.

The imperial convention is based on the use of a framing square, and the run is always expressed as 12, based on 12 inches to a foot. For example, a roof with a slope of 45° is expressed as a 12/12 slope. A roof with a 4/12 slope has a rise of 4 inches for every 12 inches of run.

When expressed as a ratio, for slopes less than 45°, the *first* number (the vertical component) is always shown as one. A ratio of 1:5, for example, indicates a vertical of 1 unit for every 5 units of horizontal dimension. For slopes steeper than 45°, the *second* number (the horizontal component) is always shown as one. A ratio of 5:1, for example, indicates a vertical of 5 units for every one unit of horizontal dimension. The use of mixed units such as 1 mm in 10 m should be avoided.

Expressed as a ratio, the imperial designation of 4/12 is 1:3. In special cases where a high degree of accuracy is required, angular expressions of slope are acceptable.

Pitched roofs vary in slope from 1:6 to 1:1 or more. Roof slope affects such factors as the minimum slope required for various

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roofing materials to reduce the risk of water backing up through the roof membrane. The minimum allowable slope for asphalt shingles is 1:6, and there are different installation requirements for roof slopes of 1:3 or greater and slopes less than 1:3. There are minimum allowable slopes for each type of roofing material.

The dimensions of roof joists and rafters for the various grades and species of lumber and for various live loads are given in Tables 29 to 32 (Appendix A).

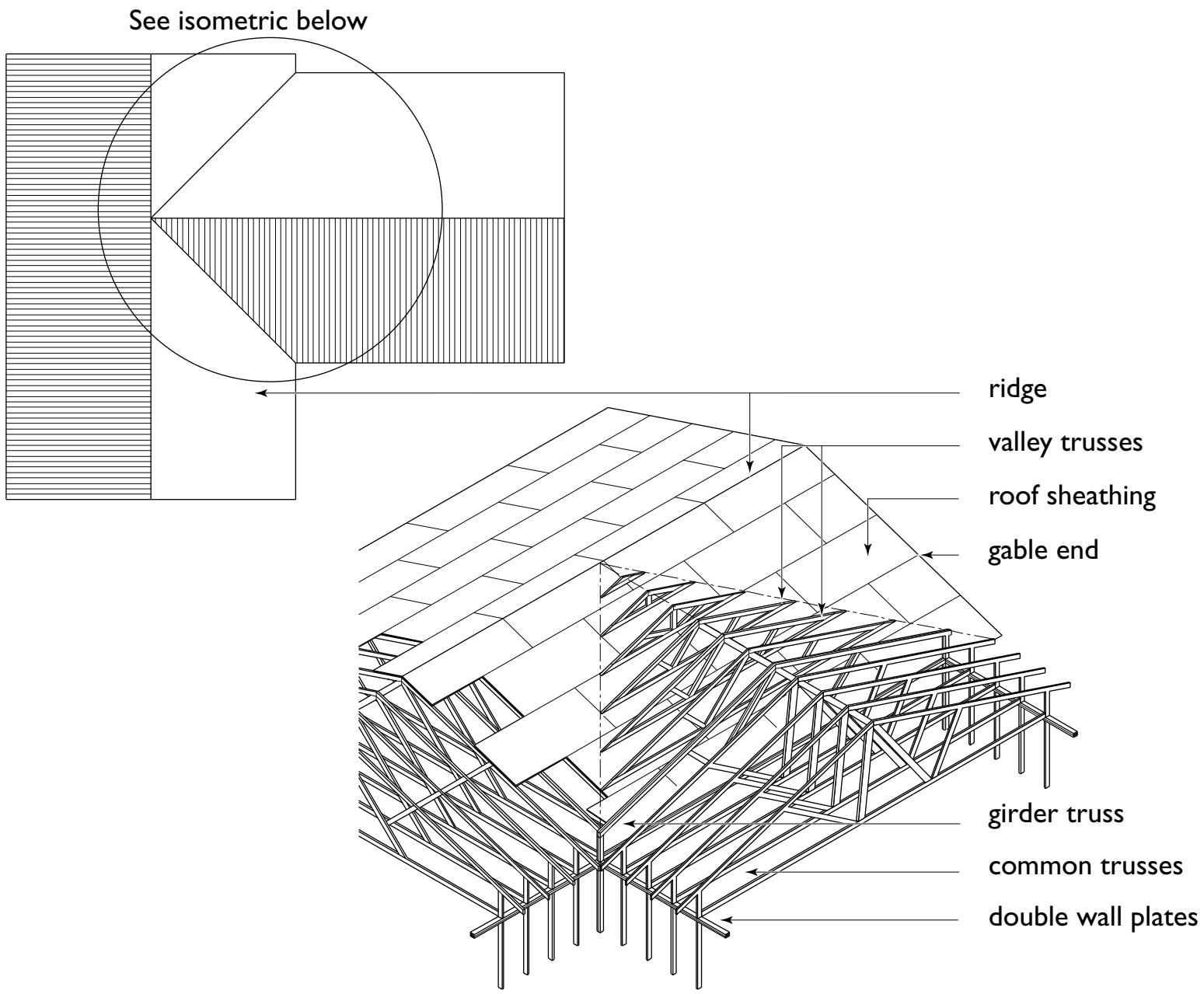
PITCHED ROOFS

Prefabricated roof trusses are most often used for framing residential roofs. Rafters framed on site are sometimes used. Of the pitched roofs, the gable roof is the simplest to construct. Other pitched configurations, such as a hip or L-shape roof, can also be framed with trusses (Figure 77).

Prefabricated Roof Trusses

Prefabricated roof trusses offer many advantages. They are designed to handle snow loads that the trusses will be subjected to, are manufactured

77 L-shape trussed roof



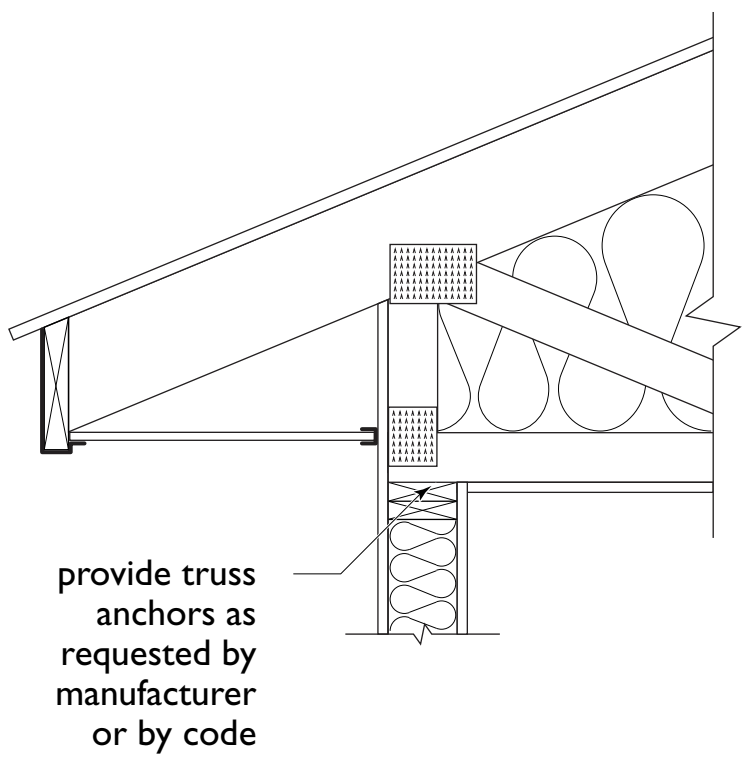
Note: For clarity, some structural members of some of the trusses have been omitted, and roof sheathing appears continuous.

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with a high level of quality control, reduce lumber waste and speed up the process of enclosing the house. They provide a surface for the roof sheathing, a surface for the ceiling finish material and a space for insulation. Raised heel trusses (Figure 78) are used in most new houses because they provide a deeper space at the eaves to accommodate greater amounts of insulation. The energy efficiency requirements in most building codes lead to the use of trusses, rafters and roof joists with a vertical dimension at the outer face of the exterior wall framing of 300 mm (12 in.) or more.

Ventilation of the attic space is easily provided through the eaves and at the ridge. In most cases, trusses are designed to span from exterior wall to exterior wall with no intermediate load-bearing walls to support the roof loads (Figure 79). This gives flexibility to interior planning because partitions can be placed without regard to structural requirements. A continuous air barrier and vapour retarder can be applied to the underside of the trusses before the interior partitions are erected.

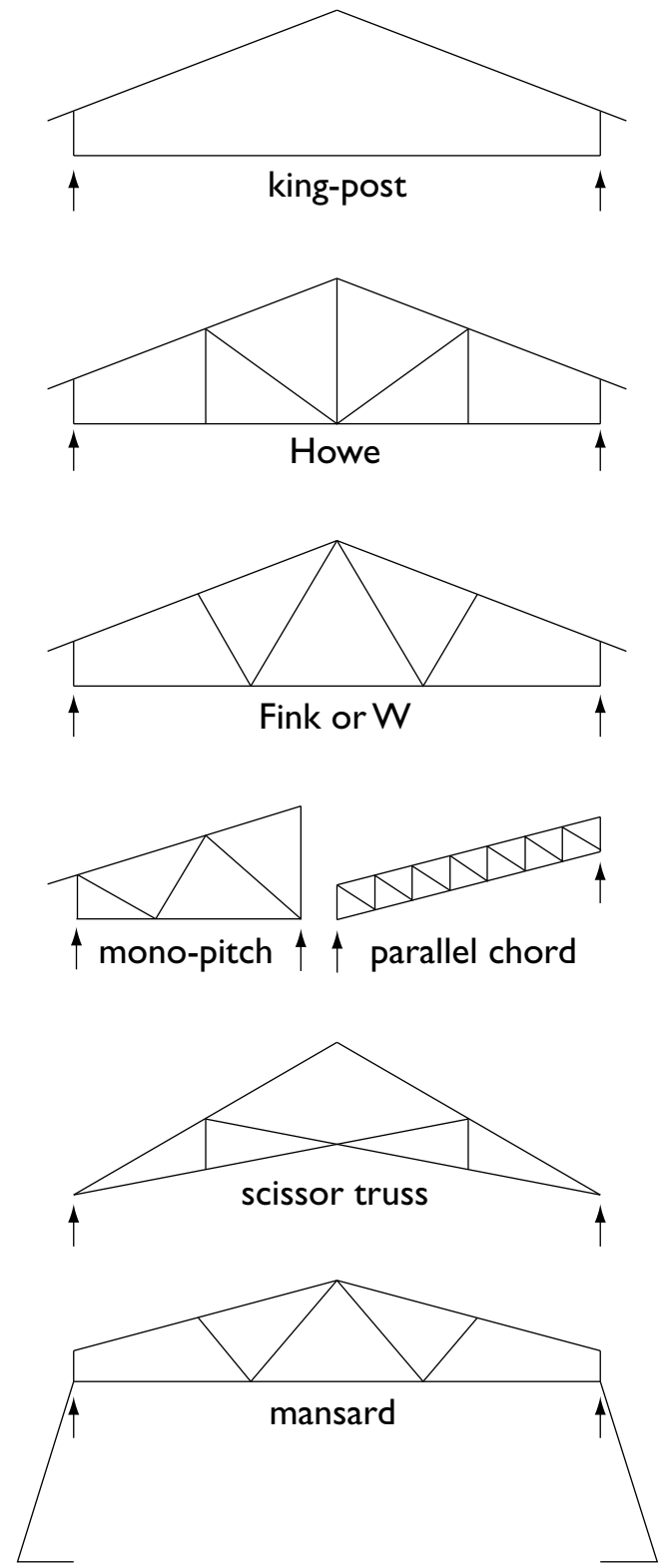
78 Raised heel roof truss provides depth for insulation



Prefabricated trusses should be stored on a flat, clean area of the construction site. Trusses shorter than a 6 m (20 ft.) span are usually installed by hand. Trusses longer than this require special lifting techniques to avoid damage.

Trusses must be lifted into a vertical position carefully to prevent excessive lateral bending. The gable truss is placed first and braced to

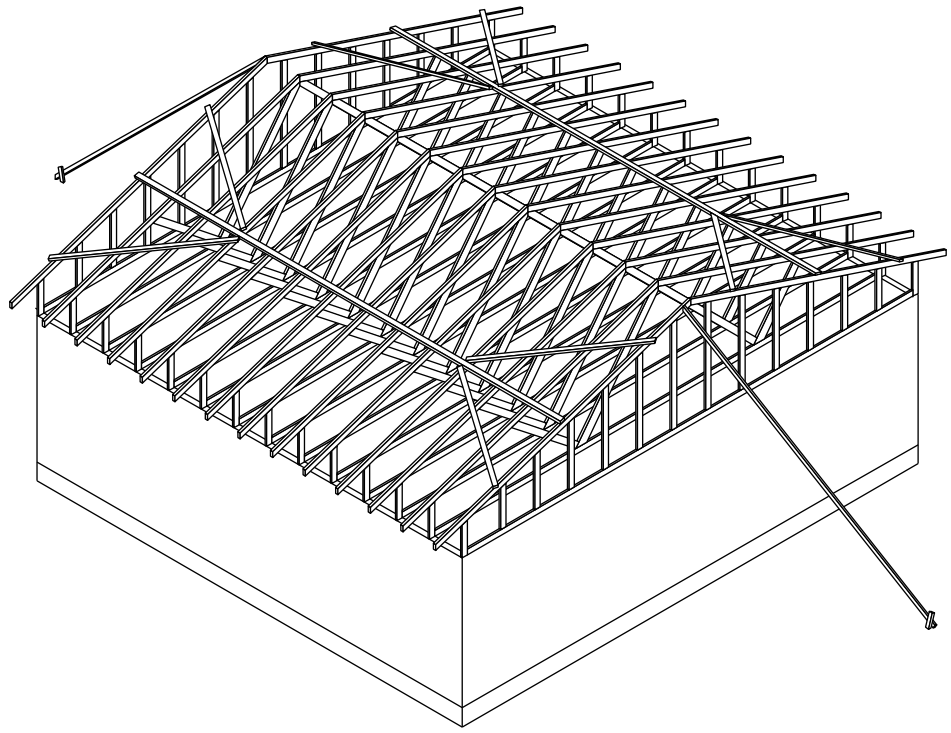
79 Types of prefabricated roof trusses



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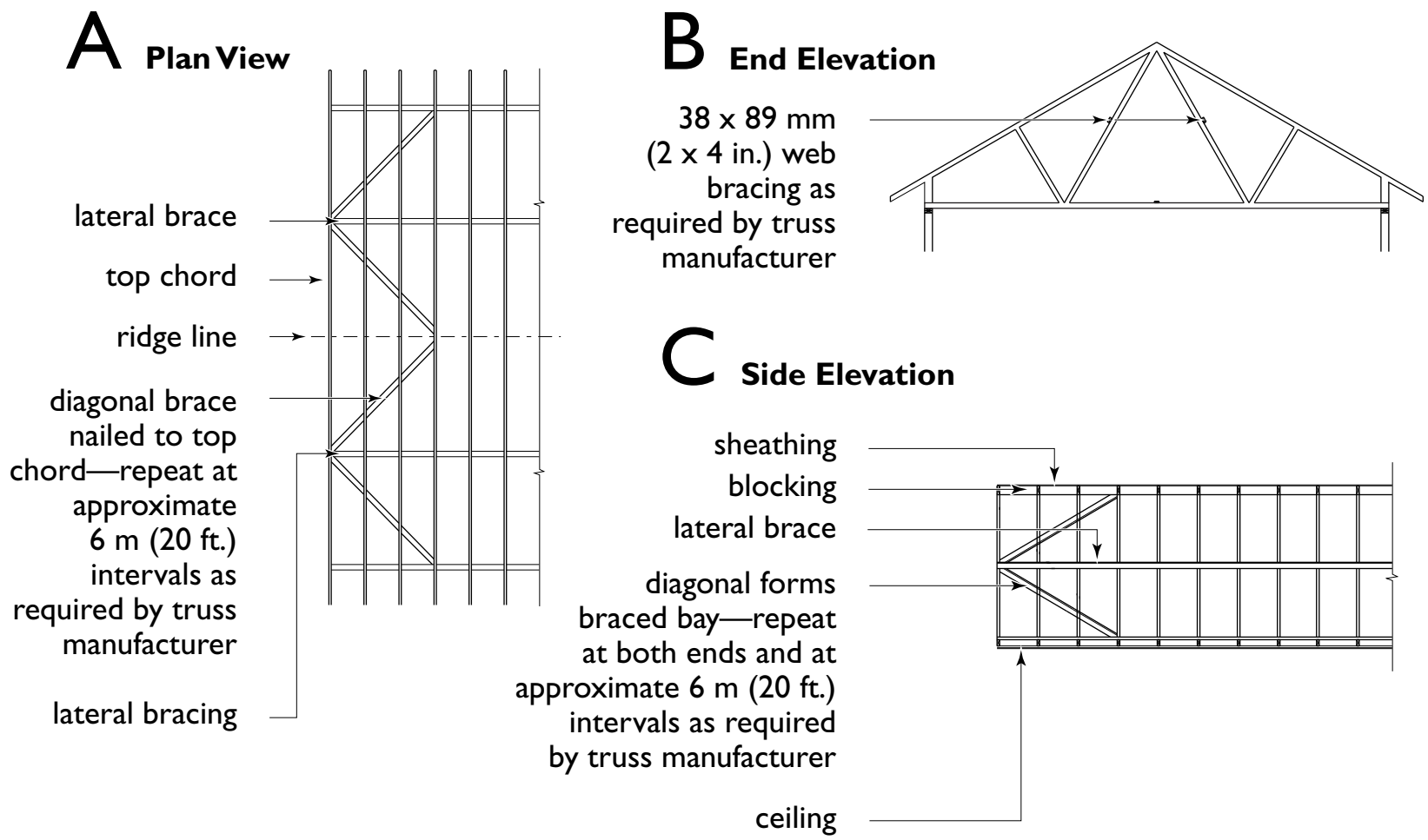
the ground and wall. Each additional truss is lifted into position, generally 600 mm (24 in.) on centre, toe-nailed to the top plates and temporarily braced (Figure 80). When all trusses are plumbed and properly positioned, they are braced permanently (Figure 81); a) permanent

80 Temporary bracing of roof trusses



Note: Gable ends are normally sheathed prior to installation of end braces.

81 Permanent bracing of roof trusses



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bracing of top chord plane, b) lateral web bracing and c) permanent bracing to web member or bottom chord plane. The stiffness of the roof is increased when the sheathing has been applied. Trusses must be installed and braced according to the manufacturer's instructions and must not be cut or altered.

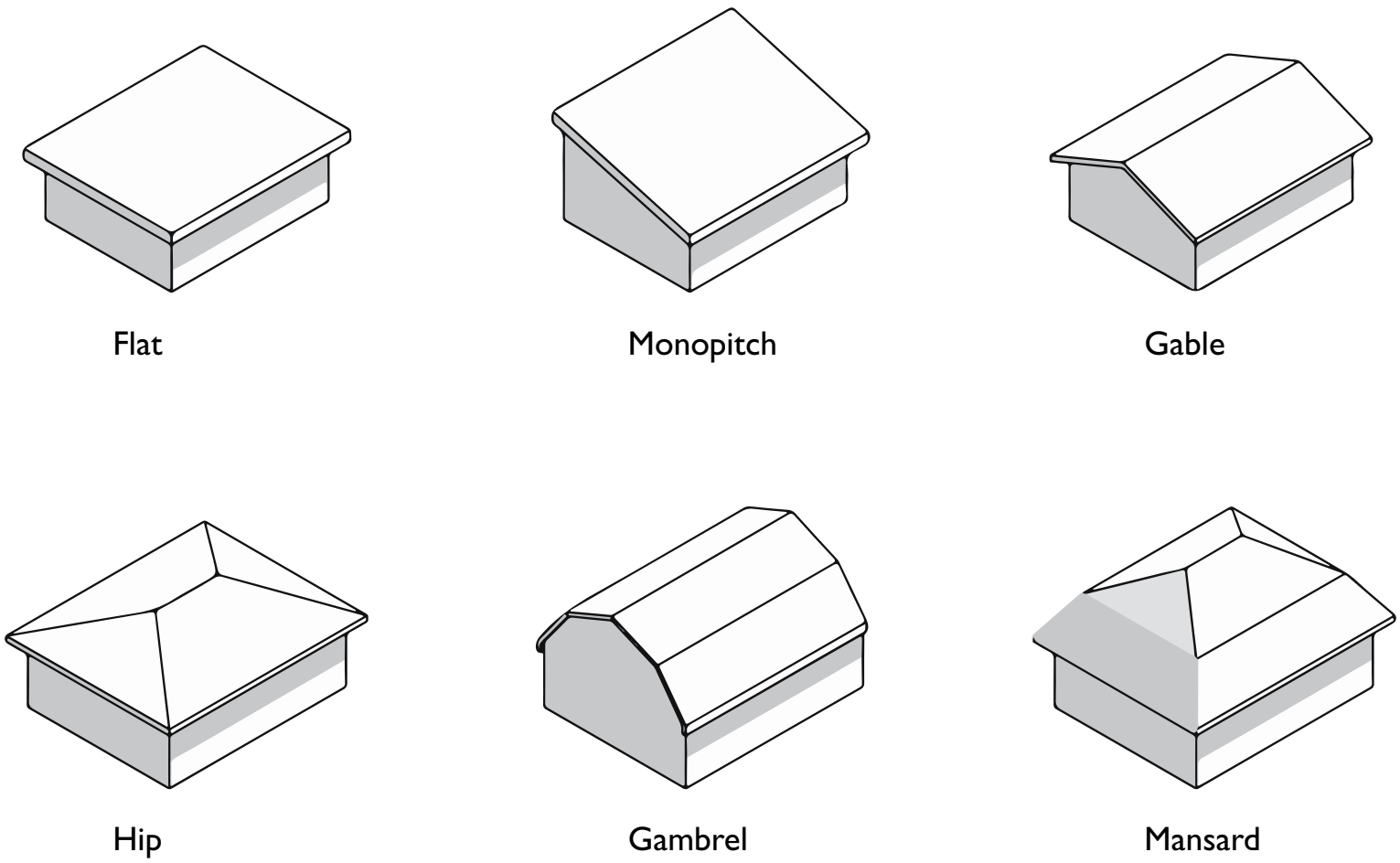
Site Assembly of Pitched Roofs

For on-site construction, the gable roof is the simplest roof constructed with rafters or trusses (Figure 82), which are the same length and pattern and can be erected rather easily. Dormers may be added to provide additional light, headroom and ventilation (see Figure 88). The hip roof design uses common rafters fastened to a ridge board, with hip rafters providing the support for the jack rafters (Figure 83b).

Liveable attic spaces need adequate insulation, an air barrier system and a vapour barrier as discussed in Chapter 5. The size of framing members found in Tables 29 to 32 (Appendix A) may need to be increased to provide space for additional insulation to meet energy efficiency requirements, or additional wood framing may be added to increase the space in the roof cavity.

Ceiling joists are used to support the ceiling finish and to act as ties between exterior walls and, in some cases, opposing rafters. They may also provide support for roof loads transferred to them by dwarf walls (knee walls) used as intermediate support for rafters, in which case they must be sized accordingly. (See Table 33 in Appendix A for ceiling joist spans.) When ceiling joists also support floor loads, determine what size is needed from the floor joist tables. (See Table 19 and Table 20 in Appendix A)

82 Types of pitched roofs

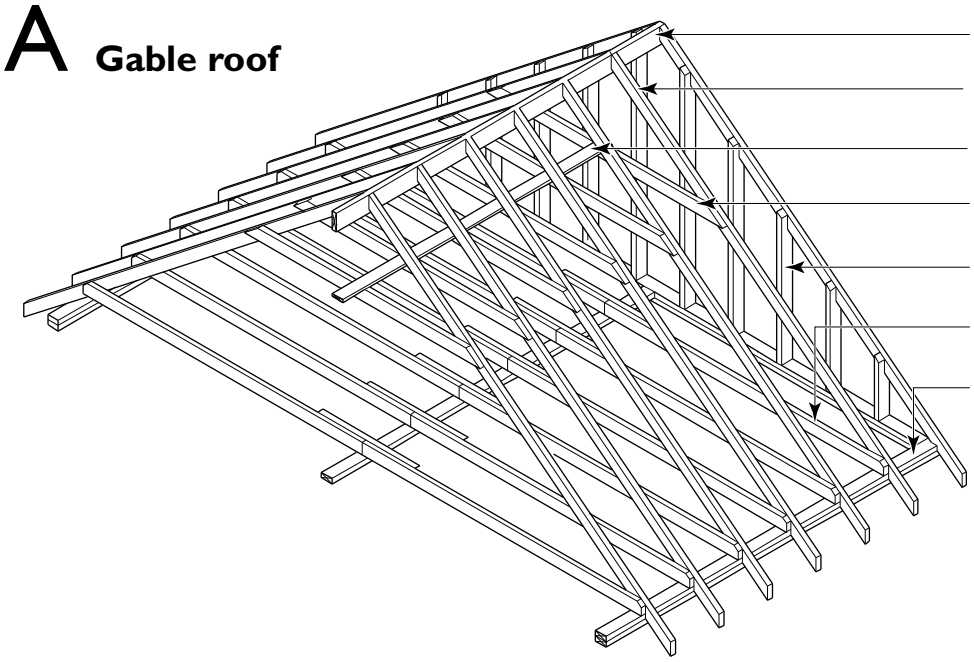


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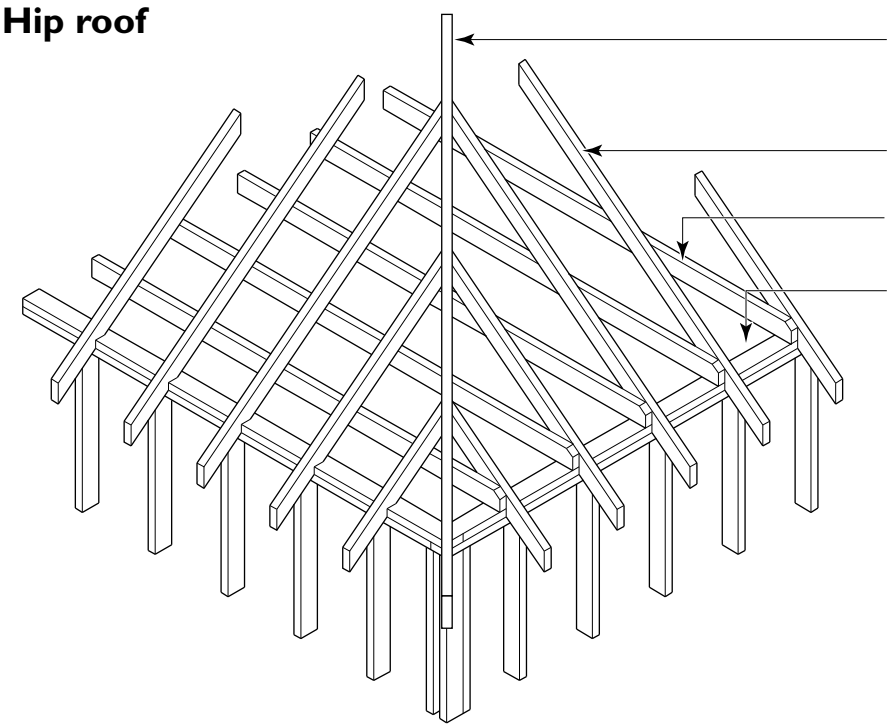
For pitched roofs framed with dimension lumber, nail the ceiling joists in place after the interior and exterior wall framing is complete but before the rafters are erected, because otherwise the thrust of the rafters will tend to push out the exterior walls. Ceiling joists are generally used to tie the lower ends of the rafters in pitched roofs that slope 1:3 or more. To prevent the rafter ends from moving outward, nail the ceiling joist to the side of each pair of rafters (Figure 83). For hip roofs where jack rafters run perpendicular to the ceiling joists, a stub joist can tie the jack rafter back to the ceiling joist (Figure 85). Lap and nail the joists together or splice them at the centre load-bearing wall to provide a continuous tie across opposing rafters. The number of nails required in the connections depends upon the roof slope, rafter spacing, snow load and the width of the house. (See Table 24 in Appendix A for nailing requirements.)

83 Roof framing and attachment

A Gable roof



B Hip roof

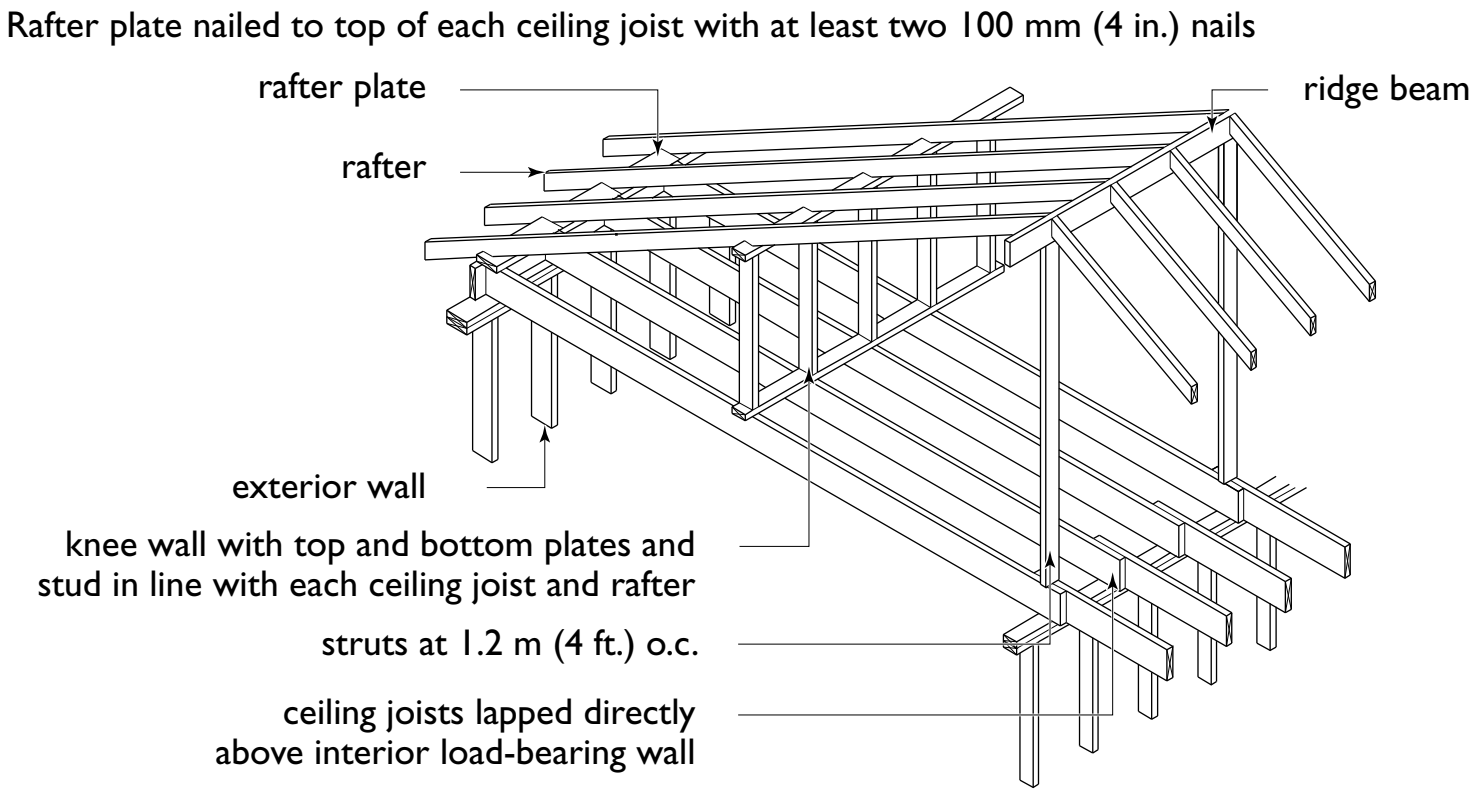


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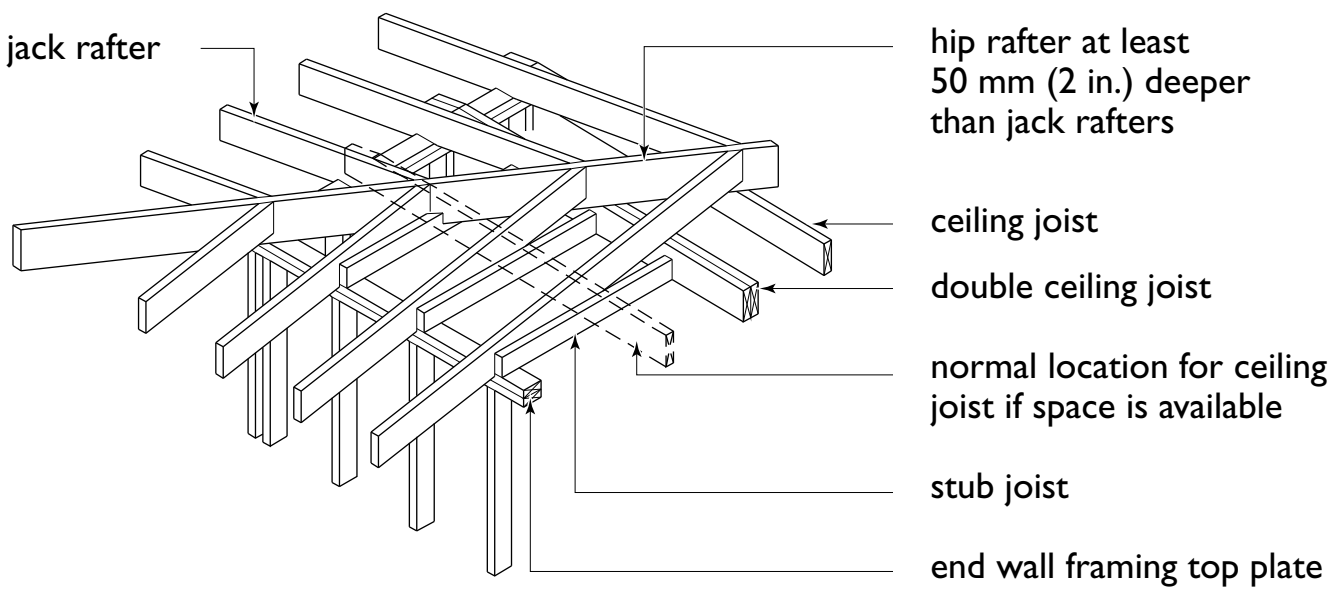
The additional roof load imposed by dwarf walls that run at right angles to ceiling joists (Figure 84) must be considered when choosing the size of the joists. An increase in the depth of the joists to the next standard depth will usually provide the additional strength required where the roof slope is more than 1:4. When the slope is 1:4 or less, determine the size of the ceiling joists from the span tables for roof joists (Tables 29 and 30 in Appendix A).

Since hip rafters are usually about 51 mm (2 in.) deeper than common or jack rafters, they reduce the space along the end walls to the extent that in low-slope roofs, there may not be enough room to install the outside ceiling joist at normal spacing from the wall. In this case, doubled joists are used and positioned to suit the available space (Figure 85). Tail joists are then added and toenailed to the outside wall plate and end-nailed

84 Rafter heel supported on a rafter plate



85 Doubled ceiling joists and stub joists used where a hip rafter reduces clear space near the end wall



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to the doubled joist. The spacing of these tail joists is usually the same as that of the main ceiling joists.

Cut rafters to length with the proper angle at the ridge and notches (known as bird's mouth joints) on the eaves. The heel or lower part of the rafters should bear directly over the exterior wall. Depending on the design of the roof and the shape of the outside walls, place the rafters:

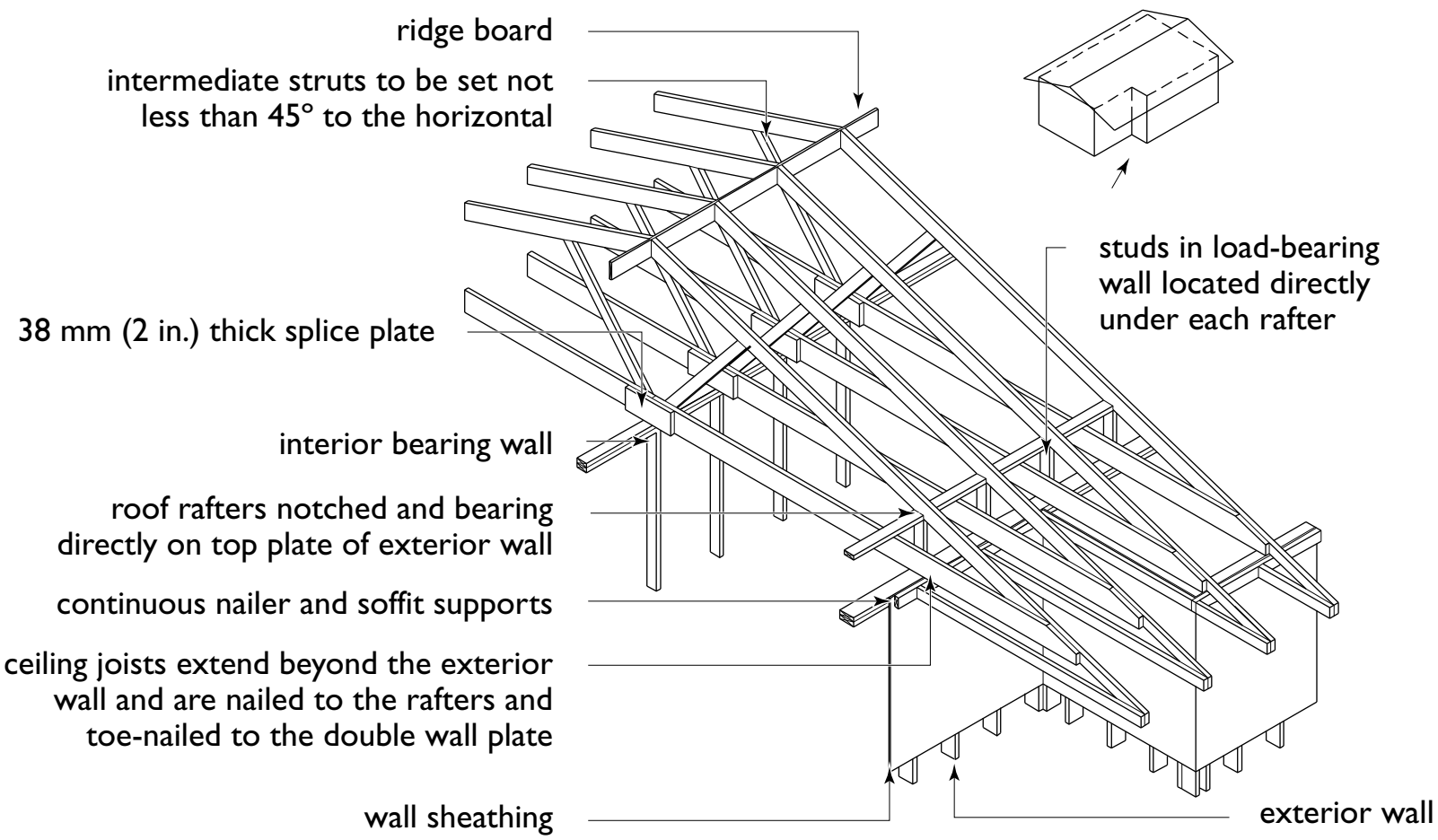
- directly on the wall plates (see Figure 83);
- on a rafter plate nailed to the top of the ceiling joists (see Figure 84); or
- on a load-bearing wall supported on the exterior wall plate (Figure 86).

The last method is used where a portion of the outside wall is inset. The ceiling joists extend beyond the exterior wall and are nailed to the side of the rafters. This provides lateral support for the bearing wall and stability for the ends of the rafters.

A ridge board (see Figure 83) or a ridge beam (see Figure 84) is used to ensure a level ridgeline and to facilitate placement of the rafters. Erect rafters in pairs and nail them to the ridge board or beam. Toe-nail the lower ends to the wall plate. Locate each pair of rafters directly opposite each other or offset at the ridge by not more than their thickness. Offsetting is required to maintain vertical alignment of the rafters when the lower ends are tied to ceiling joists that have been lapped (rather than butted together) at the centre load-bearing wall (see Figure 84).

A roof that slopes less than 1:3 should be vertically supported at the peak. This can be accomplished by providing a 38 × 140 mm (2 × 6 in. nominal) ridge beam supported at 1.2 m (4 ft.) intervals by 38 × 89 mm (2 × 4 in. nominal) vertical struts (see Figure 84). A load-bearing wall may be used instead of the ridge beam. Since the ridge support does not result in outward thrust of the roof members, continuous ties between the lower ends of

86 Rafter heel supported on load-bearing wall



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opposing rafters are not necessary. Ridge beams are also required for steeper pitched roofs when the outside ends of the rafters cannot be tied together to resist thrust.

Intermediate support is generally provided between the ridge and exterior walls to reduce the span of the rafters. This reduces the size of the rafters that is required, as the span is measured from this intermediate point to the ridge or eave support.

For rafters in roofs that slope 1:3 or more, intermediate support is usually provided by 38 × 89 mm (2 × 4 in. nominal) collar ties nailed to the side of each pair of rafters. Since these ties are in compression and subject to buckling, ties more than 2.4 m (8 ft.) long should be supported against lateral deflection. This can be done by nailing a 19 × 89 mm (1 × 4 in. nominal) continuous member at right angles to the collar ties near their centre with three, 76 mm (3 in.) nails at each end (see Figure 83).

Intermediate support for rafters in roofs that slope less than 1:3 is usually provided by a dwarf-bearing wall (see Figure 84) built in the same way as a load-bearing partition, except that a single top plate may be used where the rafters are positioned directly over the studs.

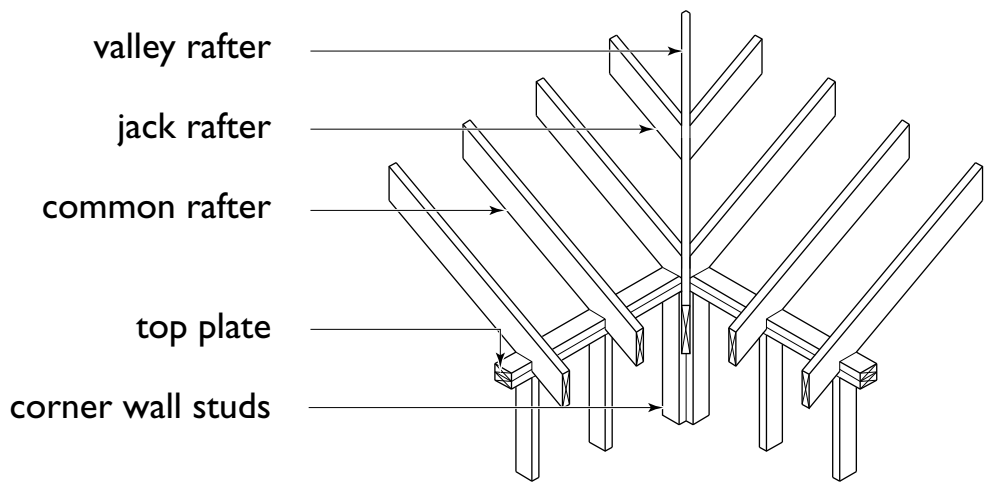
Struts may also be used as intermediate supports for rafters in pitched roofs. A 38 × 89 mm (2 × 4 in. nominal) strut (see Figure 86) is nailed to the side of each rafter and supported on a load-bearing partition. The angle of any struts should not be less than 45° from the horizontal.

Rafters at right angles to the ceiling joists may be supported at an intermediate point by a dwarf wall sitting on a beam placed between the ceiling joists. The underside of the beam is raised at least 25 mm (1 in.) above the ceiling finish by blocks inserted under the ends of the beam at the exterior walls and intermediate load-bearing partition. The space prevents the beam from damaging the ceiling finish when deflected by the roof loads.

A beam may also be used as intermediate support for hip and valley rafters. A roof strut is used to transfer the load from the hip or valley rafter to the beam. Where intermediate support is required for a few rafters in the end section on a hip roof, a simple support can be provided by a beam (sometimes called a “strongback”) consisting of two, 38 × 89 mm (2 × 4 in. nominal) members nailed together, set on edge and nailed to the bottom of the rafters. This beam is supported at points along its length by 38 × 89 mm (2 × 4 in. nominal) struts radiating from a common point of support on the intermediate load-bearing wall. The ends are cut to fit the selected angle and securely nailed in place.

Hip and valley rafters should be about 50 mm (2 in.) deeper than common rafters (Figures 83, 85 and 87). This additional depth provides full

87 Framing at a valley



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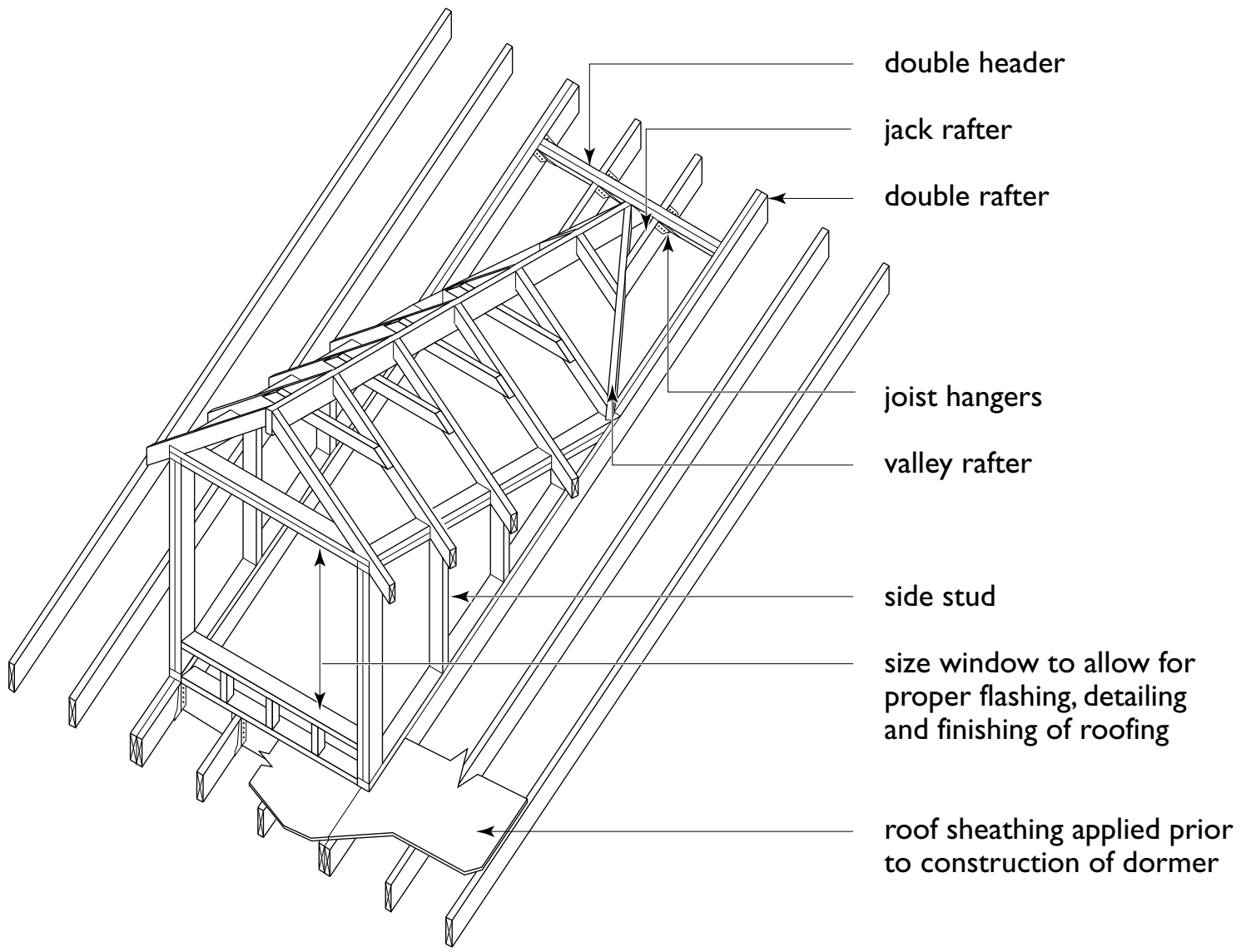
contact with the angle-cut of the jack rafters. In hip roofs, the jack rafters are nailed to the hip rafters and wall plate. Where a valley occurs, nail the jack rafters to the valley rafter and ridge.

Dormers are framed so that the rafters at each side are doubled to support the side studs and valley rafters. The top ends of the valley rafters are supported by a header spanning between the doubled rafters (Figure 88). The most common method of construction is to install the roof sheathing before the dormer is framed, and then cut the sheathing flush with the framing members around the opening. A bottom plate added on top of the sheathing supports the side studs enclosing the dormer and also serves as a nailing base for the wall sheathing.

Gable-End Framing and Projections

After roof framing members have been installed, the gable-end studs are nailed in place. Studs in unfinished attics can be placed with the wide face parallel to the wall. Cut the ends of the studs to fit the angle of the rafter and toenail them to the wall plate and to the underside of the rafter with at

88 Typical dormer framing

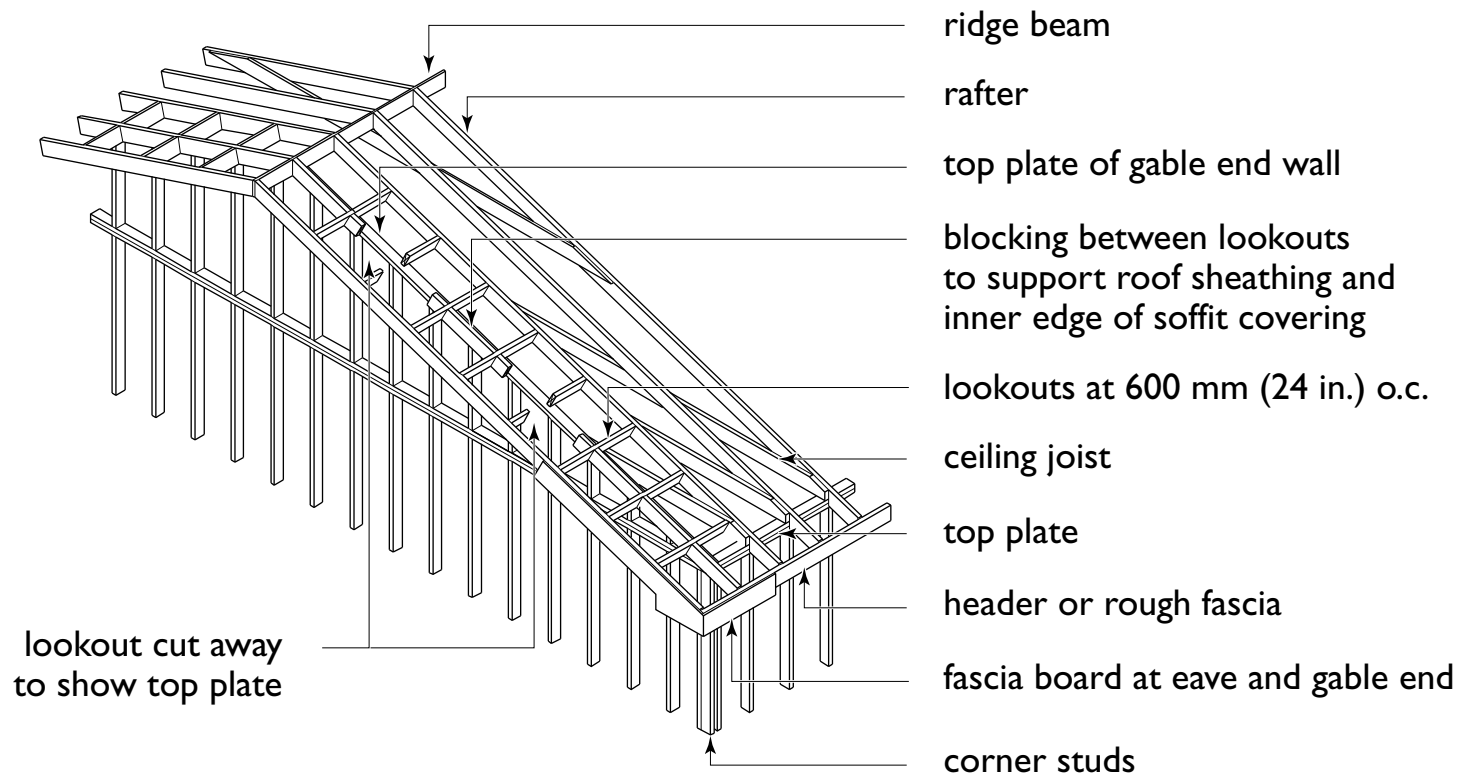


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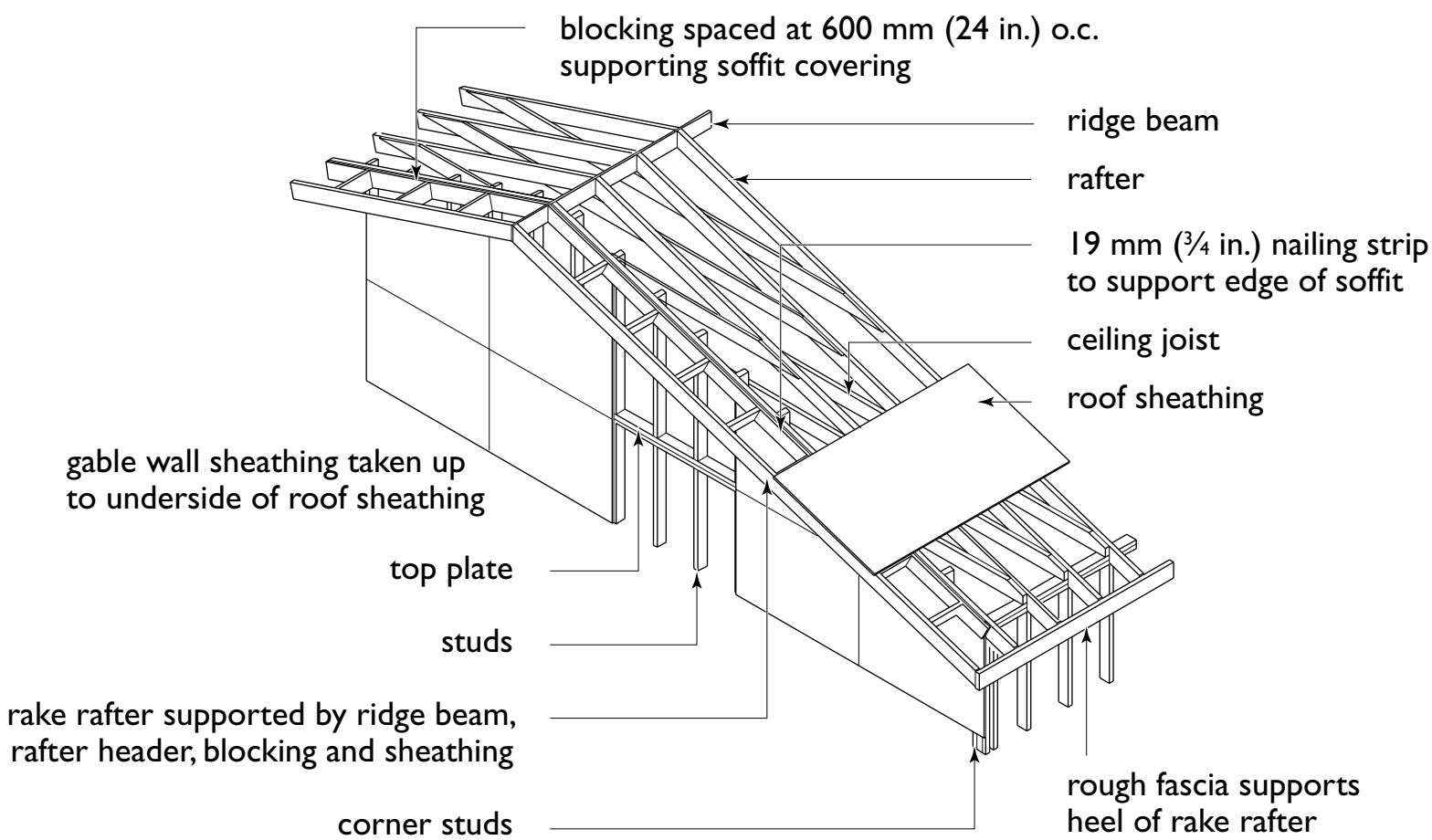
least four 63 mm (2½ in.) nails at each end (Figure 89). The framing of the roof projections at the gable ends is shown in Figures 89 and 90.

Roofs that project less than 300 mm (12 in.) over the gable-end wall usually terminate with a framing member called a rake rafter

89 Wide projection at gable end supported by "lookout" rafters



90 Narrow projection at gable end



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(see Figure 90). A 19 mm (¾ in. nominal) nailing strip is fastened to the rafter located above the gable end wall. Blocking spaced at 600 mm (24 in.) on centre is used to support the soffit covering. This blocking is toenailed to the nailing strip and end-nailed to the rake rafter. The soffit covering is then installed and nailed to these supports and a fascia board is added.

Gable-end projections extending more than 300 mm (12 in.) beyond the wall should be supported by framing members called "lookouts" (see Figure 89). Gable-end studs are placed with the narrow face parallel to the sheathing, and a top wall plate is added. The lookout members, usually the same size as the rafters, are spaced at 600 mm (24 in.) on centre.

The ends are supported by end-nailing to the first rafter and inboard of the gable end to the top plate of the gable. Blocking is then fitted between the lookouts in line with the wall line to support the roof sheathing and inner edge of the soffit covering. The soffit covering is nailed to these supports, and a fascia is added. The length of lookout members should be at least twice the width of the roof overhang. A double rafter is used to support the inner ends of the lookout members when they project into the roof more than one-and-one-half rafter spaces.

Low-Slope Roofs

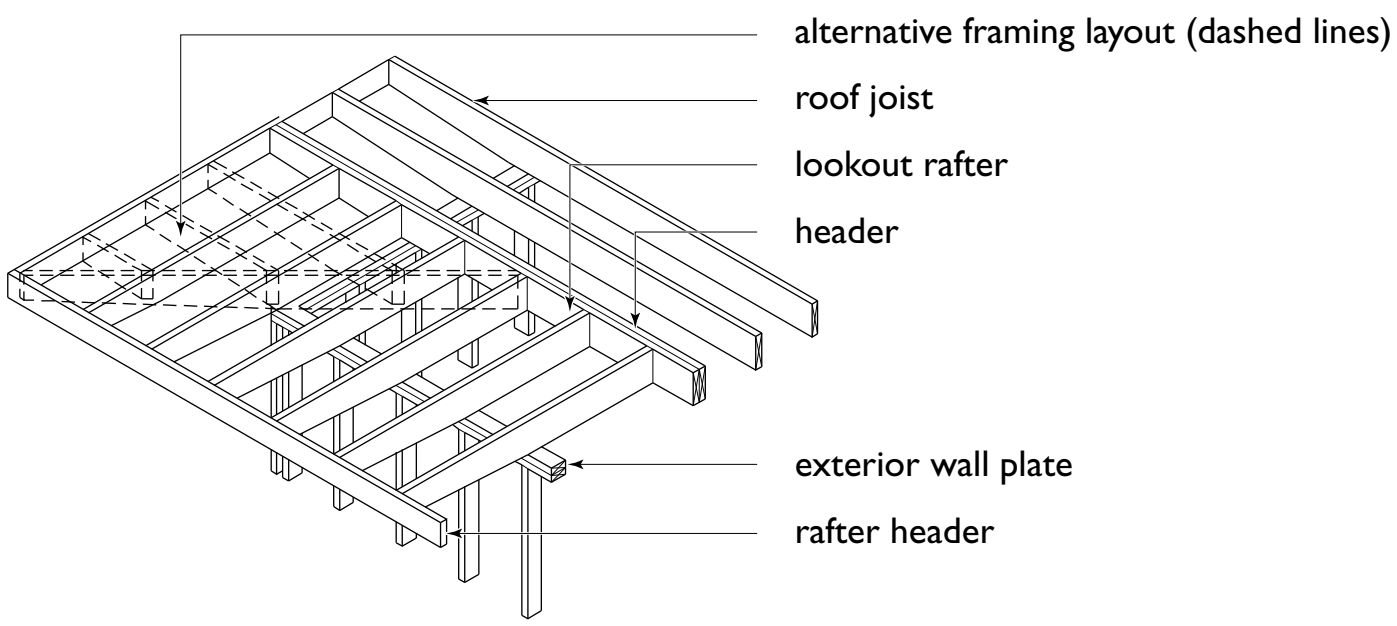
Low-slope roofs must be constructed more water-tight than pitched roofs because drainage is poorer. They sometimes support decks or terraces or occasional traffic and therefore must be protected with durable, wear-resistant materials.

Where rafters also serve as ceiling joists, the term "roof joist" is used. Their size is determined by both roof and ceiling loads. (See Tables 29 and 30 in Appendix A.) Rafters chosen for structural adequacy may not, however, provide adequate depth for insulation and ventilation of the roof space. In such cases, wider lumber or engineered wood products should be used.

Roof joists for low-slope roofs are usually laid level or nearly level, with roof sheathing and a roof covering on top. The underside of the roof joists supports the ceiling. A slope of at least 1:50 is required for drainage. Slope the joists by adding a ledger strip at the top of the bearing wall or by adding a tapered strip to the top of the joists.

Lookout rafters are usually used when an overhang is provided for a low-slope roof (Figure 91). If the lookout rafters project into

91 Typical construction of a low-slope roof with overhang



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the ceiling area more than one and one-half joist spaces, two roof joists are nailed together to form a header. One outside rafter header is then added and end-nailed to the lookout rafters and roof joists. This serves as a nailing support for the roof sheathing, fascia board and soffit covering.

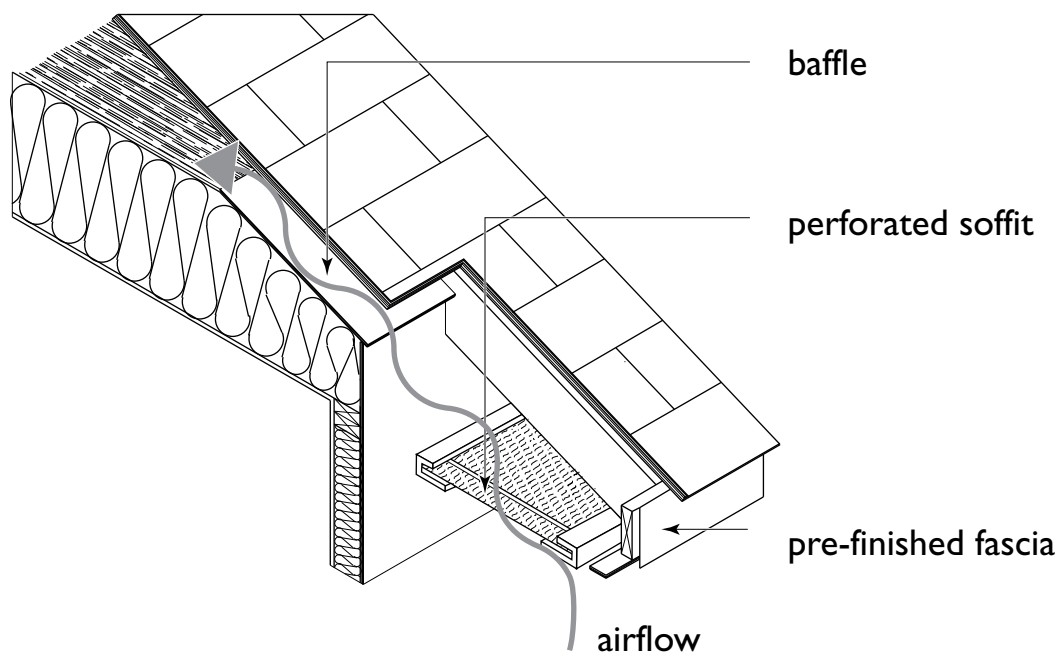
ROOF SPACE VENTILATION

Always provide adequate ventilation of the roof space above the insulation. Accumulated water vapour in attic spaces and under low-slope roofs could condense during cold weather in sufficient quantity to cause damage. Since most types of roof membranes are highly resistant to vapour transmission, vapour does not pass through them and ventilation is needed to remove vapour that enters the roof space.

During cold weather, heat lost through the ceiling insulation combined with sun exposure may provide enough heat to melt the snow on a roof but not on the projecting eaves. Water from the melting snow can freeze and form ice dams at the eavestrough and roof overhang, which are exposed to outdoor temperatures on all sides and are therefore colder than the ceiling. This may cause water to back up at the eaves, penetrate through the roof and leak into the walls and ceilings (see Figure 100). Adequate airtightening in combination with insulation and ventilation beneath the roof sheathing will keep attic temperatures low during winter and help prevent snow on the roof from melting. A space above the insulation between the exterior walls and the underside of the roof sheathing allows ventilation from the eaves to the attic space. When no air ventilation baffles are used, the clearance must be at least 63 mm (2½ in.). If baffles are used, the clearance can be reduced to 25 mm (1 in.) (see Figure 24 in Chapter 5).

Roofs with slopes of 1:6 and greater are required to have an unobstructed vent area at least 1/300 of the insulated ceiling area, measured on a horizontal plane. For roofs with slopes less than 1:6, the area must be at least 1/150 of the ceiling area. Roof-, gable- or eave-type vents can be used (see Figures 92 and 93). Vents must be uniformly

92 Soffit roof ventilation



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distributed with at least 25 per cent of the vent area located at the bottom of the space and at least 25 per cent at the top.

If batt insulation is placed between the roof-ceiling joists in a low-slope roof, a ventilated space of at least 63 mm (2½ in.) must be provided between the top of the insulation and the underside of the roof sheathing. This can be achieved by placing 38 × 64 mm (2 × 3 in. nominal) cross-purlins over the top of, and at right angles to, the roof-ceiling joists. The cross-purlins may be shimmed to provide the required roof slope (see Figure 25 in Chapter 5).

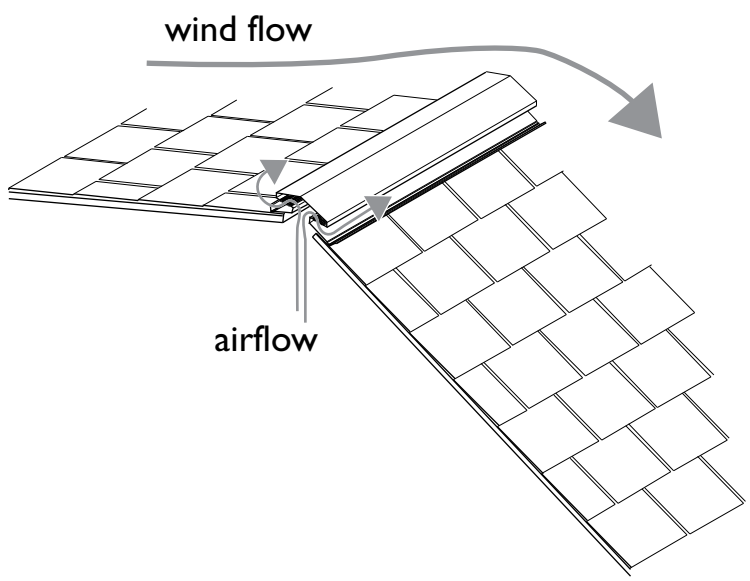
If rigid insulation is installed on top of the roof sheathing (and below the roof covering), the space above the ceiling is not ventilated.

Vents must not allow the entry of rain, snow or insects. If a vent is a potential source of moisture entry, a baffle is required to reduce air flow. Corrosion-resistant metal or plastic materials should be used for vents and to screen ventilator openings.

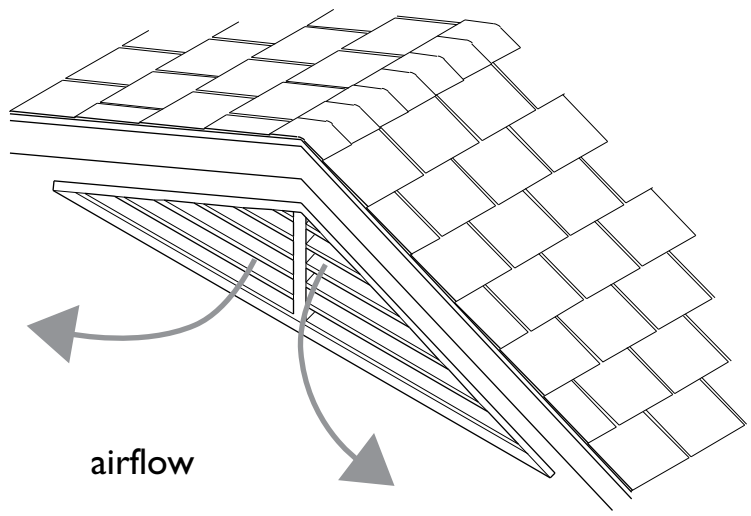
Except for very small attic spaces, attics require an access hatch. The area of the hatch must be at least 0.32 m^2 (3.4 sq. ft.) with no dimension less than 500 mm (20 in.).

93 High-level roof ventilation

Ridge vent



Gable vent



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CHOOSING THE SIZE AND SPACING OF CEILING JOISTS

Problem

Select the minimum ceiling joist that is acceptable for the following conditions:

Conditions

- Attic is inaccessible and is not used for storage.
- Ceiling supports the insulation and drywall interior finish.
- Span is 4.3 m (14 ft. 2 in.).
- Ceiling joist spacing is 400 mm (16 in.).
- Species group and grade specified is SPF No. 2 and better.

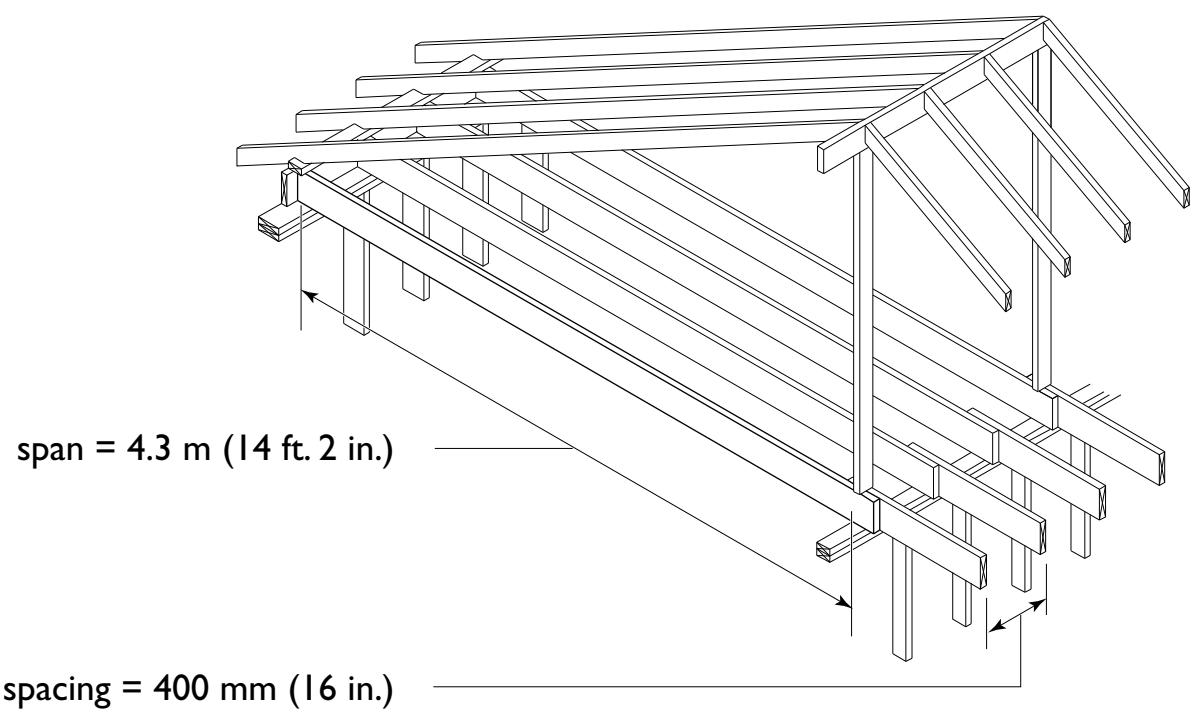
Selection

Use Table 33 (Appendix A).

For this application select 38 × 140 mm (2 × 6 in.) ceiling joist.

Note: In accordance with the National Building Code, the metric spacing of wood framing members is expressed as a "soft" conversions from the actual imperial dimensions. For example, spacing of 12, 16 and 24 inches on centre is converted to 300, 400 and 600 mm on centre, respectively. In order to suit the imperial sizes of common 1 220 × 2 440 mm (4 × 8 ft.) panel products, such as gypsum board, OSB and plywood, the actual spacing of framing members is commonly adjusted to 305, 406 and 610 mm on centre, respectively.

94 Ceiling joists



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CHOOSING THE SIZE AND SPACING OF ROOF RAFTERS

Problem

Select the smallest dimension rafter that is able to span the roof as follows.

Conditions

- Building is located in Ottawa.
- Specified roof snow load is 1.72 kPa (36 lbs/sq. ft.).
- Roof slope is 1:3.
- Rafter span is 4.7 m (15 ft. 6 in.).
- Species group and grade specified is SPF No. 2 and better.
- Shingle roofing to be used.
- Lower ends of the rafter are restrained.

Selection

Use Table 31 (Appendix A).

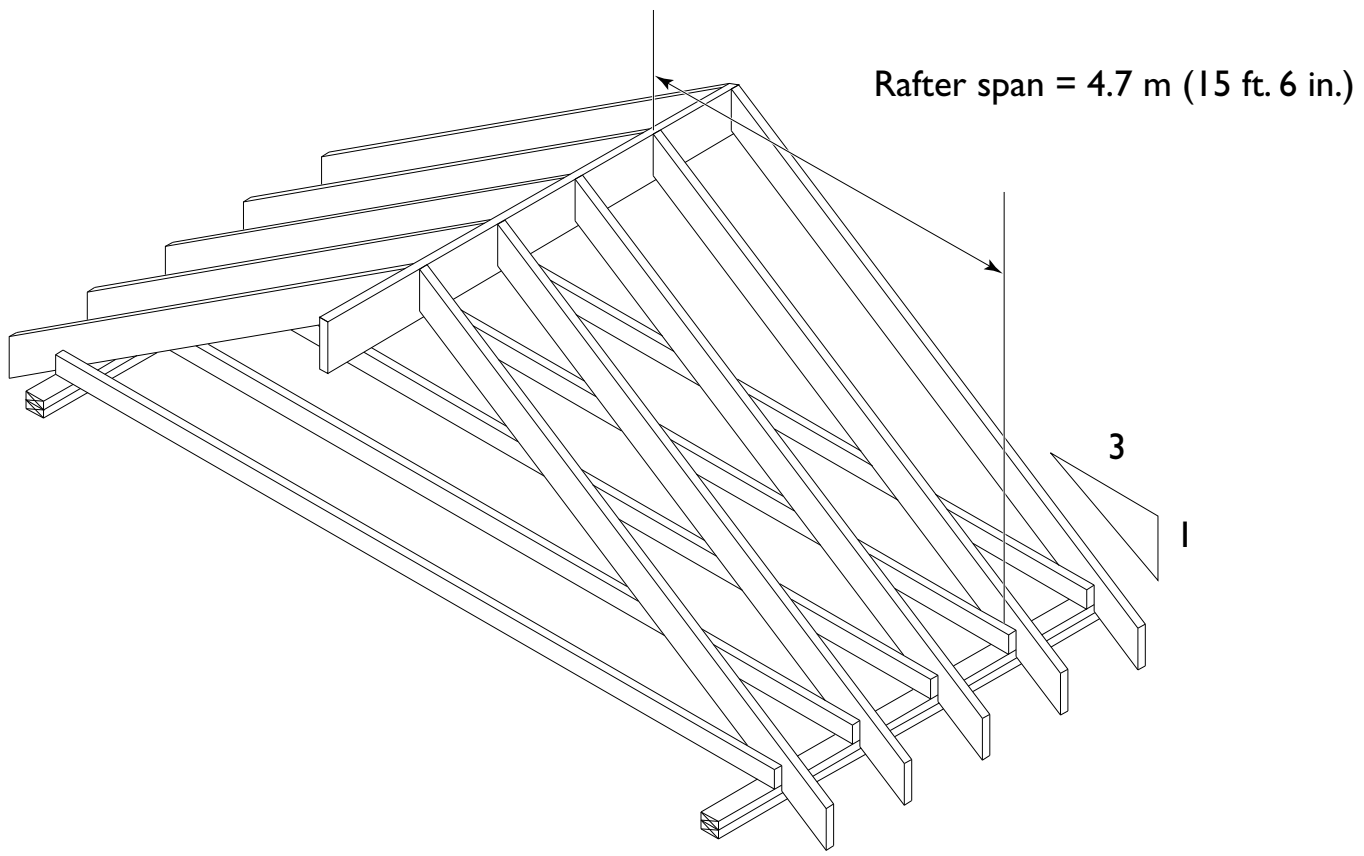
Acceptable rafters include:

38 × 184 mm (2 × 8 in.) at 300 mm (12 in.) on centre.

38 × 235 mm (2 × 10 in.) at 600 mm (24 in.) on centre.

Note: The rafters must also be deep enough to accommodate the required level of insulation.

95 Roof rafters



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CHOOSING THE SIZE AND SPACING OF ROOF JOISTS

Problem

Select the roof joists that are able to span the roof as follows.

Conditions

- Building is located in Ottawa.
- Specified roof snow load is 1.72 kPa (36 lbs/sq. ft.).
- Roof slope is 1 in 3.
- Roof joist span is 4.19 m (13 ft. 9 in.).
- Species group and grade specified is SPF No. 2 and better.
- Shingle roofing to be used.
- Lower ends of the roof joists are restrained.

Selection

Use Table 29 (Appendix A).

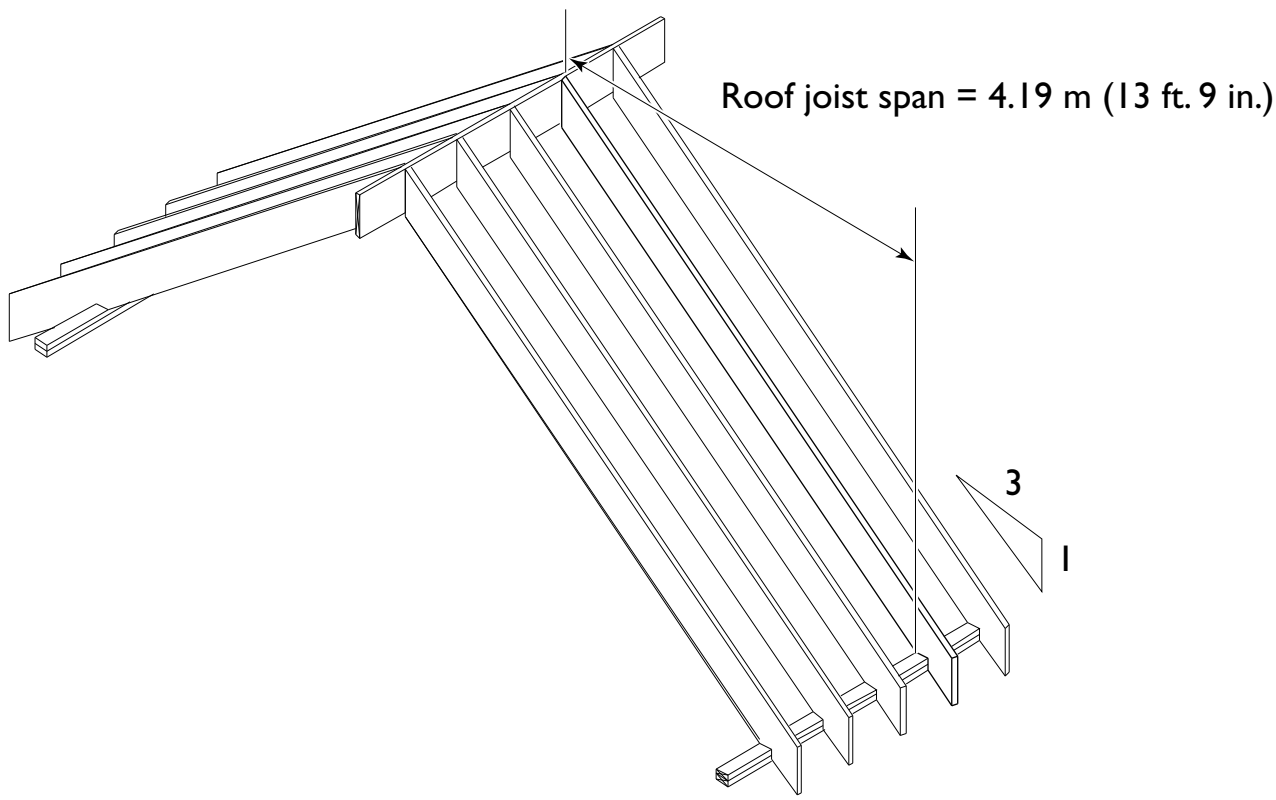
Acceptable roof joists include:

38 × 235 mm (2 × 10 in.) at 400 mm (16 in.) on centre.

38 × 286 mm (2 × 12 in.) at 600 mm (24 in.) on centre.

Note: The roof joists must also be deep enough to accommodate the required level of insulation.

96 Roof joists



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SUSTAINABLE HOUSING INSIGHT

Energy Efficiency

- Use raised heel trusses or rafters/roof joists that are deep enough to contain high levels of insulation over exterior walls.
- Consider using raised heel trusses that are deep enough at the eaves to accommodate higher levels of insulation than required by the building code.
- Consider increasing the depth of roof framing members or reducing the spacing between them to accommodate future solar thermal and photovoltaic panels. Consult a structural engineer.

Resource Efficiency

Prefabricated roof trusses are widely used for residential roof framing. Trusses use an efficient arrangement of select lumber and metal plates to provide long spans and reduce the amount of wood required as compared with framing with lumber rafters and joists. They provide the following advantages:

- Designed to suit local climatic conditions.
- Fast to erect leading to earlier close-in.
- Ample space for insulation and ventilation.
- Available to suit all possible roof shapes.
- Eliminate cut-offs at the site.

Affordability

When planned in advance, attic space can be converted to high-quality living space. This is economical because it provides additional space without increasing the building footprint and makes use of an existing roof. Consider these factors when planning attic rooms:

- Plan stair locations so access can be extended to the attic space in the future.
- Size ceiling joists as floor joists or design the attic trusses or rafters for future habitable space. Use ceiling insulation that may be moved to the roof assembly during conversion.
- Ensure that the roof assembly will accommodate sufficient insulation with a ventilation air space above it.
- Steeper roof slopes shed snow and rain more effectively and enclose more attic volume than lower slopes.
- Rough in or plan for future services such as electricity, plumbing, heating, ventilation, cable and telephone.

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CHAPTER 12
Roof Sheathing and Coverings



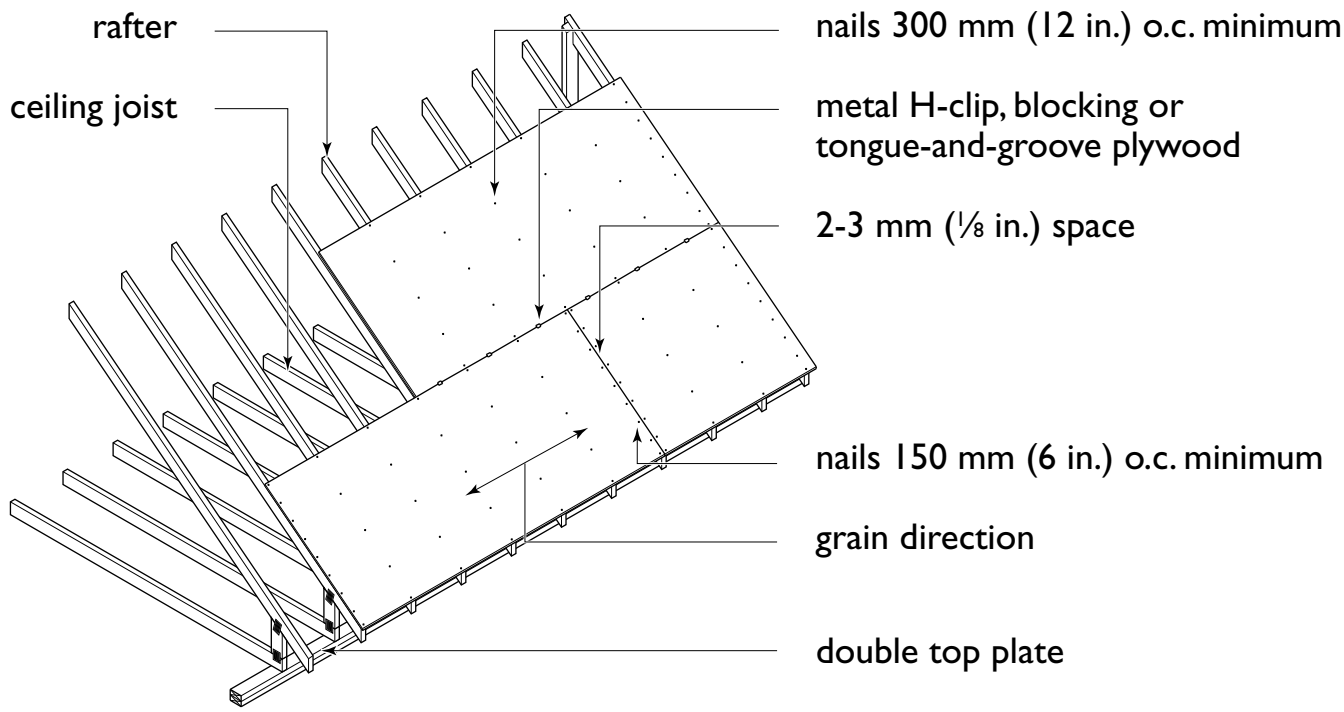
ROOF SHEATHING

Sheathing-grade plywood or OSB or lumber planks are applied over roof trusses, joists or rafters to provide a nailing base for the roof covering and lateral bracing of the roof framing.

Installing Roof Sheathing

When plywood or OSB is used for roof sheathing, sheets are laid with the face grain at right angles to the framing (Figure 97) and with the joints offset to obtain a good

97 Application of structural wood-panel roof sheathing



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tie across the roof framing. Leave a 2 to 3 mm (⅛ in.) gap between panels to prevent buckling should expansion in the sheathing occur.

The required thicknesses of the plywood, OSB or other roof sheathing are shown in Table 35 (Appendix A). Sheathing thickness depends on the spacing of the rafters, roof joists or trusses and whether the edges of the sheets are supported. To prevent damage to the roof covering when thinner panels are used, support the joints with 38 × 38 mm (2 × 2 in. nominal) blocking nailed securely between the roof framing members, or by metal H-clips inserted between sheets. H-clips are widely used because installation is simple and economical.

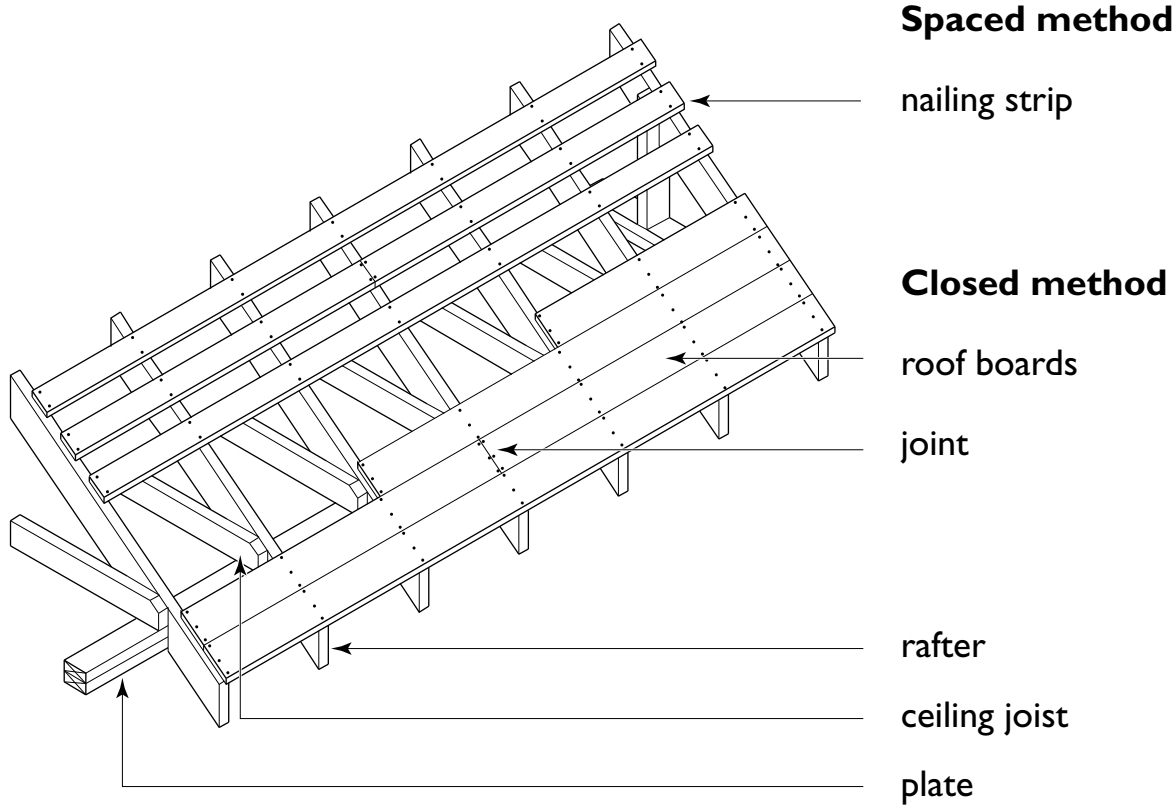
It is good practice to stagger the location of fasteners at the edges of adjoining panels. Staple fasteners for 9.5 mm (⅜ in.) roof sheathing must be at least 1.6 mm thick, 38.1 mm long with a 9.5 mm crown (1/16 in. thick, 1½ in. long with a ⅜ in. crown), and be driven with the crown parallel to the framing (Table 38 in Appendix A). Thicker roof sheathing (Table 22 in Appendix A)—no less than 15.5 mm (⅝ in.)—is required for built-up roofing on a low-slope roof to be used as a walking deck.

Lumber sheathing must be laid closed, or edge to edge (Figure 98) with all ends supported and joints staggered. For exposure to high wind or earthquake forces, lumber sheathing must be laid diagonally or be engineered. The boards are usually 19 mm (¾ in. nominal) thick, but this thickness may be reduced to 17 mm (11/16 in.) where supports are spaced at 400 mm nominal (16 in. actual) or less on centre.

Boards 184 mm (8 in. nominal) or less in width are nailed to the framing members with at least two, 51 mm (2 in.) nails per bearing. Those wider than 184 mm (8 in. nominal) should be nailed with at least three, 51 mm (2 in.) nails per bearing. For areas with high wind loads, the length of the nails must be increased to 63 mm (2½ in.).

Boards wider than 286 mm (12 in. nominal) should not be used for roof sheathing. For a wood shingle roof, the roof boards may be spaced

98 Installation of wood-board roof sheathing



Note: For areas exposed to high wind and earthquake forces, lumber roof sheathing must be installed diagonally.

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the same distance apart on centre as the shingle exposure. This method (Figure 98), commonly used in damp climates, permits air movement and allows shingles to dry between wettings, reducing the possibility of decay.

Roof Sheathing Details

Where openings occur in the roof structure for interior chimneys, the roof sheathing and framing members should have a clearance of 50 mm (2 in.) on all sides from the finished masonry, or metal chimney for fire safety (Figure 99). This clearance may be reduced to 12 mm (½ in.) for exterior masonry chimneys. Roof sheathing should be securely nailed to the rafters and headers around the opening.

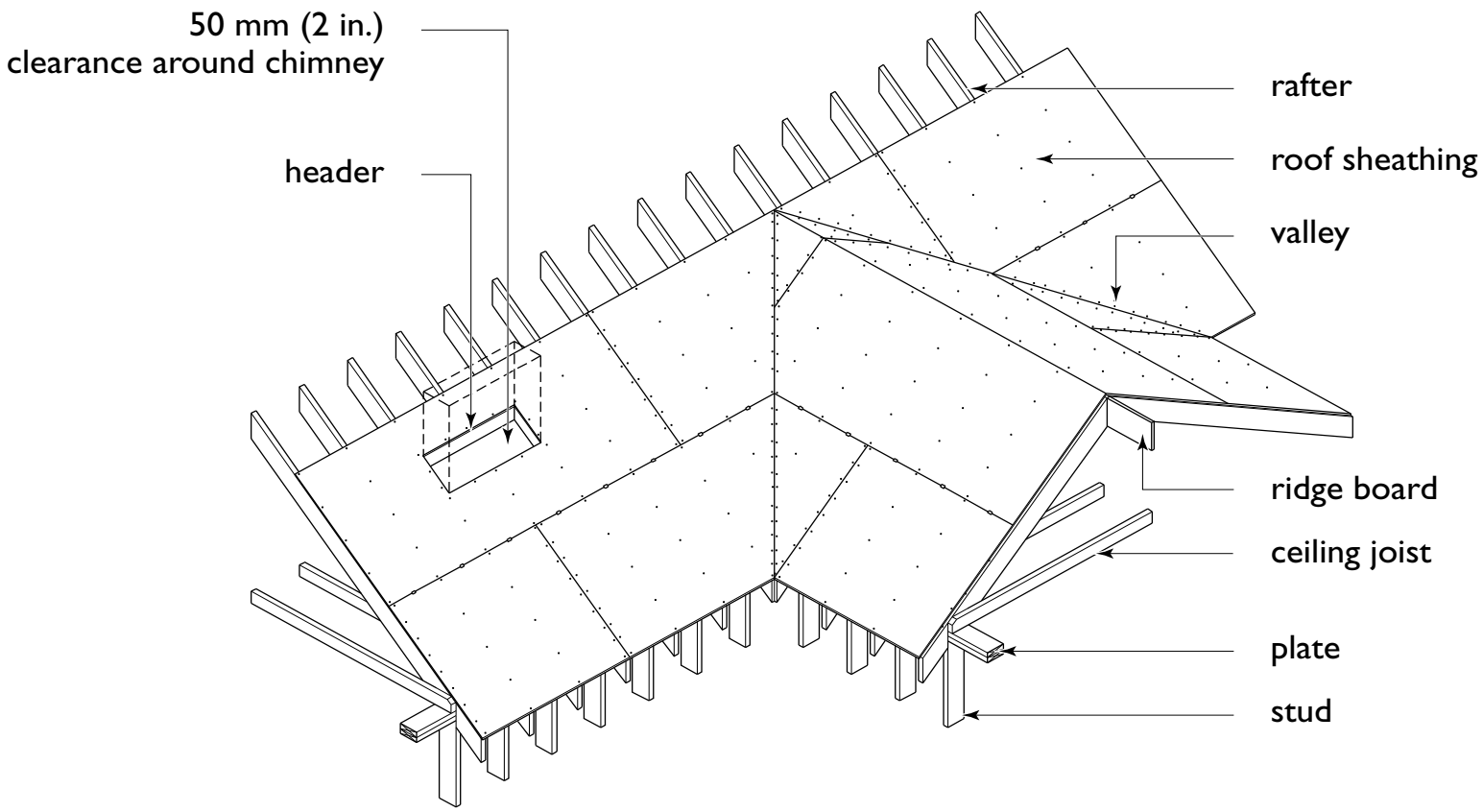
Fit sheathing at valleys and hips to give a tight joint and securely nail it to the valley or hip rafter (Figure 99). This will provide a solid, smooth base for flashing (see Chapter 14).

EAVE PROTECTION

Eave protection is achieved by installing a membrane along the edge of the roof to prevent water from entering the roof. It is not required over unheated garages and porches, on roofs with a slope of 1:1.5 or greater or in regions with 3,500 or fewer heating degree-days. Eave protection should extend at least 900 mm (36 in.) up the roof to a point at least 300 mm (12 in.) inside the inner face of the exterior wall. Eave protection is installed under the shingle starter course and is most often a self-adhering bituminous or roll roofing membrane.

During cold weather, heat loss through the ceiling insulation combined with sun exposure may provide enough heat to melt the snow on a roof but not on the projecting eaves. Water from the melting snow can freeze and form ice dams at the eavestrough and roof

99 Roof sheathing detail at a valley and at a chimney opening



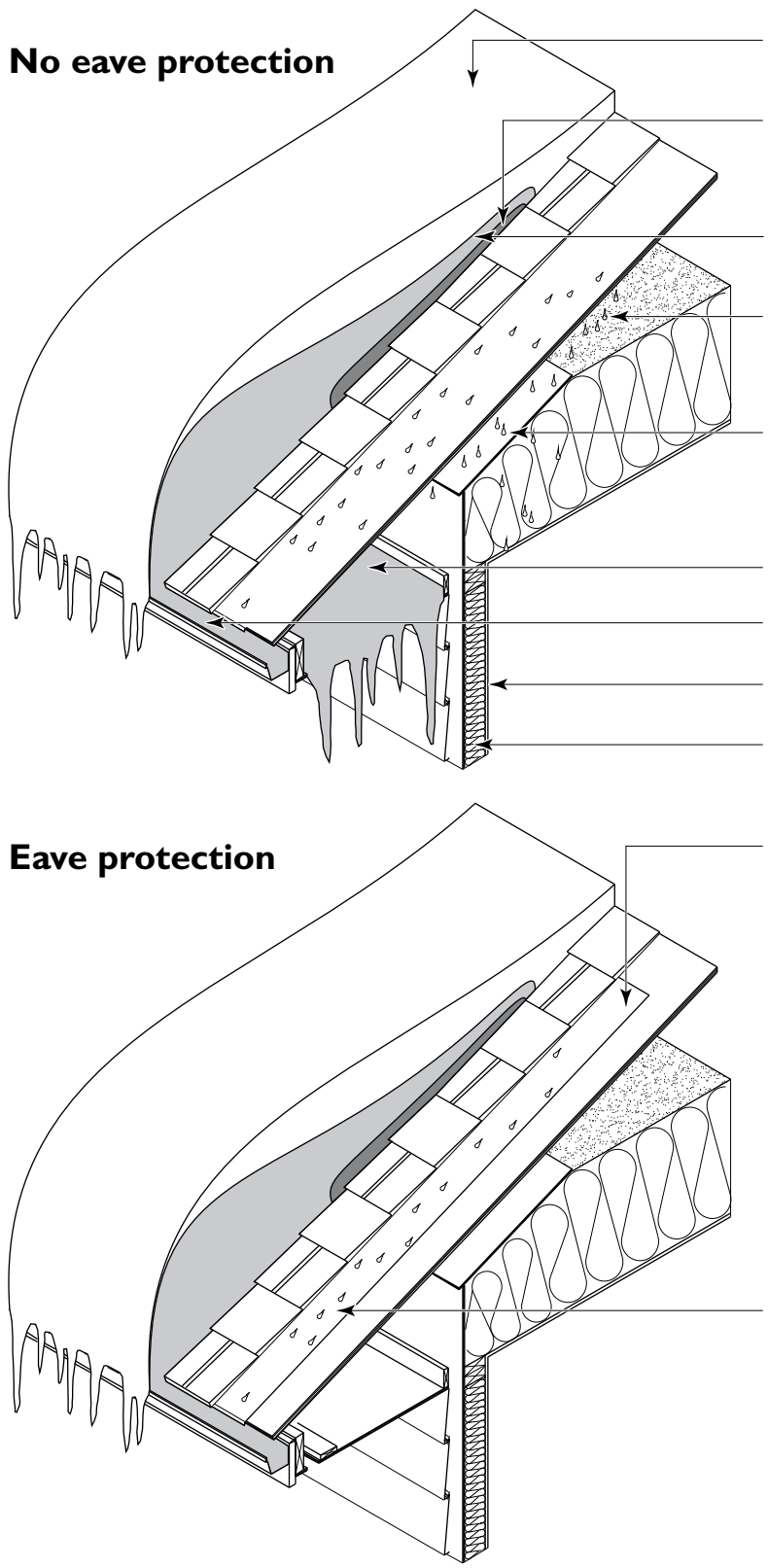
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overhang. As temperatures fluctuate, the melted snow freezes, causing the ice dam to progressively grow larger (Figure 100).

When a thaw occurs, this ridge of ice causes a dam that prevents melt water from escaping down the roof. The trapped water backs up under shingles and could leak into the attic, ceiling and wall. To prevent ice damming from occurring, do pay attention to air-sealing at the ceiling, the ceiling/wall junction and at all penetrations through the ceiling air barrier during construction. Provide sufficient ceiling insulation to comply with building code requirements for your location, and ensure that the attic space is vented to the exterior at the eaves.

Skylights should be situated away from the areas where ice damming is likely. In addition, eave protection consisting of either type S

100 Eave protection



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(smooth surface) or type M (mineral-surfaced) roll roofing should be installed over the sheathing, laid with the joints lapped at least 100 mm (4 in.) and cemented together. Alternatively, a peel-and-stick bituminous membrane may be used. Methods of flashing shingled roofs at valleys, chimneys and intersecting walls are described in Chapter 14.

ROOF COVERINGS

The roof covering should be installed as soon as the sheathing is in place to keep the building dry and to provide durable, water-resistant protection.

The choice of roofing materials may be influenced by cost, appearance, local code requirements or local preferences. Asphalt shingles are commonly used on pitched roofs. Prefinished metal, galvanized steel or aluminum roofing is also common in some regions. At normal roof pitches, metal roofs will generally shed snow, a desirable characteristic in heavy snowfall areas. Roll roofing, wood shingles, hand-split shakes, sheet metal and concrete or clay tile are also used. Built-up roofing with a gravel topping or cap sheet is usually used for low-slope roofs.

The minimum and maximum slopes for the different types of roof coverings are presented in Table 36 (Appendix A). The minimum slope of roofs is 1:6 for asphalt shingles (using a low-slope application), 1:4 for wood shingles, and 1:3 for hand-split shakes and asphalt shingles (using normal application).

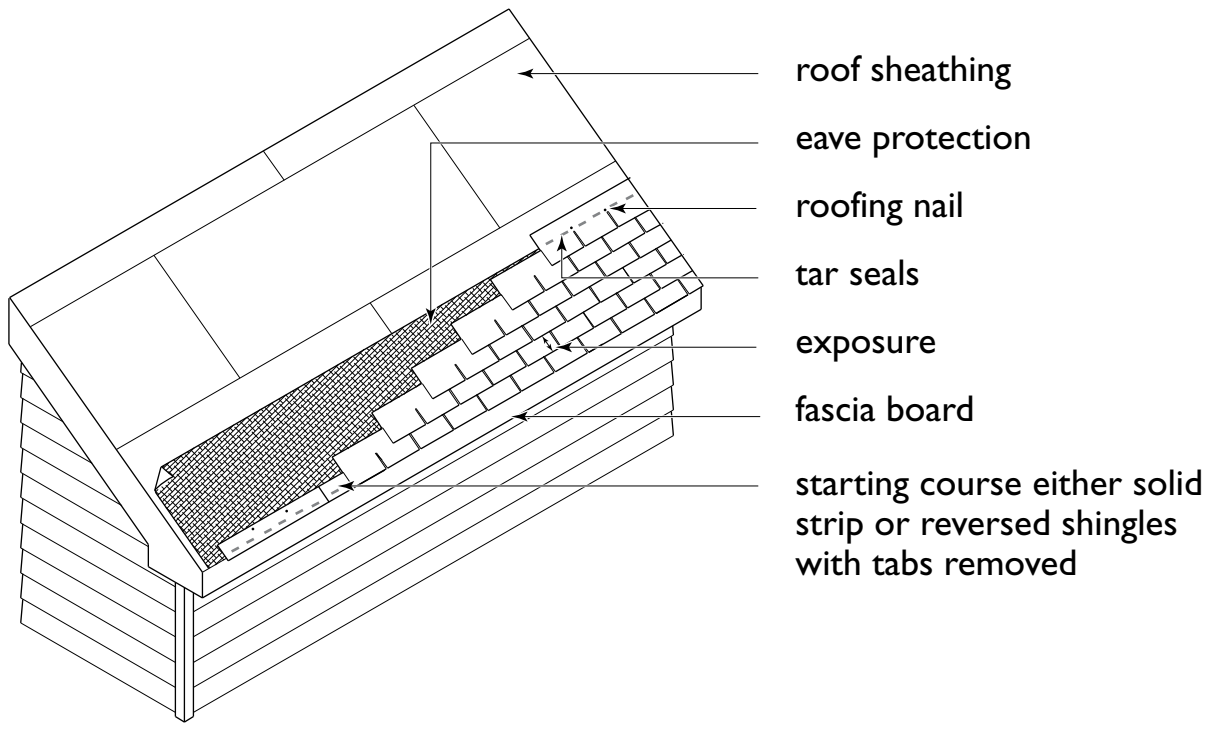
Asphalt Shingles on Slopes 1:3 or Greater

Asphalt strip shingles should be a minimum No. 210 grade. Square-butt strip shingles are usually 310 × 915 mm (12 × 36 in.) or 335 × 1 000 mm (13¼ × 39 ⅜ in.) in size, have three tabs and should be laid with 130 mm (5 in.) or 145 mm (5¾ in.) of their width exposed to the weather. Since there are approximately 21 to 26 strips in a bundle, a bundle will cover about 3 m^2 (32 sq. ft.).

Store bundles flat so that strips will not curl when the bundles are opened. Distribute the storage of shingles on roofs so that the load capacity of the framing is not exceeded.

The method for installing asphalt shingles is shown in Figure 101. Install the eave protection where required. Apply a starter

101 Application of asphalt shingles



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strip comprised of shingles with their tabs removed along the eaves before the first course of shingles, so that it extends at least 12 mm (½ in.) beyond the eaves, rakes and fascia board to form a drip edge. Starter strips with metal drip edges can also be used.

This projection prevents water from backing up under the shingles by capillary action. Alternatively, a shingle strip laid with the tabs facing up the roof slope may be used for this purpose. Type M roll roofing may also be used as a starter strip and, when continued up the roof slope, will also serve as eave protection. Nail the starter strip along the bottom edge at 300 mm (12 in.) intervals. Lay the first course of shingles with the butt edge in line with the bottom of the starter strip.

The allowable exposure distance of shingles must be respected and depends on the roof slope and the type and length of shingle used.

Chalk lines can be used to align the shingle courses so that tabs and tab notches are in a straight line. Asphalt-impregnated building paper is often placed over the roof sheathing as a shingle underlay, and the lines printed on the underlay serve as guides to help align the shingles. Use four large-head roofing nails per strip that are long enough to penetrate at least 12 mm (½ in.) into the roof sheathing. Most asphalt shingles are self-sealing; a strip of adhesive on the underside of the tab affixes the shingle to the one beneath.

Interlocking and other special shingles should be laid according to the manufacturer's directions.

Asphalt Shingles on Low Slopes of 1:6 to 1:3

Care is required to ensure that the roof covering on a low slope roof is waterproof. Except for the first two courses, use three thicknesses of shingles on the entire roof including hips and ridges. Maintain a shingle exposure of not more than one-third the full height of the shingle. Install starter strips as for higher-sloped roofs, but apply them over a continuous band of cement not less than 200 mm (8 in.) wide. The first course of shingles is then cemented to the strip with a continuous band of cement that is 100 mm (4 in.) wider than the shingle exposure. For example, a 250 mm (10 in.) band of cement should be used when the shingle exposure is 150 mm (6 in.). The succeeding courses of shingles are laid on a band of cement 50 mm (2 in.) wider than the shingle exposure, so that a 200 mm (8 in.) band is used when the exposure is 150 mm (6 in.).

To avoid defacing the exposed surface of the shingles with cement, the band should be located between 25 and 50 mm (1 and 2 in.) above the butt edge of each succeeding course of shingles. Staple or nail each shingle strip in place with four fasteners located above the exposed portion of the shingle. If cold-application cement is used, it should be applied at a rate of approximately 0.5 L/m^2 (1 gal./100 sq. ft.) of cemented area. Hot-application cement is applied at a rate of approximately 1 kg/m^2 (0.2 lb./sq. ft.) of cemented area. This technique is necessary only for slopes lower than 1:4 since there are special low-slope shingles of sufficient length to maintain the three thicknesses necessary at roof pitches of 1:4 or greater.

Wood Shingles

Western red and white cedar are the principal species of wood used for shingles because their heartwoods have high decay resistance and low shrinkage (they may also be preservative-treated). Other species are also used for shingles but should be preservative-treated. Wood shingles commonly for houses are No. 1 and No. 2 grade. The width of wood shingles varies between a maximum width of 350 mm (14 in.) and a minimum width of 75 mm (3 in.).

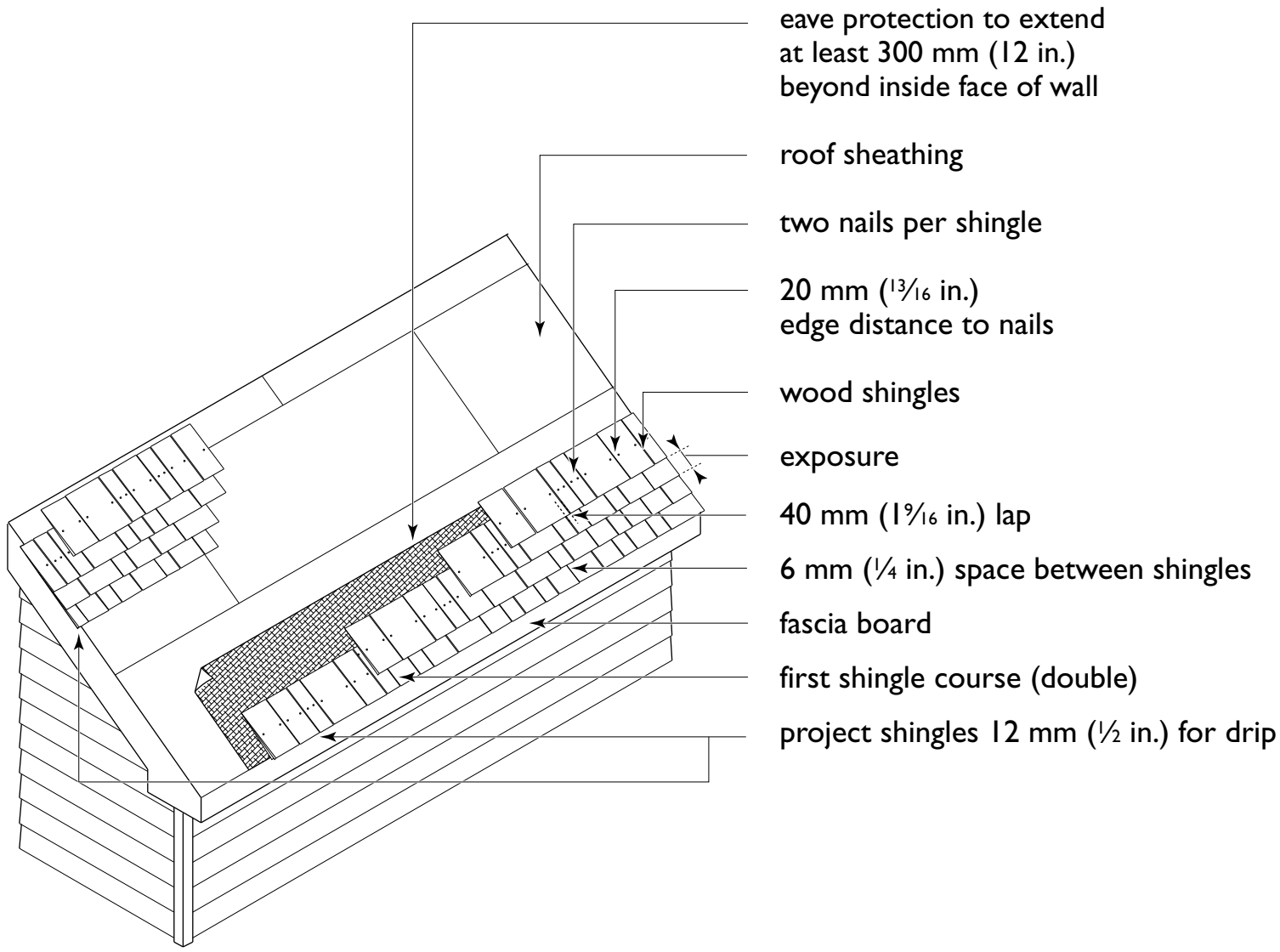
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Figure 102 shows how to lay a wood shingle roof. As for asphalt shingles, underlay and roofing felt is not usually required, but eave protection is required.

Double lay the first shingle course with the upper shingles overlapping the joints in the course beneath and both rows extending about 25 mm (1 in.) beyond the fascia boards at the eaves. This will prevent water from backing up underneath the shingles. Place shingles 6 mm (¼ in.) apart to allow for swelling. Offset the joints between shingles in one course at least 40 mm (1⅝ in.) from a joint in the course below. Space the joints in succeeding courses so that the joint in one course is not in line with the joints in the two previous courses laid.

Use only two nails per shingle. The distance of the nails from the butt edge should be the shingle exposure plus 40 mm (1⅝ in.), with an edge distance of about 20 mm (¹³⁄₁₆ in.). For example, if the shingle exposure is to be 125 mm (5 in.), a nail should be 165 mm (6⅜ in.) from the butt edge of the shingle being nailed. Use hot-dip galvanized or other corrosion-resistant shingle nails.

102 Installation of wood shingles



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Flat grain shingles wider than 200 mm (8 in.) are sometimes split and nailed as two shingles to avoid problems with cupping and warping.

Shakes

Cedar hand-split shakes must not be less than 450 mm (18 in.) long and 100 mm (4 in.) wide, and no wider than 350 mm (13¾ in.). The butt thickness should be between 9 and 32 mm (⅜ and 1¼ in.) (Figure 103).

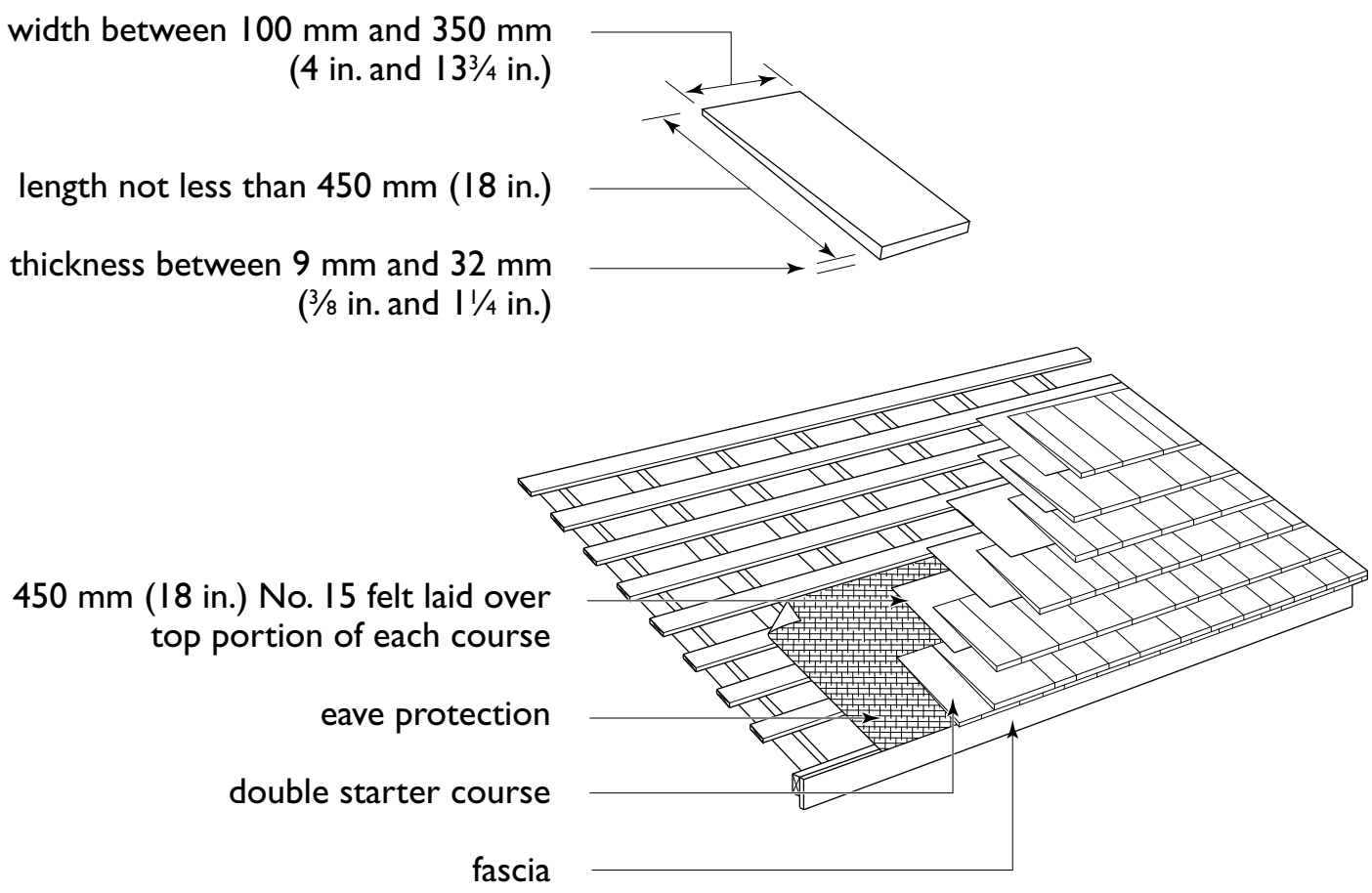
Shakes may be applied over spaced or closed roof sheathing. When spaced sheathing is used (Figure 98), apply 19 × 89 mm (1 × 4 in. nominal) or wider strips on centre equal to the weather exposure at which the shakes are to be laid, but never more than 250 mm (10 in.). Closed roof sheathing is recommended for areas where wind-driven snow conditions prevail.

An exposure of 190 mm (7½ in.) is recommended for 450 mm (18 in.) long shakes, and 250 mm (10 in.) for 600 mm (24 in.) long shakes. The minimum recommended roof pitch for hand-split shakes is 1:3.

A 900 mm (36 in.) strip of No. 15 roofing felt should be laid over the sheathing boards at the eave line. The beginning or starter course of shakes should be doubled; for extra texture, it can be tripled. The bottom course or courses can be 380 mm (15 in.) or 450 mm (18 in.) shakes.

After each course of shakes is applied, a 450 mm (18 in.) wide strip of No. 15 roofing felt should be laid over the top portion of the shakes, extending onto the sheathing. The bottom edge of the felt should be positioned above the butt at a distance equal to twice the weather exposure. For example, 600 mm (24 in.)

103 Installation of hand-split shakes



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shakes laid with 250 mm (10 in.) exposure would need to have felt applied 500 mm (20 in.) above the shake butts. Thus, the felt will cover the top 100 mm (4 in.) of the shakes and extend about 350 mm (15 in.) onto the sheathing (Figure 103).

Space shakes from 6 to 9 mm (¼ to ⅜ in.) apart. Offset side joints no less than 40 mm (1⁹⁄₁₆ in.) over the adjacent courses. When straight split shakes are used, the "froe-end" (the end from which the shakes have been split, and which is smoother) should be laid uppermost (towards the ridge).

Finish at Ridge and Hips

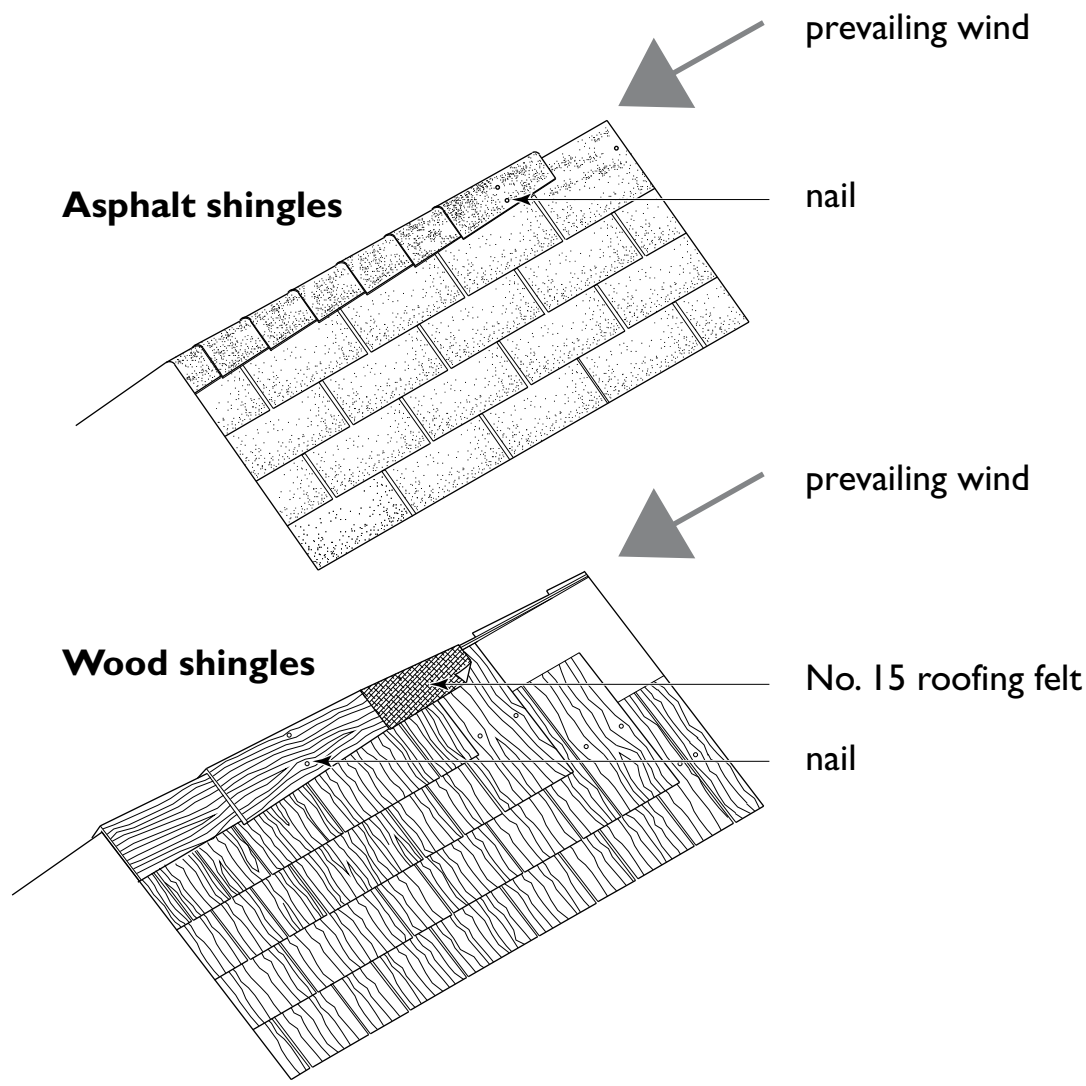
The most common type of finish for asphalt shingles is shown in Figure 104. Asphalt shingle squares (one third of a strip) are used over the ridge or hip and blind-nailed. Each shingle is lapped to provide the same coverage as the roofing shingles. Orient the ridge cap to provide maximum protection from the prevailing wind.

For wood shingles, 150 mm (6 in.) wide shingles are alternatively lapped and blind-nailed (Figure 104). Flashing is sometimes used under a wood-shingle ridge.

Built-up Roofs

Built-up roof coverings should be installed by specialized roofing installers. A built-up roof may have three or more layers of roofing felt. Each layer, including the final layer, is sealed with tar or asphalt. The surface is then covered with gravel (embedded in the asphalt or tar) or with a cap sheet. This covering provides ballast against wind uplift and protection from the sun.

104 Finish at ridge and hips



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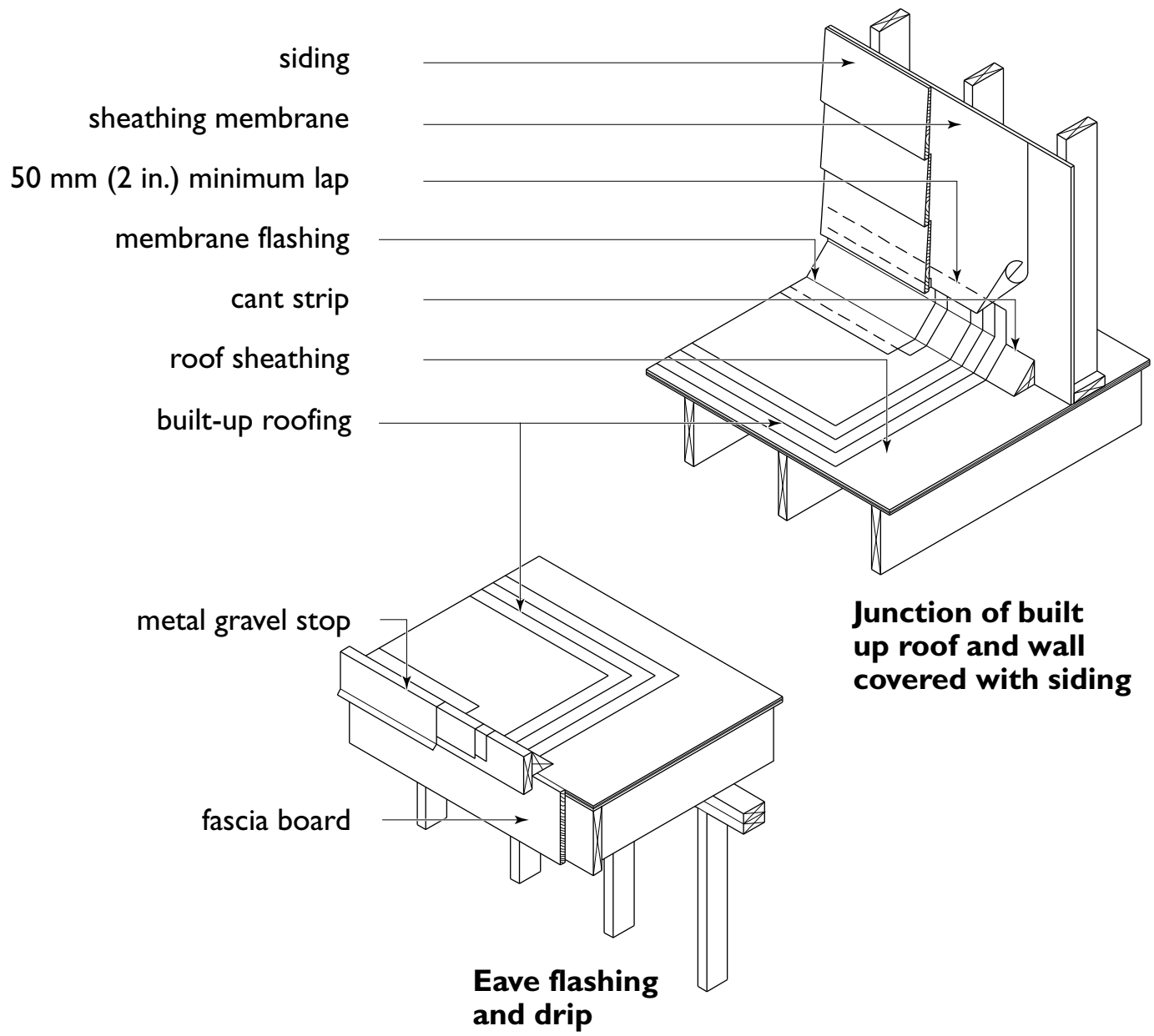
Coal tar products and asphalt products are not compatible and must not be used together.

The eave line of projecting roofs is trimmed with metal edging or flashing to direct water away from the fascia board. A gravel stop or cant strip is used in conjunction with the flashing at the eaves when the roof is covered with gravel (Figure 105). Where built-up roofing abuts a wall (except a masonry-clad wall), the roofing is mopped to the cant strip and turned up the wall at least 150 mm (6 in.). The wall sheathing paper and siding is then lapped over the roof membrane).

Where a built-up roof intersects a masonry-clad wall, the roof membrane is turned up the face of the masonry and a flashing is installed over the membrane. A counter-flashing should be embedded into the mortar joints at least 25 mm (1 in.), extend down the wall about 150 mm (6 in.) and lap over the membrane flashing at least 100 mm (4 in.).

Single-ply membranes can also be used for low-slope roofs including the small roofs typical of wood-frame construction.

105 Built-up roof



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Sheet Metal Roofing

Sheet metal roofing is manufactured in widths from 762 to 914 mm (30 to 36 in.) and in any lengths specified by the builder. Various accessories are needed for hips and valleys, eave starters and edges (Figure 106).

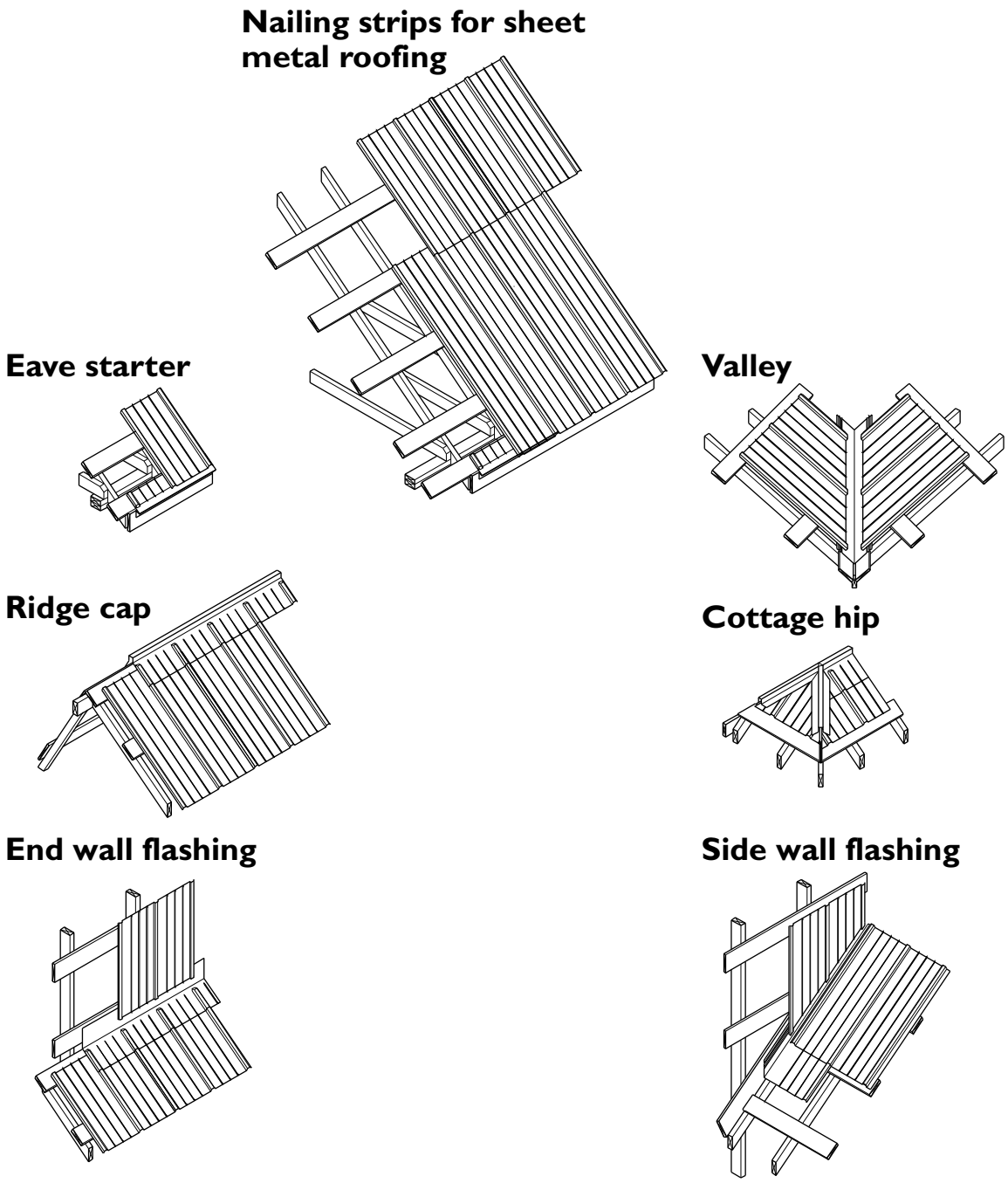
The minimum slope for sheet metal roofing is 1:4, unless the manufacturer provides written confirmation that a lower slope has been tested and proven. If sheet metal roofing is applied over spaced supports, the sheets need to be designed to support the snow load, and there must be a support under each end joint (Figure 106).

The choice of metal thickness, whether steel or aluminum, depends on the local snow load and the profile of the metal roofing, but should not be less than 0.33 mm (0.013 in.) for galvanized steel, 0.46 mm (0.018 in.) for copper or zinc and 0.48 mm (0.019 in.) for aluminum. The required thicknesses for specific snow loads are provided by the manufacturer.

Concrete and Clay Tile Roofing

Concrete or clay tile is considerably heavier than other roofing systems and the roof structure must be designed by an engineer to withstand the additional load.

106 Sheet metal roofing



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SUSTAINABLE HOUSING INSIGHT

Healthy Indoor Environment

- Design and construct the roofing system to deflect all water away from the roof and walls, and to prevent water from infiltrating the living spaces. Moisture in ceilings, walls and floors can promote mold growth, which could lead to health problems among occupants.
- Project water-shedding beyond materials below, and provide drip edges to deflect water outwards and away from cladding materials, windows, doors and penetrations.

Energy Efficiency

- Consider designing and orienting the roof so that it may accommodate solar thermal and/or solar photovoltaic renewable energy production in future. Choose a roof finish with a service life equal to or greater than that of the renewable systems.
- Consider increasing roof sheathing thickness or reducing the spacing between roof framing members to accommodate future solar thermal and photovoltaic panels.
- Building integrated solar photovoltaics such as solar roof tiles can produce renewable energy without compromising the appearance of the roof.

Resource Efficiency and Affordability

- Select the type of roof sheathing that best suits local requirements for durability, availability, place of manufacture and transportation cost.
- Select a roof covering that has a good appearance, is durable and provides the best balance between initial cost and service life.
- Reduce roof waste. Estimate quantities carefully. As much as possible, make the dimensions of roof surfaces a multiple of 400 or 600 mm (16 or 24 in.) to reduce waste from panel roof sheathing.
- Metal roofing can be re-used or recycled after the end of the building's service life.
- Asphalt-fibreglass, metal, and concrete roof coverings are made from non-renewable materials. Wood products from a properly managed forest are renewable.
- The service life of asphalt-fibreglass shingles depends on their quality, roof slope and their exposure to sun and other weather conditions. Metal and concrete roof coverings can last significantly longer. Wood shingles can also last longer but this depends on many variables (drainage and drying, grain direction, susceptibility to splitting and curling, etc.).
- The service life of roof coverings can be maximized by providing conditions that allow them to dry between wettings. This means keeping roofs clear of leaves and branches and trimming overhanging branches to permit drying and prevent the growth of moss.
- Concrete roof coverings are very durable but heavy, and additional roof framing may be needed to provide adequate structural support. In areas with a high earthquake risk, additional structural reinforcement must be provided to support heavy roofing materials.

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CHAPTER 13
Wall Sheathing and Exterior Finishes



Wall sheathing is the outside covering used over the wall framework. It is nailed directly to the wall framing members and provides a nailing base for some types of siding and backing for others. Certain wall sheathing materials such as plywood and OSB are very effective in providing lateral bracing.

Insulating sheathing materials will not normally provide the required temporary or permanent bracing, and let-in braces of wood or metal are used when bracing is needed. Sheathing must be applied to the gable ends and walls when the exterior cladding is a type that requires solid backing (see Figure 68) or intermediate fastening between supports.

Several types of sheathing are used: plywood, OSB, lumber, rigid insulation, fibreboard and gypsum board. Table 28 (Appendix A) lists types of sheathing and the minimum thickness necessary to provide sufficient backing for exterior finishing materials.

TYPES AND INSTALLATION OF SHEATHING

OSB is a structural panel made from wood strands that are bonded together under heat and pressure with a waterproof, phenolic adhesive. The strands in the outer faces are oriented along the longitudinal axis of the panel, giving added strength and rigidity in the long direction. The panels are manufactured in sheets 1.2 m (4 ft.) wide and usually 2.4 m (8 ft.) long. The O-1 or O-2 designation indicates an oriented panel, while an R1 designation indicates a panel containing randomly arranged wafers (waferboard). It must be at least 7.9 mm (5⁄16 in.) thick for studs up to 600 mm (24 in.) on centre and 6.35 mm (¼ in.) for studs up to 400 mm (16 in.) on centre. OSB is often identified with a panel mark rating rather than a thickness. When using rated OSB, the panel mark rating must correspond to the stud spacing (Table 28 in Appendix A).

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Plywood and OSB wall sheathing are usually applied vertically and are often nailed to the wall framework before a wall is lifted into position. This helps maintain squareness, avoids the need for scaffolding, and speeds construction. Window openings may be covered by the sheathing panels that are cut when window installation occurs. When sheathing is applied horizontally, vertical joints should be staggered.

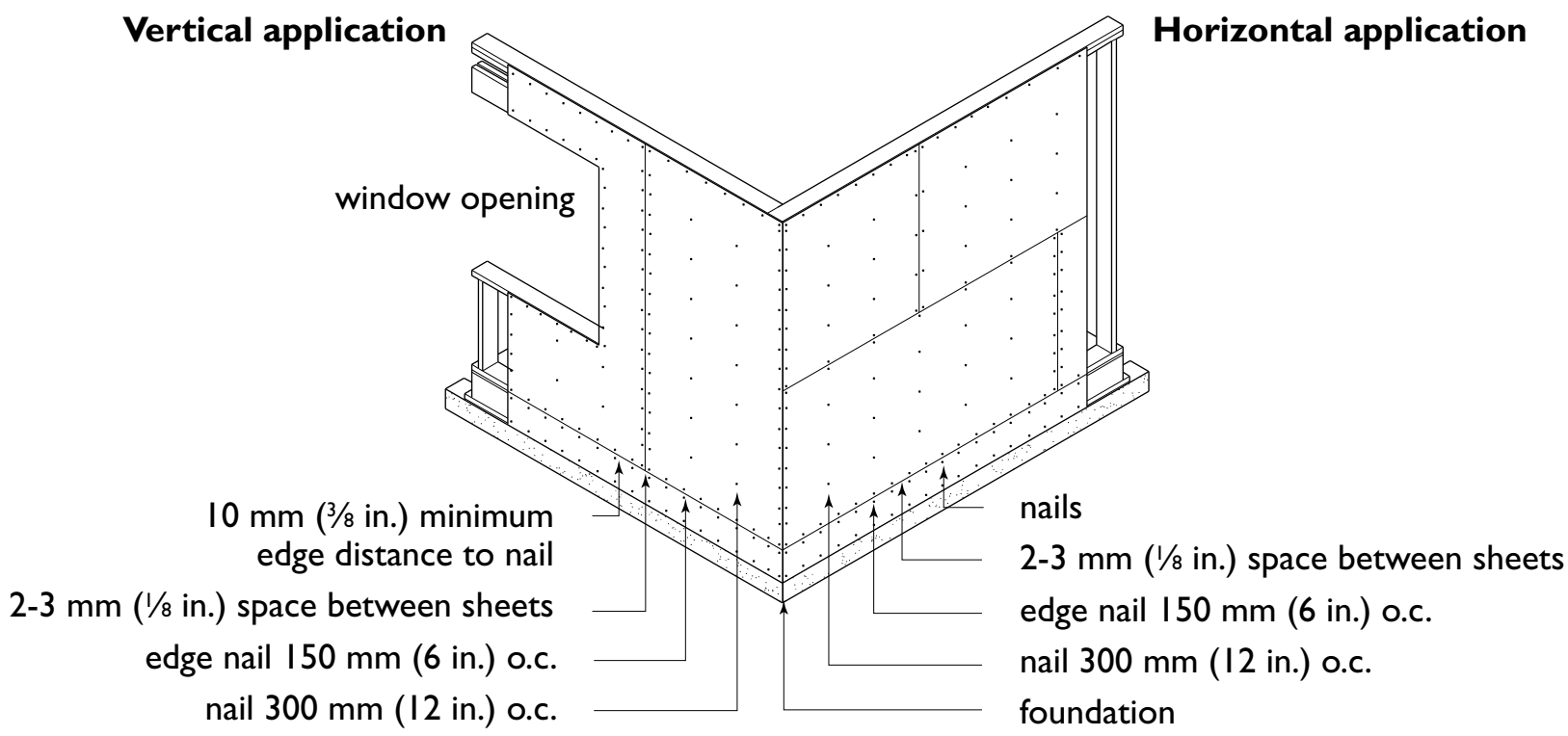
There are two methods of installing sheathing down to the foundation sill so that it covers not only the walls, but the joist header space as well. One way is to extend the low end of the sheathing panel beyond the bottom wall plate and adding a filler piece at the top. Another way is to use longer 2.74 m (9 ft.) sheathing panels that cover the wall down to the sill area. It is better to cover the header and sill with the same wall sheet because this reduces air infiltration, and when structural panels are in place, it ties the framing to the sill plates.

Leave a 2 to 3 mm (⅛ in.) wide space between the sheets to permit expansion. Nail the sheathing panels to the framing with nails spaced not more than 150 mm (6 in.) on centre along the edges and 300 mm (12 in.) along the intermediate supports (Figure 107).

Plywood is a structural panel made from wood veneers that are glued together so that the grain direction of each layer is perpendicular to the adjacent layers. The grain direction of the top and bottom surfaces is parallel to the length of the panel. Sheathing grade plywood is made with waterproof adhesive, unsanded, and may contain knots. The minimum thickness for exterior plywood wall sheathing is 7.5 mm (5⁄16 in.) for studs 600 mm (24 in.) on centre, and 6 mm (¼ in.) for studs up to 400 mm (16 in.) on centre. Sheets are made 1.22 m (4 ft.) wide and usually 2.44 m (8 ft.) or 2.74 m (9 ft.) long.

Fibreboard sheathing should be at least 11.1 mm (7⁄16 in.) thick for studs 600 mm (24 in.) on centre and 9.5 mm (⅜ in.) for studs 400 mm (16 in.) on centre. It is made in sheets 1.22 m (4 ft.) wide and generally 2.44 m (8 ft.) long, and is usually impregnated with an asphalt material to increase water resistance.

107 Vertical and horizontal application of panel-type sheathing



Note: Closer nailing patterns required for high wind/earthquake exposures

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Gypsum board sheathing consists of a gypsum filler faced on both sides with treated paper or a fibreglass matt facer. It should be at least 12.7 mm (½ in.) thick for studs 600 mm (24 in.) on centre and 9.5 mm (⅜ in.) thick for studs 400 mm (16 in.) on centre. It is made in sheets 1.22 m (4 ft.) wide and 2.44 m (8 ft.) long. The sheets are applied horizontally across the studs and nailed to the framing members.

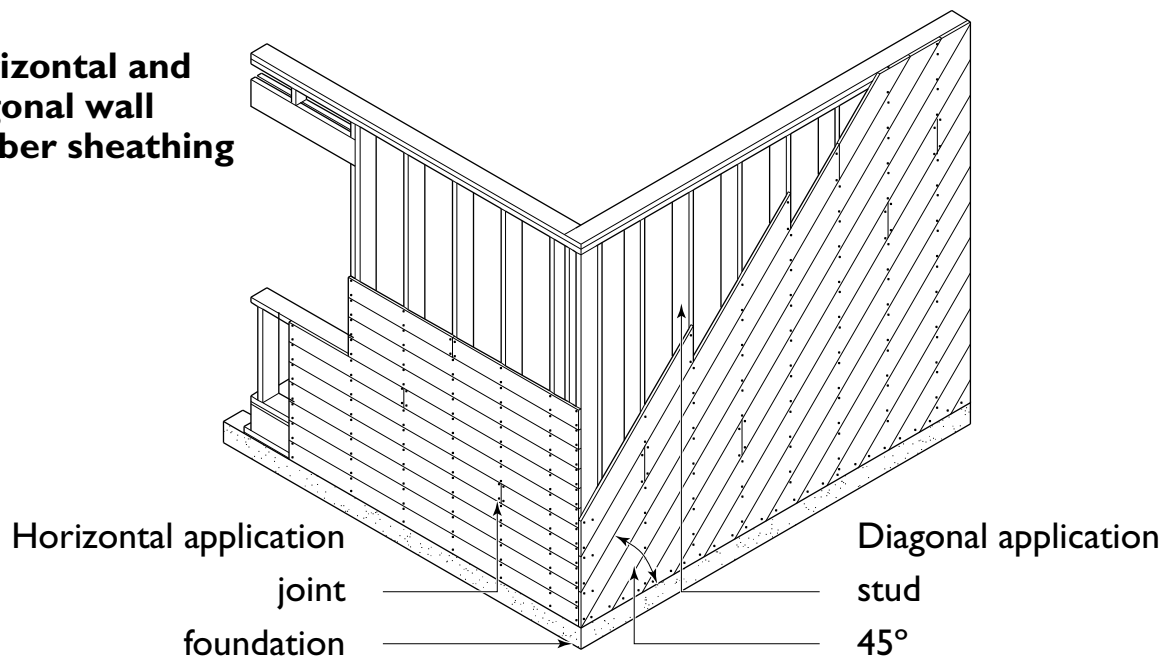
Insulating sheathing is non-structural. One type is a semi-rigid, glass-fibre panel with an exterior vapour-permeable, waterproof membrane. Another type is made of mineral fibre and has no membrane. Other types of rigid panels are made of expanded polystyrene, extruded polystyrene, polyurethane, isocyanurate or phenolic material. They are available in different thicknesses, and the insulating value per unit thickness varies. Rigid glass fibre sheathing with a vapour-permeable membrane can serve as an air barrier when the joints are sealed with sheathing tape.

Lumber sheathing, which should not be less than 17 mm (11⁄16 in.) thick, is used in boards 140 to 286 mm (6 to 12 in. nominal) wide. It is milled in a shiplap, tongue-and-groove or square-edge pattern. The boards are nailed at each stud with two nails for 140 to 184 mm (6 to 8 in.) widths and three for 235 to 286 mm (10 to 12 in.) widths. Longer nails are required in areas susceptible to extreme wind or earthquake forces.

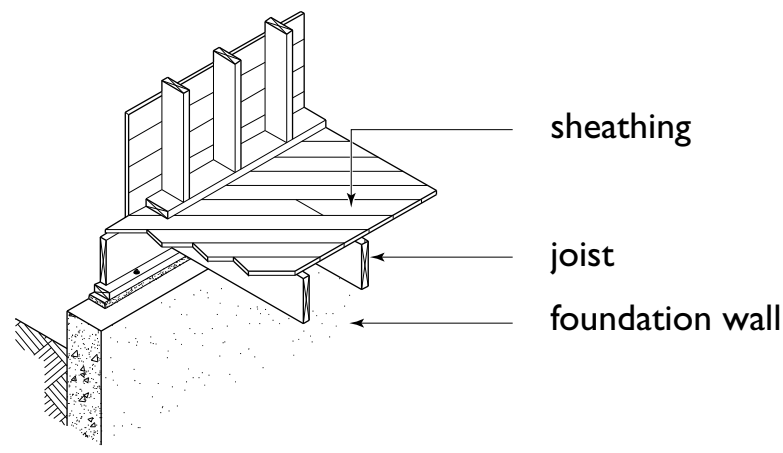
End joints in the board must be placed over the centre of the studs with the joints staggered on different studs. Lumber sheathing may be applied either horizontally or diagonally (Figure 108)

108 Lumber sheathing application

Horizontal and diagonal wall lumber sheathing



Diagonal lumber floor sheathing



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and is extended beyond the subfloor to cover the header joist and the sill plate. The angle cuts of the diagonal approach require more time and materials.

SHEATHING MEMBRANE

The sheathing membrane forms part of a second line of defence against the entry of rainwater and may also be, in some cases, a primary component of the air barrier system. Since some moisture may condense in the wall space in winter, the sheathing membrane must be capable of allowing it to diffuse outward to prevent wood decay.

Several types of sheathing membrane are commonly used in wood-frame construction:

- Building paper is bituminous-impregnated paper that is produced in 915 mm (36 in.) wide rolls and applied over the sheathing in horizontal strips, starting at the bottom of the frame wall. The paper is stapled to the sheathing, and each strip is shingle-lapped over the one beneath it.
- Spun-bonded polyolefin (SBPO), also known as "Housewrap," is produced in rolls 2.74 m (9 ft.) wide by up to 45 m (150 ft.) long. It is applied over the sheathing in horizontal strips that cover the height of a storey and is stapled to the sheathing. SBPO is strong and flexible enough to be turned into window and door openings and integrated with the moisture management features at the openings.
- Self-adhesive ("peel-and-stick") membranes are used in areas subject to large amounts of water such as at door and window sills and heads. Peel-and-stick membranes are produced in 915 mm (36 in.) wide rolls. They are strong, flexible and can be formed to make sill dams, seal the joints in other sheathing membranes, and seal the joints between sheathing membranes and flashings.
- Liquid-applied membranes are usually trowelled over the sheathing, with vertical grooves for drainage. They provide both an adhesive and a moisture barrier for the polystyrene insulation boards used in exterior insulation finish systems (EIFS).

Refer to Chapter 5 for more information concerning the design and installation of moisture barriers.

EXTERIOR CLADDING

Aside from contributing to house appearance and durability, exterior cladding is an important part of the water penetration control strategy. Common types of cladding are made of metal, vinyl, hardboard, fibre-cement board or lumber siding; panel siding made of plywood, OSB, hardboard; wood shingles or shakes; stucco; and masonry cladding such as brick and stone.

Most siding can be affected by moisture and must be kept at least 200 mm (8 in.) away from the ground and at least 50 mm (2 in.) from an adjoining roof surface. Methods of flashing over window and door openings and between different types of wall covering are described in Chapter 14.

Metal and Vinyl Sidings

Metal and vinyl sidings are factory finished and manufactured in many shapes and patterns. They are made to interlock so that only the upper side of the siding is nailed, while the bottom edge is locked to the upper part of the

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siding strip below (Figure 109). Interior and exterior corners, termination points of the soffit and gable ends as well as windows and doors, are covered using specially designed trim pieces.

Horizontal Application

Prepare the wall for cladding by applying the sheathing membrane. In wet and humid coastal climates, strapping (furring) is required to provide a vented space (rainscreen) to facilitate drainage and drying. Establish a level line around the house for the starter strip, which is normally placed a minimum of 150 to 200 mm (6 to 8 in.) above finished grade. Install all trim pieces for corners, windows, doors and openings and starter strips; and then apply the siding in successive courses up to the underside of the soffit.

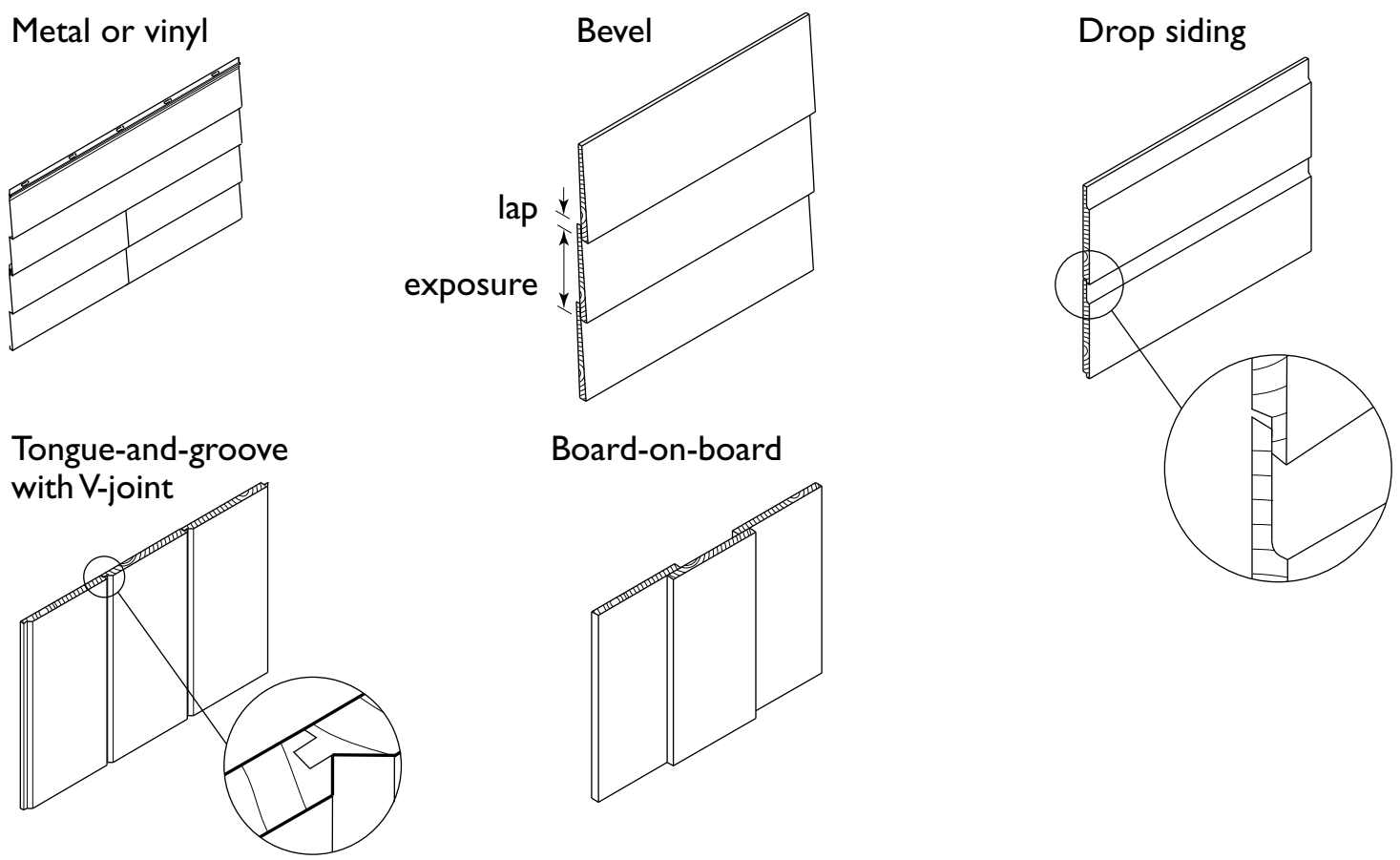
Laps of adjacent strips of siding should be staggered more than 600 mm (24 in.) apart and should all face in the same direction away from the general viewing angle.

Install metal and vinyl siding so that it can expand and contract with temperature changes without buckling, and make sure to follow the manufacturer's installation instructions. Place nails in the centre of the nail slots, and do not hammer them tight to the wall.

Vertical Application

Apply the sheathing membrane to prepare the wall for cladding. Some types of metal and vinyl siding can be applied directly over the sheathing membrane. In locations that require a rainscreen, the strapping (furring) should be applied horizontally and spaced according to the siding manufacturer's recommendations. Provide 10 mm (⅜ in.) gaps between the butt ends of the strapping to allow water behind the cladding to drain downwards and out of the wall.

109 Types of siding



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Hardboard Siding

Hardboard horizontal siding (Figure 110) is made in a wide range of colours. It often has splines for interlocking the panels and is installed in a manner similar to metal and vinyl siding. Some manufacturers require that their hardboard siding be installed over furring.

Lumber Siding

Lumber siding should be sound and free of knotholes, loose knots, checks or splits. Cedar and pine are the most commonly used species. It has also become more common to use pressure-treated lumber for siding or wood that has been factory-finished with stain or paint. The finish should cover the front and back surfaces of the siding to reduce water absorption. At the time of application, the siding should have moisture content similar to what it will be exposed to, that is, between 12 and 18 per cent, depending on a region's humidity and climate.

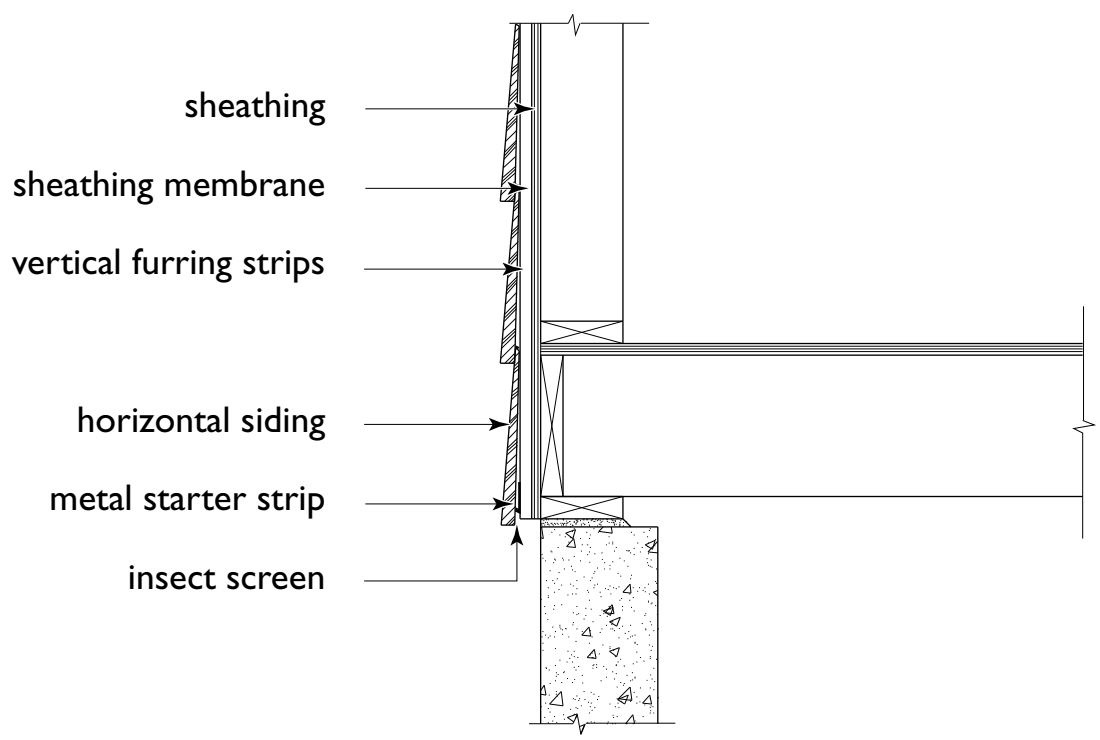
Rainscreen wall assemblies (Figure 110, for example) are required in wet, humid climates such as the coastal regions of Canada. A vertical space is created behind the siding to facilitate drainage and drying. This is accomplished by mounting the siding on furring strips nailed on top of the sheathing membrane to the studs behind.

Corrosion-resistant nails such as hot-dipped galvanized nails will hold the siding permanently and will not disfigure the paint surface. Casing or siding nails are normally used for this purpose. Drive the heads flush with the face of the siding. If finishing nails are used, set the heads below the surface and fill the holes with putty. The length of the nails required depends on the thickness of the siding and the type of sheathing used and must be long enough to penetrate at least 25 mm (1 in.) into the nailing support.

Horizontal Application

Bevel or feather-edge siding (see Figure 109) is installed from the bottom up with the bottom edge of the lowest course mounted on a 6 mm (¼ in.) thick furring strip. Overlap each succeeding course at least 25 mm (1 in.) over the lower course. Spacing for the siding should be planned before the installation starts. Deduct the minimum lap from the overall width of

110 Horizontal siding



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the siding to determine the maximum board exposure. The number of boards needed to clad a wall must respect the maximum allowed exposure. This may lead to an installation in which the exposure is less than the maximum permitted. Attempt to have the bottom of a board placed over the top of a window aligned with the top of the window cap (Figure 111).

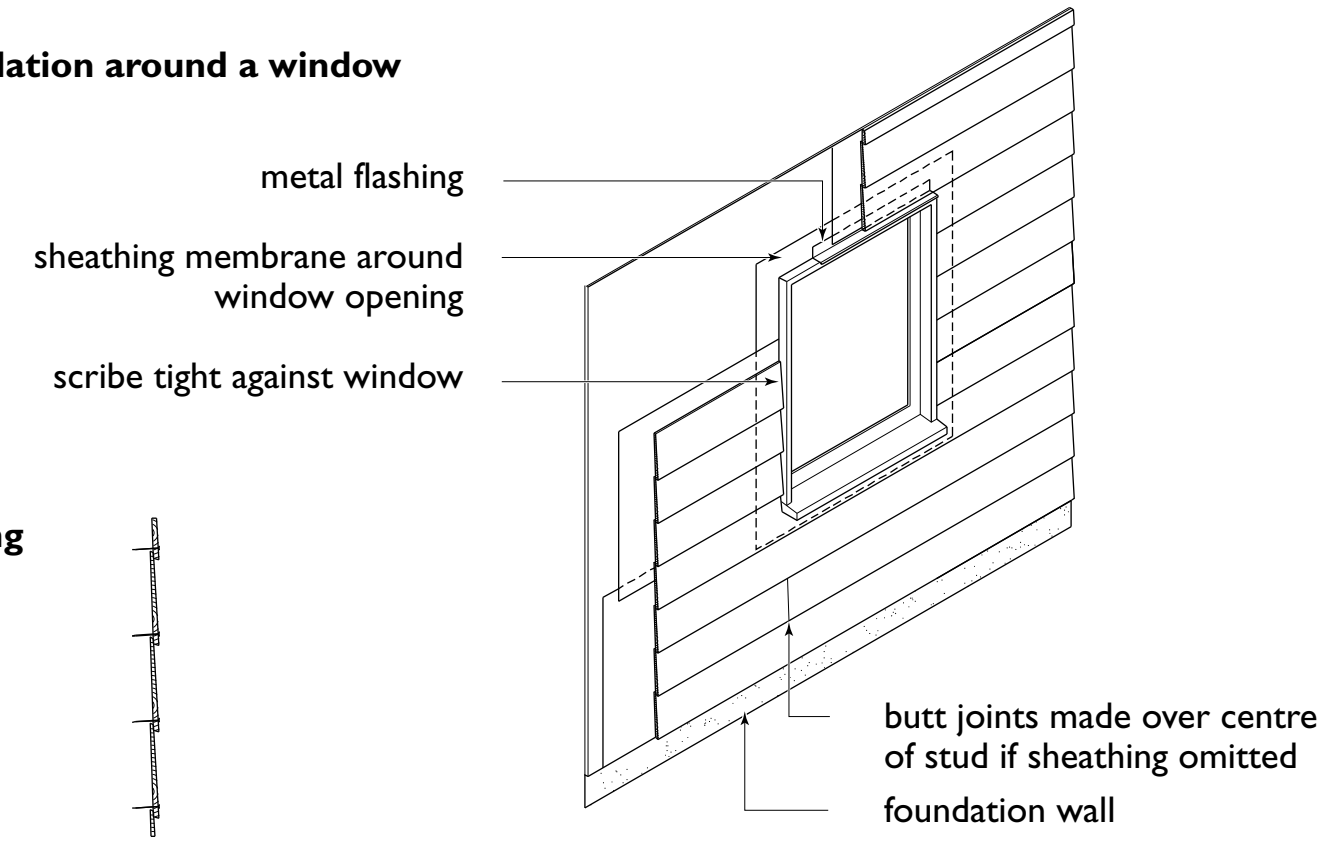
Bevel siding must have a butt thickness of at least 12 mm (½ in.) for widths of 184 mm (8 in.) or less and 14.3 mm (9⁄16 in.) for widths greater than 184 mm (8 in.). The top edge should not be less than 5 mm (3⁄16 in.) thick.

Tongue-and-groove matched siding (see Figure 109) is 184 mm (8 in. nominal) or less in width. The first board is face-nailed near the grooved edge and angle-nailed through the tongue. Each successive board is fitted tightly to the preceding board and angle-nailed through the tongue. A nail set is used to finish off the nailing.

Drop (or matched) siding (see Figure 109) should be at least 14.3 mm (9⁄16 in.) thick and 184 mm (8 in. nominal) or less in width. It is produced in a variety of patterns with matched or shiplap edges. Stagger the butt joints between

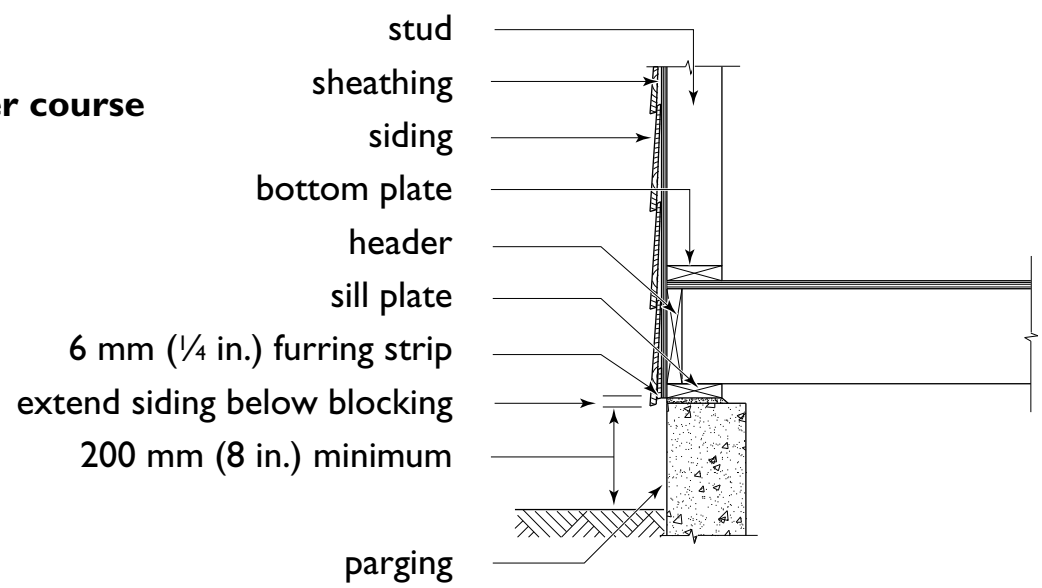
111 Siding installation

Installation around a window



Nailing

Starter course



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boards in adjacent courses. Seal the ends and fit the siding so it is in close contact with adjacent pieces. Loose joints allow water to get behind the siding, which can cause paint deterioration around the joints and lead to decay at the ends of the boards and inside the wall.

A tight, waterproof joint can be made by placing a small bead of caulking compound or putty along the end of each board after it is installed, then pressing the next board into the compound and removing the excess compound. Joints at window or door trim can be made the same way.

Bevel and drop siding should be face-nailed to structural sheathing (plywood, OSB or lumber) or to the wall studs. The size of the nail required depends on the thickness of the siding and the type of sheathing used. A good way to minimize cracking from dimensional change is to drive nails through the siding just above the lap so that they miss the top edge of the piece of siding beneath (see Figure 111).

Vertical Application

Lumber siding that can be applied vertically includes: plain matched boards; patterned matched boards; square-edge boards covered at the joints with a batten strip; or square-edge boards spaced apart and covered with another board. Vertical siding is usually 14.3 mm (9⁄16 in.) thick. Boards should not be wider than 286 mm (12 in. nominal). Vertical boards may be fastened to 14.3 mm (9⁄16 in.) lumber sheathing, 12.5 mm (½ in.) plywood or 12.5 mm (½ in.) OSB or waferboard, or to horizontal furring strips.

The furring (strapping) should be at least 19 × 64 mm (1 × 3 in. nominal) lumber where the framing is spaced not more than 400 mm (16 in.) on centre or 19 × 89 mm (1 × 4 in. nominal) lumber where the framing is spaced not more than 600 mm (24 in.) on centre. Butt joints in lumber siding should be cut at 45 degrees (mitred) and overlapped to prevent the entry of water into the joint.

When the spaced (board-on-board) method is used (Figure 109), the boards next to the wall are normally wider than the cover boards and are fastened with one row of nails near the centre of each board. The cover board is then applied so that it laps the edges of the underlying boards at least 25 mm (1 in.). Fasten the cover boards with one row of nails in the centre. Use a vertical furring behind so that nailing does not split the cover board. This arrangement allows all the boards to adjust to changing moisture without splitting.

The board-and-batten method uses square-edge boards that are ordinarily 184 mm (8 in. nominal) or less in width. The boards are applied with the edges at least 6 mm (¼ in.) apart and fastened with one row of nails near the centre of each board. A batten is used that laps the edges at least 12 mm (½ in.). The batten is fastened with one row of nails driven in the joint between the two boards. This allows all boards to adjust to changing moisture without splitting. Since the batten also serves to prevent the board edges from curling outward, the nailing should be secure and closely spaced.

Plywood Panels

Plywood sheets acceptable for use as a cladding material are made with a plain or grooved surface and are usually applied vertically. The joints may be V-grooved or flush or may be covered with battens. Some products have a resin-impregnated paper laminated to the face that provides a smooth, moisture-resistant surface that resists checking or splitting after painting or staining.

If a rainscreen is not required, plywood cladding may be applied directly over the sheathing membrane on unsheathed wall framing. The minimum thickness used is 6 mm (¼ in.) for stud spacing of 400 mm (16 in.) on centre and 8 mm (5⁄16 in.) for spacing of supports up to 600 mm (24 in.) on centre when the face grain is installed at

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right angles to supports. Where the face grain is installed parallel to supports, the minimum thickness is 8 mm (5⁄16 in.) and 11 mm (7⁄16 in.) for studs spaced at 400 mm (16 in.) and 600 mm (24 in.), respectively.

Cut edges should be protected with a suitable paint or sealer before installation. A 2 to 3 mm (⅛ in.) space between the sides and ends of the panels and butted ends of the battens will permit expansion without bulging. Fill vertical joints with caulking or cover them with battens. Flash horizontal joints or lap them at least 25 mm (1 in.).

The edges of plywood panels should be supported and fastened with corrosion-resistant nails, usually 51 mm (2 in.) long. Space the nails not more than 150 mm (6 in.) along the edges and 300 mm (12 in.) at intermediate supports.

Hardboard Panels

Hardboard is also produced in sheets with a variety of finishes and may be applied over sheathing or to unsheathed walls if a rainscreen is not required. The minimum thickness of sheets should be at least 6 mm (¼ in.) for supports that are not more than 400 mm (16 in.) on centre. Fasten the panels to framing members or sheathing with corrosion-resistant nails at least 51 mm (2 in.) long spaced not more than 150 mm (6 in.) along the edges and 300 mm (12 in.) along intermediate supports. Provide a 2 to 3 mm (⅛ in.) gap between panels.

Fibre Cement Board Siding

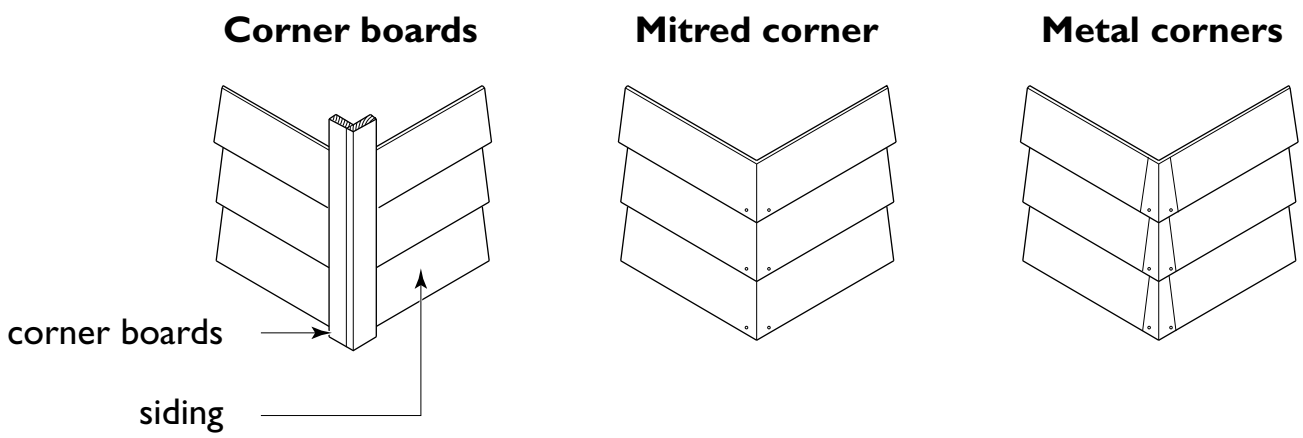
Fibre cement is a composite material made of sand, cement and cellulose fibres. In appearance, fibre cement siding most often consists of overlapping horizontal boards, resembling wood siding or shingles, and should be installed in accordance with manufacturer's directions.

Corner Treatment for Siding

There are several methods used for siding at corners (Figure 112). For siding applied horizontally, mitred corners and metal corners or corner boards are common.

Mitred corners must fit tightly and smoothly for the full depth of the mitre. To maintain a tight fit at the mitre, purchase dry siding and protect it from rain during storage. The siding can be set in putty or sealant to obtain a tight joint. At interior corners, siding is usually butted against a corner strip of 25 or 38 mm (1 or 1½ in. nominal) material, depending on the thickness of the siding.

112 Outside corner treatment of wood siding



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Where rainscreen construction is used, the furring strips should be kept back from the joints where water is most likely to enter, so that drainage and drying can occur.

Metal corners that match the colour of the siding can be used and require less skill than mitred corners or fitting siding to a corner board.

Corner boards are made of 25 or 38 mm (1 or 1½ in. nominal) material, depending on the thickness of the siding. The corner boards are applied against the sheathing with the siding fitted tightly against the narrow edge of the corner boards. Bed the siding in putty or sealant to obtain a tight joint.

Plywood and hardboard are usually lapped at the corners or fitted to a corner board. Lumber siding applied vertically is lapped at the corners.

Wood Shingles and Shakes

Wood shingles or machine-grooved shakes are sometimes used for wall cladding. They are available in lengths of 400, 450 and 600 mm (16, 18 and 24 in.) and may be factory-painted or stained. Plywood, OSB or lumber sheathing should be used under shingles or shakes.

Shingles are separated into three grades. The first grade is composed of clear shingles, all heartwood, and all edge grain. The second grade consists of shingles with clear butts and permits defects in the part of the shingle that is normally covered in use. The third grade includes shingles that have defects other than those permitted in the second grade and are only suitable for under-coursing.

First grade material is made in random widths varying from 65 to 350 mm (2½ to 14 in.) and only a small proportion of the narrow width is permitted. Shingles of a uniform width, known as dimension shingles, are also available in widths of 100, 125 or 150 mm (4, 5 or 6 in.). Table 37 (Appendix A) shows the commonly used exposure and thickness of wood shingles and machine-grooved shakes.

Wood shingles are most commonly applied in a single course using first- and second-grade shingles. When the single-course application is used, offset the joints in succeeding courses at least 40 mm (1⅝ in.), and ensure that joints in any two or three courses do not line up.

To obtain deep shadow lines, shingles can be laid in what is called double-coursing by using a lower grade shingle under the shingle exposed to the weather. The exposed shingle butt extends about 12 mm (½ in.) below the butt of the undercourse. Where double-coursing is used, wider exposure to the weather is possible. Offset joints in the outer course from joints in the undercourse by at least 40 mm (1⅝ in.).

Fasten shingles and shakes with corrosion-resistant nails. Shingles up to 200 mm (8 in.) wide require only two nails and those more than 200 mm (8 in.) wide require three. Drive nails about 20 mm (13⁄16 in.) from the edges and 25 mm (1 in.) above the exposure line for single-course application, and 50 mm (2 in.) for double coursing.

Stucco Finishes

Stucco is a mixture of Portland cement and well-graded sand, with hydrated lime or masonry cement added to make the mixture more plastic (Table 39 in Appendix A). Other proprietary stucco mixes are available. Their formulations will vary depending on the manufacturer of the mix.

Usually applied in three coats (two base coats and one finish coat), the stucco is held in place by stucco mesh or wire lath. A variety of finish coats are available, from standard coloured cement finishes to textured acrylics. Acrylic finish coats are often applied over conventional Portland cement, with good results. It is important that the chosen product be durable and vapour-permeable.

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Provide a space between the stucco and the sheathing membrane. Some sheathing membranes such as spun-bonded polyolefin can be affected by surfactants (soapy residues). Surfactants can reduce the water repelling capability of a membrane by changing the viscosity of water and can be produced by a) certain types of wood species or b) additives mixed with the stucco to improve workability during installation.

Stucco must be kept at least 200 mm (8 in.) above finished grade except where it is applied over concrete or masonry. In high exposure areas (frequent high rainfall and/or strong wind-driven rains), a furred and drained airspace of no less than 10 mm (7⁄16 in.) must be left between the stucco and the sheathing membrane to create a rainscreen. The top of the cavity should be vented and baffled to keep rain from blowing into it. The bottom of the drainage cavity must be vented to the exterior and be flashed.

Reinforcing

Stucco reinforcing (self-furring welded mesh or fully primed or galvanized woven mesh) is stretched horizontally over sheathing paper, with the joints in the mesh lapped at least 50 mm (2 in.). Reinforce external corners by extending the mesh from one side 150 mm (6 in.) around the adjacent corner, or by vertical strips of reinforcing that extend 150 mm (6 in.) on either side of the corner.

Galvanized steel fasteners should be used to hold the mesh in place such as 3.2 mm (⅛ in.) diameter nails with heads that are about 11.1 mm (7⁄16 in.), or 1.98 mm (1⁄16 in.) thick staples. Fasteners are spaced 150 mm (6 in.) vertically and 400 mm (16 in.) horizontally, or 100 mm (4 in.) vertically and 600 mm (24 in.) horizontally. Other fastening patterns may be used, provided there are at least 20 fasteners per square meter (2 fasteners per square foot) of the wall surface. Where the sheathing is other than plywood, OSB or lumber, the fasteners must penetrate the sheathing and go into the framing member (stud or plate) at least 25 mm (1 in.).

Application

A layer of sheathing membrane, lapped 100 mm (4 in.) at the edges, must be applied over the sheathing, and all openings must be flashed. Apply the membrane carefully around window openings and lap them correctly to ensure that water does not enter at the window flanges. Tar-saturated felts or papers should not be used beneath the stucco but tar-impregnated felts or paper may be used. The tar can bleed through the stucco causing unsightly discolouration.

The base coat consists of two layers of stucco. The first layer or “scratch coat” is applied in a thickness of 6 mm (¼ in.) that completely embeds the wire lath or mesh. The scratch coat surface must be scored or raked to provide a bonding key for the second coat. Curing time will depend on outdoor temperature and weather conditions. Up to 48 hours of cure time is recommended before the second coat is applied.

Just prior to adding the second coat, dampen the base to ensure a good bond between the coats. Apply the second coat at least 6 mm (¼ in.) thick and firmly trowel it into the scored surface of the base.

The second coat should be moist-cured for at least 48 hours and then left to dry for at least five days before the finish coat is applied. The second coat should be dampened to ensure a good bond and the finish coat applied to a depth of at least 3 mm (⅛ in.).

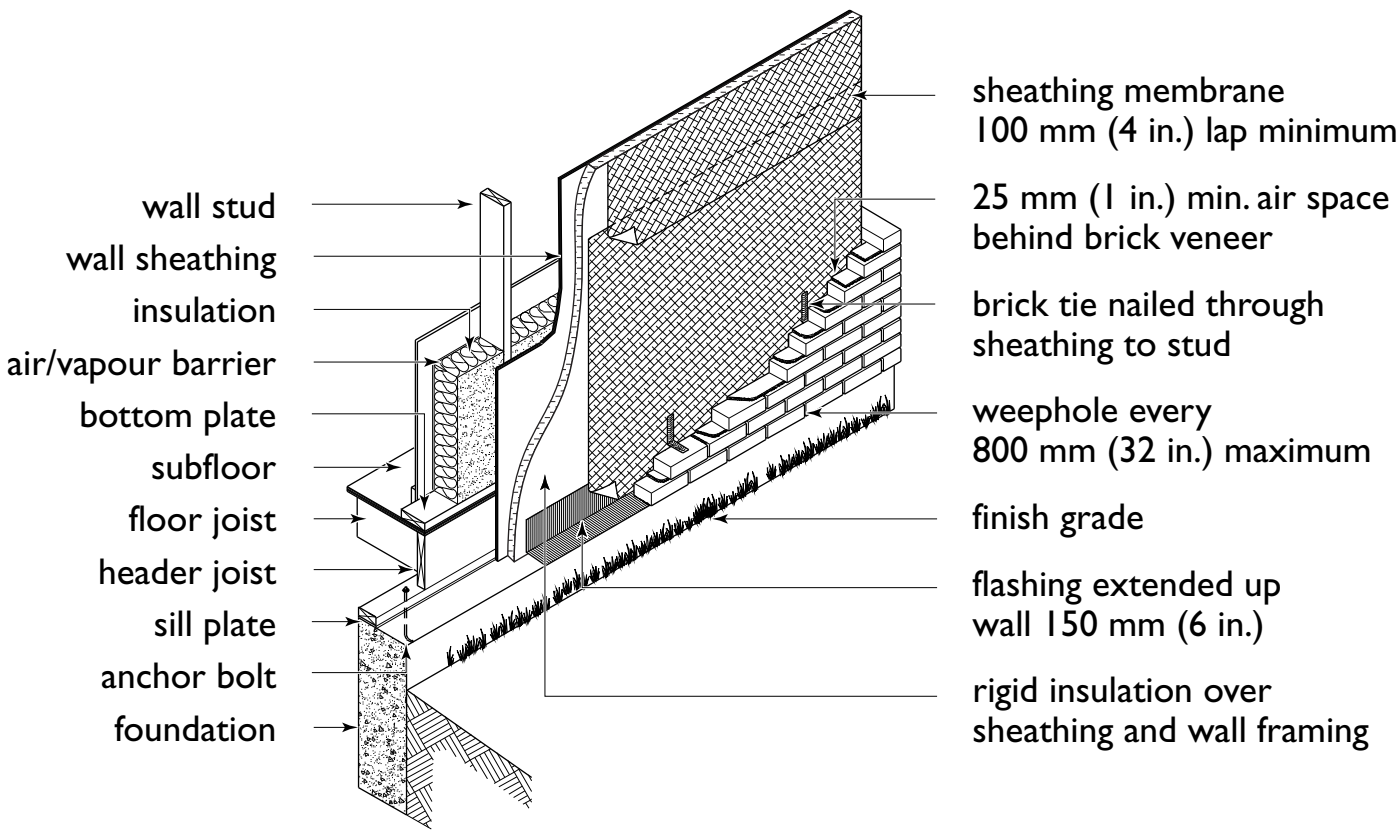
In dry, warm weather, new stucco should be kept damp to ensure proper curing. In cold weather, each coat of stucco should be kept at a temperature of at least 10°C (50°F) for 48 hours after application.

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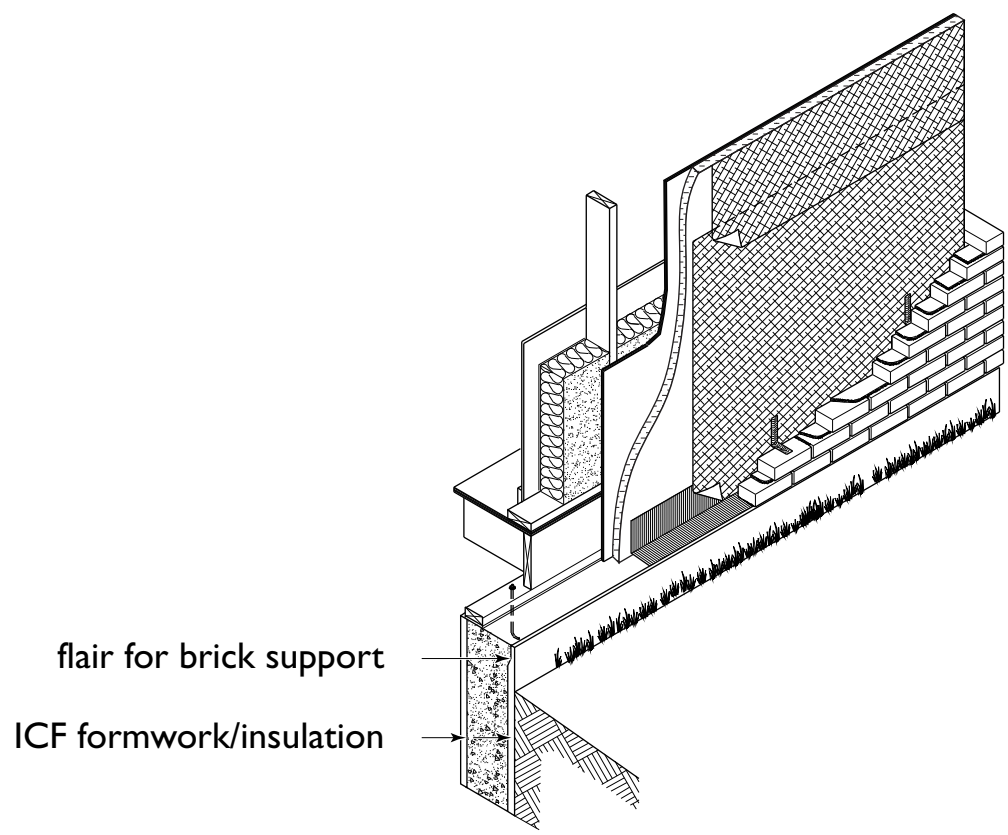
Masonry Veneer

When masonry veneer is used for cladding, the foundation must include a supporting ledge or offset wide enough to allow a space at least 25 mm (1 in.) between the masonry and the sheathing membrane (Figure 113). Insulating concrete form (ICF) foundations may use a reinforced flare at the top of the foundation to support the weight of brick veneer (Figure 114).

113 Masonry veneer support on foundation wall



114 Support of masonry veneer on an ICF foundation



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The base flashing must extend from the outside face of the wall over the top of the ledge and at least 150 mm (6 in.) up the wall behind the sheathing paper. Use corrosion-resistant metal ties nailed to the studs and embedded in the mortar joints between the masonry to tie the veneer to the framework. When fastened to every other stud, they are usually spaced 800 mm (32 in.) apart horizontally and 400 mm (16 in.) vertically. Alternatively, when fastened to every stud, they may be spaced 600 mm (24 in.) horizontally and 500 mm (20 in.) vertically, or 400 mm (16 in.) horizontally and 600 mm (24 in.) vertically, depending on the stud spacing.

Mortar mix proportions should conform to those shown in Table 6 (Appendix A). Lay brick or stone in a full bed of mortar. Ensure mortar does not drop into the space between the veneer and sheathing where it will obstruct the cavity behind the veneer. Tool outside joints to a smooth finish to provide maximum resistance to water penetration.

Weep holes serve both venting and drainage functions. They should be placed not more than 800 mm (32 in.) apart in the bottom course of the masonry veneer and above-grade windows and doors. This can be done by omitting part of the mortar from the vertical joints, or by inserting plastic tubes in the joints.

Masonry veneer should be at least 75 mm (2¾ in.) thick and masonry less than 90 mm (3½ in.) thick must have unraked joints.

Bricks should be hard, absorb little water and be manufactured for exposure to the weather. Stone veneers should be materials that are known to be durable.

Masonry laid during cold weather should be protected from freezing until after the mortar has set. The temperature of the masonry and mortar should be maintained above 5°C (41°F) for at least 24 hours after installation.

Exterior Insulation and Finish Systems (EIFS)

Exterior Insulation and Finish Systems (EIFS) are products for cladding exterior walls. These cladding systems integrate insulation with a stucco-like covering. However, EIFS differ from stucco in many respects. EIFS incorporate proprietary constituent components that have been developed and tested to be compatible and to fulfill specific building envelope performance requirements.

The fact that the term EIFS includes the word "system" is important to note. Proprietary EIFS rely on their components to interact and perform as a composite system. This is unique in comparison to most other cladding materials.

In addition to the ability to provide various forms and finishes, consider the performance capabilities offered by EIFS, and select systems from manufacturers that incorporate features that meet the project requirements. Considerations include fire safety, thermal resistance, resistance to rain penetration, interior air and moisture control, impact resistance, and other aspects of durability.

EIFS incorporate the following components:

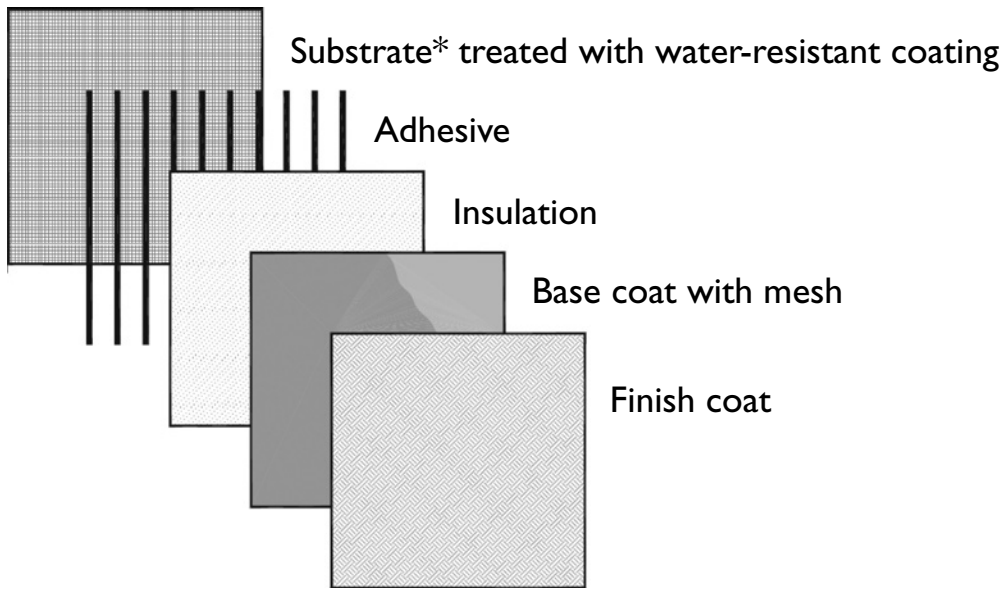
- insulation board fastened mechanically and/or with an adhesive;
- base coat with reinforcement (such as alkali-resistant glass fibre or coated glass mesh), which typically adheres to the insulation but is sometimes mechanically fastened;
- surface finish, sometimes with a primer, adhered to the base coat; and
- joint treatments, drainage accessories, seals and sealants may also form part of the system.

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The substrate to which an EIFS is attached is not considered part of the EIFS. However, the substrate must be compatible with the EIFS, and be properly designed and installed for the EIFS to perform acceptably. EIFS components are shown in Figure 115.

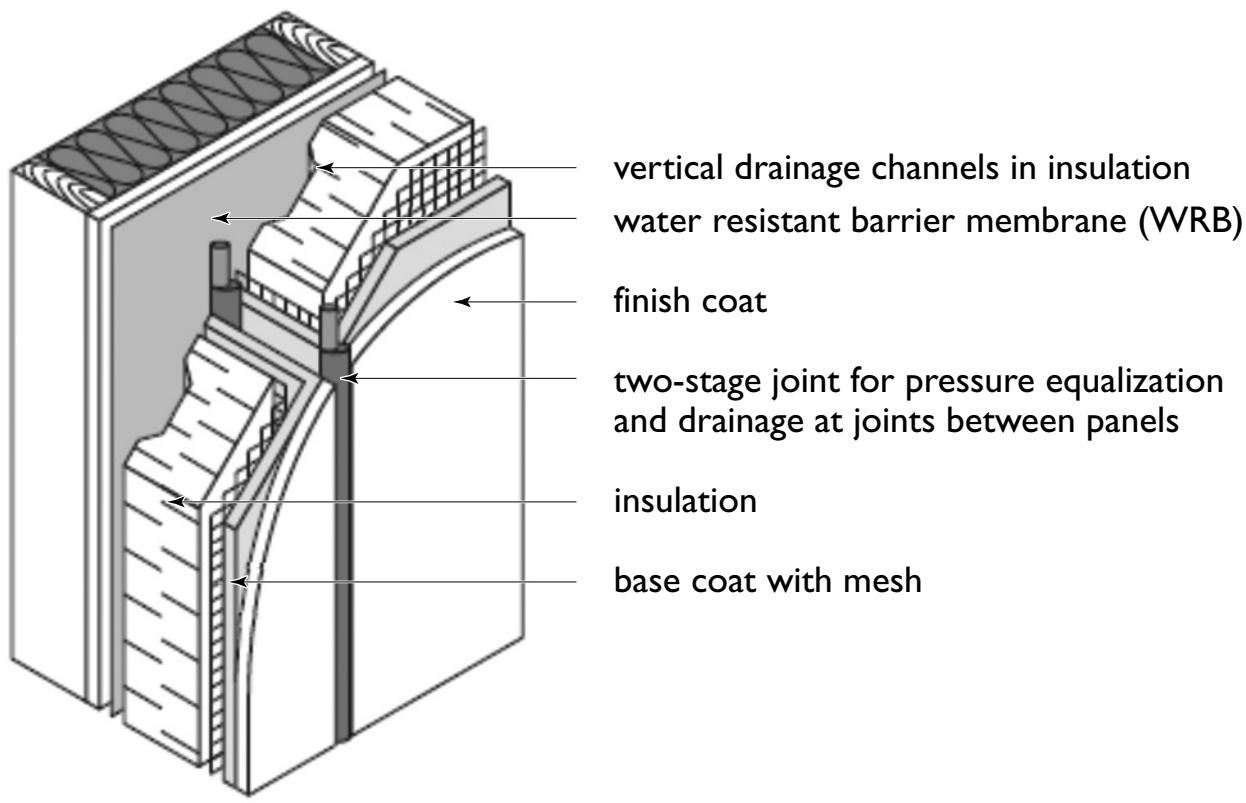
EIFS are often applied to substrates treated with a moisture, air and/or vapour barrier. Barriers that are compatible with EIFS are provided or recommended by manufacturers. A typical EIFS arrangement with a vertical joint between panels is shown in Figure 116.

115 Basic exterior insulation and finish system (EIFS) components



* Substrate is shown for clarity: it is not part of the EIFS

116 Components of an exterior insulation and finish system (EIFS)



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Some of the advantages associated with EIFS are:

- *Continuity of thermal barrier*—EIFS can provide a continuous exterior layer of insulation for the building envelope. This can be designed to protect the building and backup wall structures from temperature extremes that promote undesirable thermal movements, and to protect against moisture damage from condensation. A continuous thermal barrier helps avoid thermal bridging and takes advantage of thermal mass (heat storage in the backup wall). This can improve energy performance, promoting savings in both the initial and operating costs related to heating and cooling equipment.
- *Lightweight*—EIFS have a low weight (dead load) in comparison to masonry or concrete cladding. This can reduce structure costs, particularly where earthquake loads influence the design.
- *Water penetration resistance*—Properly applied and maintained EIFS provide good resistance to rain water penetration. The risk for rainwater penetration tends to be limited to joints, interfaces with other materials and where the lamina is damaged or otherwise defective. Most EIFS have a drained version of the system that should be used whenever the EIFS is likely to be wetted.
- *Flexibility*—In comparison with rigid cladding systems, many EIFS are relatively flexible and better able to accommodate substrate flexure or other movements without cracking.
- *Appearance*—A wide range of finish colours and textures are available. Complex surface features are easily incorporated for distinct and interesting architectural facades.
- *Reparability*—Localized damage or defects in EIFS can be easily repaired. The appearance can usually be restored or renewed by reapplying the finish or by painting.
- *Retrofit applications*—Lightweight EIFS can often be applied directly over existing cladding systems to:
  - improve appearance;
  - increase thermal performance;
  - correct problems with rain penetration;
  - improve resistance to condensation or entrapped moisture; and
  - protect the structure and existing cladding from deterioration.

Some limitations of EIFS are:

- *Combustibility*—Some EIFS incorporate combustible components and/or combustible foam plastic insulation that must be protected as required by the applicable building code.
- *Impact resistance*—EIFS can be vulnerable to impact damage as a result of the relatively thin lamina. At areas where impact damage is likely, an appropriately reinforced EIFS product must be used.
- *Compatibility*—Each EIFS constituent component and materials that connect to the EIFS must be compatible to assure acceptable performance. This includes the lamina, sealants, joint treatments, insulation, adhesive/fastening, moisture/air/vapour barriers and substrate. The manufacturer should be consulted to verify that each component and material has been tested to be compatible.
- *Staining*—If exposed to frequent wetting, staining by mildew growth can result. Frequent wetting can occur where the EIFS are not effectively protected from rain, or in high-humidity climates where areas are not exposed to direct sunlight (north elevations, shaded areas, etc.).

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- *Sensitivity to workmanship*—As is the case with many multi-component, hand-applied systems, EIFS performance is sensitive to workmanship. Quality control is necessary to assure the various components are properly applied and that they effectively work together to provide the desired performance.
- *Long-term performance*—While a minimum 30-year service life for properly designed and applied EIFS is anticipated and indicated by field performance, longer term service for many product formulations has not been determined. As with all cladding, maintenance is a prerequisite to longevity. Problems with local deterioration or moisture ingress must be dealt with promptly to achieve an acceptable service life.

SUSTAINABLE HOUSING INSIGHT

Healthy Indoor Environment

- Water entering the house can cause mold growth.
- As the cladding on a house is the first line of defence against water infiltration, it should be designed and installed to resist water penetration. It should also be maintained in good repair to keep water out of the wall system.

Energy Efficiency

- Consider using high levels of rigid insulation over the exterior wall framing to reduce thermal bridging and increase the thermal insulation in the building envelope.
- Exterior Insulation Finish Systems provide both insulation value and a finished wall surface, and can effectively reduce thermal bridging caused by the wall framing.

Resource Efficiency and Affordability

- Carefully estimate the amount of cladding material required including some allowance for wastage, rejection and future repair. When ordering materials, investigate the possibility of returning unused materials for a partial or full refund.
- Store and handle materials to avoid damage.
- Reduce cladding and sheathing waste by applying the 4 Rs: reviewing, reducing, reusing and recycling materials.

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CHAPTER 14
Flashing



Flashings are components of the exterior building envelope used to intercept and direct the flow of water to designed drainage paths. They are required to minimize the entry of water through joints and between materials. Flashings are usually installed wherever there is a discontinuity on exterior surfaces, such as:

- at the top of exposed walls;
- at roof-wall junctions;
- at roof-chimney junctions;
- around penetrations through roofing;
- at valleys in roofs;
- within walls above and below doors, windows and other wall penetrations;
- at foundation level to lead water out of the wall cavity; and
- at locations where water might enter the building through a juncture between two materials.

Flashings are also used to direct water away from building elements susceptible to deterioration, staining, erosion, frost damage or corrosion when exposed to excessive wetting. As discussed in the previous chapter, flashings are part of the primary and secondary lines of defence against rain penetration.

DESIGNING FOR FACTORS THAT INFLUENCE WATER FLOW

Flashings must deal with the forces that drive the flow of water, because water can move upward and sideways as well as downward. These forces include gravity, surface tension, capillary action, kinetic energy and differential pressure.

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Gravity

The building should have the following features to deflect water that flows downward from the pull of gravity:

- Surfaces should slope (minimum 6% slope) in the desired direction of flow, after any settlement or shrinkage has taken place.
- Points of discharge should project out beyond materials below the flashing, which may deteriorate when in contact with water or ice.
- Terminations on sloped surfaces should be lapped in shingle fashion so that the natural direction of the water is over and onto the next water-shedding surface.

Surface Tension

Surface tension allows water to flow along the underside of a surface horizontally, and even upward, in narrow spaces such as crevices. In confined spaces, spacing horizontal surfaces more than 9 mm (⅜ in.) apart will prevent the adherence of water to the two surfaces, thus allowing the water to drain away. A "drip" edge is placed at points of discharge to break that surface tension and allow water to drop by gravity.

Capillary Action

In porous materials such as concrete and brick, water can be drawn into small-diameter openings of less than 5 mm (3⁄16 in.) by capillary action or "wicking." The flashing joints should stop this from occurring. The design of joints and upturns must address this particular issue.

Kinetic Energy

Rain is often directed at flashings with high velocity and significant horizontal motion. On the upper locations of buildings, the wind actually carries rain drops upward. The momentum of wind forces can be strong enough to carry the rain drops through even small unsealed joints or openings. To prevent this, it is important to overlap and seal all joints in flashings as well as the joints between the flashing and the moisture barrier.

Air Pressure and Pressure Differentials

The combined effect of a positive air pressure on the outside of a building and a negative pressure inside, which is called a "pressure differential," can drive water through unsealed or poorly sealed joints. Wind can drive water through even small holes and gaps. To prevent this, care must be taken when incorporating a flashing into the building air barrier. Alternatively, the joint may be sealed. Flashings at the top of buildings such as at parapets are subject to uplift. They should be anchored to the wall securely and sealed to prevent water penetration.

TYPES OF FLASHING

Many types of flashing are available, as each location vulnerable to rain penetration has different flashing design needs. The most common types are described below and have been named to describe how they function and where they are located.

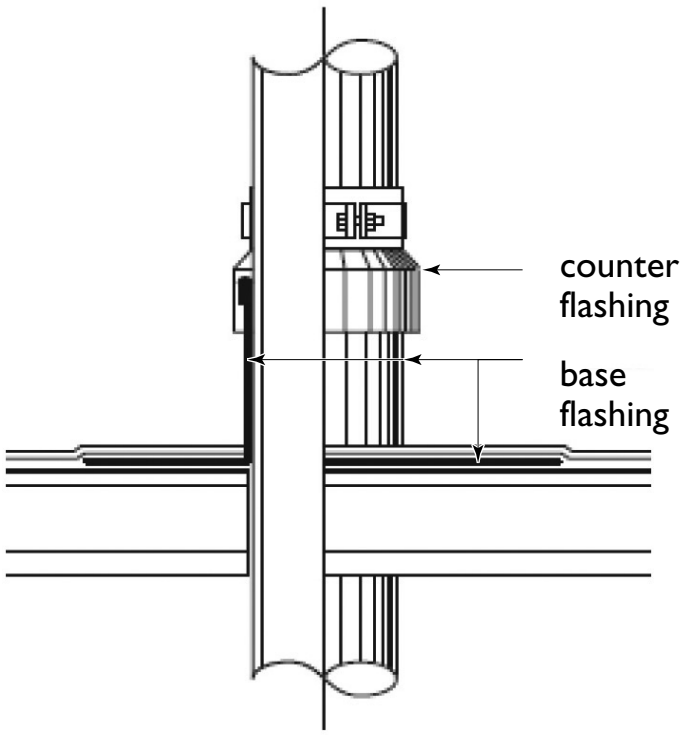
Base Flashing

When a roof intersects with a wall or another roof penetration, such as a plumbing vent, the roofing system should be turned up to make the junction watertight. The part of the roofing that is turned up is generally known as a "base flashing." It may be made

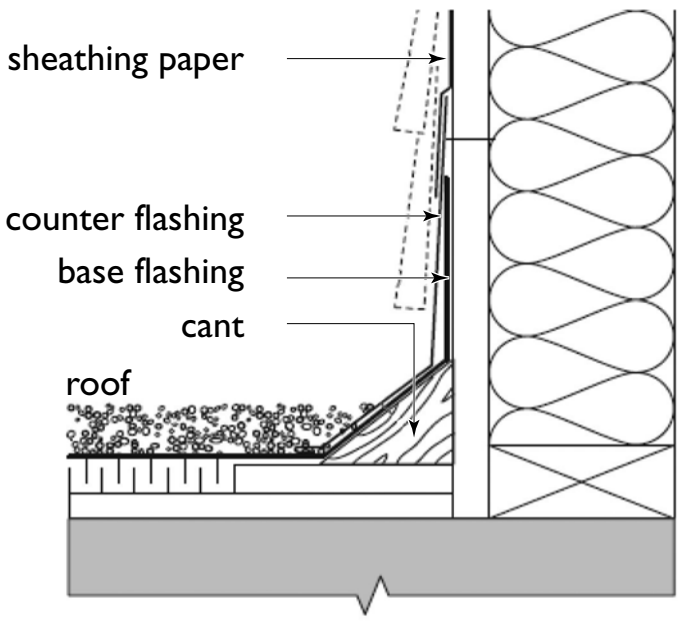
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of the same material as the main roofing membrane or of a compatible material (see Figures 117 and 118).

117 Base flashing at roof penetration



118 Base flashing at roof-wall junction

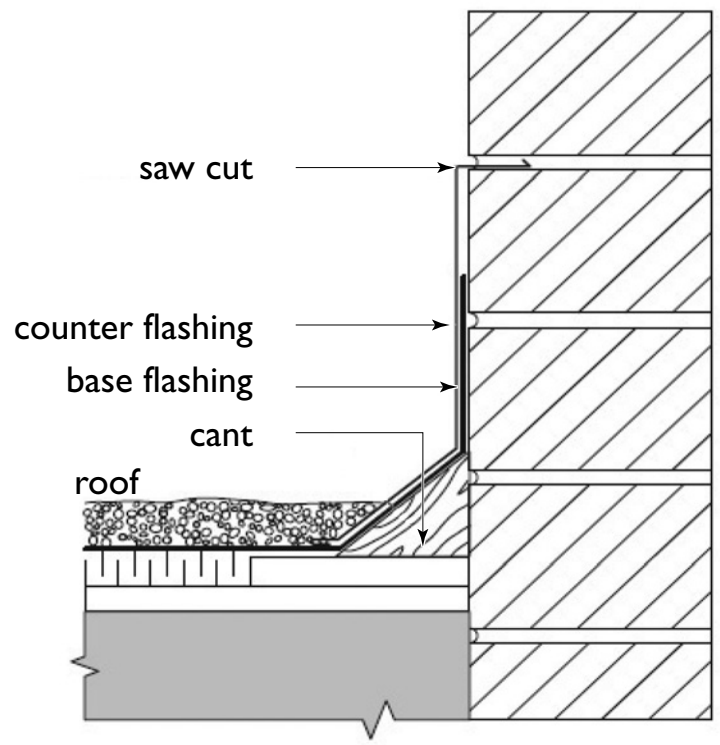


Where siding is used as cladding material, the base flashing is turned up behind the siding. Where siding abuts a roof, a space of at least 50 mm (2 in.) must be maintained between the siding and the roof surface. A cant strip should be installed where a built-up roof abuts a vertical surface to avoid a right-angle bend, which might rupture the roofing membrane (Figure 118). Membrane roofing is more flexible than built-up roofing, and usually does not require a cant strip. The roofing membrane should extend at least 150 mm (6 in.) up the wall and over the sheathing. Lap the sheathing paper at least 100 mm (4 in.) over the membrane.

Counter Flashing

To prevent water from penetrating behind the top edge of base flashing, a separate piece of flashing should be provided over the top. This flashing is known as "counter flashing" and is usually made of sheet metal (see Figure 119).

119 Counter flashing



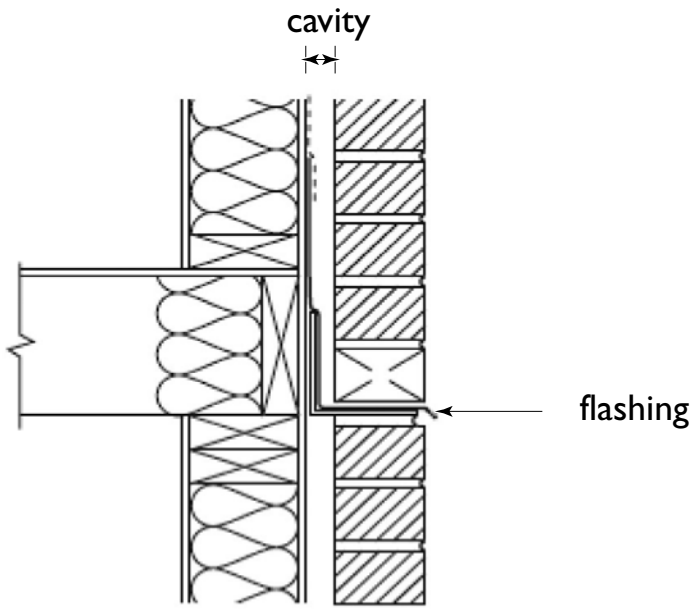
Counter flashing is also required to protect the base flashing from impact and UV radiation damage. This is necessary if the base flashing is a built-up bituminous roofing membrane or made of any material that deteriorates in sunlight. Counter flashings should be installed so that they are easily removed to allow for inspection of the flexible base flashing below.

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Through-Wall Flashing

A through-wall flashing intercepts and directs any water flowing down the cavity to the exterior (see Figures 120 and 121).

120 Through-wall flashing



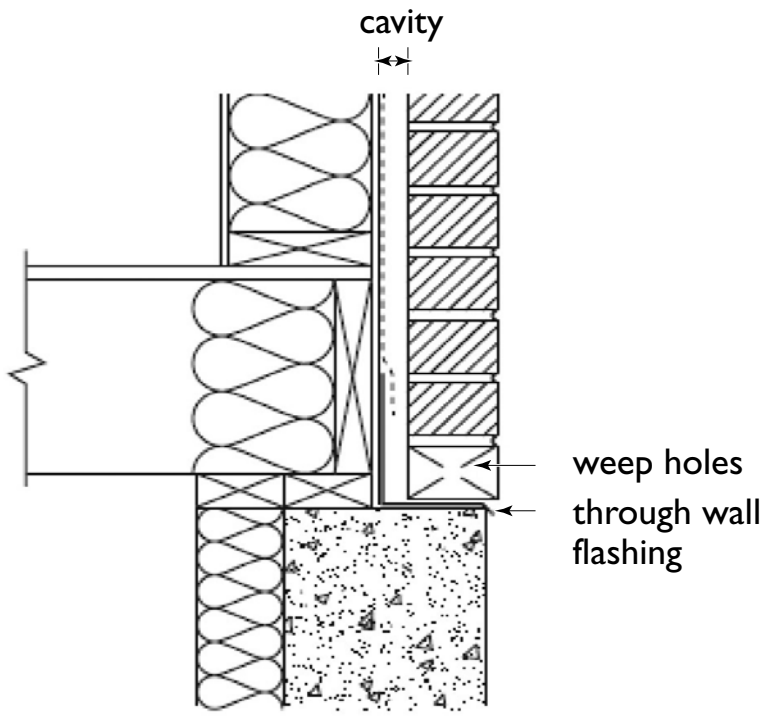
Cap Flashing

Parapet walls require a metal cap flashing to prevent water from penetrating from the top of the wall. Since a cap flashing sheds water, it must be sloped toward the roof to prevent staining of the exterior cladding. In addition, it cannot be made waterproof at the joints, and requires a secondary, continuous and waterproof flashing below it.

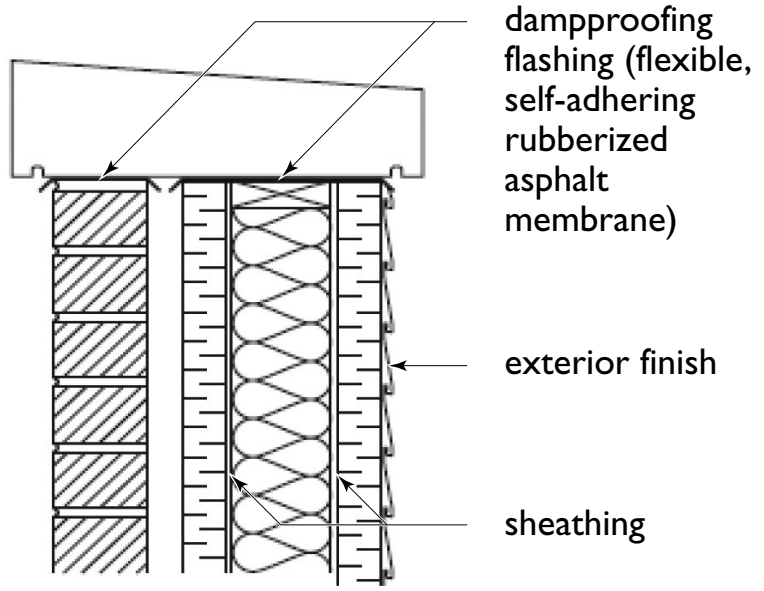
Dampproof Flashing

Precast concrete, stone masonry or brick units known as "copings" close the tops of masonry walls or act as window and door sills. These units also serve to prevent water from entering the top of the wall. If the copings are installed in sections, water may leak through the joints. A dampproof flashing should be placed between the coping and the top of the masonry wall to prevent water from penetrating into the wall below (see Figure 122). Using a dampproof flashing is also good building practice if copings or sills without joints are used.

121 Through-wall flashing at foundation



122 Dampproof flashing



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Valley Flashing

A "valley flashing" should be installed where two roof slopes intersect to form a valley. Open valleys leave the middle of the flashing exposed (see Figure 123) and must be flashed with one layer of sheet metal at least 600 mm (24 in.) wide, or with two layers of roll roofing installed over continuous sheathing. The bottom layer is Type S smooth roll roofing or Type M mineral surface roofing (mineral surface down), at least 457 mm (18 in.) wide. Centre this layer on the valley and fasten along the edges with nails spaced 400 to 450 mm (16 to 18 in.) apart.

Apply a 100 mm (4 in.) band of roofing cement along the edge of the bottom layer. Then apply a second strip of Type M mineral surface roll roofing approximately 914 mm (36 in.) wide over the first layer (mineral surface up). Fasten the top layer along the edges with enough nails to hold it in place until the shingles are applied. The roof shingles stop 100 to 150 mm (4 to 6 in.) from the centre of the valley, with the distance increasing from top to bottom.

Closed valleys are usually flashed with one layer of sheet metal. Each course of shingles is continued across the valley to conceal the flashing. Shingle nails must not be placed within 75 mm (3 in.) of the valley centre line at the ridge, or within 125 mm (5 in.) at the eaves. Rigid shingles should not be used in closed valley roofs or roofs that slope less than 1:1.2.

Stepped Flashing or Shingled, Stepped Base Flashing for Shingled Roofs

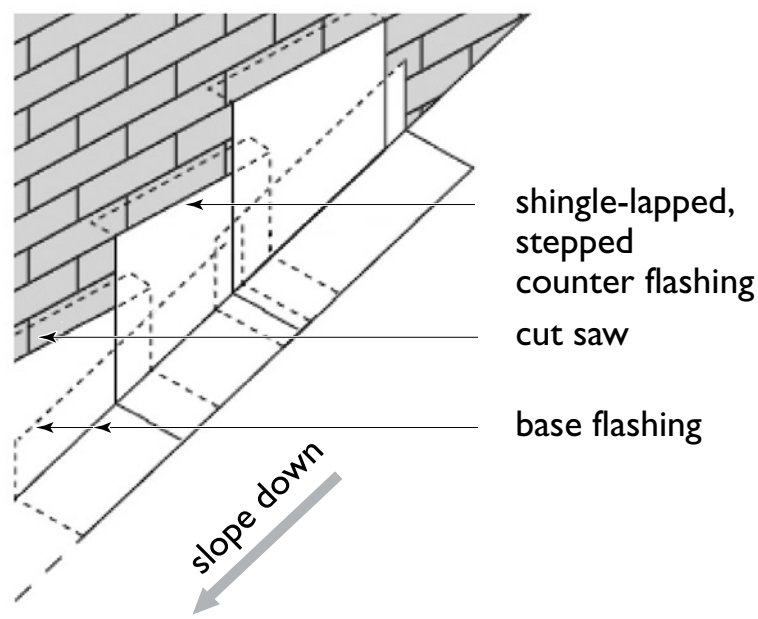
Flashing must be provided at the junction between a roof and a masonry wall or chimney. The base flashing should extend at least 150 mm (6 in.) up the side of the chimney or masonry veneer. A common approach is to bend the top of the base flashing and imbed it at least 25 mm (1 in.) into the horizontal masonry joints. The flashing is installed on all sides of a chimney where it penetrates a roof. This flashing method does not direct any water that is inside the masonry to the exterior, and this water may leak into the chimney or wall.

Stepped base flashing should be installed in pieces, following the roof slope. The flashing pieces (also called "flashing squares") are overlapped like the roof shingles, and extend at least 100 mm (4 in.) under the shingles (Figure 124). One square is used at each shingle

123 Valley flashing



124 Stepped flashing



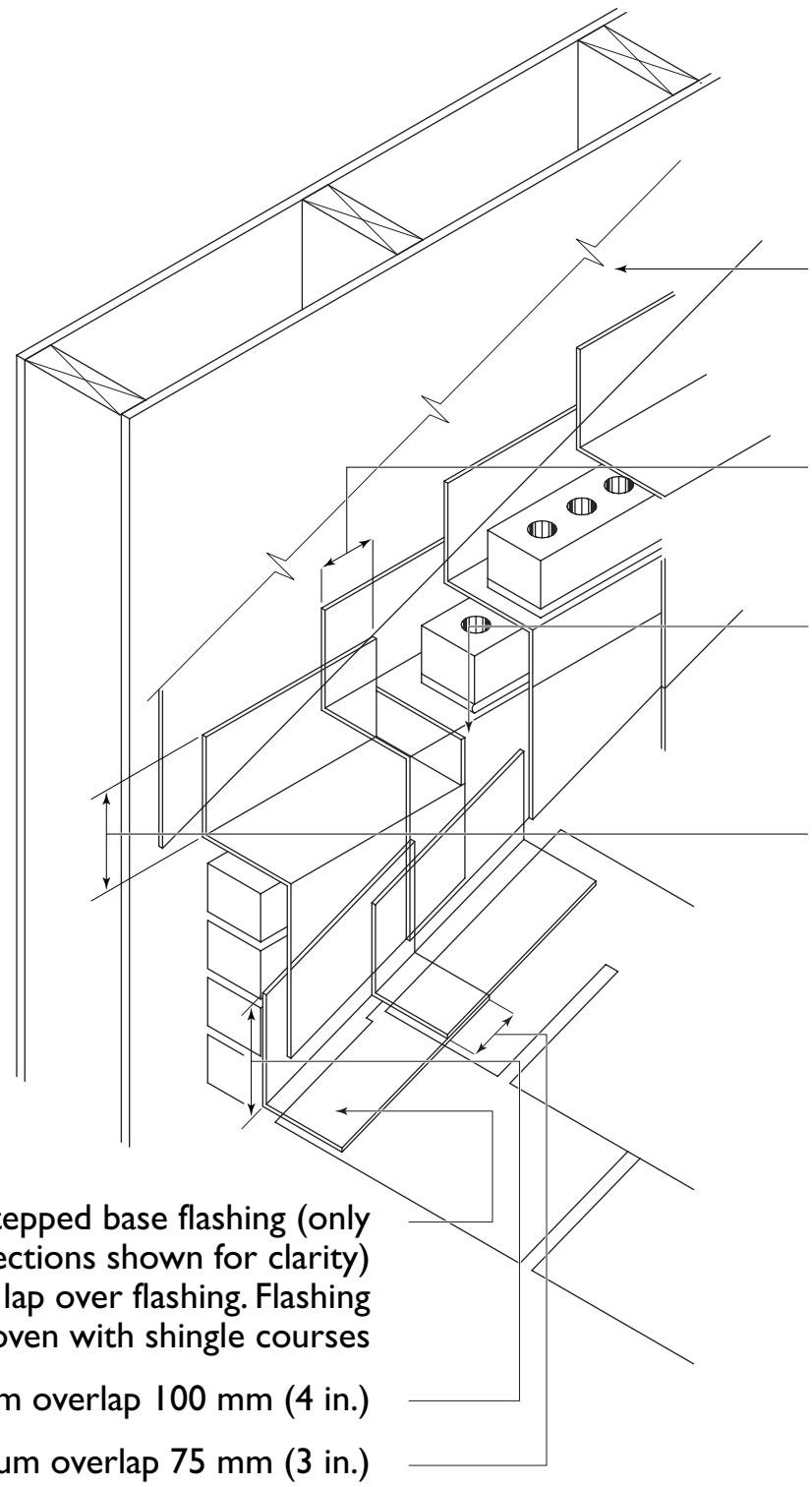
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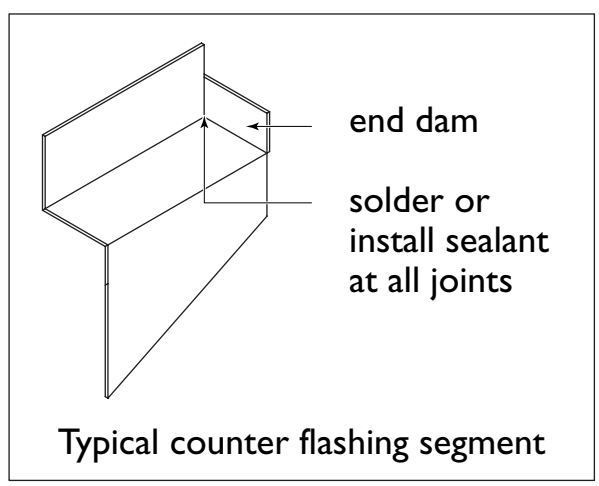
course and is bent up along the wall under the sheathing membrane. The squares must be large enough to give a good lap at the intersection of the roof and wall, and the head lap should be no less than 75 mm (3 in.). A through-wall flashing should be installed over the base flashing, through the full depth of the masonry veneer and air space behind, and extended at least 150 mm (6 in.) up the wall sheathing (Figure 125). The sheathing membrane should lap at least 75 mm (3 in.) over the top of the through-wall flashing.

Flashing should also be installed at the intersection of shingle roofs and walls clad with materials other than masonry. It should extend up the wall not less than 75 mm (3 in.) behind the sheathing paper.

A saddle or "cricket" should be installed when the upper side of a chimney is more than 750 mm (30 in,) wide. These are constructed out of wood during the roof framing operations and are usually covered

125 Flashing at wall intersection





Typical counter flashing segment

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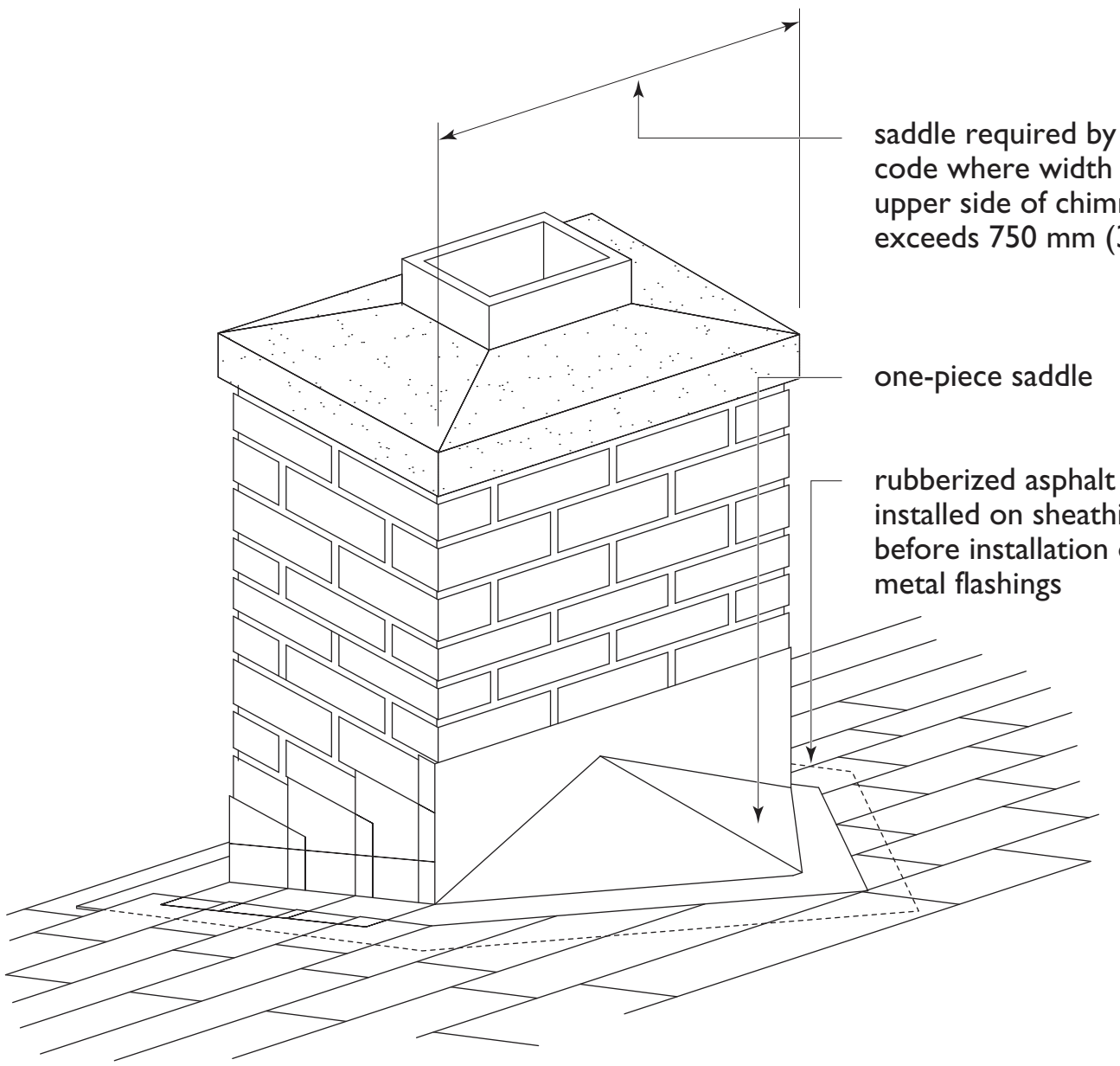
with sheet metal (Figure 126). The saddle should be suitably flashed at the roof and at the chimney.

A saddle is not required if the metal flashing is carried up both the roof and the chimney to a height at least equal to one-sixth the chimney width. On roof slopes behind a chimney, the flashing should extend up the roof and up the chimney to a point equal in height to the chimney counter flashing, but not less than 150 mm (6 in.) or 1½ times the shingle exposure. Open joints or laps should be soldered or sealed, or a locked joint used.

Drip Flashing

Drip flashings intercept moisture that has entered behind the cladding and direct it to the outside, as well as redirect water flowing down the face of the wall to prevent it from dripping down on the materials below. A drip flashing should be inserted between two different siding materials (for example, siding above stucco) or between different materials and components. To prevent water from entering the joint, a preformed drip should extend from behind the siding out over the stucco to a drip at the outside edge (Figure 9).

126 Chimney flashing



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Flashing should also be used over windows and doors (drip flashing in this location is also called "head flashing"), unless they are protected by an overhang. This flashing is required where the vertical distance between the window or door and the underside of the overhang is more than one-quarter the horizontal projection of the overhang. For example, flashing is required if the top of a window is more than 300 mm (12 in.) below an eave that projects 1.2 m (4 ft.). Head flashing should extend from the top of the window or door to up and under the sheathing paper or membrane.

Where the sills of windows and doors in exterior walls are not self-flashing, flashing must be installed between the underside of the window or door and the wall below.

FLASHING PERFORMANCE REQUIREMENTS

The following performance requirements should be considered when materials to be used as flashing are selected:

Water Barrier

The flashing assembly that includes materials and joints must shed water without allowing leakage. The ability of the flashing to seal and be detailed to avoid leakage is fundamental. Creating an effective and durable joint seal is often difficult. It is good practice to provide a secondary, continuous flexible membrane flashing under jointed materials such as brick, stone or sheet metal.

Movement Capability

The flashing must be able to accommodate differential thermal and structural movements. As a result, it must either be made of a flexible material or have joints designed to accommodate movement such as thermal expansion and contraction of all building components including the flashing itself, normal deflections under service loads, shrinkage and creep of concrete and wood; and expansion of brick after construction.

Terminations

Terminations should be formed into sharp breaks and to be sufficiently rigid at points of discharge to adequately project water away from materials below.

Durability

The flashing must be tough enough to resist physical damage during construction, as well as normal wear, which may be related to the environment and building maintenance activities. Other factors to be considered include deterioration from corrosion, metal incompatibility and galvanic action, deterioration due to exposure to ultraviolet (UV) light, extreme (hot and cold) temperatures, freezing water and fatigue due to movement.

For more information on durability, consult the CSA Standard *S478-95: Guidelines on Durability in Buildings*. In general, the service life of flashings must be equal to or more than that of the wall system or roof system at locations where maintenance or replacement of flashings would be uneconomical.

Compatibility

Flashings along with their primers and sealants must all be chemically compatible with adjacent materials. Avoid contact between dissimilar metals, as this can lead to galvanic corrosion when the metals are moist. Water acts as the electrolyte, and dissimilar metals as electrodes.

Alkaline concrete and mortar aggressively attack materials such as aluminum and copper. These materials should be protected from contact with concrete or mortar by the

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sheathing membrane or other suitable materials. Consult the manufacturers of selected materials to determine whether adjacent materials will be compatible.

Buildability

Creating a flashing detail that is easy to build will greatly increase the likelihood that the flashing will be built to perform acceptably. Ask yourself the following questions:

- Can the installation of flashings be sequenced to be separate from other construction activities, or can this be easily incorporated into other work? For example, coordination may be required between roofing and masonry activities at wall-roof junctions.
- If the installation of the flashings is to be incorporated into other work, do the workers have the required technology and skills?
- Can the flashing accommodate normal stresses?
- Is it possible to mould or modify the material to accommodate unusual conditions, or is it possible to repair damage?

Maintenance

Besides durability, future maintenance of the flashing must be considered. Materials or joint sealants with limited service lives should be avoided if the flashings are not accessible for replacement. Metal flashings built into concrete or masonry cannot be removed to allow for inspection or repair of the materials underneath. This should be considered when selecting materials and details for flashings. The flashings and sealants should be inspected annually, particularly in areas with the greatest exposure to water and sunlight.

RELATED PUBLICATIONS

CSA Standard S478-95: Guidelines on Durability in Buildings,
Canadian Standards Association

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CHAPTER 15
Windows, Exterior Doors and Skylights



The proper selection and installation of windows, doors and skylights is an important aspect of wood-frame house construction. Although windows, doors and skylights provide natural lighting and ventilation and means of egress in the event of emergency, they may allow moisture to seep into the building envelope, which adversely affects the durability. The use of low-performance units and poor installation can lead to costly repairs.

LIGHT, VIEW AND VENTILATION

Windows and doors with glazing provide light, view and ventilation. Except for bedrooms, which require windows as a means of egress from fire, the NBC does not require other rooms to have windows. However, it is recommended that certain rooms have windows large enough to admit daylight because of the psychological benefit they provide occupants and to provide natural daylighting. A general rule is for living rooms, dining rooms and bedrooms to have glazing equal to at least 10 per cent of the area of a room. Other rooms, such as family rooms, should have window areas equal to at least 5 per cent of the floor area of the room.

Operable windows provide natural ventilation and can reduce the need to operate mechanical ventilation during non-heating seasons. Windows used for natural ventilation should have an unobstructed, operable window area of at least 0.28 m^2 (3 sq. ft.). Bathrooms should have a window area of at least 0.09 m^2 (1 sq. ft.), or else require mechanical ventilation.

Because fire can spread from windows to adjacent houses, building codes place strict limits on the amount of glazing in walls that are close to property lines. Unprotected, glazed openings are not permitted in walls that are within 1.2 m (4 ft.) of a property line. The allowable area of windows in walls more than 1.2 m (4 ft.) from a property line depends on their distance from the property line and the area of the wall facing the property line. Consult the local building department for specific requirements.

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AIRTIGHTNESS, WATER RESISTANCE AND WIND LOAD RESISTANCE

Windows, doors and skylights provide environmental separation (resistance to water entry, thermal resistance and airtightness), perform a structural function by resisting wind loads, offer stability under operational loads and withstand forced entry.

Windows, doors and skylights in Canada are expected to conform to the Harmonized Standard *NAFS—North American Fenestration Standard/Specification for windows, doors, and skylights (A440-11)* and the *Canadian Supplement: A440S1-09*. It replaces a number of Canadian standards that were previously referenced for doors and skylights as well as its window predecessor CSA A440. The primary performance designator required for a window, door or skylight indicates a certain performance level and by itself indicates compliance with the Harmonized Standard.

The Canadian Supplement contains a checklist for selecting performance levels for windows, doors, and skylights. For a window, door or skylight to bear a label in Canada, it must meet all of the applicable requirements of both the Harmonized Standard and the Canadian Supplement, including those pertaining to forced entry.

The Harmonized Standard includes a classification system that rates a window, door or skylight assembly according to airtightness, watertightness and wind load resistance. The ratings achieved are marked on the window, door or skylight and indicate the level of performance that can be expected.

Builders must ensure that windows, doors and skylights are suited for the climates where they will be used by determining the test pressure required (Canadian Supplement) and select fenestration based on the manufacturer's information, which will meet or exceed the pressure for a given locale.

ENERGY RATING

Windows, doors and skylights must have maximum overall thermal transmittance (U) not greater than the values listed in the NBC for the applicable heating-degree day category, or a minimum energy rating not less than the values listed in the NBC (Table 13 in Appendix A).

The Energy Rating (ER) is a useful measure of the overall heating season performance of a window based on three factors: (1) solar heat gain; (2) heat loss through frames, spacers and glass; and (3) air leakage heat loss. The ER rating is based on a standard test-size window and depends on the type of window. For example, fixed windows typically have a better (higher) ER rating than operable windows. Because all windows are evaluated the same way, this rating method compares the energy performance of window types made by different manufacturers.

Table 14 compares the thermal efficiencies of several glass configurations. The window industry typically uses U value, which is a measure of thermal transmittance and is the inverse of R value. A U-value indicates the rate of heat transfer through an object. The lower the U-value number, the slower it transfers heat from a warm area to a cold area.

The energy rating (ER) value is calculated using a formula that balances a product's U-value with its potential solar heat gain coefficient (SHGC) and its airtightness. The higher the ER number, the more energy-efficient the product and the better the product's thermal performance will be. It is recommended that new windows have an ER of at least 25 for operable windows and at least 33 for fixed windows (or higher, depending on the NBC requirement for your

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region). This means windows should be at least double-glazed, be low-E coated and have argon gas fill. Higher-efficiency windows are recommended for the colder regions of Canada.

ER is a heating-only rating and therefore achieving a good ER can sometimes result in situations where overheating is a problem. The energy benefit from passive solar heat gain due to a higher ER must be balanced with thermal comfort and impact on cooling.

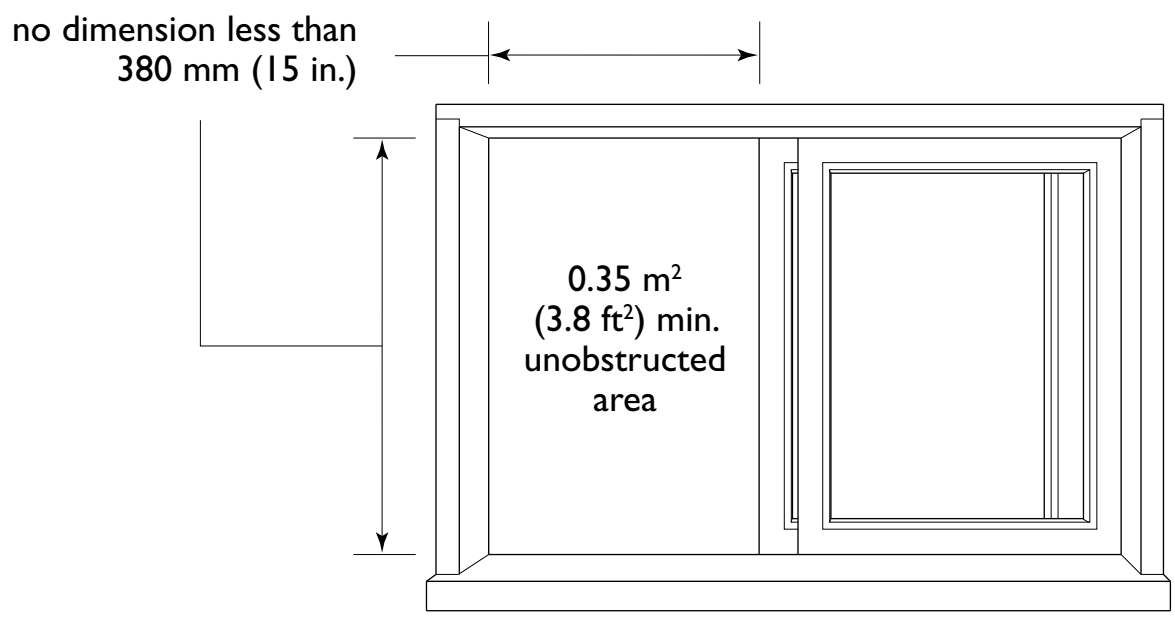
MEANS OF EGRESS

Windows can allow occupants to escape to the outdoors (provide a means of egress) if fire blocks the usual exit paths from a room. Each basement bedroom must have at least one outside window (or exterior door) operable from the inside without the use of tools or special knowledge and without the need to remove sashes or hardware. Windows in these locations must have an unobstructed open portion with no dimension less than 380 mm (15 in.) and with an open area of at least 0.35 m^2 (3.8 sq. ft.) as shown in Figure 127. For example, a casement window with an opening that measures 450 × 750 mm (18 × 30 in.) would conform to this requirement, but an awning window of the same size might not, if the awning hardware restricts the size of the opening. Awning windows with simple-to-use and quick-release hardware should provide acceptable means of egress.

It is recommended that the sill for the escape window be no higher than 1.5 m (5 ft.) above the floor. Access to escape windows can be improved by using built-in furniture as a step.

Where a security grill is installed over a bedroom window, it must be possible to remove the grill from the interior without special tools or knowledge. The window must be capable of staying open during an emergency without the need for props or supports. Where a window opens into a window well, a clearance of at least 760 mm (30 in.) must be provided between the window and the well to provide room for a person to exit. For windows that swing out, the 760 mm (30 in.) requirement is measured from the edge of the window in its open position.

127 Minimum dimensions for egress windows



Horizontal slider

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WINDOWS

Window Types

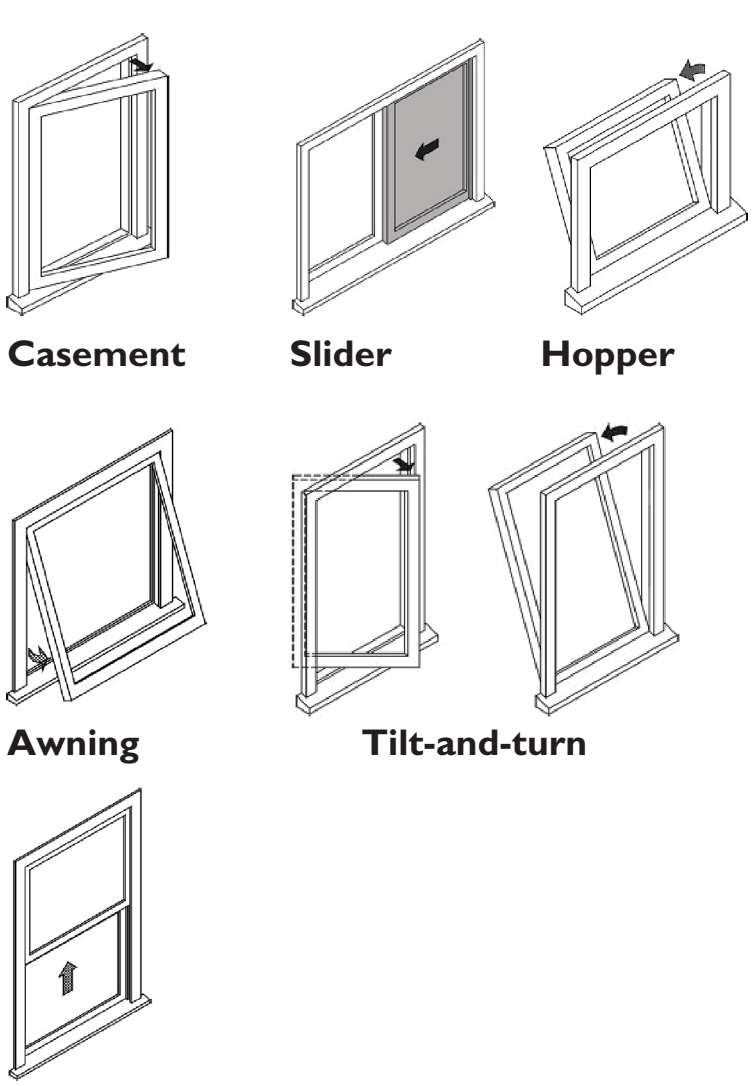
Many types of windows have different characteristics (Figure 128) along with their own advantages and disadvantages. Common window terms are shown in Figure 129.

Fixed windows cannot be opened and are generally the least expensive. Though they usually offer the best level of energy efficiency and resistance to forced entry, fixed windows do not provide natural ventilation and cannot serve as a means of egress in case of fire.

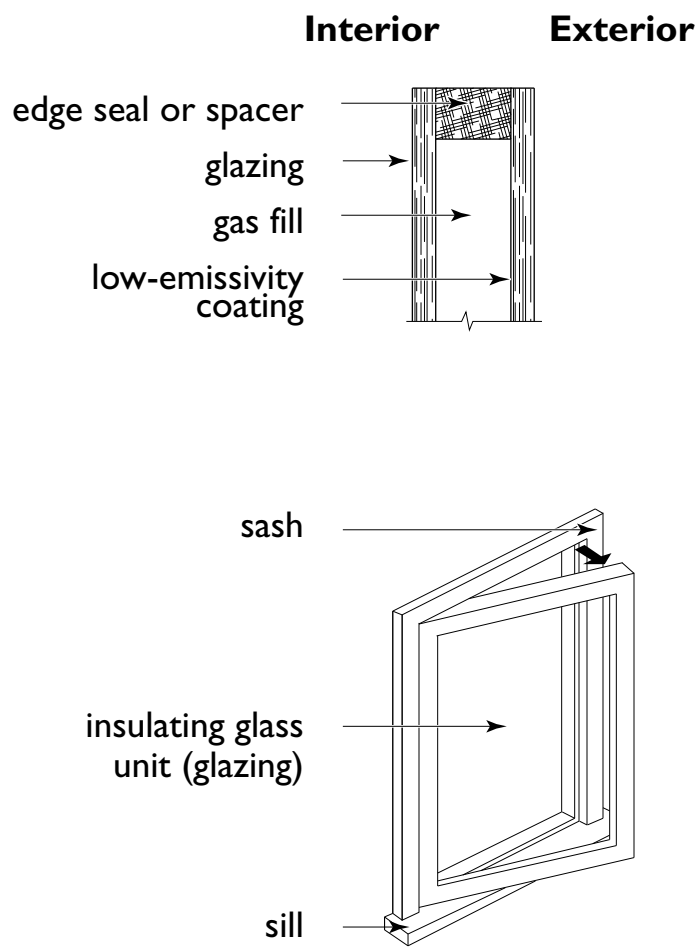
Single- or double-hung windows open vertically. A single-hung window has only one operable sash (usually the bottom unit) and a double-hung window has both sashes operable. Because of their design, only half the window area can open for ventilation. Older hung windows were difficult to open or close and were prone to air leakage. Modern hung windows are much improved and provide good resistance to forced entry.

Horizontal and vertical slider windows are easy to operate and do not swing into or obscure living space. Similar to single- and double-hung windows, only half the window area of a slider can open for ventilation. Sliders tend to be less airtight than casement windows, awning and tilt-and-turn windows because their weatherstripping is subject to wear.

128 Common window types



129 Window terminology



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Casement and awning windows swing open to the exterior and are among the more expensive types. They are very airtight and offer good resistance to forced entry. The entire window area can be open for ventilation. Casement windows are well suited to deflecting prevailing winds into the dwelling for natural ventilation and passive cooling. Awning windows have the advantage of shedding rain effectively when open.

Tilt-and-turn windows are the most flexible of all window types. Some can act like casement and awning windows. Similar to casements, the entire window area can be open for ventilation. These windows can be very airtight when fitted with compression-type closing devices.

Window Performance

Several technological advances have vastly improved the performance of windows over the past 20 years.

Multiple Glass Layers

Condensation on interior window surfaces can be reduced by installing energy-efficient windows, using efficient glazing and low-conductivity frames. Each layer of glass and air space works to increase the inside surface temperature of the innermost layer of glass, thereby reducing the potential for condensation. Windows that separate heated space from unheated space or the exterior must be at least double-glazed.

Some condensation around the edges of windows can be expected during cold weather, particularly if the humidity in a house is high. Double-and triple-glazed windows with glazing that have low-conductivity edge seals and low-conductivity frames create warmer interior surface temperatures and reduce the potential for condensation.

Low-Emissivity Coatings

Much of the heat lost and gained through a window is due to radiation, a process whereby warmer objects radiate heat to cooler objects, as in the case of sunlight passing through a window and warming objects in a room. Low-emissivity (low-E) coating is a thin metallic film deposited on glass that acts as a mirror to radiate heat back into a room during cold weather, and back to the outdoors during hot weather, thereby reducing heating and cooling bills. It provides a double-glazed window with about the same energy performance as a window with uncoated triple-glazing, but at less additional cost. Many window manufacturers offer low-E glazing as a standard feature.

Gas Fills

Another innovation is the use of inert gas between layers of glass in a sealed unit in the place of air. Inert gases have a higher insulating value than air because they are heavier, resulting in lower convective and conductive heat losses between the panes of glass. Argon is the most commonly used gas due to its availability and low cost. Many window manufacturers offer windows made with inert, gas-sealed units.

Solar Heat Gain Coefficient

The solar heat gain coefficient (SHGC) is the fraction of incident solar radiation admitted through a window, both directly transmitted and absorbed and subsequently released inward. It is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits. Solar heat gain can provide free heat in the winter but can also lead to overheating in the summer. The appropriate SHGC for a given window depends on the climate, orientation, shading conditions and other factors.

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Edge Seals

The thermal efficiency of a sealed glazing unit can be significantly improved by using a low-conductivity edge spacer between panes of sealed glass units. Aluminum was commonly used for window spacers but resulted in cold areas around the edges of glazing units. Plastic, silicone and glass fibre spacers are now used to reduce thermal conductivity at the glass edges.

Thermally-Efficient Frames

Window frames are typically constructed of aluminum, vinyl (polyvinyl chloride, or PVC), wood or fibreglass. Each of these materials has unique properties suited for window frame construction, but differ in terms of thermal performance. Aluminum is very conductive (1,000 times greater than vinyl, wood or fibreglass) and, therefore, performs poorly from a thermal efficiency standpoint. Aluminum frames must be thermally broken using low-conductivity materials such as PVC or nylon, which improve the performance of the frame significantly. Frames constructed of wood, PVC and fibreglass all have similar low-conductivity properties. Further improvements can be made in PVC and fibreglass by filling the voids and airspaces in the frames with insulation. While the frames may only make up a small portion of the overall window area, the thermal performance of a window is significantly influenced by the frame selection.

Window Selection

The following list shows window selection factors:

- Cost
- Warranty
- Energy performance
- Solar heat gain coefficient
- Appearance

In addition, the Harmonized Standard and Canadian Supplement require manufacturers to make windows that are:

- suitable to local climatic loads (water penetration resistance, wind load and airtightness); and
- resistant to forced entry.

All manufactured windows and entrance doors are required to meet forced entry requirements. All site-built doors and site-built windows located within 2 m (6 ft. 6 in.) of the ground must meet the same requirements.

Window Installation

Windows are usually installed after the house framing and roof covering have been completed. Windows should arrive just in time for installation. If they are delivered early, store them upright in a secure, dry and level area in their original packaging with any temporary bracing left in place. Screens are susceptible to damage and should be removed, labelled and stored until construction is complete.

Prior to installation, review the manufacturer's installation instructions, and ensure that all of the proper tools, fasteners and materials are available. Install windows plumb and level within the rough opening using shims to position and temporarily secure them.

Improper window installation can result in water and air leakage problems and poor functioning of operable units. Correct window installation includes lapping and sealing the water-impermeable sheathing membrane to the window to form a continuous second

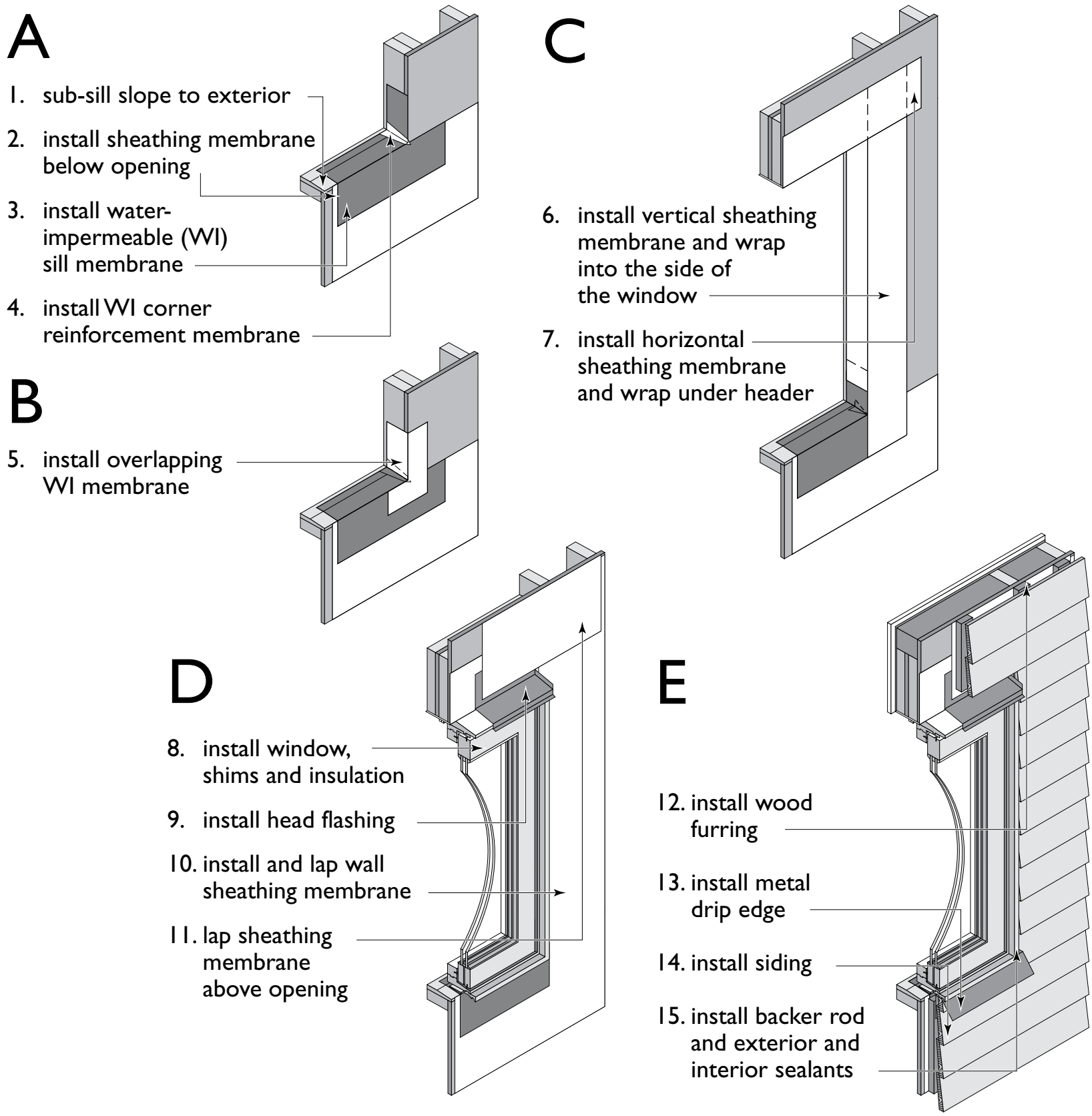
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plane of protection at the window perimeter, and in particular, provide drainage of the sub-sill area (Figure 130).

Depending on the technique used to insulate and air seal the window breaching (the gap between the window and the rough opening), air sealing may be performed after the window is installed. The most common technique now involves applying closed-cell sprayed foam to insulate and air seal the breaching in one step after the window is installed.

The window must be connected to appropriate materials in the adjacent wall construction to maintain the continuity of the first and second planes of protection as well as the air barrier. It is best to connect the air barrier at the interior edge

130 Sequence for window installation



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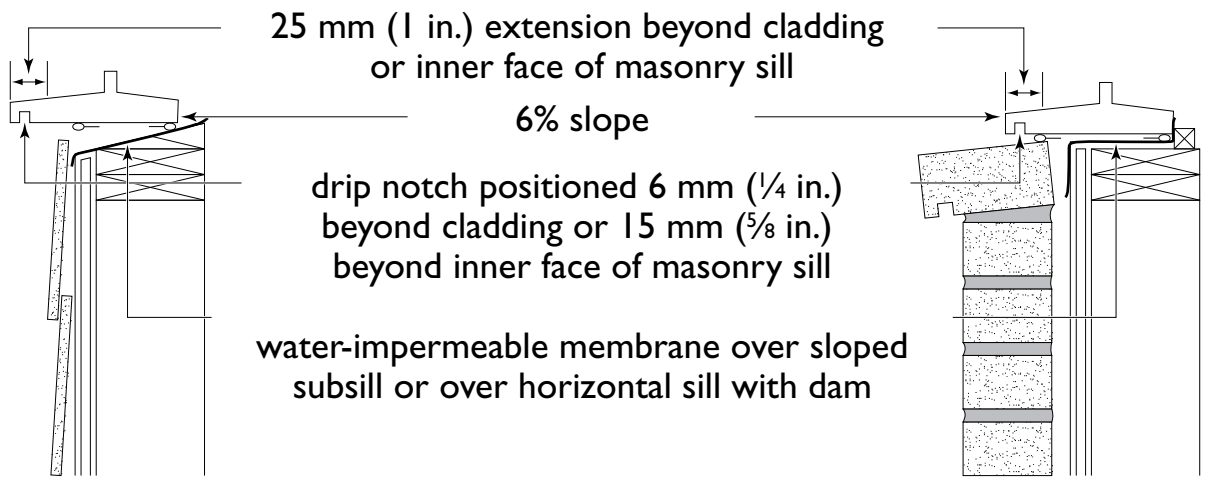
of the window so that any incidental water leakage through the window can be readily drained to the exterior.

Although insulating around the frame in the rough opening can provide some thermal benefit, it does limit the drainage capability. In areas of higher exposure, the use of sealant in the interior and an insulation material that can readily drain and dry is preferred. When exterior perimeter insulation is used, space should always be provided for drainage and drying between the insulation and the cladding.

Provide continuity of the water shedding surface at the first plane of protection by using sealant and trim at the window perimeter. A drip edge is recommended at the sill because it causes water to drip free of the cladding below, reducing the probability of water running back into the wall assembly and the staining created by concentrated water run-off.

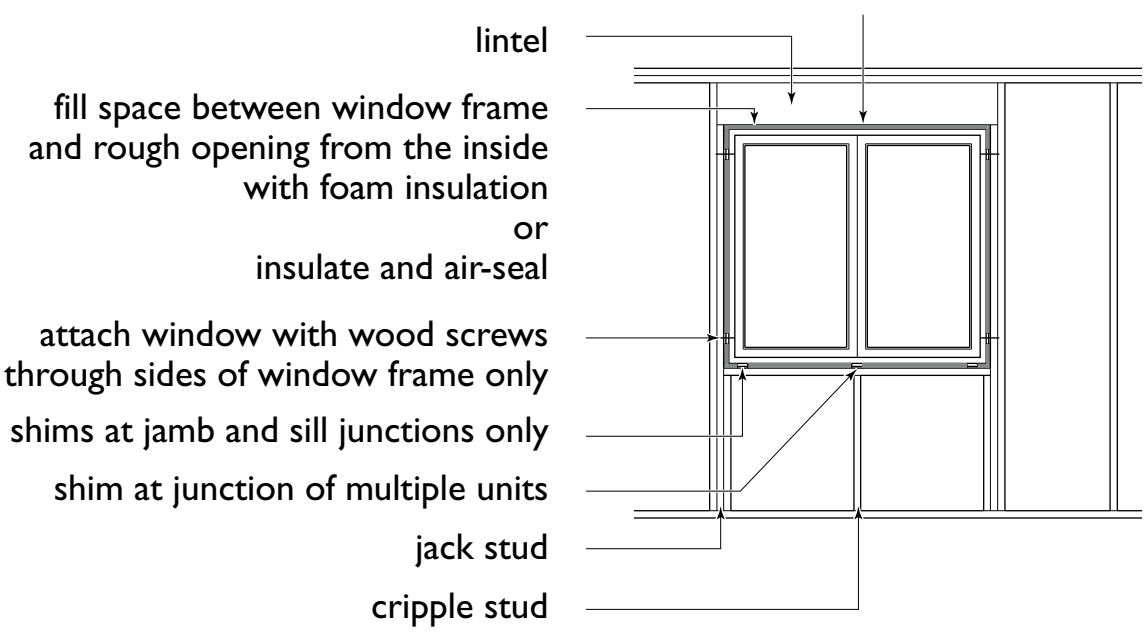
Figure 131 shows two drip edge arrangements for a window sill. Attach windows securely to framing members (Figure 132).

131 Window sill



132 Window attachment

rough opening dimensions 25 mm (1 in.) larger than outside of window frame to provide a minimum 12.5 mm (½ in.) space between the window frame and rough opening



Note: Always refer to manufacturer's instructions.

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Energy-efficient windows that come with double or preferably triple glazing and low-conductivity frames can provide significant energy savings. They should be installed with spray foam or sealant around the perimeter between the frame and the rough opening to reduce air leakage and water ingress. There should also be flexible membrane sub-sill flashing across the rough sill and extending at least 100 mm (4 in.) up the sides of the rough opening. The sill flashing should be sloped towards the exterior to prevent bulk water from entering the wall (Figure 11 in Chapter 5). Position the window in the rough opening so that the insulated glazing is in line with the wall insulation. In thick walls, the window should be placed close enough to the interior to allow heated room air to 'wash' the inner surface of the glass to prevent condensation and inwards from the exterior wall surface so that it is protected from rain and snow, yet near enough to the exterior so that flashings and membranes are not excessively large.

EXTERIOR DOORS

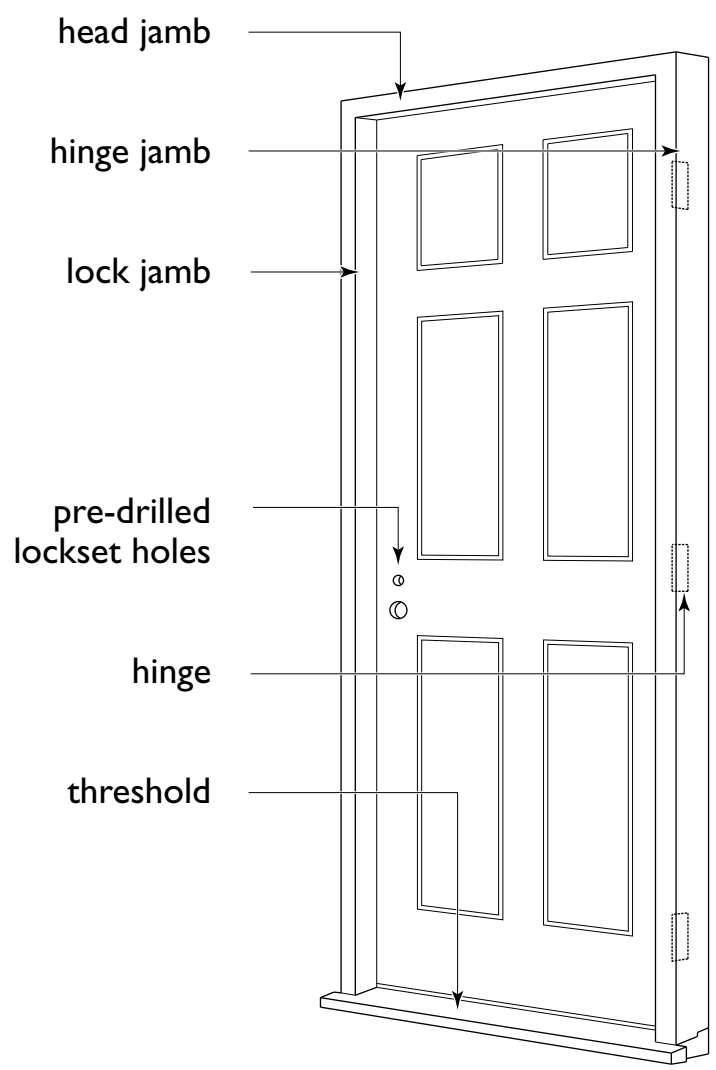
Exterior doors, like windows, affect the appearance of a dwelling and are often selected on the basis of style and finish. Most manufactured exterior doors come as manufactured units pre-hung in their frames and ready for installation within a rough opening.

Exterior doors are usually manufactured of wood, steel, plastic or fibreglass. Wood doors are normally solid, while other types consist of inner and outer structural panels filled with insulation and are more energy-efficient. However, wood doors have proven performance and a traditional appearance that have contributed to their popularity.

Main doors should not be less than 45 mm (1¾ in.) thick. They should be at least 810 mm (32 in.) wide and 1.98 m (6 ft. 6 in.) high.

Nearly all doors are purchased and installed as complete manufactured systems (Figure 133). When custom doors are required, they must meet the same durability and performance requirements as manufactured units. In addition, some components may have to be milled prior to assembly and installation (refer to Chapter 16).

133 Pre-hung manufactured door



Note: Exterior doors to have water-impermeable sill membrane and flashing

Weatherstripping is the primary line of defence against air leakage around doors. It should fit tightly and be effective, durable and easy to replace. It is good practice for doors to be protected by overhangs to limit exposure to wetting. Exterior doors should be installed with the same attention to sealing and flashing as windows.

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Doors that lead from the house to the garage must provide a gas-tight barrier to prevent automobile exhaust fumes from entering the house. These doors should be tight-fitting, weatherstripped and provided with a self-closing device.

Glazing

Glazing in exterior doors should be thermally efficient, and depending on their size and location, may also have to be tempered for added safety. Glass sidelights greater than 500 mm (20 in.) wide that could be mistaken for a door and glass in storm or sliding doors is required to be safety glass. Sidelights must be double-glazed. When no glazing is provided, a door viewer is required for security purposes. As is the case for windows, the amount of glazing in side doors near property lines may be restricted depending on the distance to the property line.

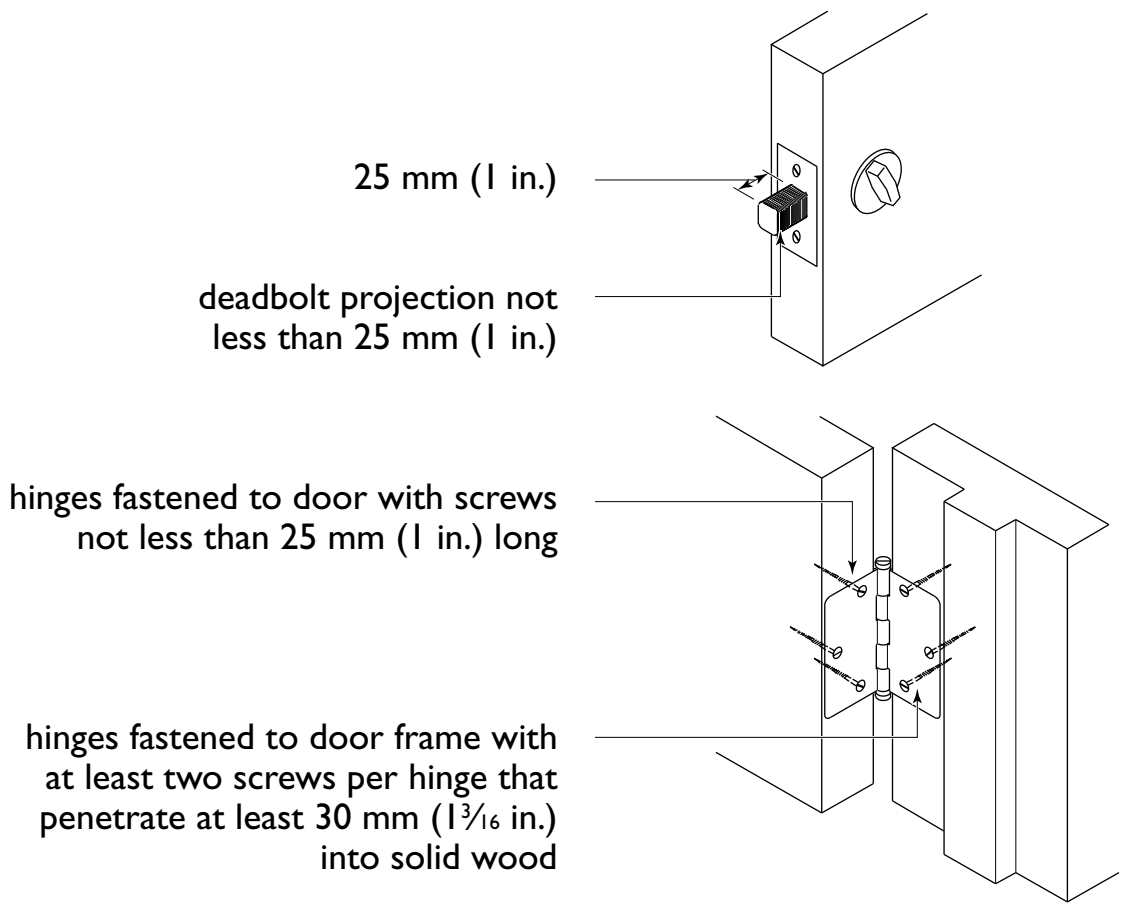
Resistance to Forced Entry

Hardware, in particular locksets and hinges, must be both functional and durable. The main entry door to a dwelling will be locked and unlocked, opened and closed numerous times over its useful life. Low-cost hardware will eventually need to be replaced and may cost more in the long run.

The Harmonized Standard and Canadian Supplement contain requirements pertaining to resistance to forced entry for door hardware. Manufactured and site-built doors must meet these requirements.

Deadbolt locks in exterior doors to houses must have a cylinder with no fewer than five pins and a bolt throw of at least 25 mm (1 in.) (Figure 134). Double doors must have heavy duty bolts top and bottom with an engagement of at least 15 mm (⅝ in.). Hinges must be fastened to wood doors with wood screws not

134 Door hardware requirements



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less than 25 mm (1 in.) long, and to wood frames penetrating at least 30 mm (1 3/16 in.) into solid wood.

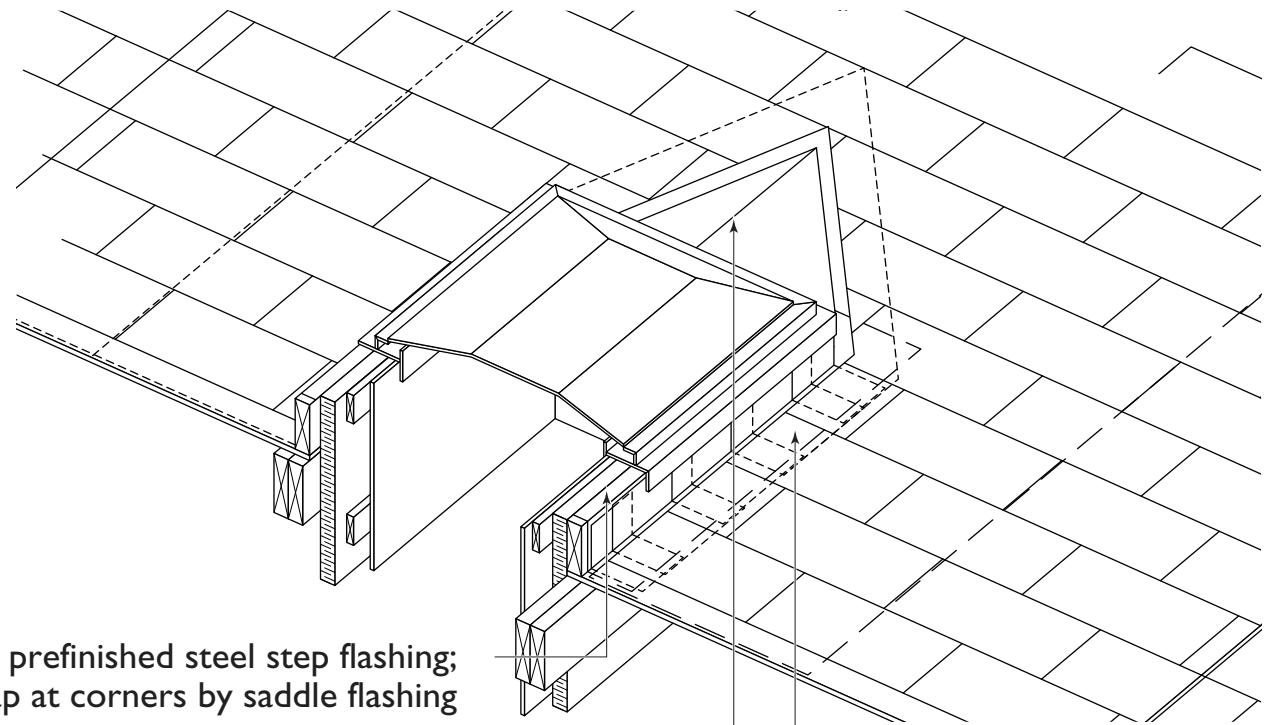
Resistance to forced entry extends beyond door hardware to the framing for the door as well. Solid blocking must be provided on both sides of the doorway at lock height between the jamb for the door and the structural framing so that the jambs resist spreading by force. Additional screws in the drywall around the doorframe will also strengthen resistance to forced entry. Doors conforming to the Harmonized Standard and Canadian Supplement meet these requirements.

SKYLIGHTS

Skylights are windows designed and manufactured for installation in a roof assembly. They must be installed carefully because they are exposed to severe climatic conditions and their remote location makes them difficult to maintain. Skylights must be securely attached to the roof framing and sealed to the air barrier system in the roof, at the walls of the skylight opening and at the ceiling.

When the air barrier in a wood-frame building consists of polyethylene attached to the inside surface of the roof framing, the polyethylene must be extended up and sealed to the inside face of the skylight frame. When the air barrier is a membrane on the exterior of the roof sheathing, it should be sealed to the outside of the skylight frame and covered with a prefinished metal flashing to protect it from exposure to ultraviolet radiation, water, snow, ice and mechanical damage. Some skylight manufacturers supply step flashings specifically designed for their units and for a variety of roof slopes and finishes, which enables the installer to effectively integrate the skylight unit into the roof waterproofing system. Figure 135 shows a stepped base flashing for a skylight unit on a pitched roof.

135 Stepped flashing for skylight



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SUSTAINABLE HOUSING INSIGHT

Healthy Indoor Environment

- Proper window location, size and design can lead to improved comfort, reduced heat loss and reduced glare.
- Consider using exterior shading for windows facing south or west to reduce overheating and glare.

Energy Efficiency

- Choose new windows and doors with durable, tight-fitting seals and gaskets to reduce heat loss and water ingress.
- Tight-fitted and weather stripped storm doors can reduce heat loss in winter and heat gain in summer.
- Windows and doors are responsible for much of the heat loss in a house. Choosing higher-performance windows and doors should result in substantial savings in space-heating energy over the life of the building.
- Windows can be customized with low-e coatings to optimize solar gains and reduce losses. Window suppliers can advise on the best choices for the orientation of windows.

RELATED PUBLICATIONS

AAMA/WDMA/CSA 101/I.S.2/A440-11 Standard: NAFS—North American Fenestration Standard/Specification for windows, doors and skylights,
Canadian Standards Association

CSA A440S1-09: Canadian Supplement to AAMA/WDMA/CSA 101/I.S.2/A440, NAFS—North American Fenestration Standard/Specification for windows, doors, and skylights,
Canadian Standards Association

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CHAPTER 16
Exterior Trim and Millwork



Exterior trim and millwork include window and door trim, soffits, rake, gable and fascia trim that are cut and installed on site and other accessories such as louvers and shutters that are usually shop-manufactured.

Trim should be low maintenance, resistant to weathering, workable and dimensionally stable (low tendency to warp, shrink or contract and expand).

Prefinished sheet metal is now widely used because it is impermeable to water and can maintain its finish for many years without having to be repainted. Correct detailing and sealing are a must to prevent water from running behind the metal trim. When wood trim is used, seal the end joints or mitres of lumber exposed to moisture.

Nails or screws used for fastening trim should be corrosion-resistant, aluminum, galvanized or stainless steel. They must be compatible with the metal trim to avoid galvanic reaction between dissimilar metals, such as aluminum and steel. If finishing nails are used, they must be countersunk and then sealed after the prime coat is applied to prevent rust stains at nail heads. When the siding is prefinished, matching pre-painted nails may be used.

EAVE PROJECTION

The eave overhang gives some protection to the wall. Soffits are usually clad with prefinished perforated metal or vinyl panels (Figure 136). These are low maintenance and provide ample area for venting roof spaces without permitting insects to enter the space. A narrow eave projection is sometimes used on roofs with steep slopes. Soffits should not be used to vent rainscreen wall spaces.

Plywood was once commonly used for soffits and still is at times. Apply 6 mm (¼ in.) sanded plywood nailed at 150 mm (6 in.) on centre along the edges and 300 mm (12 in.) at

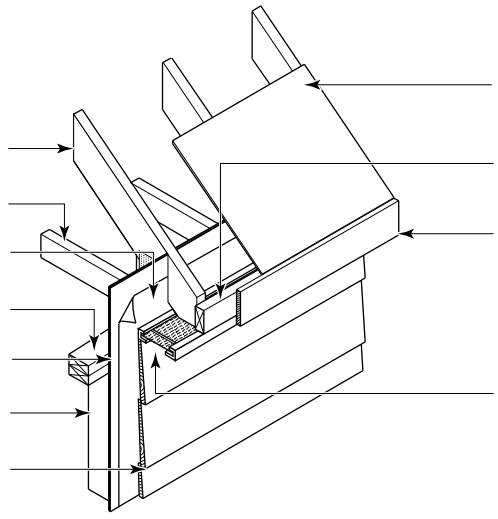
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intermediate supports. Cut openings in the plywood to provide the required ventilation area and install screening. Butt the exterior finish to the underside of the soffit. Add a fascia board to the ends of the trusses or rafters and apply wood or prefinished metal fascia extending about 12 mm (½ in.) below the soffit to form a drip edge.

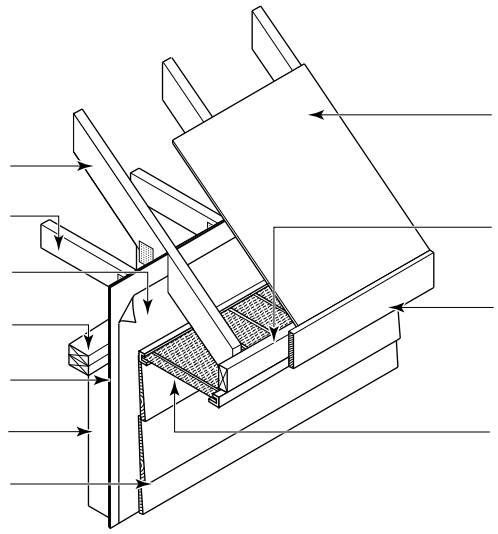
Special trim pieces are made for metal and vinyl soffit materials to provide support at the wall and at the fascia. For plywood soffits, nail a 19 × 19 mm (1 × 1 in. nominal) strip on top of the sheathing along the wall. This strip supports the inner ends of the blocking and edges of the soffit covering.

136 Roof projection at eaves

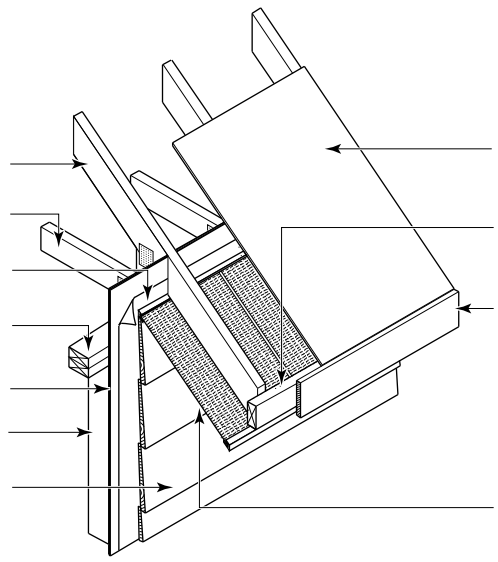
Narrow eave protection



Wide eave projection with horizontal soffit



Wide eave projection with sloped soffit



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Sloped soffits that follow the line of the projected rafter are sometimes used instead of horizontal soffits.

EAVE AND GABLE-END INTERSECTIONS

There are several ways to trim eave/gable-end intersections. The two most common methods of trimming the eaves at the gable end are as follows (Figure 137):

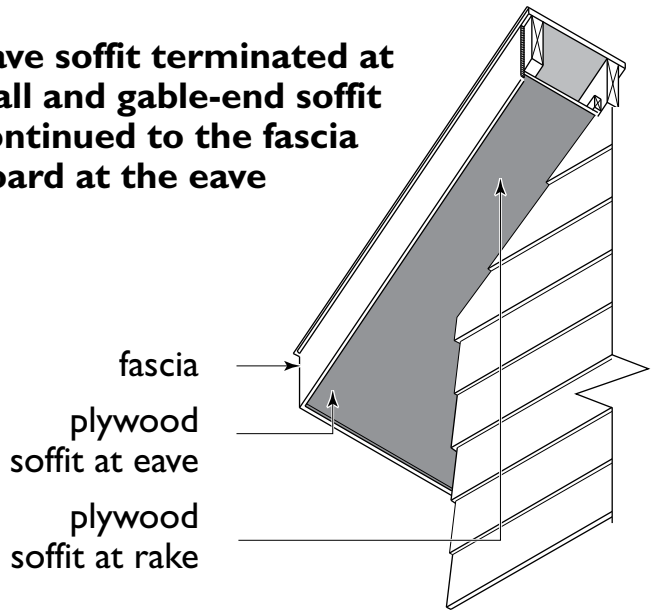
- Slope the gable soffit parallel to the roof, until it meets the lower fascia. In this case, the lower soffit is parallel to the roof slope.
- Interrupt the gable soffit with a "box" at the end of the gable wall. The horizontal soffit under the lower fascia forms the bottom of the box, and the sloped soffit of the gable is parallel to the roof slope.

WINDOW AND DOOR TRIM

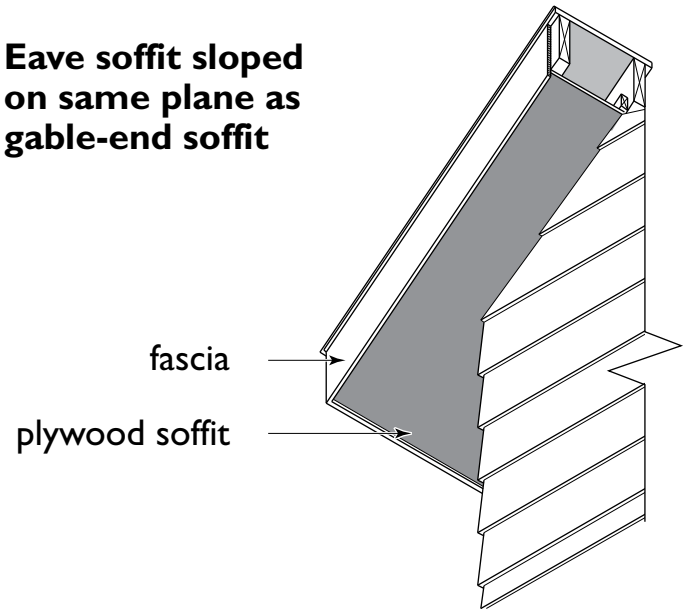
As described in Chapter 15, windows and doors must be installed so that they are sealed to the air barrier and must be flashed and sealed to keep water out (see Figure 130 and Figure 138). Exterior trim is used to conceal gaps around windows and doors and cover the exposed ends of the siding. The trim can be wood or prefinished metal, which is the most commonly used.

137 Eave and gable-end intersections (viewed from below)

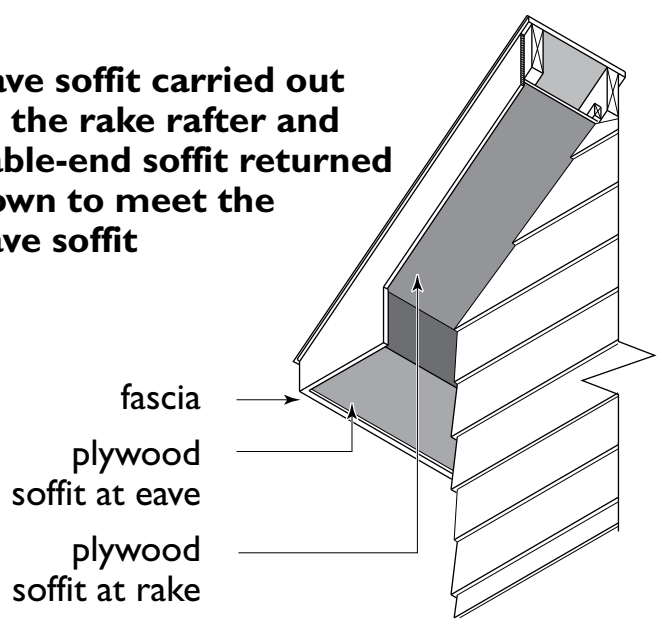
Eave soffit terminated at wall and gable-end soffit continued to the fascia board at the eave



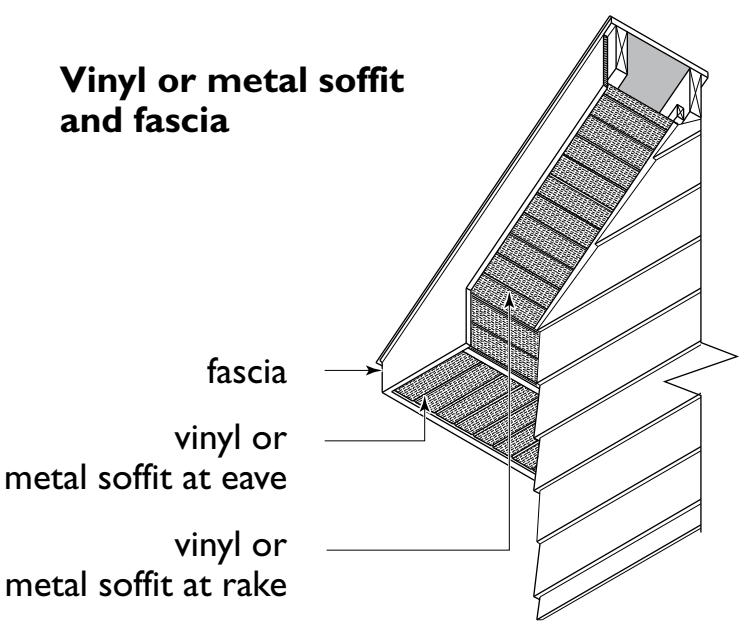
Eave soffit sloped on same plane as gable-end soffit



Eave soffit carried out to the rake rafter and gable-end soffit returned down to meet the eave soffit

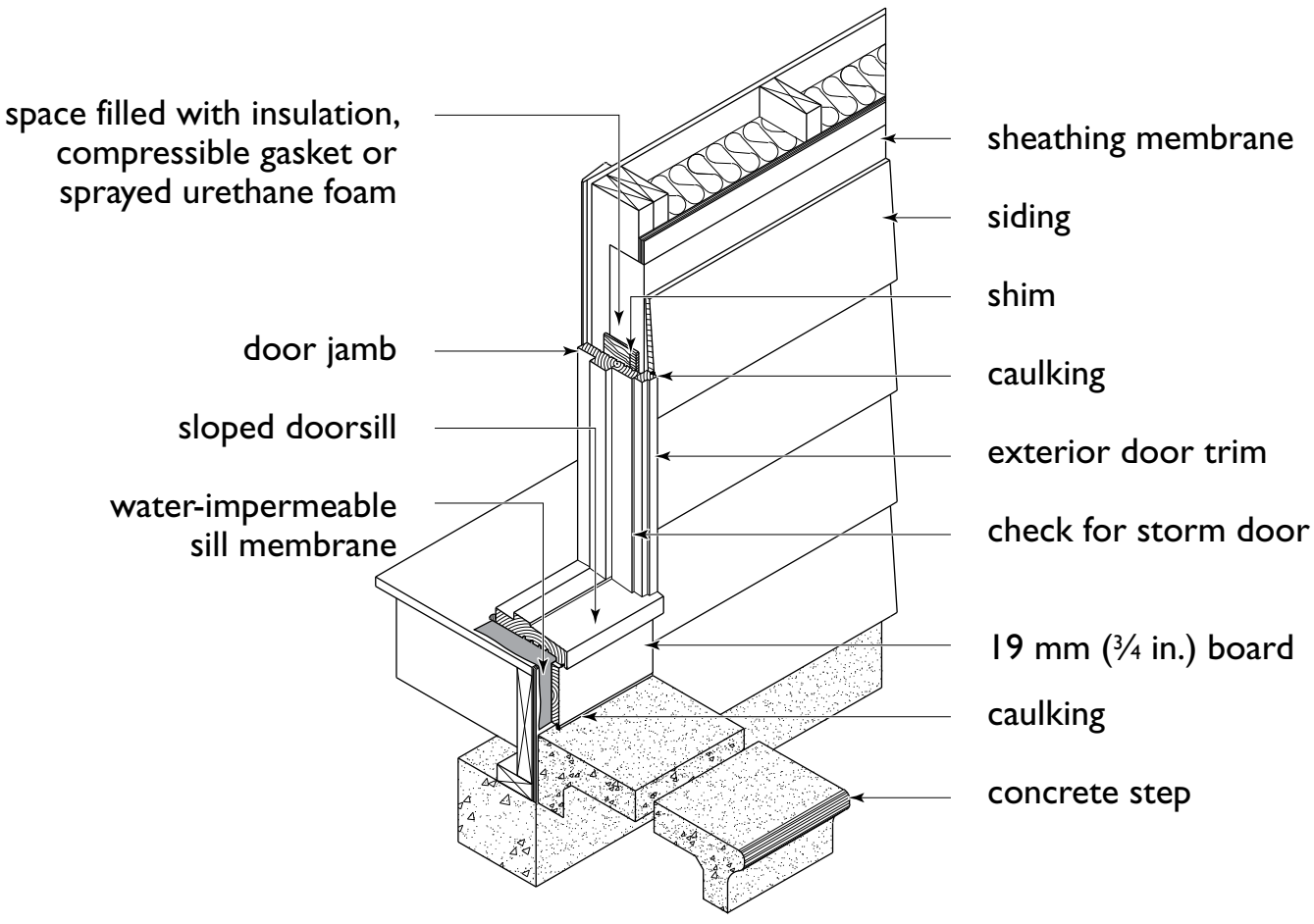


Vinyl or metal soffit and fascia



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138 Section through doorframe at sill



SUSTAINABLE HOUSING INSIGHT

Affordability

- Exterior trim and millwork that needs to be periodically coated with paint, stain or clear finishes is becoming increasingly less popular. Chapter 24 provides more detailed information about the expected service life of coatings. Exterior, site-coated surfaces can be expected to require maintenance at least every three years. Exterior trim and millwork is often difficult to access without ladders or other special equipment, further increasing the cost of maintenance.
- Factory-finished metal and other trim materials are recommended because their appearance can be maintained for a long period of time by cleaning rather than recoating.

Resource Conservation

- Exterior trim and millwork that uses finger-jointed wood, or medium/high density fibre, board conserves forest products.

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CHAPTER 17
Stairs



Stairs provide access between floors, and their configuration, clearances and tread design must meet or exceed NBC requirements to ensure safety during regular use and safe and efficient exiting in the event of fire. Common terms for stairs (Figures 139 to 145) are as follows:

STAIR RISE AND RUN

For safety and ease of use, stairs must comply with specific requirements. The rise and the run must be uniform for all treads in a flight of stairs. For stairs in houses, the minimum run for rectangular stairs is 210 mm (8¼ in.), and the maximum is 355 mm (14 in.). The minimum rise is 125 mm (5 in.), and the maximum is 200 mm (8 in.). The minimum tread depth is 235 mm (9¼ in.), and the maximum is 355 mm (13$^{15}/_{16}$ in.).

STAIRWAY DESIGN

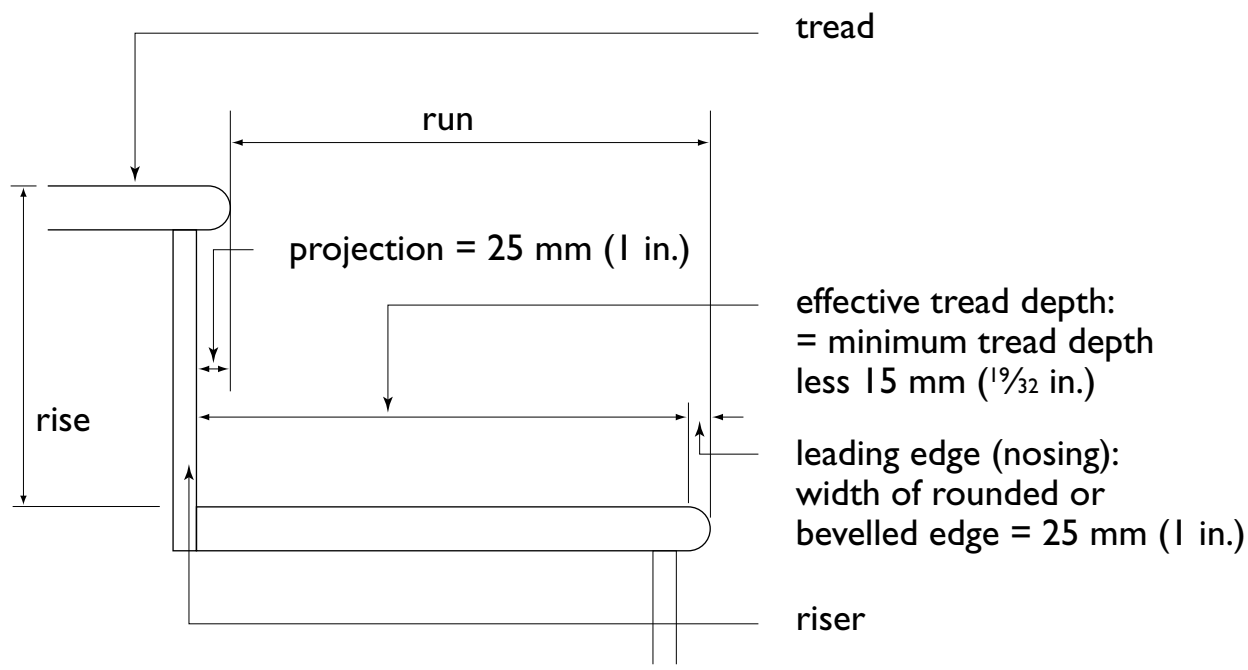
Stairs may be site built but are most often factory manufactured. Stairways in houses can have a straight, continuous run without an intermediate landing, or consist of two or more runs with changes in direction, or may be curved, in which case special design criteria apply. The minimum allowable stairway headroom is 1.95 m (6 ft. 5 in.) (see Figure 141).

The width of any landing must not be less than the width of the stairs. Stairs in houses and houses with a secondary suite must be at least 860 mm (34 in.) wide measured between wall faces.

The length of a landing in a house cannot be less than 860 mm (33⅞ in.). The vertical height of any flight of stairs cannot exceed 3.7 m (12 ft.). Each step in a flight of stairs should have the same height.

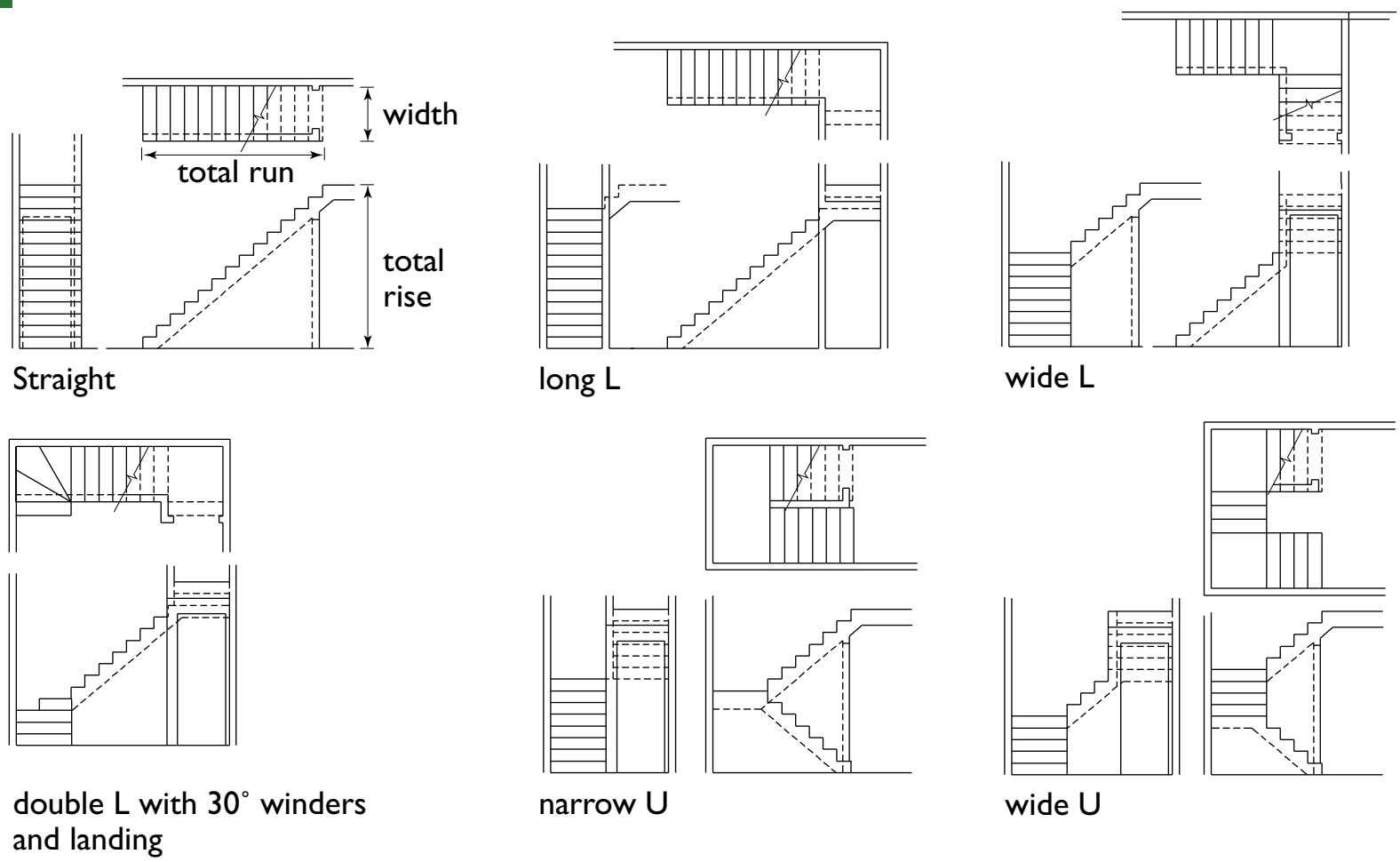
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139 Stair detail



A change in direction can be made with landings or winders. Figure 140 shows different types of stairway designs. If winders are used, they must form an angle of either 30°, (three treads for a maximum allowable 90° turn), or 45° (two treads for a maximum allowable 90° turn). Only one set of such winders is permitted between floor levels. Experience has shown that 30° winders are easier to negotiate than 45° winders.

140 Types of stair layouts



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Once the location and width of a stairway and any required landings have been determined, the next step is to figure out the rise and the run. To establish the rise, measure the exact distance between the finished floors of the two storeys under consideration and divide by 184 mm (7¼ in.), a comfortable riser height.

This calculation gives the number of risers needed over the total rise. Round up the number that results from this calculation to the next whole number. The run is determined by dividing the required number of treads into the total run of the stairs.

For example, if the total rise is 2 718 mm (107 in.) and if each riser is 184 mm (7¼ in.), then 14.8 risers are needed (that is, 2,718/184 = 14.8). Rounding up, 15 risers will be required with each one having a rise of 181 mm (7.13 in.) (that is, 2,718/15 = 181.2). Alternatively 14 risers at 192 mm (7.64 in.) rise would be appropriate when space is limited.

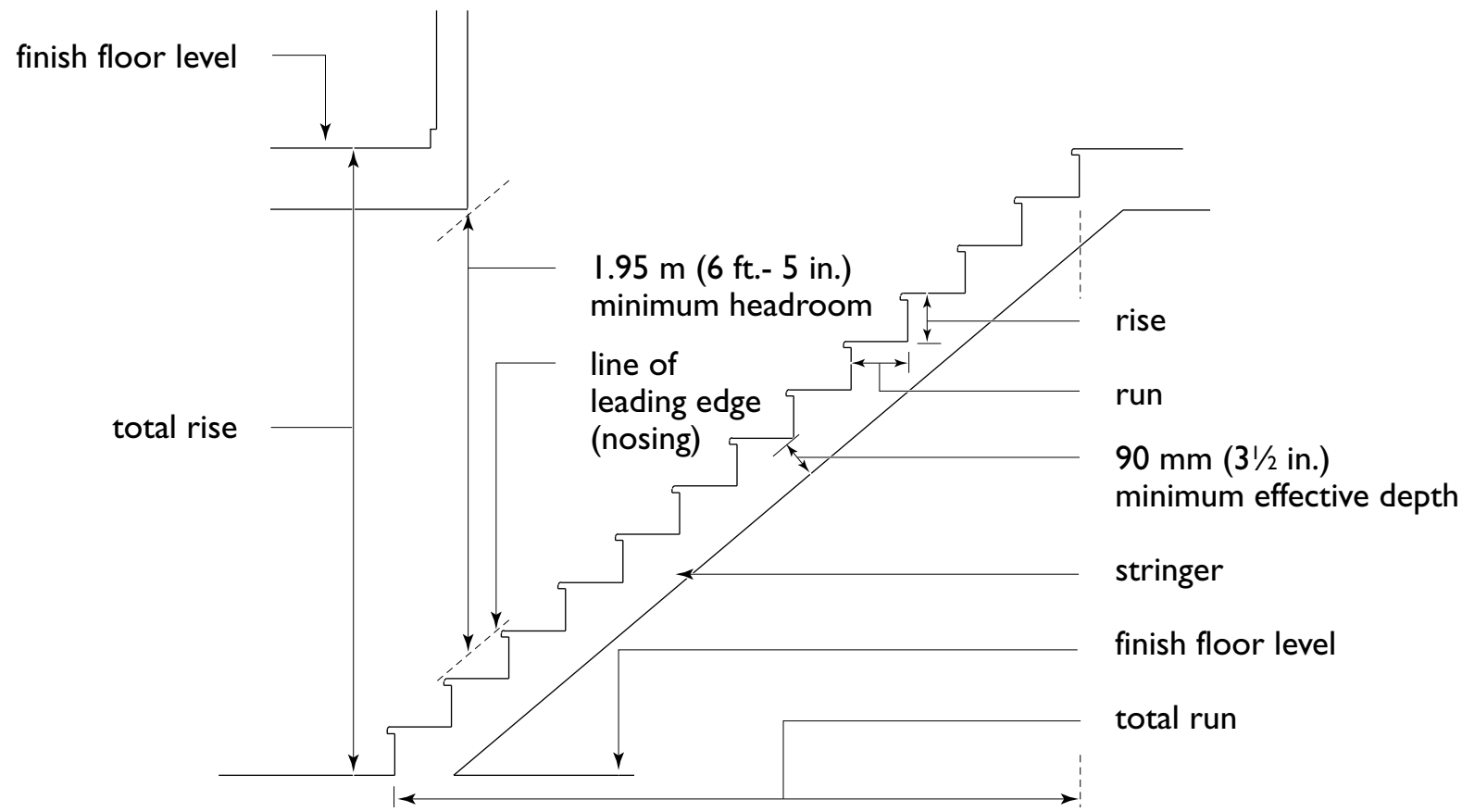
A sloped or bevelled edge on leading edges (nosings) makes treads more visible. The size and shape of the slope or bevel is limited by the building code to safeguard against tripping or slipping (see Figure 139).

Stringers

Treads and risers are supported on stringers that must be solidly supported, firmly fixed and properly positioned. The stringers may be either cut (see Figures 142 and 143) or ploughed to fit the outline of the treads and risers.

Wood stringers must not be less than 25 mm (1 in.) thick when they are supported along their length or 38 mm (1½ in.) when supported only at the top and bottom. The overall depth must be at least 235 mm (9¼ in.), and when the stringer is cut out to fit the treads and risers, the portion remaining (the "effective depth") must not be less than 90 mm (3½ in.) deep.

141 Stairway design



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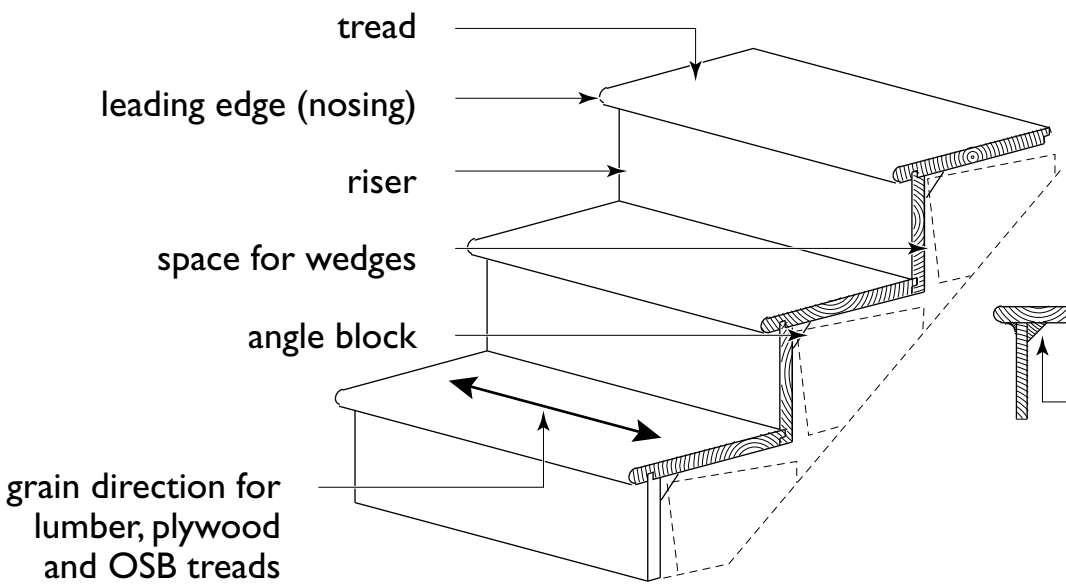
A third stringer is required when the width of the stairs is more than 900 mm (35 in.). The width may be increased to 1200 mm (48 in.) where risers support the front of the treads.

Treads must be at least 38 mm (1½ in.) thick when used with open risers. This thickness can be reduced to 25 mm (1 in.) where the stringers are not more than 750 mm (29 in.) apart or where the tread is supported by a closed riser attached to the treads.

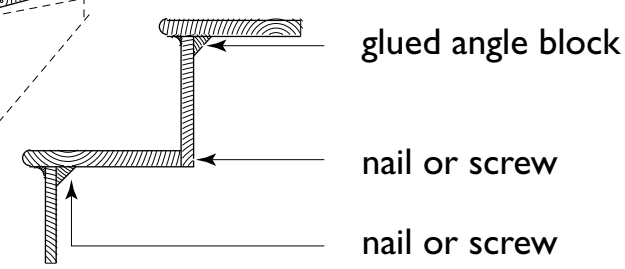
The wall stringer may be ploughed out to the profile of the tread and riser with sufficient space at the back for wedges (see Figure 142). The treads and risers are fitted into the space ploughed into the wall stringer and wedged and glued in place. The wall stringer extends above the line of the leading edges and serves as trim that can mate with baseboards at the top and bottom of the stairs.

142 Stair components

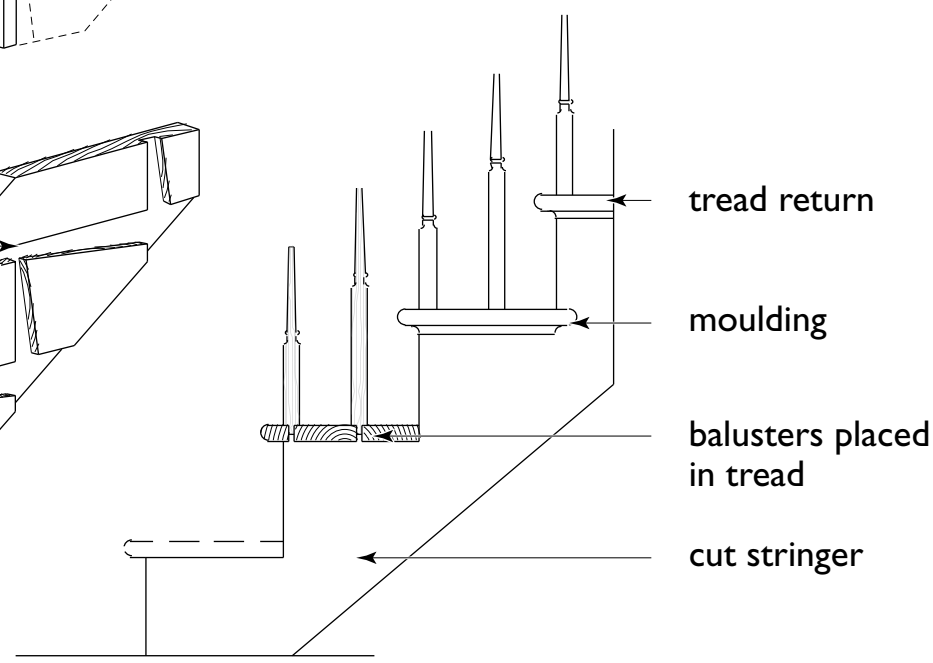
Risers and treads tongue and grooved together



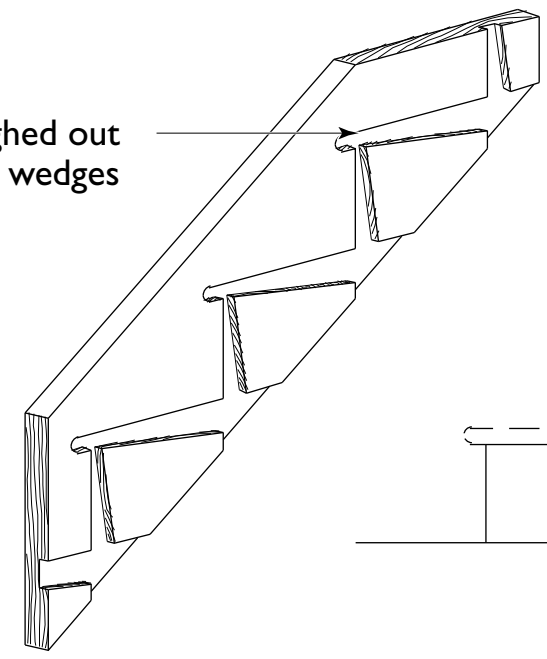
Risers and treads connected with angle blocks



Cut-out (open) stringer



Housed stringer



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The top of the riser may be connected to the bottom of the tread by angle-blocks glued to the concealed (back) side of both surfaces with screws added to reinforce the joint. The bottom of the riser is attached to the back of the tread with screws (see Figure 142) or the top of the riser is tongued into the front of the tread and the back of the tread is tongued into the bottom of the next riser (see Figure 142). The wall stringer is screwed behind the treads and risers to the wall.

If the outside stringer is an open stringer, it may be cut out to fit the risers and treads. The edges of the risers are mitred with the corresponding edges of the stringer, and the leading edge of the tread may be returned on its outside edge along the face of the stringer (see Figure 142).

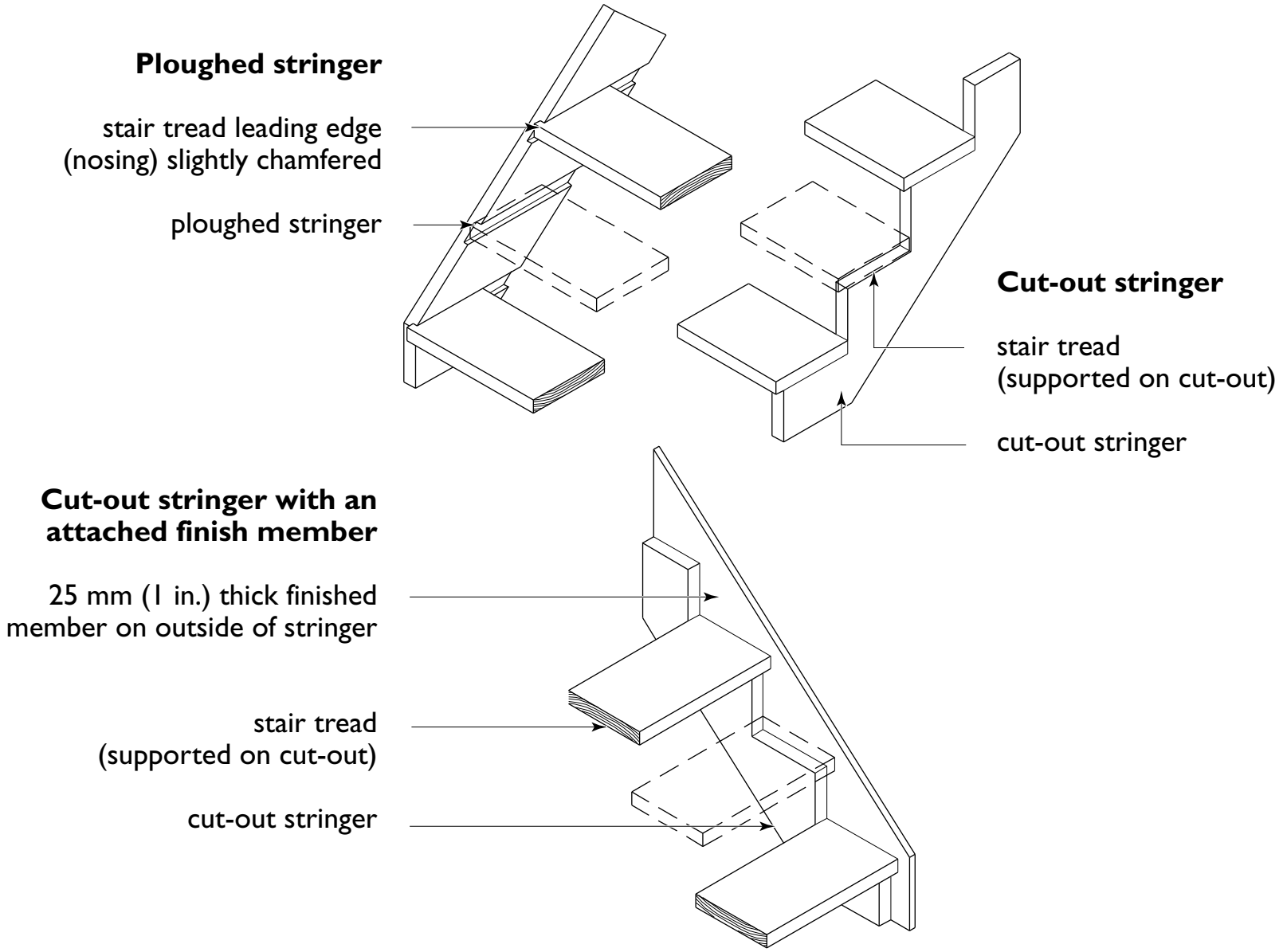
Basement Stairs

Closed risers are safer but open risers may be used for basement stairs (see Figure 143).

Exterior Stairs

Exterior stairs can be wood or concrete. Concrete stairs with more than two risers must be supported on piers or cantilevered from the foundation wall. The dimensions of risers and treads for exterior stairs are the same as for interior stairs.

143 Basement stairs



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Concrete for exterior stairs must have a compressive strength of at least 32 MPa (4600 psi) and air entrainment of 5 to 8 per cent. Portions of wood stairs in contact with the ground must be treated with a wood preservative.

Handrails and Guards

Handrails run parallel to stairs to provide support for stair users. All stairways with three or more risers in houses must have a handrail from floor to floor, and on both sides if the stair is 1100 mm (43 in.) or wider.

For stairways with enclosing walls, attach the rail brackets to the wall with at least two screws penetrating at least 32 mm (1¼ in.) into solid framing members. Space the supports no more than 1.2 m (4 ft.) apart, with the first and last supports no more than 300 mm (12 in.) from the ends of the handrail.

For stairs that are open on one or both sides, handrails are usually supported by balusters and end at newel posts. Handrails should be between 800 and 965 mm (32 and 38 in.) above the tread at the leading edge line, with at least 50 mm (2 in.) clearance from the wall, and be built so that there is no obstruction that could break a handhold. The start and end point of handrails must not obstruct pedestrian traffic or create a hazard.

Guards surround openings to protect against falling and are required around openings at landings, decks and balconies that are more than 600 mm (24 in.) above the adjacent level, and alongside the open portions of stairways.

Guards for stairs in houses and houses with a secondary suite must be not less than 900 mm (36 in.) high measured vertically from the leading edge.

Guards for exterior balconies or landings, porches or decks that are more than 600 mm (24 in.) but less than 1800 mm (71 in) above the ground must be at least 900 mm (36 in.) high. For decks and landings higher than 1800 mm (71 in.), guards must be at least 1070 mm (42 in.) high.

Young children can use horizontal features in a guard as a ladder, resulting in climbing and possible falling. Spacing between balusters for all guards must not permit a 100 mm (4 in.) sphere from passing through. Some ornamental features are permitted between guards but must meet limitations in their form so that they do not facilitate climbing.

Guards must be strong enough to provide protection from falls during normal usage. The specific loads that guards need to resist to meet this requirement should be verified at the permit approval stage.

Ramps

When a ramp is required for wheelchair access (a barrier-free path of travel) to a house or a house with a secondary suite, certain conditions must be met so that it is safe and easy to use. A level area must be provided at the top and the bottom of the ramp and intermediate level areas are required every 9 m (29 ft.)or where there is a change in direction. The clear width must be at least 870 mm (34¼ in.) and the slope must not be greater than 1:12. Consult the local building department for additional information.

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SUSTAINABLE HOUSING INSIGHT

Energy Efficiency

- Ensure that the air barrier system is continuous and uninterrupted where stairs occur on exterior walls. To avoid interruptions, install the air barrier before the stair is put in place.

RELATED PUBLICATIONS

About Your House: Accessible Housing by Design—Ramps,
Canada Mortgage and Housing Corporation (product no. 65023)

About Your House: Preventing Falls on Stairs,
Canada Mortgage and Housing Corporation (product no. 63637)

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CHAPTER 18
Chimneys, Flues and Fireplaces



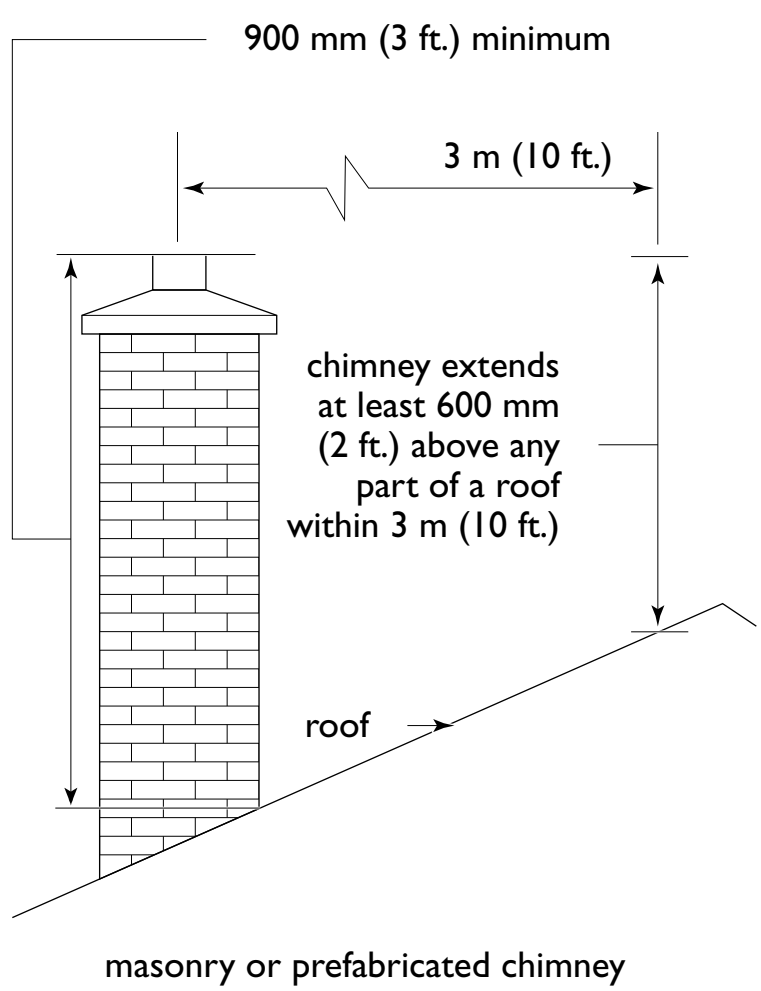
CHIMNEYS AND FLUES

A chimney is a structure containing a flue or flues, which route any smoke and gases produced by a fire or furnace to the outside. A flue is a sealed pipe or channel that may be contained within a chimney or a self-contained unit independent of the chimney.

Chimneys and flues must be capable of producing sufficient draft to maintain the fire and remove the products of combustion. Chimneys, flues and fireplaces must be carefully built to minimize fire hazards. Ideally, they should not be located on outside walls. Locating them within the house keeps the chimney, flue and fireplace warmer, giving a better draft and reducing condensation inside them.

Chimneys and flues must extend at least 900 mm (36 in.) above the highest point where the roof meets a chimney and must be at least 600 mm (24 in.) higher than any roof surface within 3 m (10 ft.) of the chimney (Figure 144).

144 Chimney height above the ridge



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Chimneys may be used to vent oil- and gas-burning equipment, provided the flue lining complies with oil and gas appliance installation codes. Alternatively, the equipment may be vented through special gas vents approved for this purpose.

A flue that serves a fireplace or wood stove cannot also serve as a flue for a gas- or propane-fired furnace.

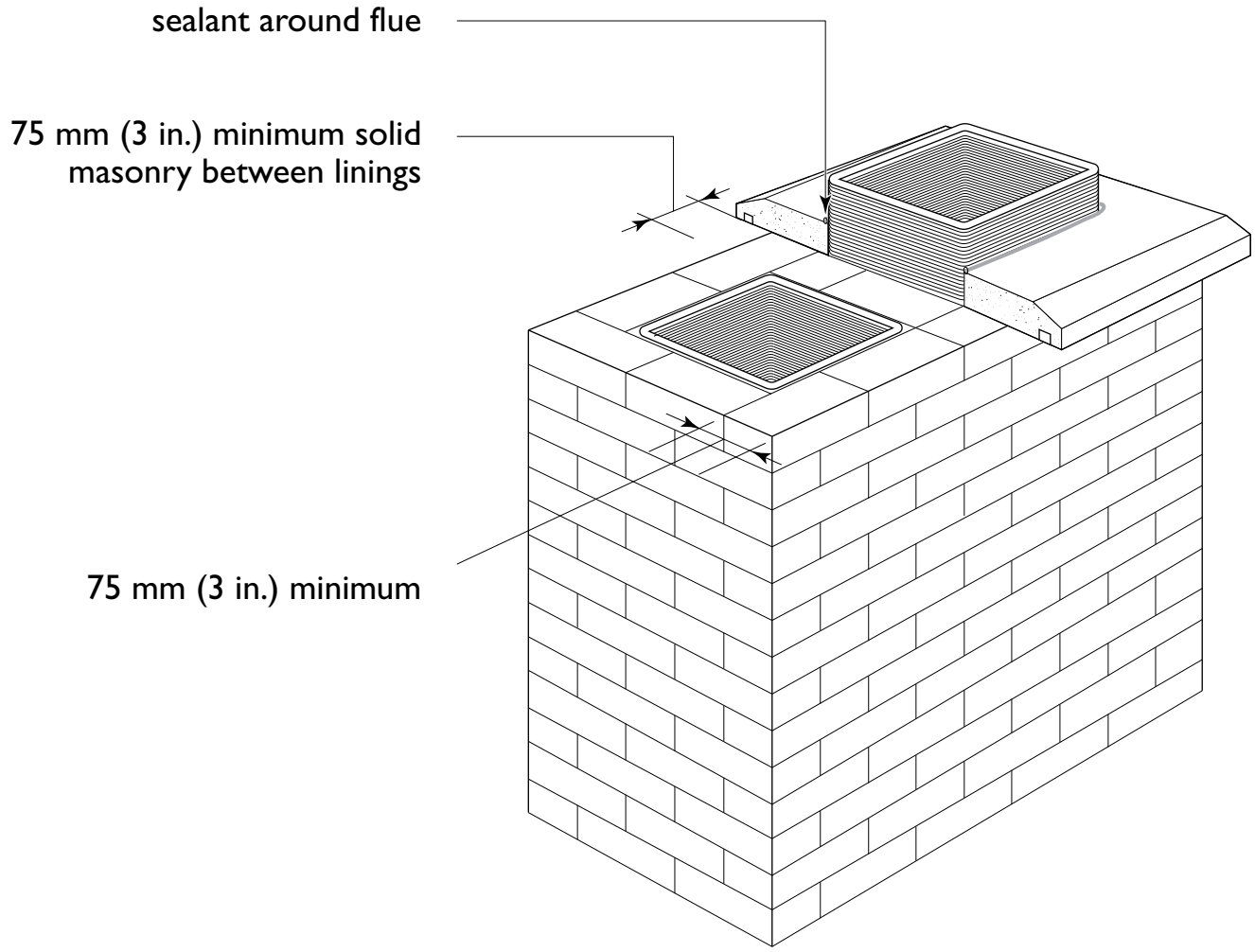
A furnace and hot water tank or a fireplace and wood stove can be connected to the same flue but there are limitations that should be checked with the local building department. A flue should be as vertical as possible and cannot be sloped at an angle of more than 45° from the vertical.

There are two types of chimneys and flues commonly used in residential construction: masonry chimneys and factory-built flues.

Masonry Chimneys

A masonry chimney consists of a liner and an outer wall (Figure 145). Masonry chimneys must be built on a concrete footing designed to support the load. The size of the chimney depends on the number, size and arrangement of flues. The outer wall of a masonry chimney must not be less than 75 mm (3 in.) and must consist of solid masonry units. The NBC provides minimum sizes for round and rectangular flues for fireplace chimneys.

145 Installation of flue linings



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The size of the flue required depends on the size of the fireplace opening and the chimney height. The rule of thumb is for the area of the flue opening to be at least one-tenth of the area of the fireplace opening but not less than 200 × 200 mm (8 × 8 in.).

There must be at least 12 mm (½ in.) clearance between chimneys and wood framing for chimneys on exterior walls and 50 mm (2 in.) for interior walls.

The liner must start not less than 200 mm (8 in.) below the lowest flue pipe connection and must extend between 50 and 100 mm (2 and 4 in.) above the chimney cap. It can be clay, concrete, firebrick or metal that meet established standards. Rectangular glazed clay sections 600 mm (24 in.) long are most often used. The liner is installed as the concrete or masonry outer wall is erected. A space of at least 10 mm (7⁄16 in.) that is not filled with mortar is required between the liner and the surrounding masonry. The mortar used for the liner must be suitable for high temperatures.

If there are two or more flues in a chimney, they should be separated from one another by at least 75 mm (3 in.) of solid masonry or concrete, or 90 mm (3½ in.) of fire brick where fire-brick liners are used (see Figure 145).

The top of masonry chimneys should be capped to keep water away from masonry joints. The top of the cap should be sloped away from the flue lining and extend beyond the chimney wall at least 25 mm (1 in.) to form a drip edge. A drip notch should be provided around the underside of the cap.

Factory-Built Flues

Factory-built flues do not require a foundation (see Figure 147). The flue sections are comprised of inner and outer stainless steel liners separated by insulation. Provide clearance between the outer wall of the flue and the framing and provide lateral support with clips attached to the framing. Use only factory-built flues that have been tested and approved for use in Canada.

FIREPLACES

Fireplaces can consist of solid masonry construction, be factory-built, have steel inserts for masonry or wood frame construction, or be factory-built natural gas appliances. Special wood pellet burning appliances are available as well.

All fireplaces must be designed properly to provide heat, safely remove combustion by-products and not pose a fire hazard. Fireplaces should have an external air supply so that warm, room air is not used for combustion. A fireplace that is a solid-fuel-burning appliance requires that CO alarms be installed in living spaces, especially near bedrooms.

Masonry Fireplaces

A conventional masonry fireplace has very low heating efficiency because it draws large amounts of room air up the flue that must be replaced by air leakage through the building envelope elsewhere in the house. This results in a warm room where the fireplace is located but a cold house elsewhere due to increased air leakage. Masonry fireplaces located on an exterior wall can be a significant source of

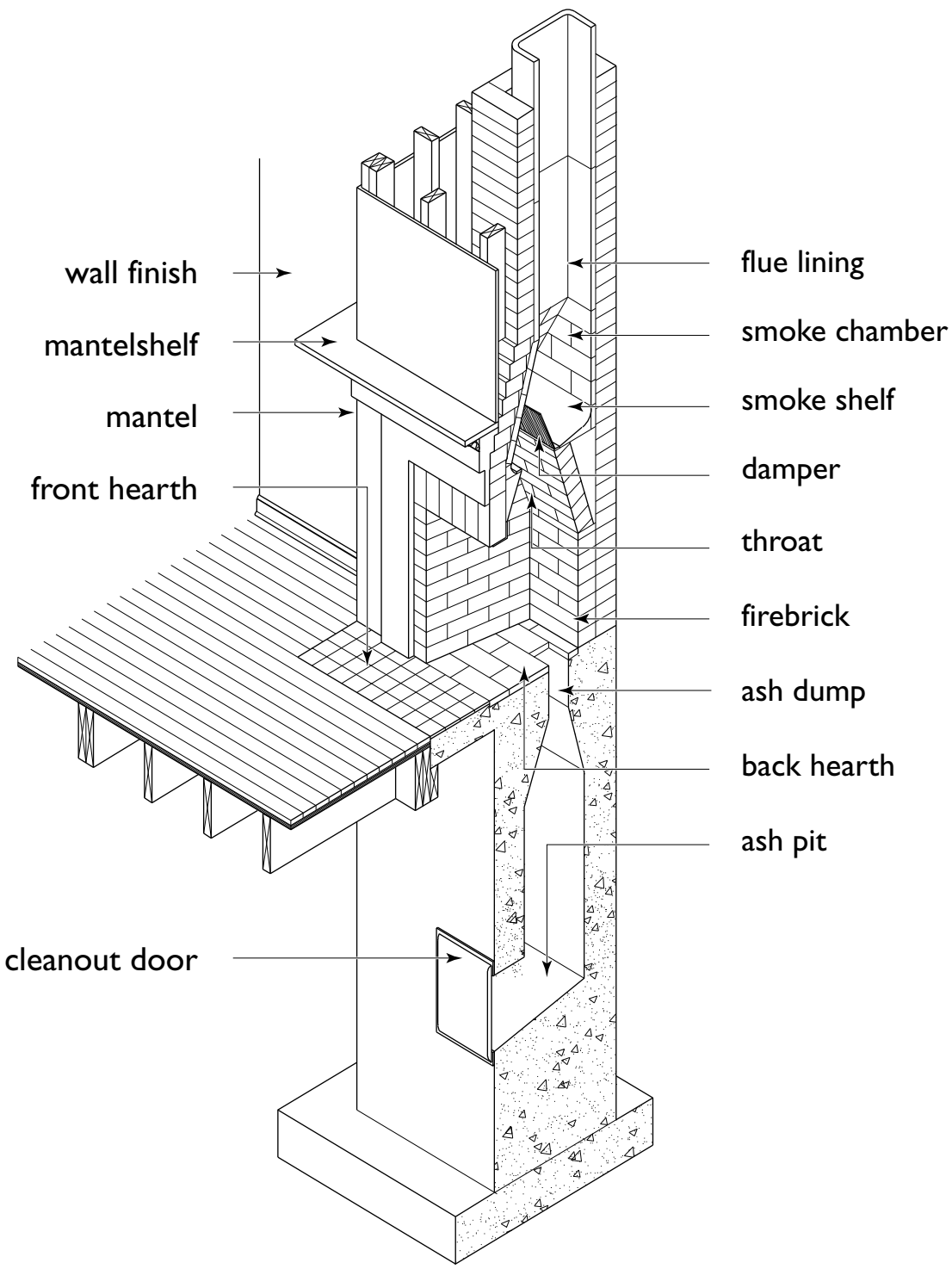
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conductive heat loss and air leakage through walls. The components of a masonry fireplace are shown in Figure 146.

It is convenient but not essential to have an ash dump through which ashes can be dropped into an ash pit with a cleanout door in the basement for periodic removal of ashes. Other design guidelines are:

- The distance from the back of the fire chamber to the face of the fireplace cannot be less than 300 mm (12 in.);
- The front of the fire chamber should be wider than the back;
- The upper part of the back should tilt toward the face of the fireplace for better burning performance;
- The back, which should rise one half the height of the opening before sloping forward, should be about two thirds of the opening in width;

146 Fireplace terms



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- Provide a smoke shelf to reduce backdrafts by projecting the throat toward the face of the fireplace.
- The throat should be as wide and as shallow as possible, but its area cannot be less than the area of the flue. The sides of the fireplace above the throat are drawn together to abut the flue over the centre of the width of the fireplace;
- The slope of the sides of the smoke chamber must not be more than 45° from the vertical: and
- Provide an adjustable damper to regulate the draft. It should be fully closable to minimize heat loss up the chimney when the fireplace is not in use.

The lining of the fire chamber must be firebrick at least 50 mm (2 in.) thick and high temperature cement mortar or steel.

If a firebrick liner is used, the back and sides of the fireplace must be at least 190 mm (8 in.) thick including the thickness of the masonry liner. For a steel fireplace liner with an air circulating chamber surrounding the fire chamber, the back and sides may be solid masonry units at least 90 mm (3½ in.) thick or hollow units at least 190 mm (8 in.).

The hearth may be even with or above the floor and consists of two parts: the front or finish hearth and the back hearth under the fire. The back hearth is built of firebrick as it must withstand more heat. The front hearth guards against flying sparks and is made of reinforced concrete at least 100 mm (4 in.) thick that is often finished with ceramic tile. The front hearth must extend at least 400 mm (16 in.) in front of the fireplace opening and at least 200 mm (8 in.) on each side.

Provide a clearance of at least 100 mm (4 in.) between a fireplace and interior wood framing and at least 50 mm (2 in.) for wood framing at an exterior wall.

Factory Built Fireplace Inserts

Factory-made fireplace inserts are available that reduce the amount of room air used by the fireplace and achieve better heating performance. To be most effective, the unit should have draft-tight doors and a separate combustion air supply from the outside. Airtight wood stoves are also more efficient than open fireplaces. A fireplace insert can be added to a masonry fireplace to improve safety and efficiency or can be installed with a framed surround, if the required clearances are present. Inserts often have blowers that significantly improve heating efficiency and circulation. A steel flue liner is installed inside an existing flue to remove combustion gases (Figure 146). Special installation procedures must be followed. Review installation and fire safety requirements with the local building department. Many if not most jurisdictions require that solid fuel burning fireplaces be installed by qualified contractors.

Natural Gas Fireplaces

Natural gas fireplaces have become a more popular fireplace option in areas served by natural gas. Aside from being more affordable, relatively efficient and lightweight, they can be directly vented through the wall behind the unit (or up a chimney), can be sealed combustion (meaning the combustion process never comes in contact with house air), and can effectively heat the room where they have been installed without cooling off the rest of the house.

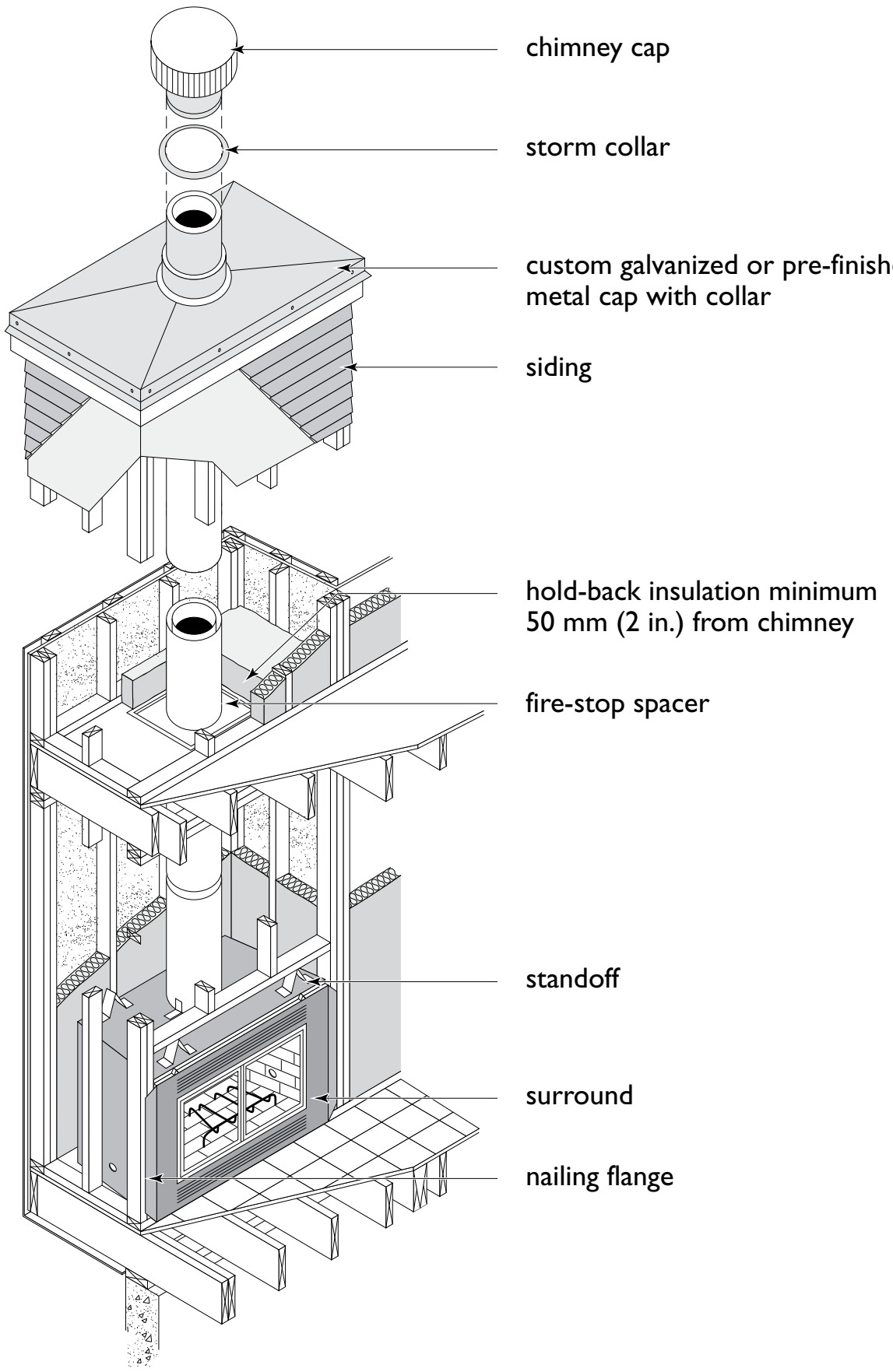
A gas-burning, factory-built fireplace (natural gas or propane) may be installed in an existing masonry fireplace or in new

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construction (Figure 147) without masonry. Units usually come with fans that increase heating performance. Where floor space is limited, natural gas fireplaces can be installed in small cantilevered projections secured to the side of the house and covered by a small shed roof.

Ensure the fireplace is approved for use in Canada. Install it according to the building code, the manufacturer's requirements and natural gas or propane installation codes.

147 Factory-built fireplace



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SUSTAINABLE HOUSING INSIGHT

Wood-burning appliances can provide effective and affordable home heating with a renewable energy resource. It is important to select appropriate appliances, fittings and accessories that function safely, cleanly and efficiently.

Healthy Indoor Environment

- Only use chimneys or flues that have been certified for use with the appliance. Follow the manufacturer's installation instructions and have the completed installation inspected by the local building inspector prior to closing it in.
- Wood burning results in the generation of gases that are harmful to health. Backdrafting is prevented by not using spillage-susceptible, fuel-fired appliances (those that do not have sealed combustion) or by providing active make-up air to balance exhaust air flows.
- Burning wood releases particulates to the outdoor environment, which may be a health concern to people in the vicinity.
- Burn dry wood to avoid creosote build-up that can cause chimney fires.
- Store firewood outside to prevent moisture release inside the house.

Energy Efficiency

- Locate the appliance in an area of the house where its immediate heating output is needed. Rooms where occupants spend a great deal of time, such as family rooms or living rooms, will benefit most from a wood stove or fireplace. Appliances with glass doors provide a view of the fire and improve heating efficiency.
- Distribute the heat to other parts of the home using a forced-air heating system or a ventilation system with a recirculating mode of operation.
- Use high-efficiency condensing-type space- and water-heating appliances, which may be side-wall vented or vented through the roof. High-efficiency heating equipment does not lose as much heat up the flue as lower efficiency equipment.

Resource Efficiency

- For wood-burning fireplaces, use wood from sustainably operated wood lots.
- Wood pellets are a fuel source made from waste wood and are a good environmental choice. Some pellet stoves have feed systems that control the feed rate and heat.

Environmental Responsibility

- When selecting a wood-burning appliance, make sure that the one you have selected has an Underwriters' Laboratory certification and is EPA- or CSA-B415.1-certified to ensure it is clean-burning, safe and efficient.

Affordability

- For people willing to do the extra work involved in storing and moving wood fuel, wood heating can be economical compared with other heating fuels. A backup system is recommended to maintain minimum temperatures for times when the house is not occupied.

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CHAPTER 19
Plumbing, Electrical and Appliances



The space between the framing members in wood-frame walls, floors and roofs provides convenient space for locating heating, plumbing and electrical services.

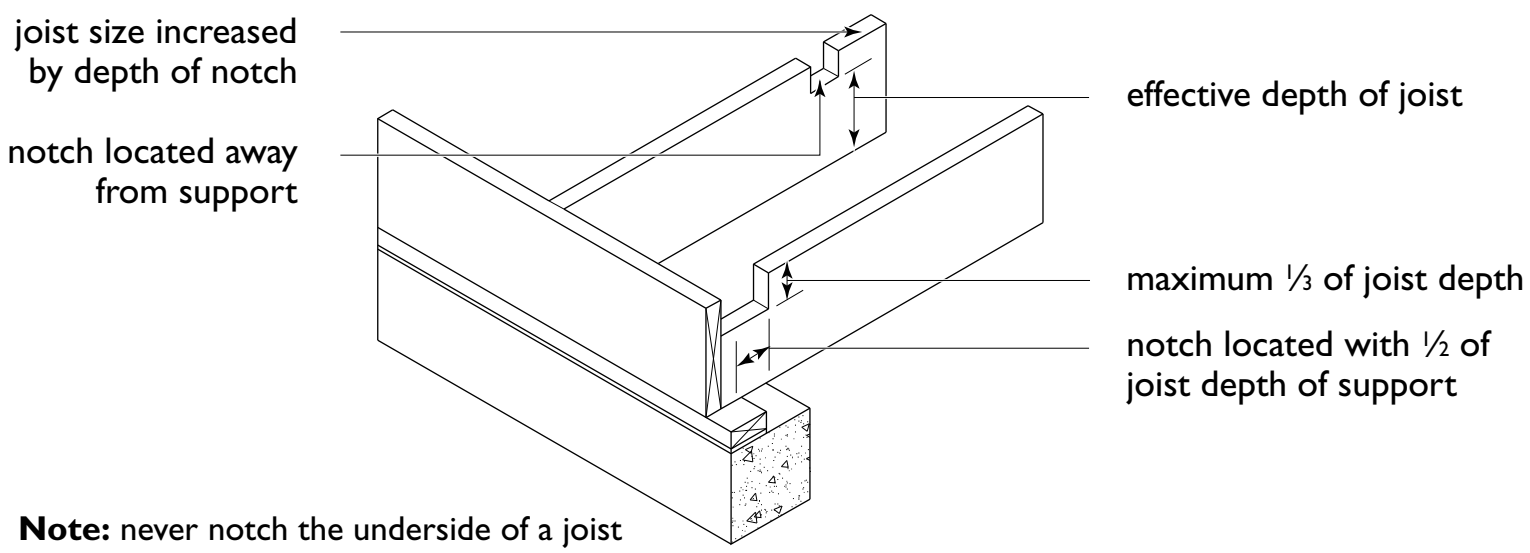
Where pipes or wires must be run at right angles to the framing, wood members may be notched or drilled *within strict limitations* without adversely affecting the structural strength of an assembly.

CUTTING FRAMING MEMBERS

Notching of Lumber Roof, Ceiling or Floor Joists

Notches made on the upper side of lumber joists near their ends (Figure 148) must be located within one-half the joist depth from the edge of the bearing and their depth cannot be more than one-third of the joist depth. Notches are

148 Example of notch limitations



Note: never notch the underside of a joist

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not permitted on the bottom of joists. If notches are necessary elsewhere in the top of a joist, deeper joists must be used so that the net depth at the notch is equal to or greater than the joist depth required for the span and load conditions. The flanges of wood I-joists and truss chords and web members must not be notched or cut.

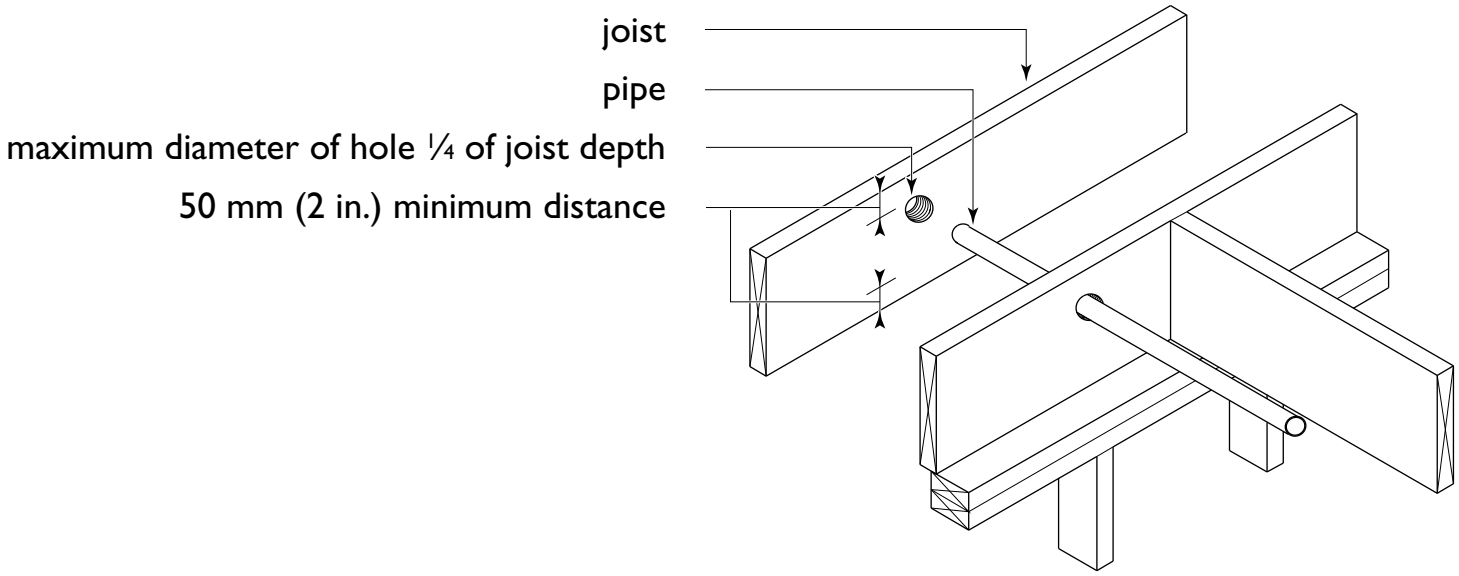
Drilled Holes in Joists

Holes drilled in joists must not be larger than one-quarter the joist depth or closer than 50 mm (2 in.) to either edge (Figure 149). Holes in engineered wood products must conform to the product manufacturers' guidelines for size and location.

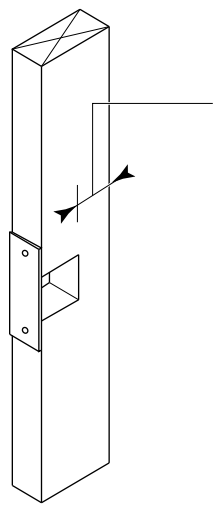
Notching and Drilling of Studs

Load-bearing wall studs that have been notched or drilled to more than one-third of their depth must be reinforced (Figure 150), usually with 38 mm (2 in. nominal) lumber nailed to the side of the studs and extending

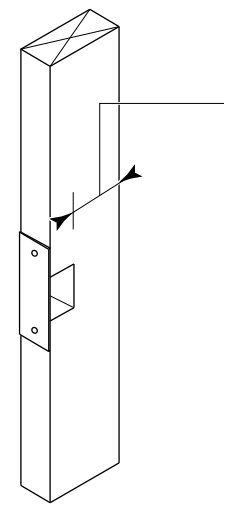
149 Maximum size of holes drilled in joists



150 Notching studs for plumbing



In partitions, notched studs need not be reinforced if remaining portion is at least 40 mm (1⁹⁄₁₆ in.).



In load-bearing walls, notched studs need not be reinforced if remaining portion is at least ⅔ the depth of the studs.

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at least 600 mm (24 in.) on each side of the notch or hole. Also use reinforcing when notched partition studs have less than 40 mm (1 9/16 in.) of solid wood remaining.

Notching and Drilling of Top Plates

In load-bearing walls, top plates must be reinforced with 38 mm (2 in. nominal) lumber when the solid wood remaining in the plates is less than 50 mm (2 in.) in width. If required reinforcing must be placed on the face of the plate or stud, sheet metal may be used to support the wall finish and to protect the plumbing and electrical wiring from gypsum board fasteners.

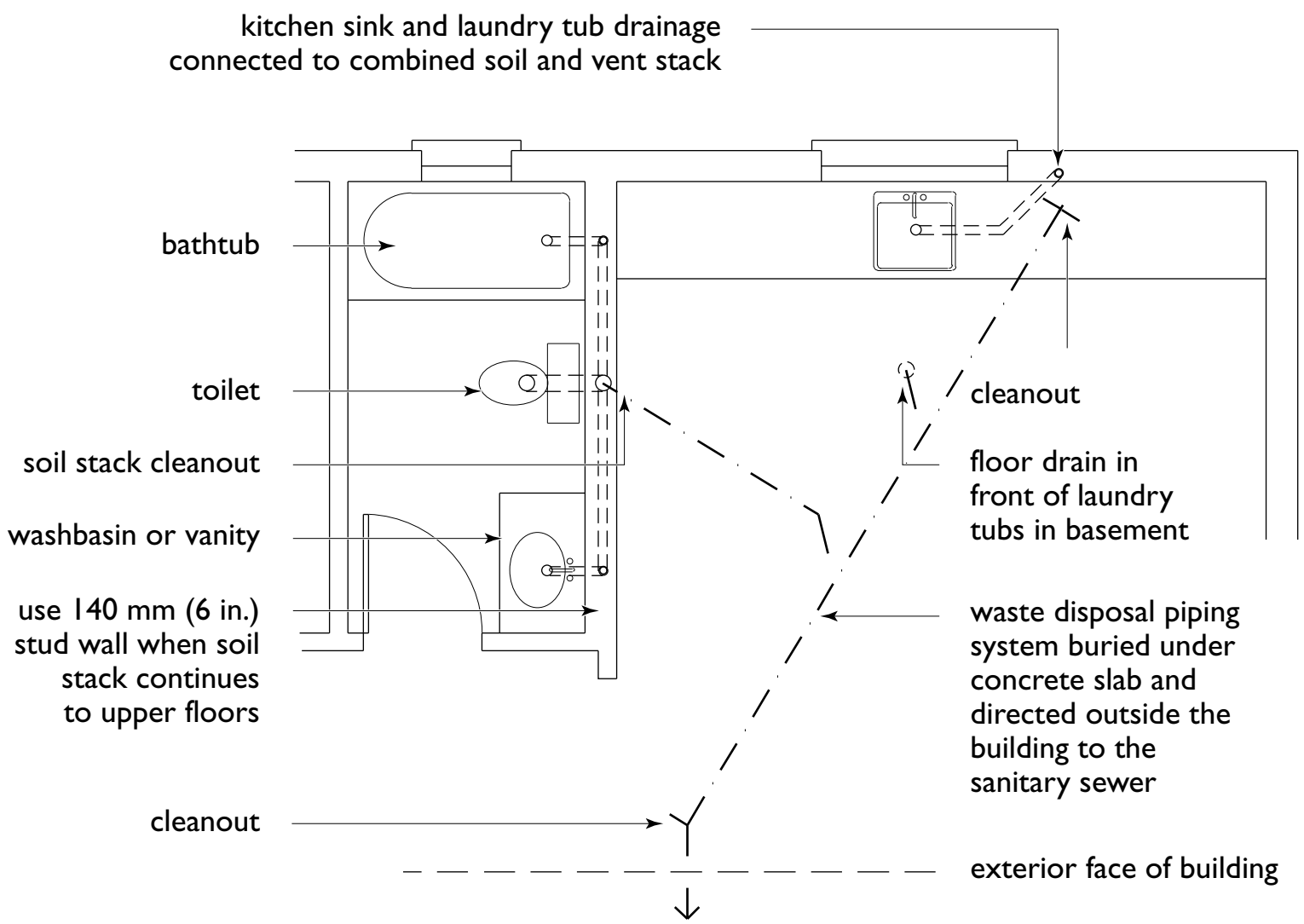
Roof Trusses

Roof trusses cannot be notched or drilled.

FRAMING FOR PLUMBING SYSTEMS

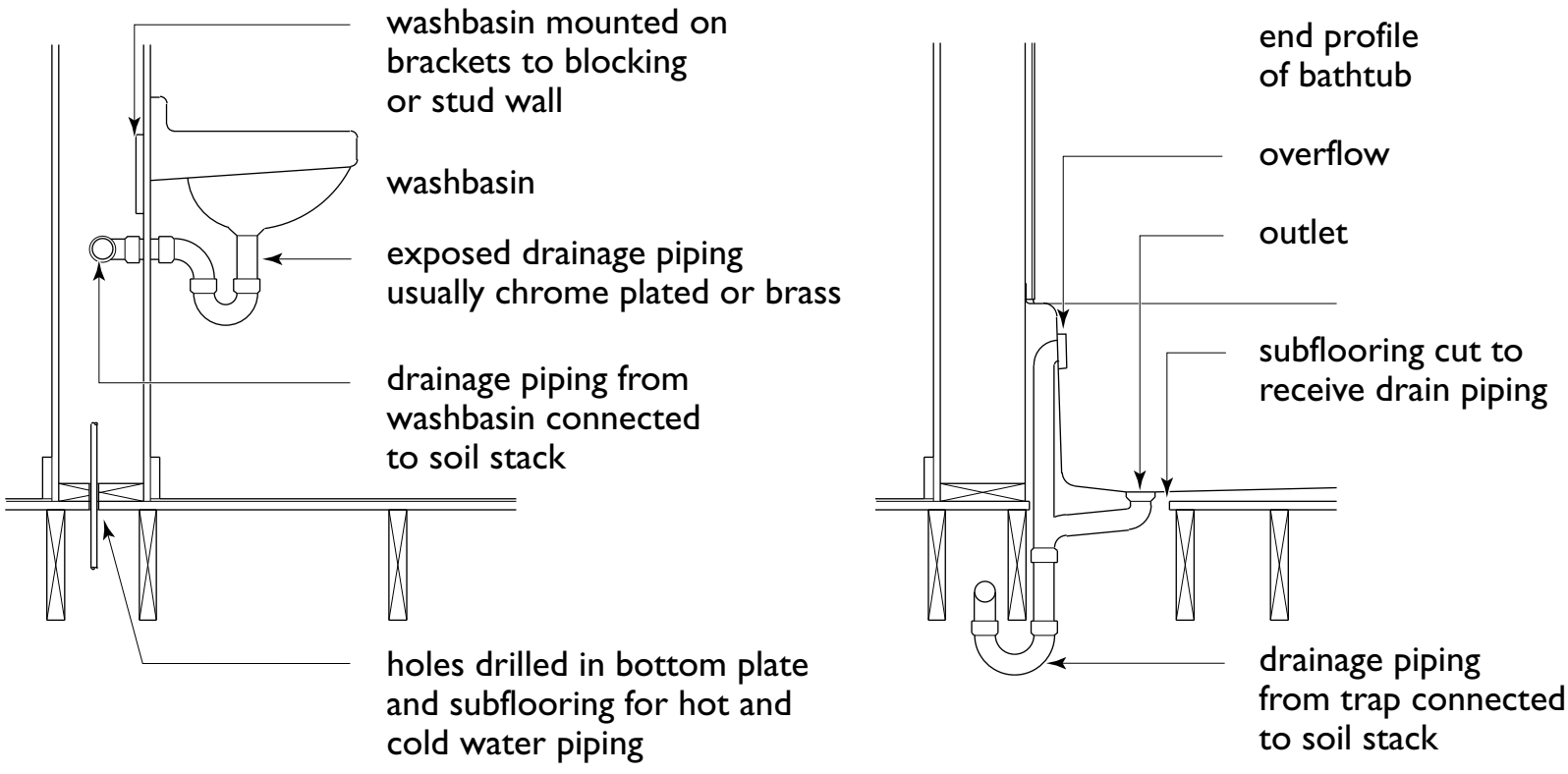
The installation of the plumbing system usually begins after the framing is complete. The initial work is called "roughing-in" and includes installing plumbing vents and drains and all hot and cold water piping that will be enclosed in the walls and ceilings and under the basement floor. Since the bathtub must be installed before the wall finish can be applied, bathtub installation is usually included in roughing-in.

151 Kitchen and bathroom in proximity for minimum pipe length



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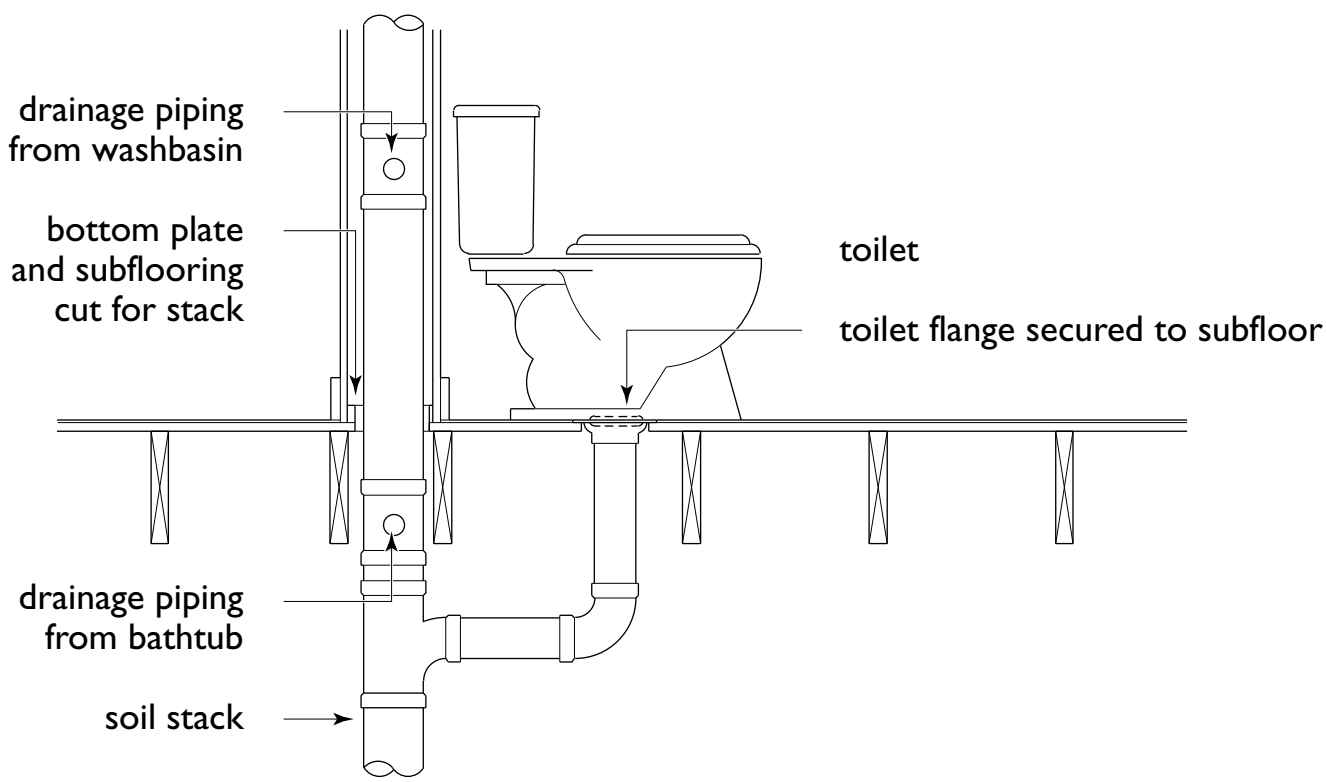
152 Washbasin and bathtub fixtures



Wherever plumbing reduces insulation or affects an air barrier, provide additional insulation on the exterior and ensure that the air barrier is continuous and uninterrupted.

Connect plumbing fixtures and accessories after the installation of the interior finish has been completed. Figures 151 to 154 show typical plumbing arrangements for wood-frame construction. Check local or provincial plumbing requirements.

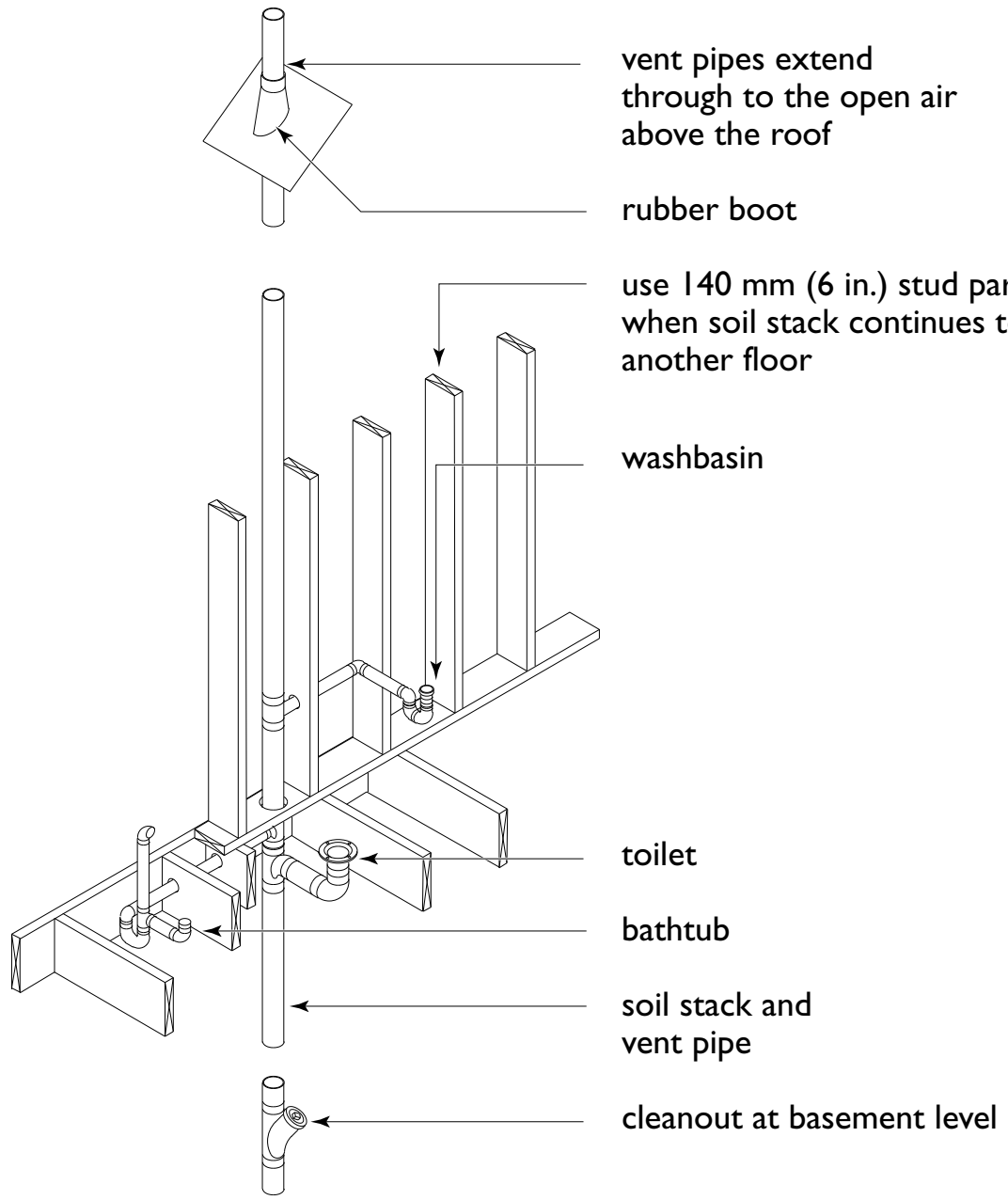
153 Toilet fixture



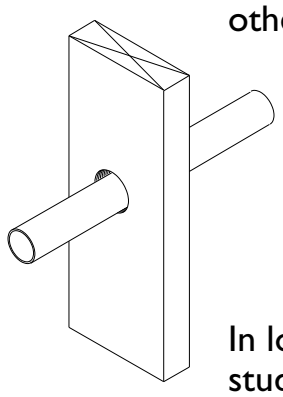
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When 75 mm (3 in.) copper or plastic piping is used, the plumbing stack wall may be made of 38 × 89 mm (2 × 4 in. nominal) material (Figure 154). Seal around the ceiling penetration to maintain air barrier continuity and prevent air leakage into the attic space

154 Venting for plumbing



In partitions, holes may be drilled in studs if the remaining portion totals at least 40 mm (1½ in.); otherwise studs must be suitably reinforced.



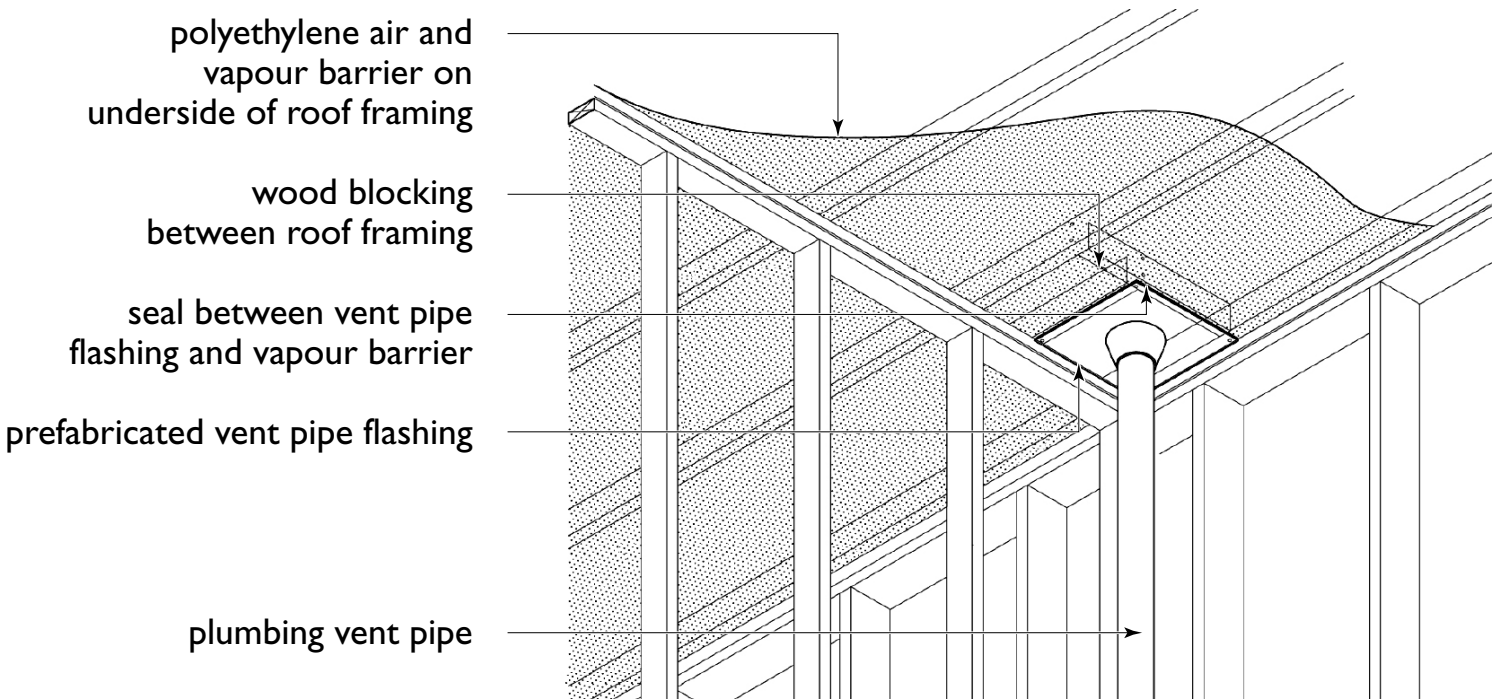
In load-bearing walls, the remaining portion of the stud must be at least ⅔ the depth of the studs; otherwise, studs must be suitably reinforced.

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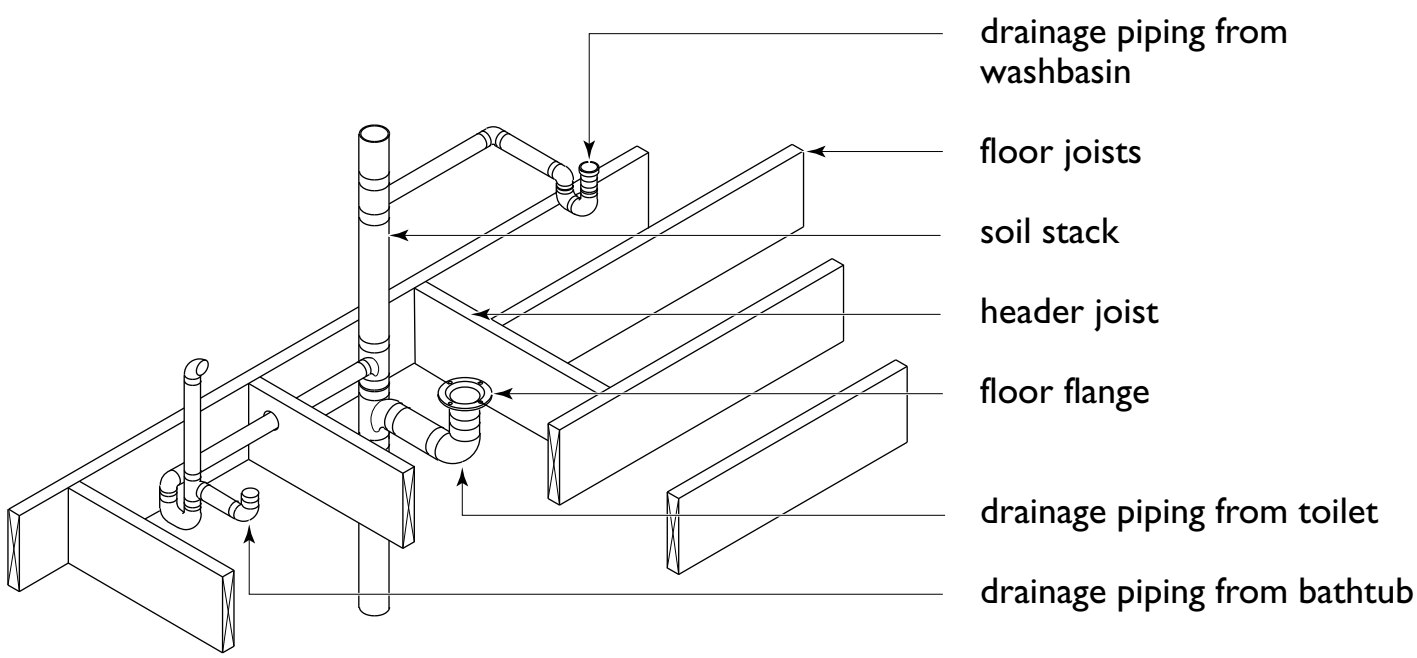
(Figure 155). A flexible sheet rubber or neoprene flange placed around the vent stack provides an effective, flexible air seal. It can also move with the vent stack as it contracts and expands with the heat of air within it.

Where soil stacks or large pipes must run horizontally at right angles to the joists, it will be necessary to frame out the joists. To do this, headers are installed between the joists (Figure 156). Alternatively, services are suspended below the joist and enclosed in a bulkhead or dropped ceiling chase.

155 Sealing a plumbing vent below an attic



156 Framing for soil-stack pipes



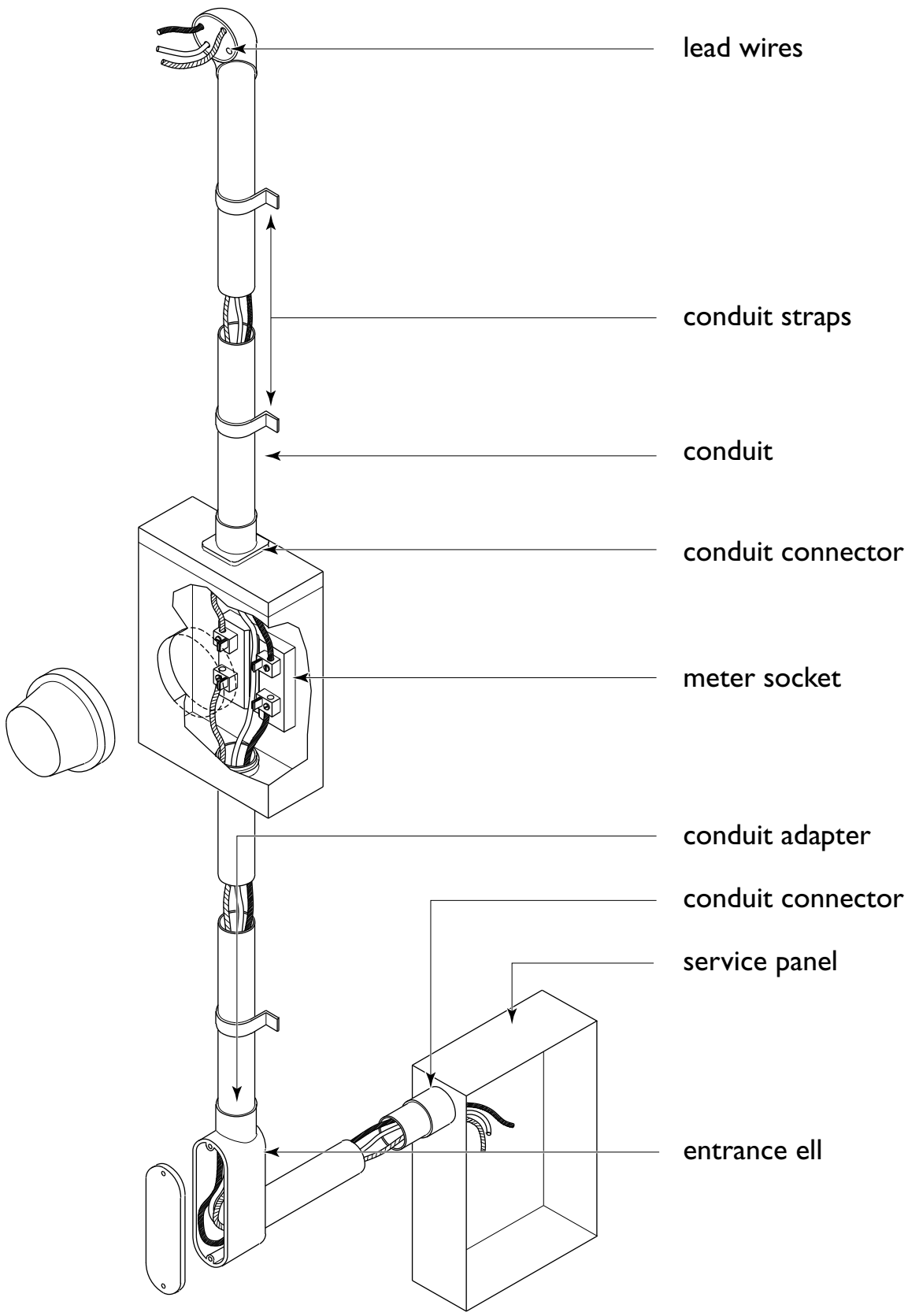
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FRAMING DETAILS FOR WIRING

The design and installation of the entire wiring system is usually regulated by a provincial electrical code, all of which are closely modelled on the Canadian Electrical Code published by the Canadian Standards Association. The provincial codes usually require that the installation be done by a licensed electrician. Owners are advised to check with the local authority when planning a wiring installation.

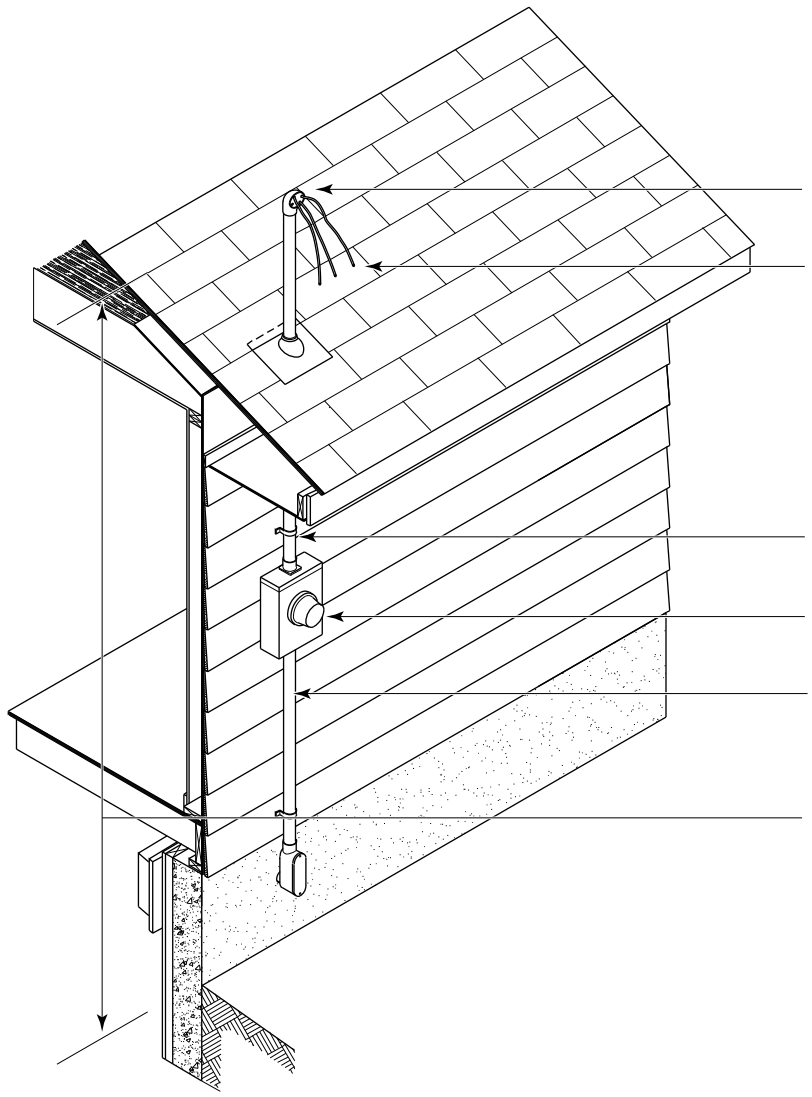
Figures 157 and 158 show the typical arrangement of electrical service entrance equipment. The limitations for drilling structural members for wiring are shown in Figure 159.

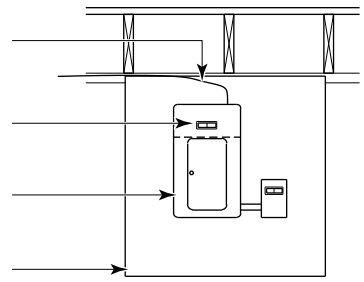
157 Typical arrangement of service entrance



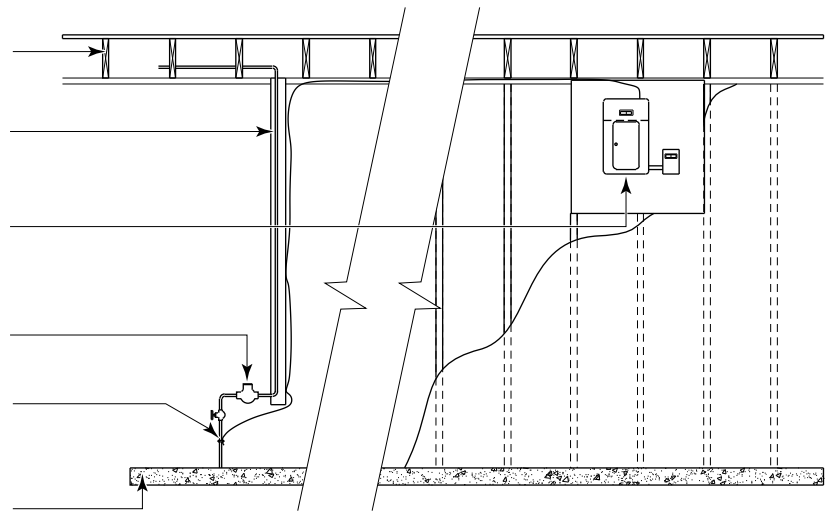
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158 Service entrance equipment





Note: Capacity 100 to 200 amps. The service wires are brought to the main breaker located in the basement through a rigid conduit. The main breaker and distribution panel containing branch circuit protection (breakers or fuses) are mounted on a plywood or OSB back-up panel.

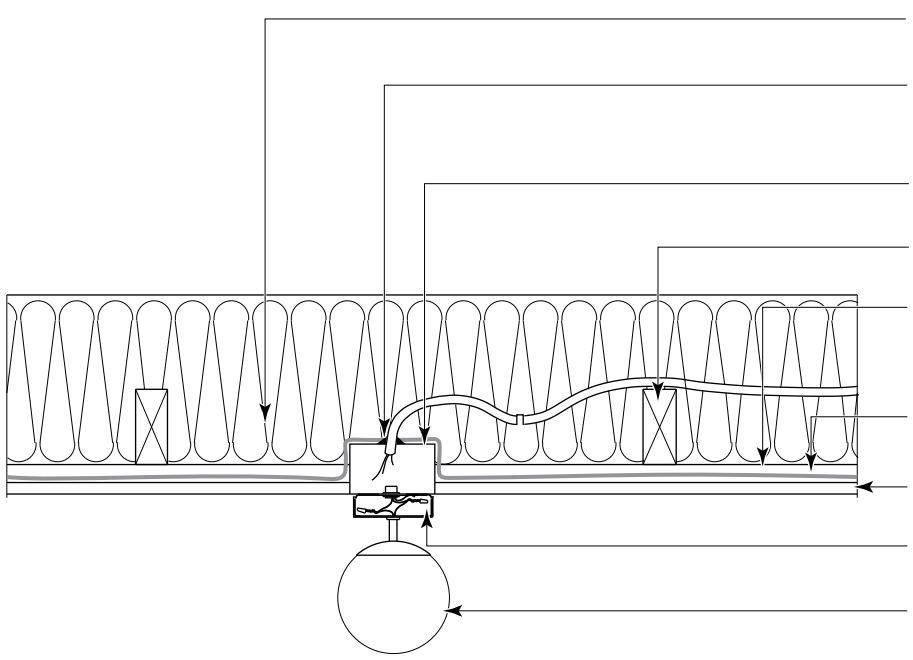


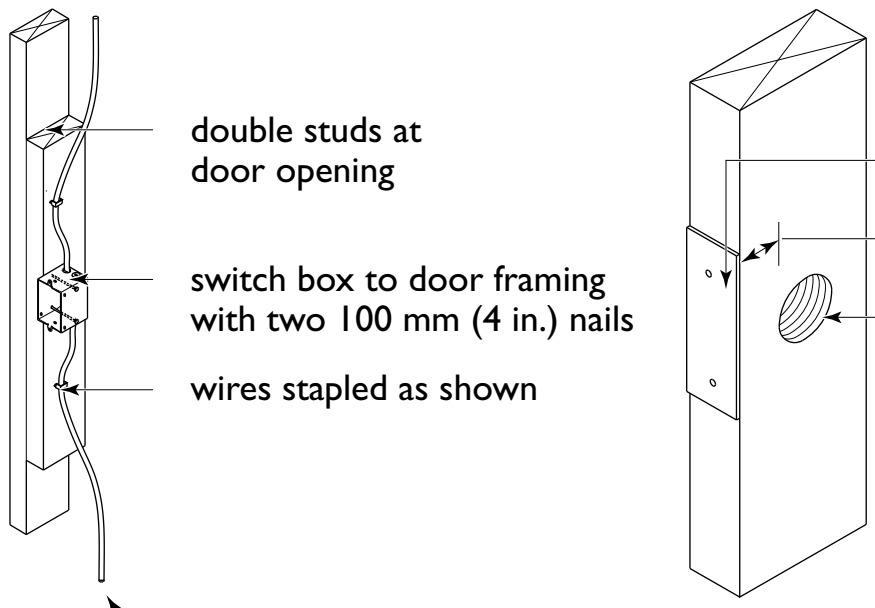
Note: Service equipment must be grounded.

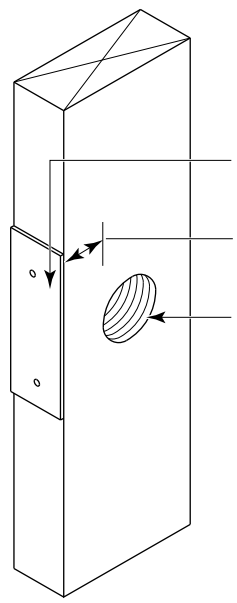
Note: Ground wire from main entrance panel must be clamped to the water service entrance pipe below shut-off valve as shown (metallic pipe only).

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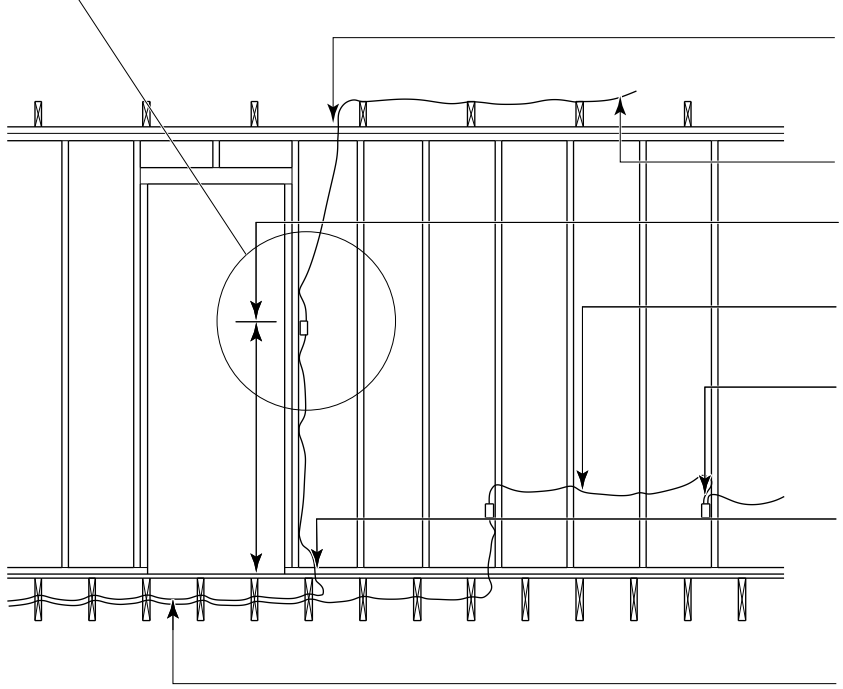
159 Drilling of structural members for wiring







Note: When holes are drilled closer than 30 mm (1¼ in.) to the edge of a stud, metal protection plates are required.



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The amperage of the electrical service and the number of circuits and outlets installed should take future needs into account. Modern house services usually require 200 amps.

Wiring is usually started after the house has been enclosed. The initial phase of wiring is called roughing-in and includes the installation of wiring and the boxes for the switches, lights and outlets. Figure 160 shows some typical electrical equipment.

Roughing-in is done before the inside finish is applied and usually before insulation is placed in walls and ceilings. Lighting fixtures, switches, outlets and cover plates are installed after the interior finish and painting operations are complete.

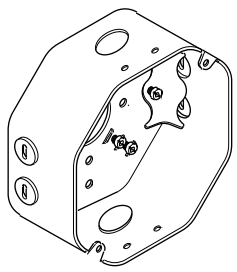
Location of Switches and Outlets

Plan the location of switches and outlets carefully. Electrical boxes located in insulated ceilings and exterior walls must be sealed to prevent air leakage. Solid plastic airtight electrical boxes are recommended for use in exterior walls and ceilings.

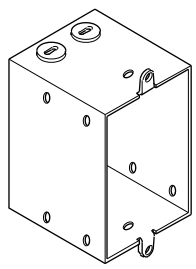
Switches are typically located just inside a door opening so that they may be easily reached when the door is opened. Switches may activate a wall outlet for a table or a floor lamp or ceiling or wall lights. Locate switches about 1.4 m (4 ft. 6 in.) above the floor, or 1.2 m (4 ft.) above the floor for a person in a wheelchair (see *About Your House* fact sheet *Accessible*

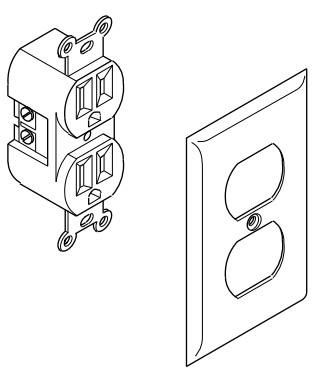
160 Typical electrical equipment

octagonal boxes for use with fixture or junction outlets

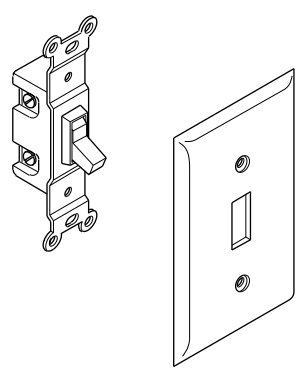


use approved boxes for switches and outlets in the house

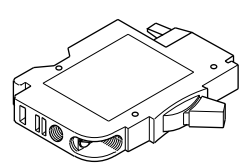




duplex wall outlet and plate



toggle switch and plate



circuit breaker

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Housing by Design: Living Spaces for more information about accessible placement of switches and outlets).

Three-way switches can control power from more than one location. For example, a living room light could have a switch near one entrance and one at another door leading to the kitchen or to a hallway.

In houses with two or more storeys, three-way switches must be provided at the bottom and at the top of the stairway to control stairway lighting. Three-way switches are required for stairs to finished basements, but not for unfinished basements.

Smoke Alarms

The National Building Code and most local building codes require early-warning, fire- and smoke-detecting devices in dwellings. Smoke alarms must be located in or near each bedroom on each storey including basements and mounted on or near the ceiling.

Building codes usually require smoke alarms to be permanently connected (hard-wired) to an electrical circuit. There must be no disconnect switch between the smoke alarm and the electrical service panel, and the circuit should not be connected to a wall outlet.

Where electric power is not available, battery-powered smoke alarms may be used. These units are designed to operate for at least one year and provide a seven-day trouble signal when the battery runs down.

Smoke alarms in houses are not required to be interconnected such that one alarm activates one or more others. However, smoke alarms in a house with a secondary suite are required to be wired so that the activation of any one alarm causes all alarms in both suites to sound.

Only install smoke alarms that are certified by a recognized testing agency such as the Underwriters' Laboratories of Canada.

SUSTAINABLE HOUSING INSIGHT

Healthy Indoor Environment

- Smoke alarms should be wired directly to the electrical panel so they always function, which renders battery replacement unnecessary.
- Additional smoke alarms in bedrooms can improve safety, especially when occupants are asleep.

Energy Efficiency

- Select appliances that have low energy needs as determined by the EnerGuide rating, or ENERGY STAR label.
- Maximize natural lighting from windows, skylights and light tubes to reduce the need for artificial lighting during the day.
- Use compact fluorescent or light-emitting diode (LED) bulbs to reduce the amount of electricity needed for lighting.
- Consider installing a drain water heat recovery stack on shower drain piping.
- Install an "all-off" master switch to turn off non-essential power when there are no occupants in the house. This can reduce phantom electrical loads from appliances and equipment that do not require continuous power.

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Continued

- Consider making the house ready to accept solar hot water and photovoltaic systems.

Environmental Responsibility

- Select water-conserving toilets, showerheads, dishwashers and clothes washers. Low consumption (6 L) and dual-flush toilets use the least amount of water for flushing. Water-saving showerheads and showerheads with a built-in on/off valve use about half the water of conventional types.
- Water-conserving fixtures and appliances also reduce the energy needed for providing potable water and treating waste water.
- Consider using landscaping materials or grass species that need less watering than standard lawns.

RELATED PUBLICATIONS

About Your House: Accessible Housing by Design—Living Spaces,
Canada Mortgage and Housing Corporation (product no. 66095)

2010 National Plumbing Code of Canada,
National Research Council of Canada

Canadian Electrical Code,
Canadian Standards Association, product no. C22.1

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CHAPTER 20
Space Conditioning Systems



Houses are equipped with a number of space conditioning systems that maintain healthy and comfortable indoor conditions.

Space heating systems not only keep indoor air temperatures at a comfortable level throughout cold winter months, but they also prevent plumbing systems from freezing. Space heating systems also help control indoor moisture conditions by keeping the relative humidity of the indoor air low enough (and surfaces warm enough) to prevent condensation.

Space cooling systems (typically referred to as "air conditioning" systems) maintain comfort conditions through hot summer months and can also help control indoor moisture conditions by reducing humidity levels.

Ventilation systems exchange indoor air with outdoor air and help control moisture and odours.

Humidification systems are used to add moisture to the indoor air–particularly in regions that experience cold and dry winters.

Dehumidification systems are used to remove moisture from the indoor air, usually during hot and humid summers.

Air filtration systems are used to remove particulates from the air to protect occupants from inhaling potentially problematic particulates, reduce the proliferation of dust throughout the house and protect air handling equipment from dust build-up.

While a house must have a space heating and ventilation system, the other systems are optional and are based on occupant demand or local trends that may dictate the amenities that should be provided in a house to make it marketable. While each of the systems may be separate, more often than not, they are integrated. For example, it is common to combine a space heating and cooling system—particularly when a forced air system is used. It is also possible to integrate ventilation and humidification systems with forced air space heating systems. Dehumidification systems tend to be stand-alone equipment and are provided on an as-needed basis.

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The following sections describe typical house space conditioning and ventilation systems and identify the wood frame construction required to accommodate installation, operation and maintenance.

SPACE HEATING SYSTEMS

In Canada, natural gas, oil and electricity are the most commonly used energy sources. The most common space heating systems are: forced-air electric, forced-air fuel-fired, electric baseboard and forced-flow hot-water (hydronic) heating, which includes in-floor radiant heating systems, radiators and baseboard convectors. Air, ground or water-source heat pumps (typically with electric backup heat) coupled with forced air systems are also available. Solid fuel-burning (wood or wood pellet) furnaces and wood stoves are also used, particularly in remote locations where other options are limited. Natural gas fireplaces have become increasingly common, though they are often supplied for aesthetic and local room comfort purposes, not for house-wide heating.

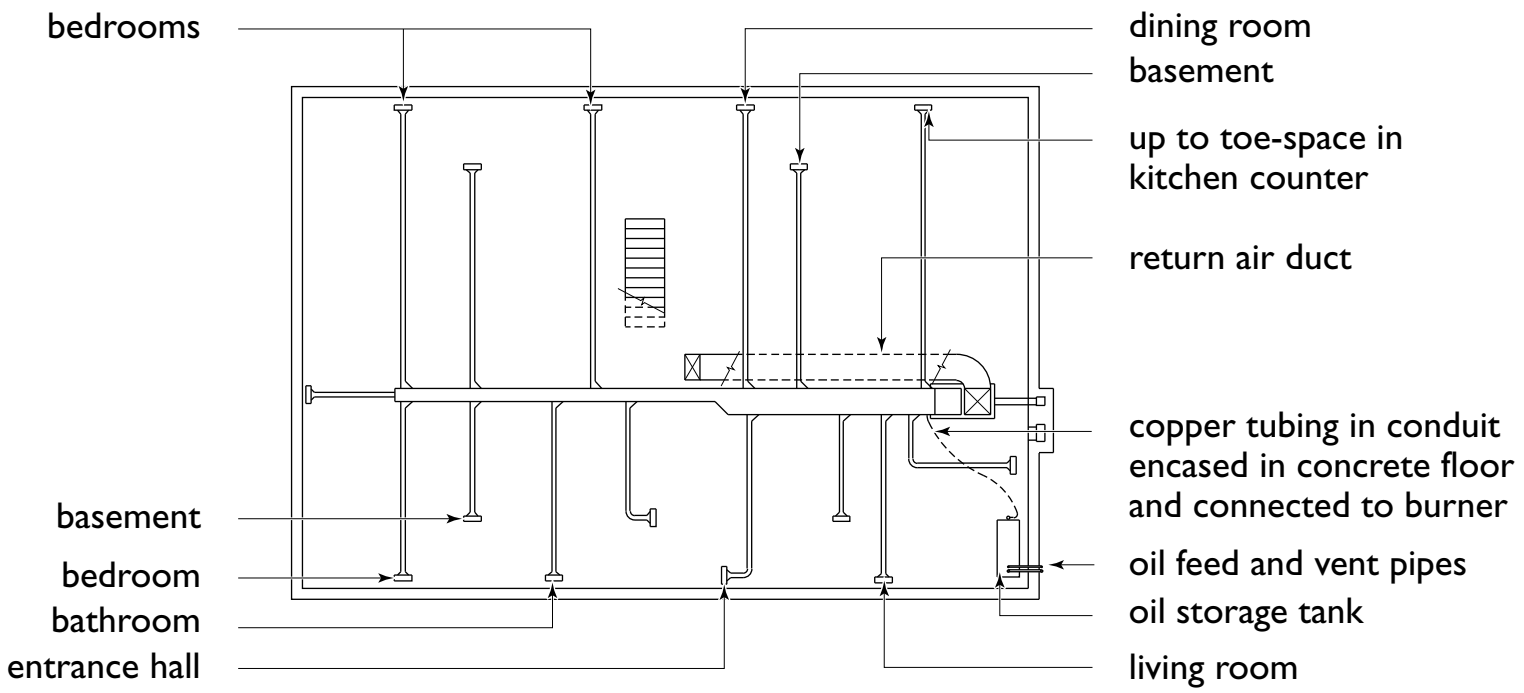
Space heating systems are typically installed by qualified mechanical or electrical contractors that are properly trained and certified for the work involved. A knowledgeable contractor will install space heating systems in accordance with code, regulations, utility requirements and manufacturers' instructions.

For builders, the main consideration for space heating systems in wood frame construction is to ensure required clearances between heating appliances, piping and ductwork and wood framing and other combustible materials. Builders must also provide space for the heating appliance and the supply and return air duct system for forced-air systems or supply and return piping for hydronic systems. Wood framing is often required to support heating system components, and additional support may have to be provided beyond that simply needed to frame the house. Accommodations for venting fuel-fired appliances directly through exterior walls or up through chimneys must also be carefully planned and constructed to ensure safe, effective and efficient operation.

Forced Air Heating Systems

Forced-air heating systems are comprised of a heating appliance such as a furnace, fan-coil, or heat pump and duct work to carry the heated air to all rooms in the house and return cooler air back to the heating appliance. Figure 161

161 Basement plan showing typical heating layout



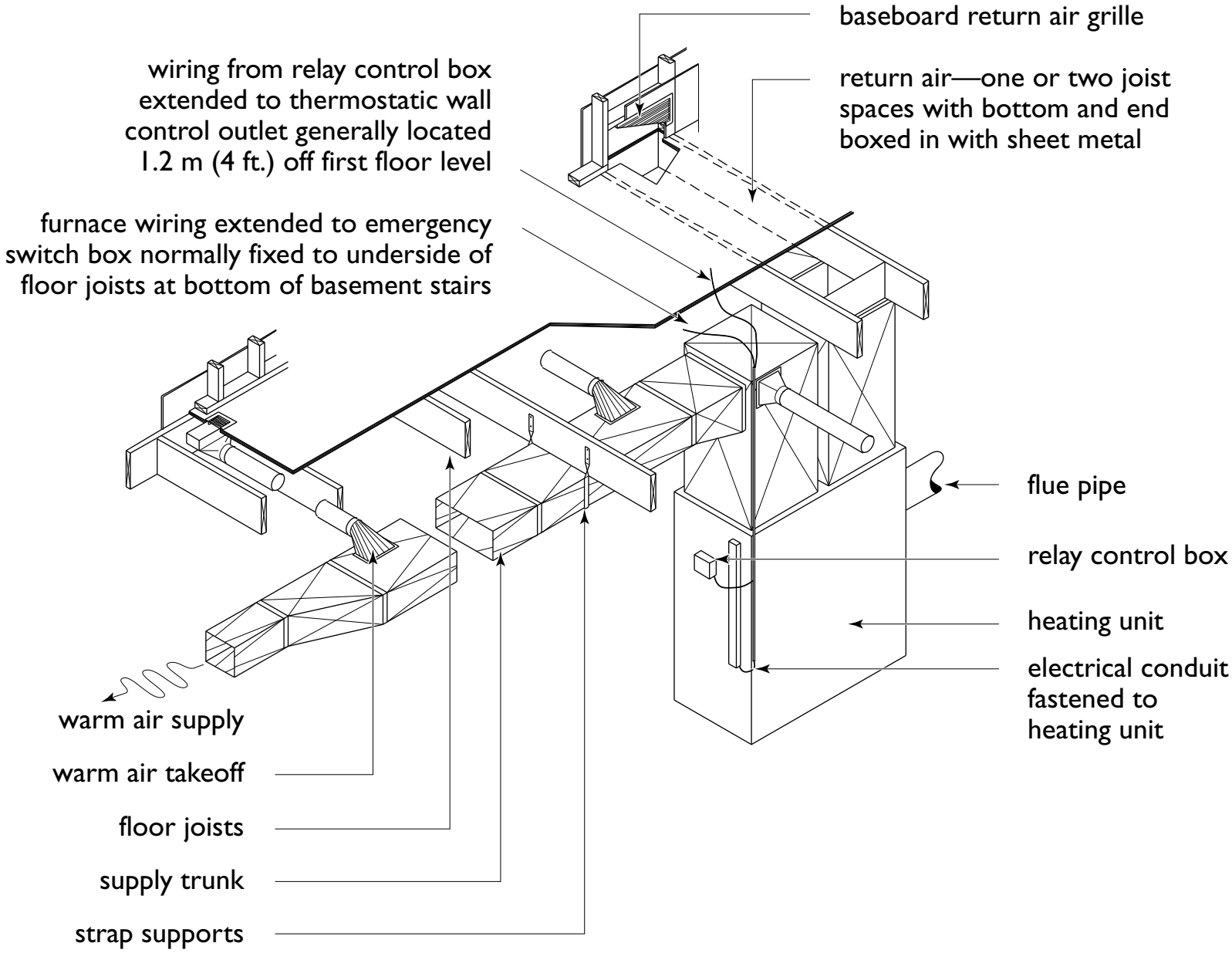
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illustrates a typical heating layout, and Figure 162 shows an isometric view of a typical heating system. Work with the heating contractor early in the framing process to map out the location of the furnace, venting system (if needed) as well as the supply and return air branches, trunk ducts and plenums. If space is provided through and around floor joists and wall framing, and if any additional supportive framing needed as construction proceeds is planned, far less cutting and repairs will be required later to accommodate the air distribution system.

Furnaces

Furnaces heat houses by transferring the heat produced from burning natural gas, propane or oil, electric elements, or hydronic coils to air that is distributed throughout the house and circulated within each room by a supply and return duct system. Furnaces are controlled by thermostats installed in a central location. Today, furnaces tend to be quite compact, lightweight, and are easily installed in the basement or crawl space, or in purpose-built service rooms.

162 Isometric view of forced-air heating system



Note: Maintain clearance between conbustible materials and heating appliances in accordance with manufacturer's instructions

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Fuel-fired (oil, natural gas, propane) furnaces require a supply of combustion air from outside. Therefore, a hole of sufficient size has to be roughed into the foundation wall, rim (header) joist or exterior wall through which a combustion air duct can be passed. It is preferable to provide this hole when framing so that the duct can be properly integrated into the air and vapour barrier, exterior moisture protection and insulation systems of the building envelope. If not provided during construction, the mechanical contractor may damage the wall when the combustion heating appliance air duct is installed. The air intake must be situated where snow and drifting snow will not block airflow into the combustion air duct. The air intake must also be located to avoid contamination from local sources such as automobile exhaust or other exhaust vents including those serving clothes dryers, central vacuums or other fuel-fired appliances. Except for approved concentric vents, the separation between the air intake and other vents must be at least 900 mm (36 in.). Concentric vents must be installed in accordance with *CAN/CSA B149.1 Natural Gas and Propane Installation Code*.

Fuel-fired systems must also be connected to a combustion venting system that is either side-wall vented or vented through a chimney. For side-wall vented systems, plan where the vent must be passed through the foundation wall, floor rim (header) joist or exterior wall. Certain clearances from combustible material may be required if the vent conducts hot combustion gases. As is the case with the combustion air duct, it is important that the hole for the combustion venting system be roughed in such that the vent is easy to install and that there is continuity of the air and vapour barrier systems, exterior moisture protection and insulation around the opening. Some fuel-fired appliances use one-piece concentric, combustion air/combustion venting equipment that helps limit the number of holes required in the building envelope and simplifies the installation.

For furnaces connected to chimneys and flues, a framed space must be provided to allow the passage of the chimney or flue vent up through the house to the roof. Provisions must be made to ensure the continuity of the attic air and vapour barrier and insulation around the chimney or flue in such a way that also respects the clearances required between the chimney or flue and combustible materials. Framed chimney chases may also be provided up an exterior wall, though the cooler location may undermine venting performance under certain conditions (see Chapter 18).

Earthquake vibrations can rupture fuel supply lines to heating appliances and cause appliances to tip or move enough to break fuel lines. In areas subject to earthquake vibration, appliances must be secured (strapped or braced) to the structure to resist overturning and displacement. Even in areas not subject to earthquakes, local regulations may require the securing of appliances. Therefore, it may be necessary to rough in framing or other structural support prior to the installation of the heating appliance. If they are located on an exterior wall, also provide the air and vapour barrier and thermal insulation in the support framing so continuity of all materials can be maintained when the rest of the wall area is finished.

Sometimes humidification equipment may be added to the forced air system. It is typically connected to the furnace supply and return plenums so that it can add moisture to the air being circulated around the house through the forced air system. When a humidifier is added to maintain specific humidity levels, an automatic humidity control device must be provided.

Ductwork and Grilles

The main supply and return air plenums connected to the furnace are typically suspended immediately below the main storey floor joists. Branch ducts leading to and from the plenums are usually located between studs in partition

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walls and between joists in floors. While supply air ducts are always formed from sheet metal, return air ducts can take advantage of stud and floor joist spaces to transfer air back to the furnace. When an enclosed joist or stud space is used as a return air duct, non-combustible material such as sheet metal should be used to line the joist space that is within 600 mm (24 in.) of the furnace, under floor registers and at the bottom of vertical ducts. It should be noted that framed spaces tend to be very leaky and therefore may not return air from the different rooms of the house as expected. Sealed sheet metal return ducts provide more predictable and better performance but are less commonly provided due to increased material and installation costs.

Where ducts cannot be concealed within the floor and wall framing, bulkhead chases—typically aligned along wall-ceiling intersections—can be constructed to conceal the ducts where they pass through finished rooms. Such framing work should be considered at the design stage to avoid large and unsightly bulkheads in locations that intrude too much on room space and head room. Provisions such as access hatches must be made in the framing and room finishes for access to any dampers or other adjustable fittings installed in the ductwork system.

The spread of fire is a major concern for ducts and associated fittings. Heating ducts, duct connectors, associated fittings and plenums must be constructed of steel, aluminum alloy, copper or appropriate non-combustible material. An exception is made for systems where the air temperature will not exceed 120°C (250°F), which is typical for most residential space heating systems. This means that polyvinylchloride pipe-type ducts are permitted for high velocity heating systems.

Return air grilles are usually located on inside walls at floor level. The bottom plate of the wall and subfloor below are cut to make a passage between the wall grille and the return air duct located in the joist below. When a partition that houses a supply heating or return air duct is supported on doubled floor joists, the joists should be separated by blocking to provide room for the duct and to avoid cutting framing members.

A lintel is required when a stud has to be cut to accommodate a large return air grille. It is framed in the same way as the door opening shown in Figure 69. Even if no studs are cut, blocking must be tightly secured in place within the stud space above the return air grille opening to ensure that air is returned from the room and not the wall space above. Return air grilles may also be located at high-wall locations near the ceiling. In this case, the wall framing must accommodate the cross section of the return air duct branch from ceiling to floor. Blocking above the return air grille is not required due to the presence of the wall top plate.

A return air grille should be provided in each bedroom, living room, dining room, family room and any other space where people may spend time—apart from kitchens and bathrooms. As a minimum, one or two return air grilles can be located in central locations on each floor, but the airflow route between the supply air diffusers and return air grilles can become restricted when interior doors are closed. Restricted airflow routes can reduce the amount of heat delivered to a room, which, in turn, can cause comfort and condensation problems within the room. It can also cause unfavourable air pressures between rooms and across the building envelope. Transom grilles installed above doorways, or air transfer grilles installed in interior doors, can help prevent these problems but sound transmission and privacy problems may result.

The supply air ducts running between the main supply air trunk duct and each room are typically 100 mm (4 in.), 125 mm (5 in.) or 150 mm (6 in.) in diameter, depending on

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the heating or cooling requirements of the rooms and the number of ducts running to each room. Plan the framing to allow the supply ducts to be easily run through joist spaces and partition walls in as direct a path as possible between the furnace trunk duct and the rooms served. This will help ensure that proper airflows are achieved. Supply registers are usually located in the floor under windows or along outside walls to help counter heat losses where they occur. Blocking may be required to support the edges of the floor opening around a register.

High-velocity, forced-air systems that use small diameter flexible duct to deliver air from the furnace to each room are available. The smaller diameter ducts can be run more easily through wall and floor framing with less cutting and blocking. Other framing provisions are similar to conventional forced air systems.

Although it is always preferable to run supply and return air ducting within the building envelope, any ducts and plenums forming part of a heating, ventilating or air conditioning system that are located outside the building envelope must be sealed and insulated to the same level required for exterior walls.

Electric Baseboard Heating Systems

Electric baseboard heating systems are common in some provinces and territories. They are installed at the wall-floor intersection in all rooms, typically under windows. Most rooms have thermostats located on interior walls to control the baseboard. As baseboards are connected to the electrical system by conventional wiring, there are few implications for wood frame construction. It may be necessary to ensure there are an adequate number of studs in the walls behind a baseboard to allow it to be firmly connected to the wall—otherwise additional blocking may be required.

Hot Water Space Heating Systems

Whether or not the hot water system is an in-floor radiant heating system, baseboard convectors or radiators, the supply and return piping is relatively small so preplanning the structural framing layout to accommodate the pipes is not usually necessary.

Similar to electric baseboards, hydronic baseboard convectors are usually located under windows along outside walls so that warm air reaches the outside walls. Baseboard convectors are positioned on the surface of the wall, and studs or joists need not be cut to install them. An adequate number of studs or blocking should be present in the wall behind the convector so that it can be securely fastened to the wall.

In-floor radiant heating systems consist of tubing that is either secured to the underside of the subfloor or embedded in a thin layer of lightweight concrete poured over the floor. Specialized subflooring is available in which the tubing can be run to eliminate the need for concrete topping.

Service water heaters, boilers and storage tanks serving hydronic heating systems must be insulated. The supply and return pipes connected to the heater or storage tank must also be insulated. Service water heating systems with storage tanks must also be equipped with automatic temperature controls that can be adjusted between the lowest and the highest acceptable temperature settings for the intended use.

Space Heating System Control

Space heating systems must be controlled by at least one thermostatic control that responds to the temperature within the heated space. Except for manually fuelled, solid fuel-fired appliances, the thermostat must be capable of controlling the temperature within 1°C. Where heating and cooling are controlled by

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separate thermostatic controls, these controls must be designed in a way that one cannot heat and cool simultaneously.

Carbon Monoxide Detectors

Carbon monoxide (CO) is a colourless, odourless gas that can accumulate in lethal concentrations in enclosed spaces without occupants being aware of it. Fuel-fired space or water heating equipment is a potential source of CO. Most well-tuned heat-producing appliances do not produce CO and even if they do, it is removed through the venting system. However, heating appliances can operate poorly and venting systems can fail.

All residential buildings that have fuel-burning appliances must have CO detectors located either in each bedroom, or located not more than 5 m (16 ft.)—measured along hallways—from each bedroom door. In addition, CO detectors are required where a bedroom shares a wall with a garage, or shares a wall with an attic space that abuts a garage.

AIR CONDITIONING SYSTEMS

Since air conditioning (space cooling) systems are generally coupled with forced air heating systems, the wood framing considerations are much the same. For houses with electric baseboard or hydronic heating, air conditioning can be provided by a compact, quiet fan-coil installed in each room (or in as many or few rooms as desired) that is connected to an outdoor condenser unit. Such systems, often referred to as “mini-split systems”, provide local cooling but, if strategically placed in a few central locations, can cool an entire house.

A common feature of most residential air conditioning systems is the outdoor condenser unit that is either placed on a concrete pad or is mounted on metal framework that is secured to the exterior wall (or foundation wall) of the house. A hole is required in the exterior wall for the supply and return refrigerant piping between the indoor and outdoor units. Advanced planning with the mechanical contractor should determine if structural support is to be added to the exterior wall framing to accommodate a wall-mounted condenser unit and the location of the conduit for the refrigerant piping.

Air conditioning systems are typically controlled by the same thermostat that controls the space heating system. Mini-split systems are controlled by unit-mounted thermostats (on the indoor fan-coil unit) or handheld remote controls.

VENTILATION SYSTEMS

House ventilation is needed to maintain acceptable indoor air quality (IAQ) and to control indoor moisture levels. Air quality is important for human health and well-being. High interior moisture levels can promote the growth of mold and mildew and adversely affect human health and the durability of the building envelope.

Ventilation can be provided naturally, typically through operable windows, and mechanically with fans and other equipment. Non-heating season ventilation can be provided either naturally or mechanically. Heating season ventilation must be provided by a mechanical system.

Houses must be designed to make efficient use of energy by using effective heating, ventilating and air conditioning equipment that is properly sized. Install mechanical equipment inside the plane of insulation or ensure the equipment is suited for installation outdoors or in unheated space.

NATURAL VENTILATION

Natural ventilation through operable windows can meet air change requirements during the non-heating season when the air entering the

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house is at a comfortable temperature and humidity level. However, natural ventilation is unpredictable and therefore may not meet needs at all times. During the heating season, natural ventilation results in an unacceptable level of heat loss and comfort problems—hence a controlled mechanical ventilation system is required.

The NBC specifies the minimum unobstructed operable area to the outdoors for rooms that are not mechanically ventilated. Where air is exhausted from or supplied to a room by mechanical means, no operable windows are required. In practice, however, occupants normally expect operable windows in most rooms, and in some cases, operable windows are required as a means of egress in case of fire.

If the type, location and orientation of operable windows are carefully planned, some measure of natural ventilation and summer cooling can be achieved. However, in locations where natural ventilation does not provide adequate temperature or humidity moderation, mechanical air conditioning can be used to provide the required level of comfort.

MECHANICAL VENTILATION

It is well understood that the combination of an airtight building envelope and an effective and efficient mechanical ventilation system can outperform a leaky house with no mechanical ventilation system. A house that is built tight and ventilated right will have lower heating costs and greater year-round comfort. For this reason, the NBC requires the installation of a mechanical ventilation system in houses intended for year-round occupancy. As a minimum, the system must include a principal fan capable of providing an air flow rate suitable for the number of bedrooms; in most cases, supplemental exhaust fans to ventilate high moisture generation in areas such as kitchens and bathrooms; and protection against depressurization that might otherwise allow fuel gases from fuel-fired appliances (for example, furnaces, water heaters and fireplaces) to be drawn back into living spaces.

Mechanical ventilation systems are required for occupant health and comfort, as well as to maintain the integrity of the building envelope. Ventilation systems must be carefully designed to ensure they can manage the full range of normal household activities without overventilating or underventilating.

In households with frequent moisture-generating activities such as cooking, bathing and floor washing, continuous mechanical ventilation at a low speed may be needed to control indoor humidity and odours. There may be occasions when operating the mechanical ventilation system at its peak capacity on a continuous basis is needed to control contaminants arising from activities such as painting or social events. In households with sedentary occupants, or when the house is not occupied for extended periods of time, intermittent operation of the mechanical ventilation system may be all that is required to maintain acceptable indoor air quality.

System Design Options

Though mechanical ventilation systems are often designed and installed by qualified mechanical contractors, it is important for builders to understand the basics. There are two options for designing mechanical ventilation systems for houses. The first option is to apply the requirements stated in the NBC. The second is to develop a design based on *CAN/CSA-F326-M91: Residential Mechanical Ventilation Systems*. The discussion that follows is based on the NBC.

There are three types for mechanical ventilation systems:

*Ventilation system **coupled** with a forced-air heating system*—The ventilation and heating system share ductwork to supply fresh and heated air to

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the rooms of the house. The simplest example is that of a forced air heating system that has a duct running from outside to the return air trunk duct. The operation of the furnace fan draws outdoor air into the forced air system where it mixes with the return air and is then distributed throughout the house by the forced-air system ductwork. Exhaust fans are used to vent bathrooms and the kitchen. A more efficient option involves connecting a heat recovery ventilator (HRV) to the furnace ductwork system so the heat of the air exhausted from the house is recovered to warm the incoming outdoor air. The ventilation and heating system controls are interlocked so that the furnace fan mixes and circulates the outdoor air that is delivered to the distribution ductwork. Installation costs are lower because one duct system serves both heating and ventilation. Operating costs may be higher depending on the efficiency of the furnace circulating fan (brushless direct current motors are best). If an HRV is not used, proper design is necessary to ensure that outside air is mixed and adequately warmed before entering the furnace heat exchanger so that it is not damaged.

*Ventilation system **not coupled** with a with a forced-air heating system (stand-alone ventilation system)*—This system consists of fans, ducts, grilles and controls that exhaust air from selected rooms in a house and supply air to rooms that are not being exhausted. It is usually installed in houses with baseboard, radiator and in-floor radiant heating systems that do not use forced-air heat distribution. It is designed for ventilation only, independent of the need to deliver heating or cooling. Incoming outdoor air must be tempered (warmed) during the cold season to maintain a comfortable air supply temperature. Heat recovery ventilators are often used as it is important to raise the temperature of the outdoor air as much as possible before it is delivered to a room to prevent comfort problems and reduce heating costs.

Exhaust-only ventilation system—This system expels air from a house and relies on leakage through the building envelope into the house for replacement air, resulting in some depressurization of the house. Consequently, exhaust-only ventilation systems should not be used in houses that have fuel-fired appliances that use natural draft and unsealed venting systems to vent combustion products. This includes wood fireplaces and woodstoves, naturally aspirated gas furnaces with draft hoods and oil furnaces with barometric dampers. It should also be noted that exhaust-only systems rely on the availability of air leakage through the envelope to make-up the air being exhausted. As it is not possible to ensure uniform air leakage around the house, it is also not possible to predict with any certainty that an exhaust-only system will be able to adequately ventilate any given room in a house.

In the case where interior pools and tubs are installed, those with an area less than 10 m^2 (107 sq. ft.) must be equipped with a pool cover, and those with larger areas are required to have exhaust fans capable of recovering at least 40 per cent of sensible heat.

Heat and Energy Recovery Ventilators

A heat recovery ventilator (HRV) is a device designed to recover heat from the exhaust air and transfer this heat to the incoming outdoor air during the winter. In air conditioned houses in the summer, the process is reversed where the cold is recovered from the outgoing exhaust air and helps reduce the temperature of the incoming air. This not only brings down heating and costs, but, in the winter it also helps bring the temperature of the incoming outdoor air up to a point where it can be introduced into the occupied space with little risk of comfort problems. In addition, HRVs temper incoming air and reduce the risks of the colder outdoor air damaging furnace heat exchangers for coupled systems. Numerous studies have concluded

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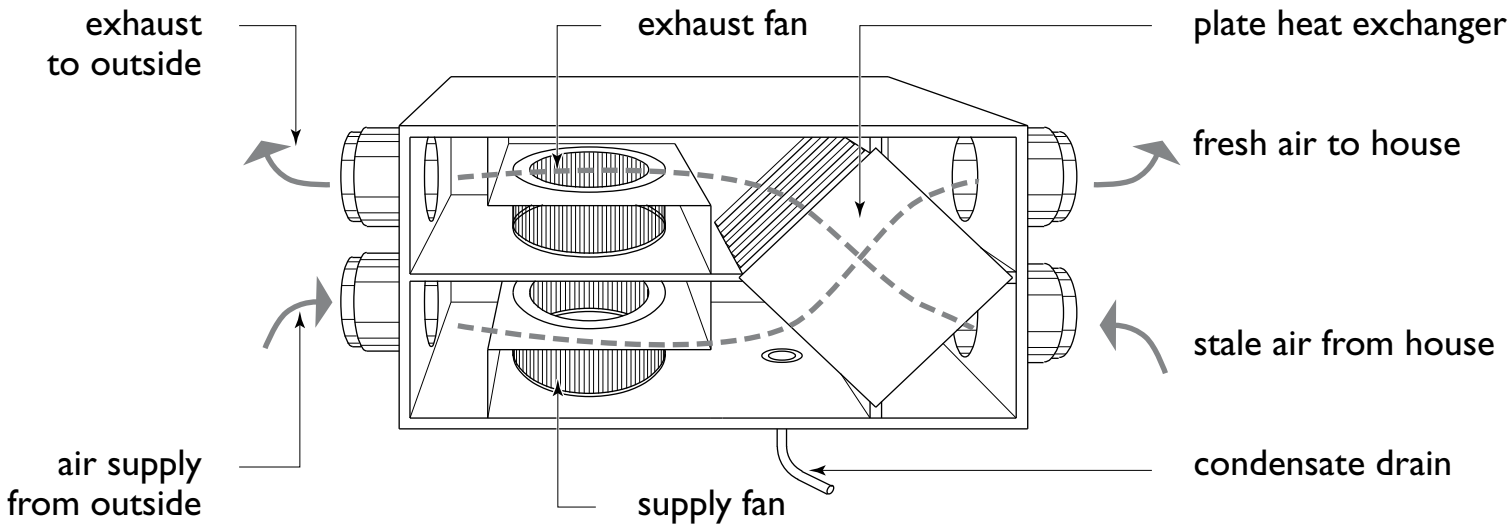
that in the long-term, HRVs are cost-effective because energy savings more than offset their higher initial capital costs.

An energy recovery ventilator (ERV) is a device designed to recover heat and moisture from the outgoing airstream and transfer it to the incoming outdoor air. In the winter, this not only reduces heating costs, but it also helps prevent the indoor house air from becoming drier than it otherwise would be due to continuous ventilation. In the summer, the ERV helps reduce the temperature and humidity of the incoming outdoor air, bring down cooling costs and increase comfort.

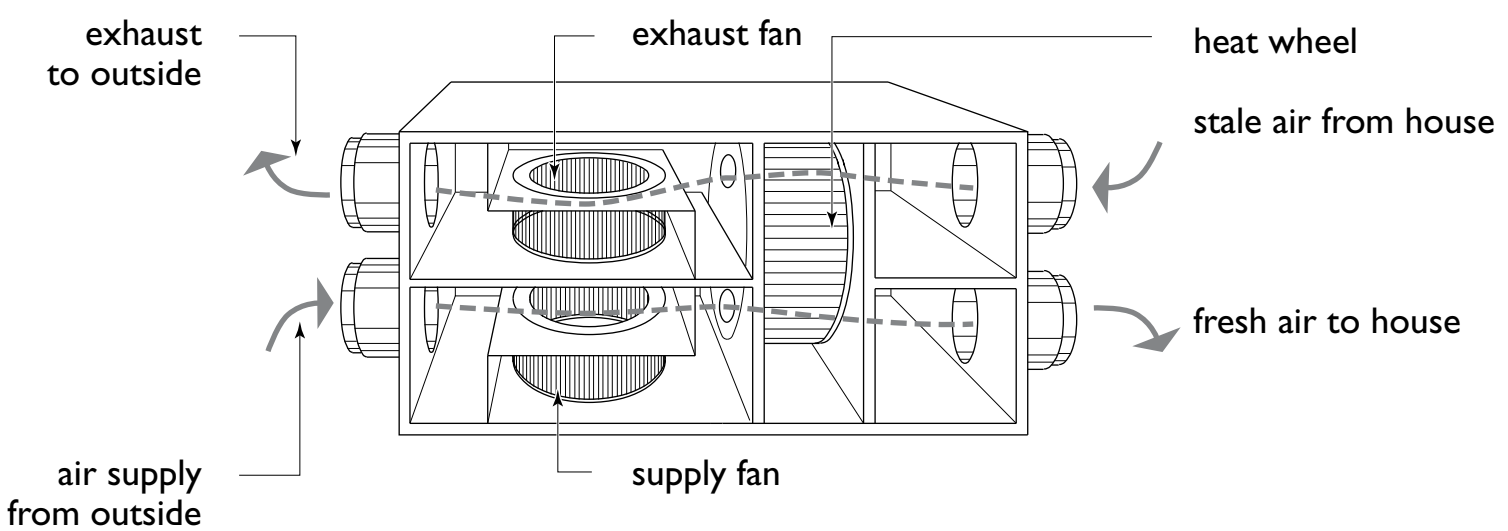
Plate heat exchangers—In plate heat exchangers, outdoor air and indoor exhaust air flow through channels in alternate, adjacent plates (Figure 163). During the winter, heat is passed from the warm exhaust air to the incoming outside air. ERV plate heat exchangers transfer both heat and moisture while HRV plate heat exchangers transfer heat only. The latter must be connected to the plumbing system or floor drain since the exchange of heat between adjacent plates causes moisture from the indoor exhaust air to condense and drip out of the heat recovery core where it must be collected and drained.

163 Common types of heat recovery ventilators

Plate heat exchanger



Wheel heat exchanger



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Heat or rotary wheel heat exchanger—This type of heat exchanger is used to transfer both heat and moisture. Indoor air passing through the heat wheel deposits heat and moisture into a desiccant material. As the wheel rotates into the outside air stream, the moisture and heat are released into the air supply (Figure 163).

ERVs or HRVs may be installed as a stand-alone ventilation system or as a ventilation system coupled to a forced-air heating system. In most areas of Canada, high indoor relative humidity is more of a problem than low indoor relatively humidity. For this reason, heat recovery ventilators tend to be the ventilator of choice. Properly installed, HRVs and ERVs deliver a balanced flow of supply and exhaust air, neither pressurizing nor depressurizing the house. Moreover, some types of HRVs can operate in a recirculation mode to even out room to room temperature and humidity conditions. Recirculation mode can also help distribute heat from wood-burning appliances throughout the house.

Ventilation System Ductwork

The installation of mechanical ventilation system ductwork involves many of the same considerations for builders as do forced air heating systems. Supply and exhaust duct runs through joist spaces and wall stud cavities must be as direct and straight as possible to limit pressure losses along the system. Ventilation system motor fan sets do not have the same pressure flow characteristics as forced air furnace fans, and they are particularly sensitive to pressure losses due to turns, abrupt transitions and leakage.

Penetrations of the building envelope for exhaust fan ducts or HRV ducts should be carefully planned to ensure the continuity of the air and vapour barriers, external moisture protection and insulation in the building envelope. Except for exhaust ducts, all ducts and plenums forming part of a heating, ventilating or air conditioning system and located outside the building envelope must be sealed and insulated to the same level required for exterior walls. Ducts or openings intended to discharge air to the outdoors must be equipped with a motorized damper or gravity or spring-operated backflow damper.

Operation and Maintenance

To be effective, mechanical ventilation systems must be appropriately maintained and operated by occupants. This typically includes cleaning screens and filters, as well as servicing the equipment according to manufacturer's instructions. It is important to provide enough space to access the equipment. Consult with the heating contractor prior to finalizing the house design so that the mechanical ventilation system may be properly integrated within the house.

SUSTAINABLE HOUSING INSIGHT

Healthy Indoor Environment

- Keep construction drywall dust and debris out of ductwork.
- Ventilation is required to remove stale air and excessively moist air.
- Houses equipped with electric baseboards would benefit from a fully ducted ventilation system to supply outdoor air to each room and to exhaust air from kitchen and bathroom areas.

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Continued

- The comfort zone for relative humidity is 30 to 40%. Lower levels may be necessary in winter to reduce condensation on windows. Dehumidifiers can reduce humidity to a comfortable level.
- Provide CO detectors in or near bedrooms and in rooms adjacent to an attached garage.

Energy Efficiency

- Heat recovery ventilators (HRVs) and energy recovery ventilators (ERVs) can substantially reduce heat loss in tightly constructed houses.
- Use high-efficiency heating appliances. Specify high-efficiency motor fan sets for continuously operating equipment.
- To operate efficiently, space-heating, space-cooling and water-heating equipment should be the proper size for the heating and cooling requirements and for hot water demand.

Environmental Responsibility

- Seek ways to use renewable energy sources such as geothermal and solar energy, and use non-renewable sources such as natural gas, oil and propane less frequently.

Affordability

- Energy efficient mechanical systems reduce operating costs

RELATED PUBLICATIONS

2010 National Building Code of Canada,
National Research Council of Canada

CAN/CSA-F326-M91: Residential Mechanical Ventilation Systems,
Canadian Standards Association

CAN/CSA B149.1-10: Natural gas and propane installation,
Canadian Standards Association

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CHAPTER 21
Interior Wall and Ceiling Finishes



Interior wall and ceiling finishes should have a pleasing appearance and resist normal wear and tear. The most common interior finish used in house construction is painted gypsum board (drywall). Plywood, hardboard, simulated veneer hardboard and lumber are also used occasionally.

GYPSUM BOARD FINISH

Gypsum board is the most widely used interior finish because of its speed of installation, low cost, consistent result and fire resistance. Several types have special characteristics such as additional fire resistance or water resistance for use in humid areas such as bathrooms. Various accessories such as corner beads and coves are also available.

Gypsum board is a sheet material composed of gypsum filler between two layers of paper. Sheets are 1.22 m (4 ft.) wide and are supplied in various lengths, 2.44 m (8 ft.) and longer. The edges along the length of the sheet are tapered on one face to receive joint compound and tape. To obtain an even surface, install gypsum on studs and ceiling joists and furring strips that are straight and aligned.

Although 9.5 mm (⅜ in.) thick gypsum board may be used on walls with support spacings up to 400 mm (16 in.) on centre when the boards are oriented perpendicular to the framing, 12.7 mm (½ in.) gypsum board is more commonly used because of its extra stiffness and strength. Where supports are spaced at 600 mm (24 in.) on centre, the minimum thickness should be 12.7 mm (½ in.). When gypsum board supports insulation, it must be at least 12.7 mm (½ in.) thick. Some ceiling gypsum board is specially designed to resist sagging when water-based textured finishes are applied to a ceiling. A 12.7 mm (½ in.) panel can be installed perpendicular to supports at spacings up to 600 mm (24 in.).

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Gypsum board is usually applied in single sheets directly on the framing members. On ceilings, the board is applied with the long dimension at right angles to the trusses or joists. When ceilings are strapped with 19 × 89 mm (1 × 4 in. nominal) lumber, the long dimension would run parallel to the trusses or joists.

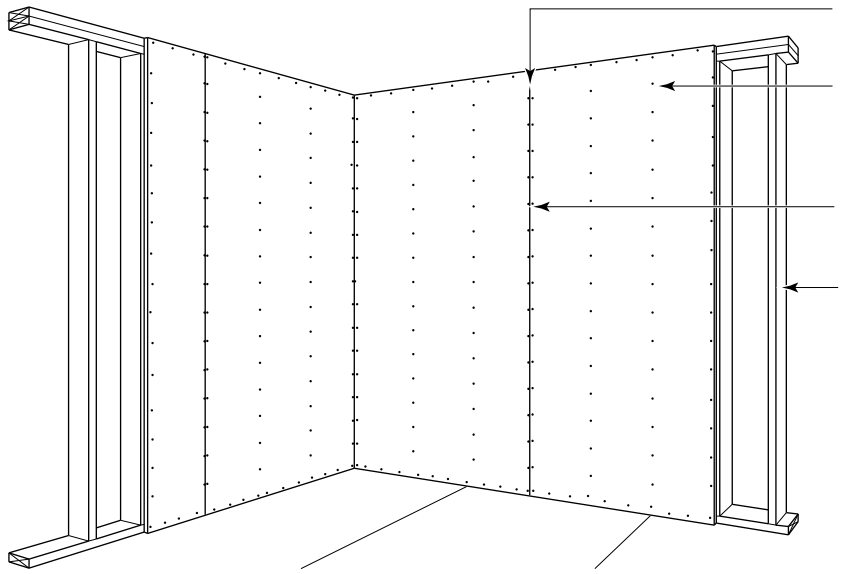
On walls it is more common to apply the sheets horizontally because horizontal joints are located at a convenient height for taping and sanding. Ends of sheets should terminate at a corner and always on a support.

Nail Attachment

Gypsum board panels can be attached to wood members by nails or screws (Figure 164). Nails should be ringed, with 2.3 mm (3⁄32 in.) shanks and 5.5 mm (7⁄32 in.) diameter heads. The nails should be long enough to penetrate at least 20 mm (¾ in.) into wood supports. Screws should be long enough to penetrate at least 15 mm (⅝ in.) into wood supports.

The fastener heads are set slightly below the surface without damaging the paper so that a slight dimple is formed in the face of the board,

164 Application of drywall finish



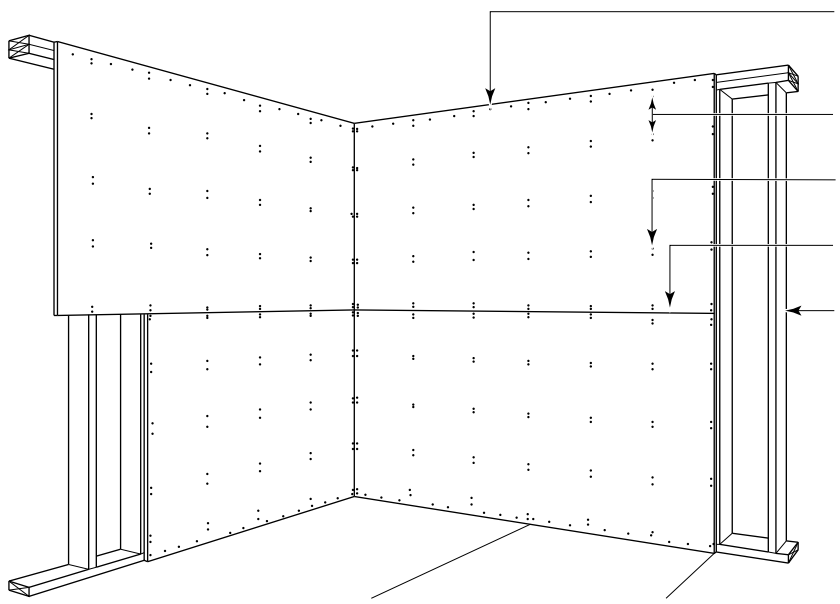
Vertical application and single nailing

moderate contact

space 150-200 mm (6 to 8 in.) o. c.

recessed edge

stud



Horizontal application and double nailing

double-nailing pattern nail 50 mm (2 in.) apart

300 mm (12 in.) intervals

nail or screw to stud

recessed edge

stud

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which will be filled with joint compound (Figure 165). The fasteners at the recessed edge of the sheet may be driven with the heads flush since they will be covered with tape and joint compound.

Gypsum board may be "double-nailed," that is, nails are driven in pairs about 50 mm (2 in.) apart at the required intervals (Figure 164). For ceilings, double nails are spaced no more than 300 mm (12 in.) on centre along the supports. For walls, double nails are spaced no more than 300 mm (12 in.) on centre. For single-nailing, the ceiling nails are spaced no more than 180 mm (7 in.) on centre and for walls, at 200 mm (8 in.) on centre.

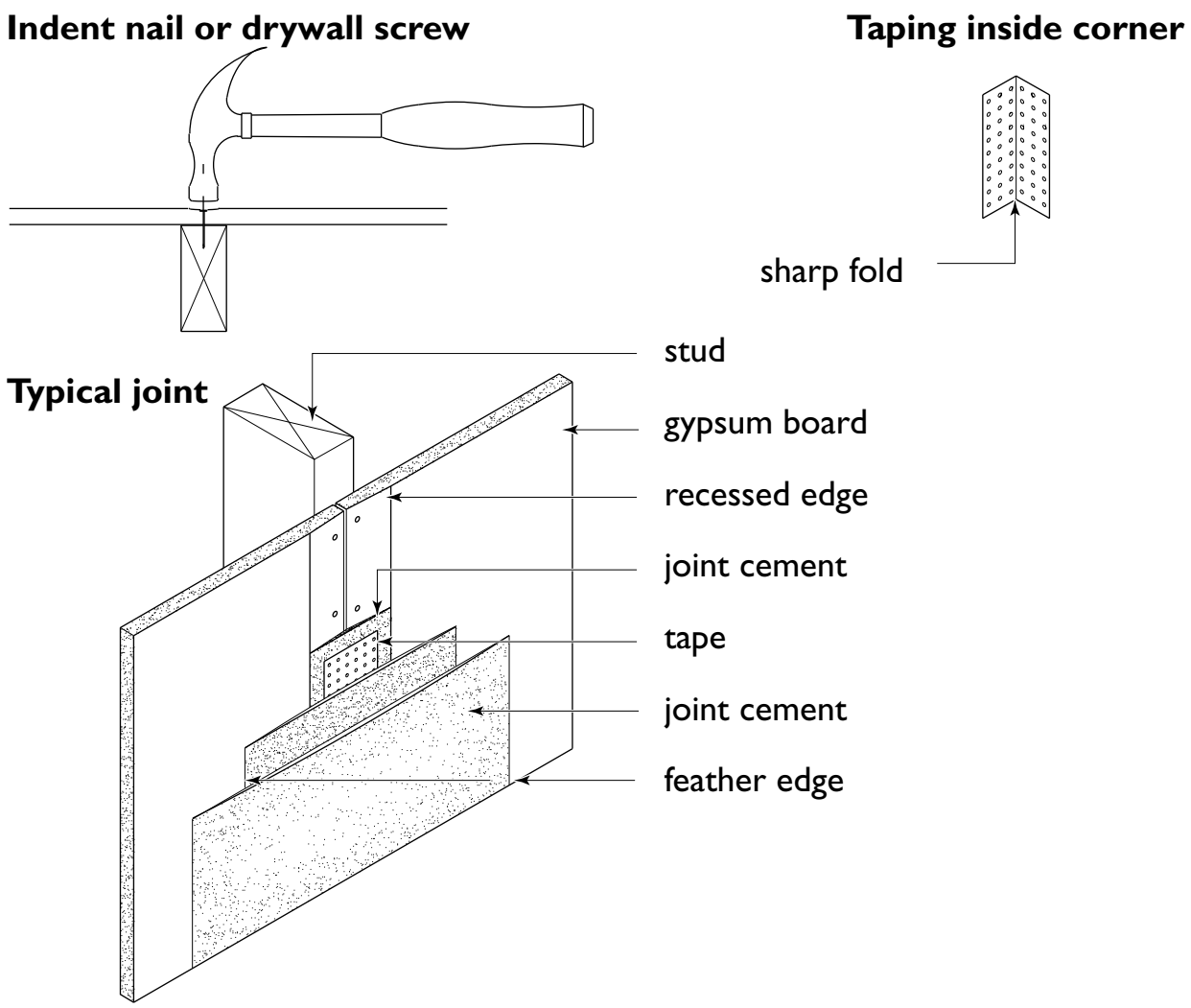
Where gypsum board provides required bracing in braced wall panels in areas exposed to high wind or earthquake forces, the nail spacing must not be more than 200 mm (8 in.).

Screw Attachment

Special drywall screws are often used to fasten gypsum board using screw guns. Screws are usually spaced 300 mm (12 in.) on centre at both the edge and intermediate supports. The distance can be increased to 400 mm (16 in.) on walls when the supports are not more than 400 mm (16 in.) on centre. Where gypsum board provides required bracing in braced wall panels in areas exposed to high wind or earthquake forces, the screw spacing must not be more than 300 mm (12 in.).

If two layers of gypsum board are needed, such as for sound control or additional fire rating, fasten the boards in the usual manner with nails or screws. The fasteners for the second layer must penetrate as much as for the first layer.

165 Finishing of gypsum board



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If gypsum board is not to be directly attached to the structural members but instead to channels (for example, resilient metal channels) for sound control and/or fire resistance, the channel must be secured to the structure and the gypsum board affixed to the channel.

Finishing Joints

The taping and finishing of gypsum board should be done at 10°C (50°F) or higher. Before the joints are taped, remove all loose paper and clean the joints. Fill all joints wider than 3 mm (⅛ in.) with joint compound and let it dry. Protect external corners with metal corner beads, and tape inside corners using paper tape folded as shown in Figure 165.

Joint compound is supplied premixed or in powder form that is mixed with water to a soft putty consistency. Apply the first layer of joint compound in a band 125 mm (5 in.) wide along the joint. Apply the tape and press it into the wet compound with a trowel or wide-blade putty knife. Remove excess compound, smooth the tape and feather the compound band to zero thickness at its outer edges.

After the first layer has dried, apply a second layer in a band 200 mm (8 in.) wide on recessed joints and 250 mm (10 in.) wide where the edges of the board are not recessed. Feather the edges.

Apply a third layer and feather to a band 250 to 300 mm (10 to 12 in.) wide on recessed joints and 400 mm (16 in.) on joints that are not recessed. Make this layer as smooth as possible to reduce sanding. When the third layer has set, sand the feathered edges lightly with fine sand paper and avoid damaging the paper surface of the gypsum board.

Nail and screw heads and indentations in the centre of the board are filled with two layers of joint compound.

Nail and Screw Popping

Popping can occur with both drywall nails and screws. It results from wood shrinkage and will likely occur, if at all, during the first heating season as the moisture content in the wood acclimatizes to the average humidity level in the house. Popping can be minimized by using framing lumber with a moisture content of not more than 19 per cent as stipulated in the NBC and nails or screws that are just long enough to meet code requirements so that a minimum length of fastener is embedded in the area where shrinkage takes place.

WALL TILE FINISHES

Ceramic, porcelain, glass, marble and granite tiles are used for wall finishes in bathrooms and kitchen areas. Ceramic, porcelain, marble and granite tiles can be applied with an adhesive or in a mortar base. Glass tiles are installed with adhesive. Porcelain tile on walls around showers or bathtubs must be installed over a moisture-resistant backing. Typically, adhesive is used to affix tiles to a moisture-resistant gypsum board in these areas.

The joint between a bathtub or shower stall and wall finish is an obvious location for water leakage. Joints must be caulked with sealants that conform to CGSB standard *CAN/CGSB-19.22-M: Mildew-Resistant Sealing Compound for Tubs and Tiles*.

OTHER FINISHES

Other products such as plywood, OSB, particleboard and lumber can be used for interior finishes. Lumber, plywood and medium density fibreboard (MDF) wainscoting are often used as decorative finishes. In this application, they are installed over and attached to the gypsum board finish. Typical softwood species include cedar, pine or hemlock; hardwoods include maple, birch or cherry.

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Insulating fibreboard tiles are occasionally used to finish ceilings in basements. Tiles vary in size from about 300 mm (12 in.) square to 400 × 800 mm (16 × 32 in.). The tiles are tongue and grooved and supported by concealed nails, clips or staples. They should be 12.7 mm (½ in.) thick when supported not more than 400 mm (16 in.) on centres.

SUSTAINABLE HOUSING INSIGHT

Healthy Indoor Environment

- Use low pollutant-emitting, water-based paint to finish gypsum board surfaces.

Energy Efficiency

- Gypsum board is an effective air barrier when sealed to other components of the air barrier system, and can reduce heat lost through air leakage.
- Ensure that the various construction activities do not damage the air barrier system.

Resource Efficiency

- Use local materials where possible and avoid those that must be transported long distances.

Affordability

- Drywall is a durable and cost-effective finish for walls and ceilings. It is inexpensive to repair and maintain and is the preferred covering for most occupants.

RELATED PUBLICATIONS

About Your House: Accessible Housing by Design—Living Spaces,
Canada Mortgage and Housing Corporation (product no. 66095)

CAN/CGSB-19.22-M: Mildew-Resistant Sealing Compound for Tubs and Tiles,
Canadian General Standard Board

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CHAPTER 22
Floor Coverings



Finished flooring includes products such as wood strip flooring, engineered (laminate) flooring, resilient flooring, ceramic tile and carpet. The two essential properties of finished flooring are durability and ease of cleaning.

Hardwoods such as birch, maple, beech and oak are used in a variety of widths and thicknesses as strip flooring. Parquet flooring is also made from some of these species. Floor coverings should not be laid until interior wall and ceiling finishes are completed.

SUB-FLOOR AND UNDERLAY REQUIREMENTS

Sub-flooring is required under any finish flooring that is not capable of supporting specified live loads. The thickness of wood-strip flooring required for various support conditions is shown in Table 41 (Appendix A). When wood strip flooring at least 19 mm (¾ in.) thick is laid perpendicular to the joists, no underlay or sub-floor is required for joist spacings up to 400 mm (16 in.), but all end joints must be staggered and be located over joists. When the wood strips must be run parallel to lumber subflooring, an underlay is required to provide support. When lumber subflooring is used under wood strip flooring, it must be laid diagonally and the wood strips can be laid either parallel or at right angles to the joists.

Sub-flooring is required under laminate flooring, parquet flooring, resilient flooring, ceramic tile and carpet. A panel-type underlay is also required for these types of flooring when the sub-flooring is lumber. Some engineered wood flooring does not require an underlay.

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Ceramic tile must be set in a mortar bed. For ceramic tile applied with an adhesive, the edges of the sub-floor must be supported by means of tongue-and groove panel edges or blocking. In either case, underlay is recommended.

Plywood or OSB sheets at least 6 mm (¼ in.) thick commonly serve as underlay and particleboard may also be used. Ensure that the particleboard is approved for use with the finished flooring material by checking the manufacturer's installation instructions.

Attach the underlay to the subfloor with annular grooved nails spaced not more than 150 mm (6 in.) apart along the edges and at 200 mm (8 in.) centres in both directions over the rest of the panel. Use nails at least 19-mm (¾ in.) long for 6 mm (¼ in.) sheets and at least 22 mm (⅞ in.) long for 7.9 mm (5⁄16 in.) sheets.

Staples or screws may also be used. Fill joints between the underlay and any surface defects with non-shrinking filler compound that will bond to the underlay. Sand the filler smooth after it has set.

WOOD STRIP FLOORING

Wood-finish flooring is widely used in living and dining rooms, bedrooms and hallways. Hardwoods such as birch, maple, beech and oak are used in a variety of widths and thicknesses as strip flooring. Vertical-grain softwoods such as fir or hemlock are sometimes used. The flooring may be stained and finished after installation or it may be factory finished.

Wood-strip flooring, which is manufactured in various widths and thicknesses, comes in several grades and is bundled in random lengths.

Strip flooring looks best when laid lengthwise in a rectangular room. The tongue-and-groove strips are profiled on the back to control cupping and checking. The top face is slightly wider than the bottom so that when the strips are driven together the upper edges touch, but the lower edges are slightly apart. A tight fit is necessary to avoid squeaks.

Wood strip flooring should not be brought into a house until the concrete in basements has cured (shed moisture) and the gypsum board finishing has been completed so that the house humidity level has moderated. The flooring should be kept in a warm, dry place until it is installed. If installed with a high moisture content, it will be prone to shrinkage as it dries and may develop openings between the joints.

Various types of nails, including annular and spiral-grooved types, are used to attach the flooring. Minimum nail lengths and nail spacing are listed in Table 42 (Appendix A). Staples applied with manual and pneumatic tools are also used.

Many installers use a mallet-driven nailing tool that drives the nail in the proper location, at the correct angle, and sets the head to the proper depth.

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Figure 166 shows the method of nailing the first strip of flooring with the nail driven down through the board at the grooved edge. Drive the nails into the subfloor or joist and near enough to the edge so that the base or shoe moulding will cover the nail heads. Also nail the first strip of flooring through the tongue.

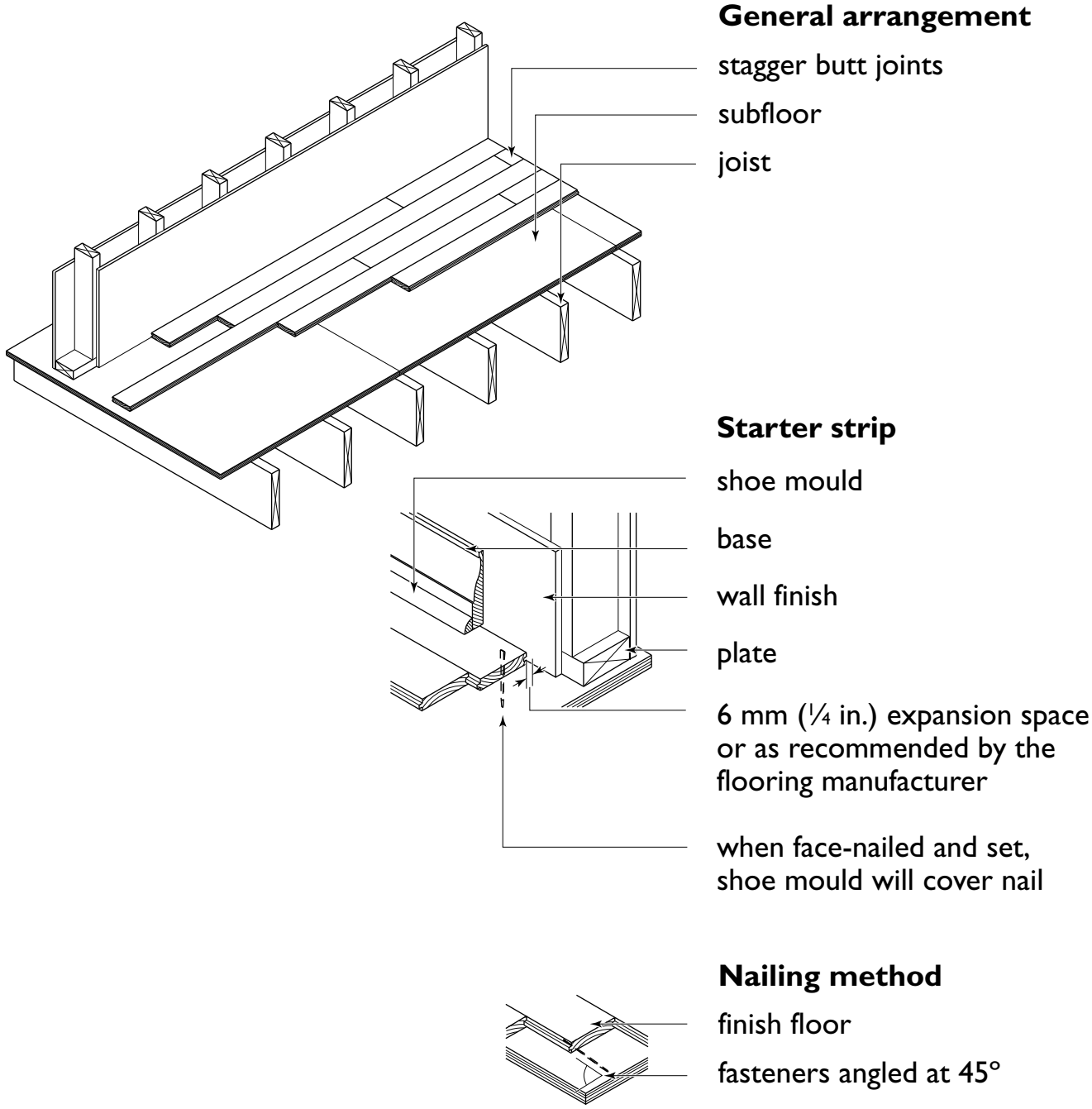
Succeeding strips of flooring can be fastened with a hammer by driving nails into each strip at a 45° angle at the spot where the tongue adjoins the shoulder. Use a nail set for the final driving so that the wood is not damaged.

To avoid splitting the wood, nail holes sometimes have to be drilled through the tongue. For all courses of flooring after the first, the pieces should be selected by length so that the butt joints are well separated from those in the previous course. Use a piece of scrap flooring to force each piece against the previous course.

LAMINATE AND ENGINEERED FLOORING

Laminate flooring, an economical option, is made of a melamine-infused paper laminated to a particleboard substrate and comes with

166 Application of strip flooring



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interlocking joints that make it easy to install with instructions included in the packaging. The thin decorative surface cannot be easily repaired if it is scratched.

Engineered flooring is made by gluing wood veneer to a plywood substrate and applying a factory finish. It is generally more economical than wood strip flooring because only a small proportion of high-quality wood is used. It is made with interlocking joints that make it easy to install according to the instructions that come with the packaging.

PARQUET FLOORING

Parquet flooring is made of small pieces of wood arranged in a pattern and glued to a backing to make tiles. Typical species used for parquet flooring are birch, maple, beech and oak. The tiles have mating edges. Flooring manufacturers have developed a wide variety of special patterns of flooring referred to as parquet flooring with specific installation directions. If parquet flooring is placed over lumber subflooring or panel subflooring whose edges are not supported (blocked or tongue-and-groove), panel underlay is required.

RESILIENT FLOORING

Resilient flooring is water-resistant and is used in bathrooms, kitchens, laundry rooms, entrance halls and general storage areas. The more common types of resilient floor covering are vinyl and rubber. Both types are available in tile and sheet form. If resilient flooring is placed over lumber subflooring or panel subflooring whose edges are not supported (blocked or tongue-and-groove), panel underlay is required.

Resilient flooring is usually cemented to the underlay with an adhesive recommended by the manufacturer for its compatibility with the flooring product. Waterproof adhesives are preferable to the non-waterproof types, especially in kitchens, bathrooms, entranceways and laundry rooms.

Both tile and sheet material should be installed according to the manufacturer's recommendations. Immediately after the flooring is laid, it should be rolled in both directions.

Resilient flooring applied over concrete slabs must be a type recommended by the manufacturer for this use and must be affixed with a compatible waterproof adhesive.

CARPET

Carpet is commonly used in living rooms, bedrooms and family rooms. It should not be used in areas where water damage or staining is likely to occur. When carpet is desired in such areas, a synthetic-fibre type should be used. For hygienic reasons, carpet is not recommended for use in rooms containing a toilet.

Except for cushion-backed carpeting, felt or polymeric carpet underlay should be used.

When a subfloor is not constructed as a combination subfloor and underlay as described in Chapter 9, an underlay must be installed.

CERAMIC, PORCELAIN, GRANITE AND MARBLE TILE

Ceramic, porcelain, granite and marble tile is water-resistant and is typically used in bathrooms, kitchens, entrances and for fireplace hearths. It is available in different colours either with glazed or unglazed surfaces.

Tile may be laid either directly on a concrete, plywood or OSB base with an adhesive or in a mortar bed about 30 mm (1³⁄₁₆ in.) thick over

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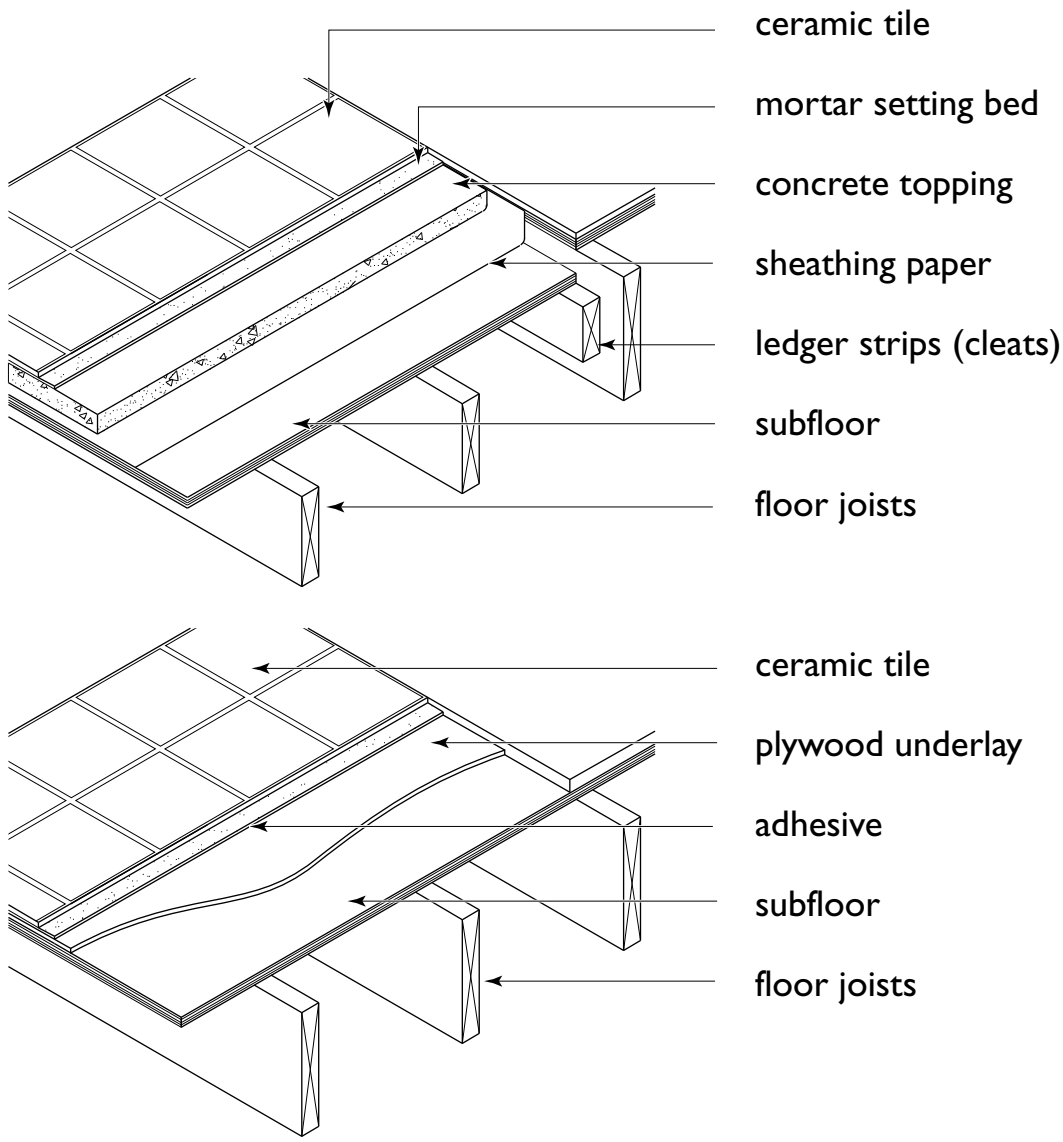
a concrete or wood-frame floor (Figure 167). If ceramic tile is to be placed over lumber subflooring or panel subflooring whose edges are not supported (blocked or tongue-and-groove), panel underlay is required. The edges of the subfloor joints must be offset.

Bedding mortar may consist of 1 part Portland cement, ¼ part lime and 3 to 5 parts coarse sand. A number of manufacturers have pre-packaged mortar mixes formulated for various subfloor conditions. The tiles are pressed into the fresh mortar. To ensure a good bond between the joint material and base, the joints between the tiles should be filled the same day the tile is installed.

Tile applied to a wood floor with an adhesive is particularly sensitive to deflection. The base must be smooth and free from surface irregularities. The adhesive is applied to both the tile and the base, and each tile is then pressed firmly in place. After the adhesive is well set, the joints between the tiles are filled with grout recommended by the tile manufacturer.

Ceramic, porcelain, granite and marble tiles in shower bases should be laid on a proprietary or site-constructed, waterproof liner that is connected to the shower drain. This will prevent water damage to the ceiling below, should the tile and its cement base develop a crack.

167 Installation of ceramic tile floor



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SUSTAINABLE HOUSING INSIGHT

Healthy Indoor Environment

- Carpet collects dust and dirt and can be unsuitable for people with respiratory ailments. Solid-surface finishes, such as hardwood, ceramic and vinyl are easy to clean and are suitable for most people with environmental sensitivities.
- Wood and engineered wood flooring are durable and easy to clean, and are less likely to retain dust and allergens than carpet.
- Use prefinished flooring or water-based floor varnish for hardwood flooring.

Environmental Responsibility

- Select adhesives that are compatible with the materials and have low emissions.
- Bamboo and cork flooring are natural alternatives to wood, vinyl composite tile and ceramic tile.

Affordability

- Floors are high-use surfaces and using better quality flooring materials may result in lower costs over time.

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CHAPTER 23
Interior Doors, Frames and Trim



This chapter covers interior doors, trim and cabinetry installed in the finishing stages of house construction.

The decorative treatment for interior doors and trim may be paint or natural finish with stain and varnish. Prefinished products are also available. The finish selected for woodwork in various rooms may determine the type or species of wood to be used.

INTERIOR DOORS

Interior doors are used to separate living areas and provide privacy. Options include single and double swinging doors, and pocket doors. Sliding doors and folding doors are popular choices for clothes closets.

Bedroom and passageway doors must be at least 760 mm (30 in.) wide and 1.98 m (6 ft. 8 in.) high. Doors providing access to laundry and utility rooms must be at least 810 mm (32 in.) wide. The standard thickness of interior doors is 35 mm (1⅜ in.). They are available in various widths and heights.

Install doors so that they open in the direction of natural entry. Doors should also swing against a blank wall wherever possible and not be obstructed by other swinging doors.

Interior doors are usually made of wood, wood composites or plastic. There are two general types of interior doors: flush and panel.

The flush door is made up of facings of plywood or other sheet material glued to a light framework. For a natural or varnished finish, the face plies are selected for quality and colour. For a painted finish, the face plies may be less expensive or non-select grades.

The panel door consists of solid stiles and rails with panel fillers of various materials. These create relief panels in the door and are available in a number of designs.

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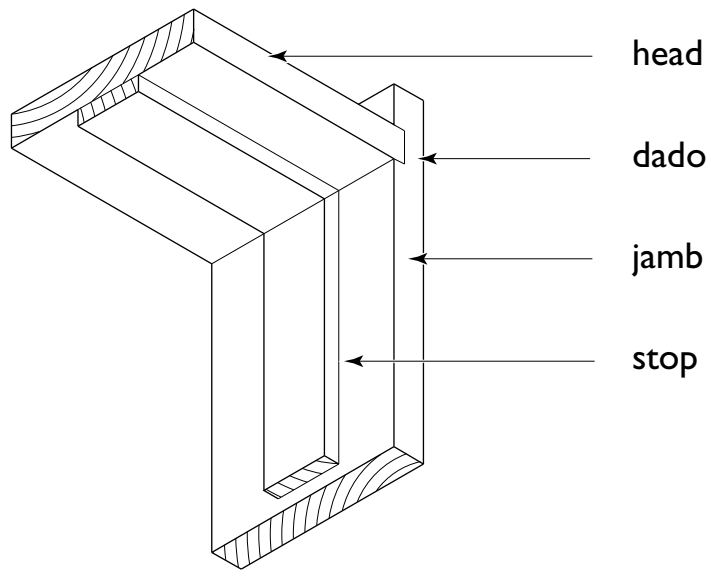
Door Installation

Interior doors are most often purchased as "pre-hung," meaning that the door, hardware and frame are provided and holes and notches for the hardware are ready for installation into the framing rough opening.

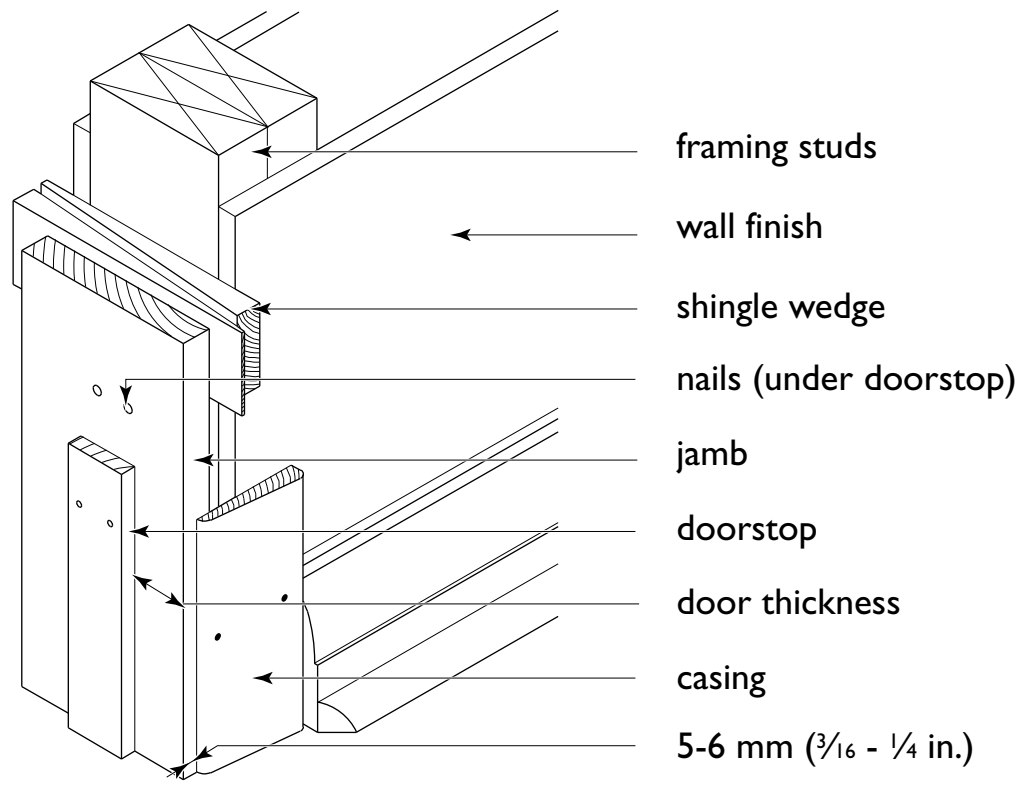
Door frames are made up of two jambs and a head, together with separate mouldings called doorstops. Stock jambs are made of 19 mm (¾ in. nominal) lumber, cut to widths to suit the thickness of the finished wall and usually shaped at the mill, with doorstops and head cut to size (Figure 168). Frames may also be rabbeted to form the stop, in which case the thickness of the frame is usually increased to 32 mm (1¼ in.). If frames come unassembled, attach them with nails or screws at each corner.

Use shims (usually wood shingles) between the jamb and rough-opening studs (Figure 169) to align the frame. Place shims at the ends of

168 Interior door frame showing typical connection between jamb and head



169 Door frame and trim showing frame blind-nailed under doorstop



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the jambs and at hinge and latch locations. Set the frame so that it is plumb and square, and then screw or nail the jambs securely to the studs through the wedges. After nailing, the wedges are sawed flush with the face of the wall. Drive nails in pairs.

Doorstops are usually 10 × 32 mm (⅜ × 1¼ in.) and nailed to the jamb with finishing nails after the door is hung.

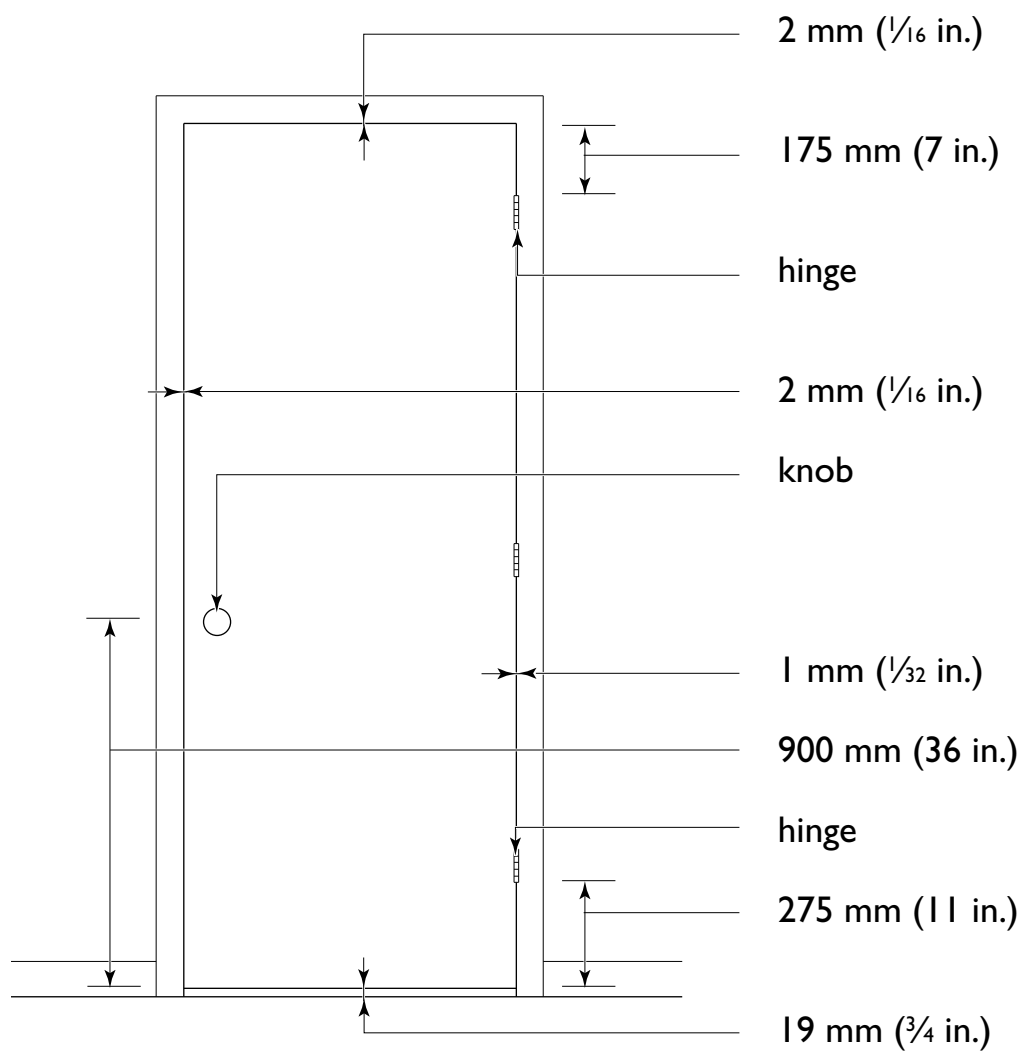
Figure 170 shows standard clearances and the location of door hardware. Where three hinges are used, the centre one is spaced midway between the top and bottom hinges. Standard knob height is 860 to 960 mm (34 to 38 in.) from the floor, and locks or latches should be installed accordingly. Lever-type handles permit easier operation by persons with limited dexterity.

The clearance between the door and frame allows for smooth operation even if the door expands during humid weather and when clearance is reduced from painting. The clearance at the bottom may have to be increased to clear carpet.

Casing is the framing or edging trim used around door openings and comes in several patterns. Casing is made from wood, finger-jointed wood and pre-primed medium density fibreboard, which can be cut and worked like wood. The top casing joints are usually mitred but other designs such as corner blocks may be used.

Place the casings 5 to 6 mm (3⁄16 to ¼ in.) from the inner edge of the jamb and nail them to framing studs and jambs with finish nails. Space nails about 400 mm (16 in.) apart, countersink and fill them with wood filler.

170 Suggested dimensions and location of hardware



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HARDWARE INSTALLATION

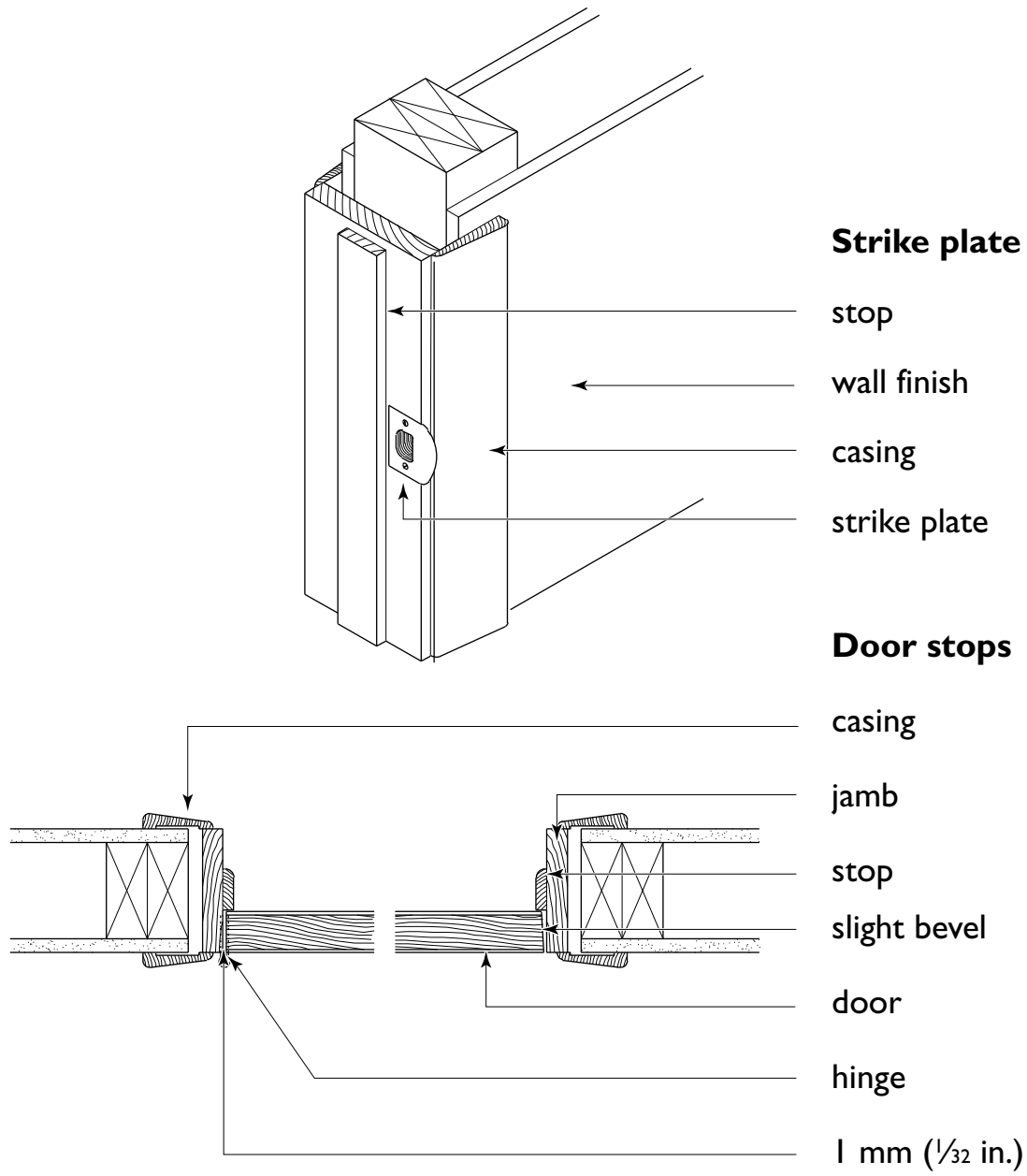
Hinges must be the proper size for the weight of door they support. For 35 mm (1 ⅜ in.) thick interior doors, use two 76 × 76 mm (3 × 3 in.) butt hinges. For heavier doors, use three hinges. Fit the door into the jamb opening to ensure it has the proper clearances, then remove it and install the hinges.

If not factory prepared, mortise the door to nest the half hinges. The edge of each hinge should be at least 3 mm (⅛ in.) back from the face of the door. When the hinge halves are screwed in place, they must be flush with the surface and square.

Place the door in the opening and shim it at the bottom to provide the proper clearance. Mark the jamb at the hinge locations and mortise it to accept the other hinge halves and screw them into place. Place the door into the frame and insert the hinge pins.

To install the knob/handle and latch, mortise an inset for the latch and attach the latch and knob/handle. Mark the latch location on the jamb, and mortise an inset for the strike plate (Figure 171) and affix it so it is flush with or slightly below the face of the jamb. When the door is latched, the face of the door should be flush with the edge of the jamb.

171 Door installation



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Nail the doorstop permanently in place. Affix the stop at the jamb on the latch side first (Figure 170). Then attach the doorstop on the hinge side by leaving a 1 mm (1/32 in.) clearance from the door face to prevent rubbing when the door is opened or closed. Nail the head doorstop in place. Use finishing nails, and countersink and fill them.

Locks are not required for interior doors but are often installed when privacy is an issue (bathrooms, for example).

TRIM AND MOULDINGS

Trim is usually made from solid or finger-jointed wood or from medium density fibreboard (MDF). Wood trim is manufactured at a moisture content of around 12 per cent and should be kept dry during storage.

Solid wood trim should be smooth and knot-free and used if the trim will have a clear finish. Common species are oak, pine, fir, basswood and poplar.

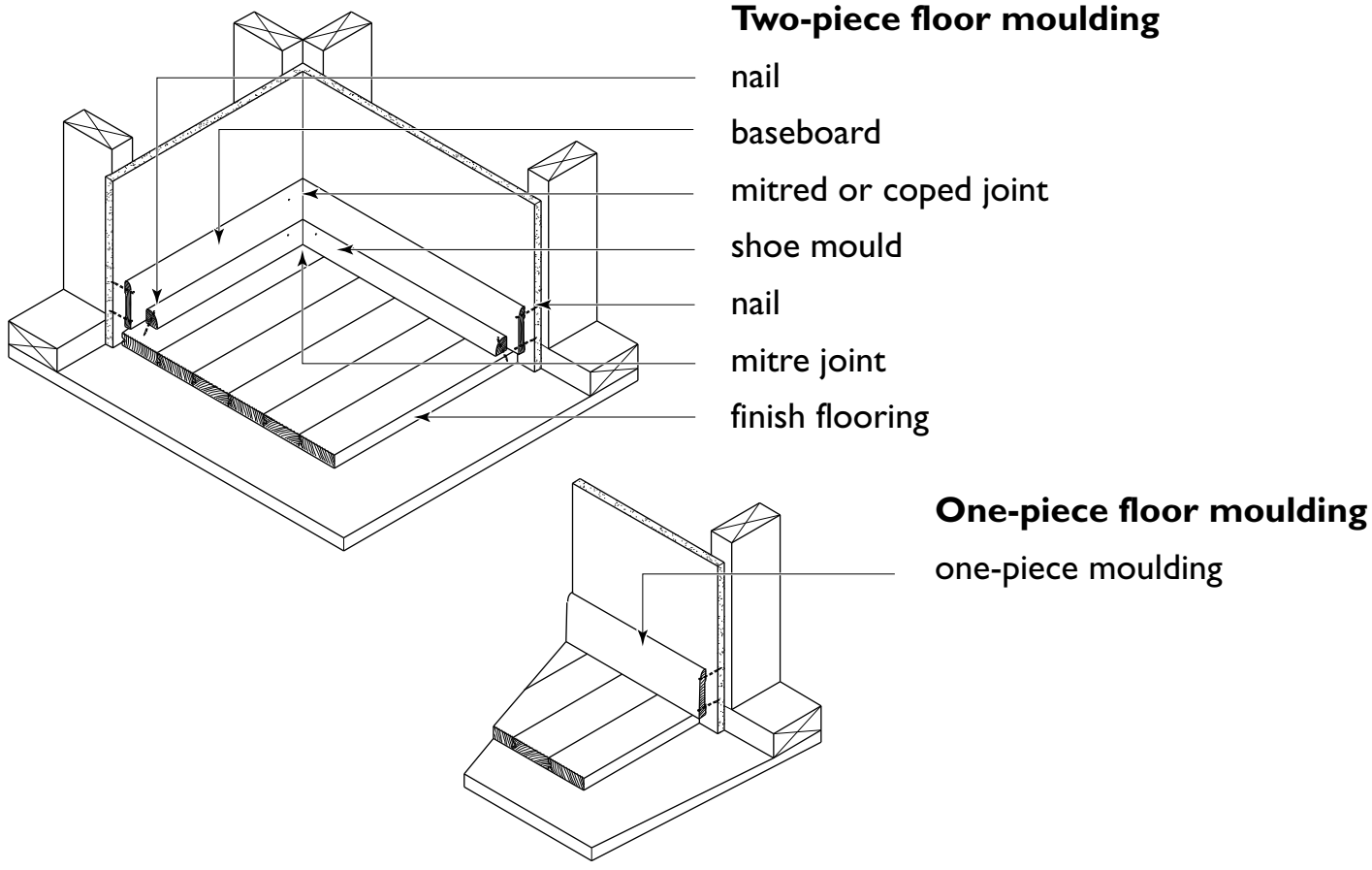
Finger-jointed wood trim is acceptable for painted applications. MDF can be purchased finished or primed.

Window trim is usually the same pattern selected for the doors. Casing is applied with finishing nails on all four sides of the window, except where a sill is used. In this instance, the casing terminates on top of the sill, and an apron is added as a finish trim below the sill.

Base moulding (baseboard) is applied at the base of walls. Many shapes and sizes are available in solid wood, finger-jointed wood and MDF. A two-piece base moulding consists of a baseboard fitted with a shoe mould at the bottom (Figure 172). A one-piece base is milled with a thickened edge at the bottom to cover the flooring joint. Another type of two-piece moulding consists of a baseboard and a cap that fits smoothly against the finished wall.

When a two-piece base is used, the baseboard is nailed through to the wall plate and studs, high enough so that the lower edge clears the finish

172 Base moulding



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floor. The shoe mould is later nailed to the floor using a long thin nail driven at an angle that holds the shoe mould tightly against both the baseboard and the finish floor. A one-piece base is fitted tightly to the finish floor and nailed to the wall plate or studs. The one-piece base or the shoe mould is installed after the resilient floor or carpet has been laid or after strip flooring has been sanded.

Joints at interior corners may either be mitred or butted and coped. Butted and coped corners are made by butting the first piece of trim against the corner. The second piece is then coped to match the profile of the first piece. Exterior corners are mitred. Fasten with finishing nails with heads countersunk and filled.

MILLWORK

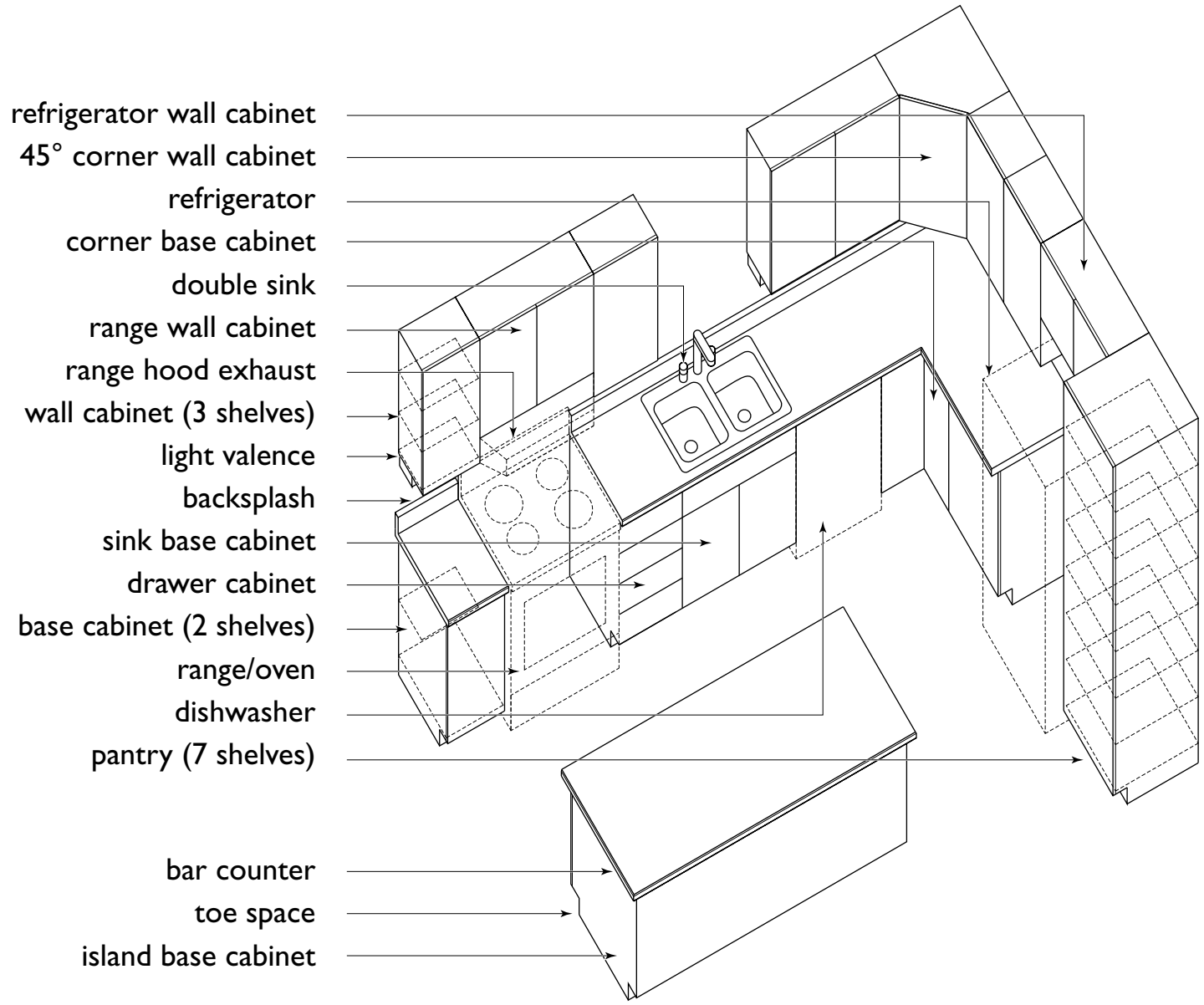
Kitchen cabinets, shelving, mantels and other items of millwork are often installed at the same time as the interior trim, usually before strip flooring is sanded or resilient flooring is laid. Most cabinets are shop-built to order based on customized layouts and desired wood species, finish and hardware.

Kitchen Cabinets

An efficient arrangement of kitchen cabinets, sink, refrigerator and appliances, such as microwave ovens and range, provides an efficient work area and saves steps.

Base units of kitchen cabinets are approximately 900 mm (36 in.) high, and countertops are 625 mm (25 in.) deep (Figure 173). Various

173 Kitchen cabinets



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combinations of drawers and doors may be included in the base. A corner cabinet can be fitted with revolving shelves to maximize space utilization. The countertop and backsplash are usually one piece and faced with plastic laminate or other impervious covering.

To provide workspace, wall cabinets are set about 400 mm (16 in.) above the counter. Cabinets above the stove and sink are usually higher. The finishes and cabinetry installed directly above cooktop burners must be at least 750 mm (30 in.) from the elements or burners. Where the cabinets are protected by non-combustible surfaces or are fitted with a metal hood projecting 125 mm (5 in.) beyond the edge of the cabinets, the distance between them and the burners can be reduced to 600 mm (24 in.).

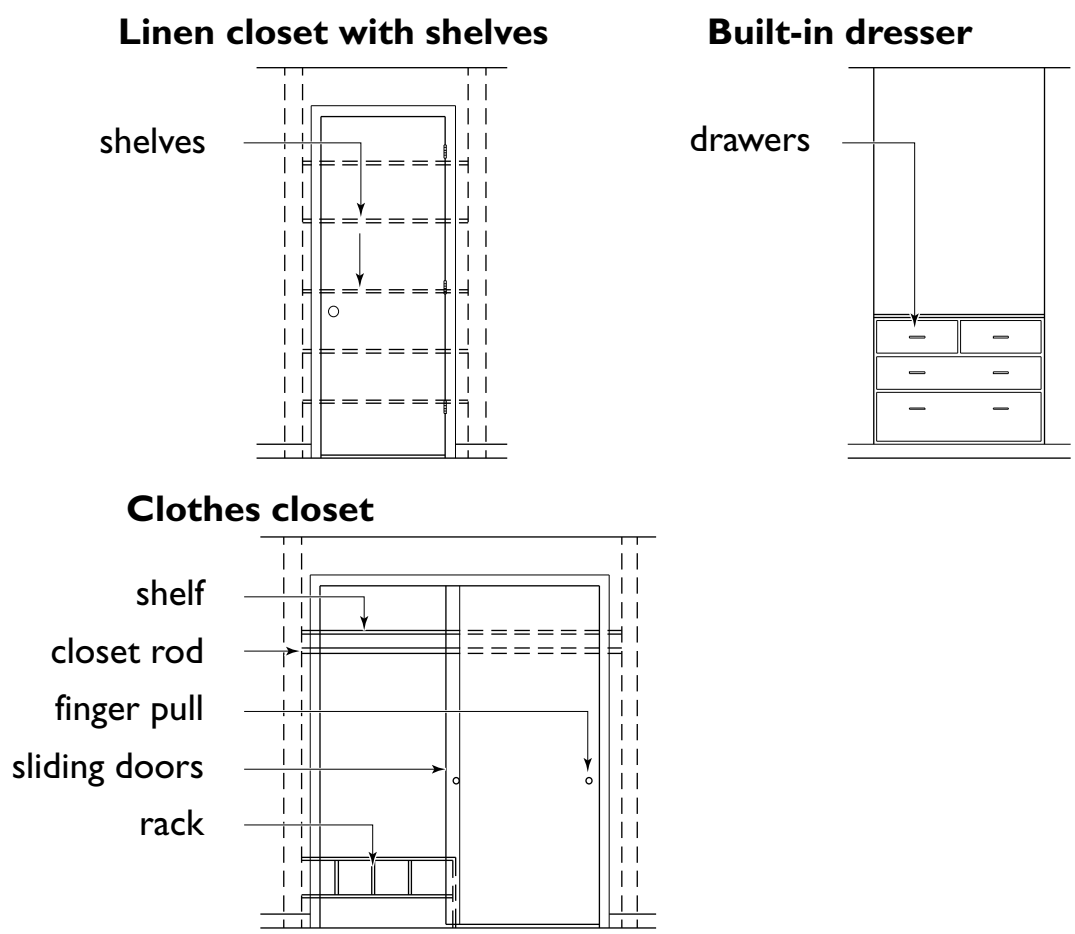
Kitchen cabinet shelves are usually 275 to 300 mm (11 to 12 in.) deep. Wall cabinets may extend to the ceiling or a space may be left above the cabinets.

Closets

Clothes closets are commonly provided with shelves and a closet rod or metal track. Manufactured storage units may be used in lieu of a site-built closet or may be installed in closets to maximize storage room. Built-in cabinets may also be used in bedrooms. Larger houses may have small rooms (walk-in closets) for clothes storage. Closets on exterior walls should be avoided—the lack of air circulation and presence of clothing and other items act as unintentional insulation, lowering the interior wall temperature and increasing the risk of condensation.

A standard interior door (Figure 174), sliding doors, multiple doors or bi-fold doors can be used in pairs or other multiple combinations to provide optimum access to closet space.

174 Storage closets



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SUSTAINABLE HOUSING INSIGHT

Healthy Indoor Environment

- Select cabinetry built with materials having low VOC emissions.
- Deeply-profiled surfaces and projections can collect dirt and dust. Consider choosing doors, trim and cabinets with easy-to-clean surfaces, hardware and finishes that prevent the accumulation of dust and dirt.

Environmental Responsibility

- High-density fibreboard (HDF), medium-density fibreboard (MDF) and particleboard are made from wood residue, which reduces the number of trees that need to be harvested. Consider using low pollutant-emitting products.
- If MDF is used in doors, cabinets and trims, all holes and cuts should be sealed to prevent off-gassing.

Affordability

- Solid doors and trims intended to have a paint finish can be made from MDF or finger-jointed wood, options that are less costly than solid wood.

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CHAPTER 24
Coating Finishes



The choice of coatings and coating techniques can seem overwhelming. Moreover, terminology can vary from one manufacturer to another. This chapter explains the properties and applications for the major coatings used in house construction: paint, varnish, stain and lacquer.

These types of coatings provide varying degrees of protection by retarding moisture fluctuation, reducing the effect of ultraviolet light, or providing increased resistance to abrasion. These products also accentuate wood grain and texture or give partial or full colour to wood surfaces.

COMPOSITION OF COATINGS

Paint, varnish, stain and lacquer have three major components:

Solvent: The solvent in a coating product thins the pigment/resin mixture to make it flowable (easy to apply). During the drying process, the solvent evaporates and has no effect on the physical properties of the cured paint film. Water and mineral spirit solvents are the types of solvent in most house coatings. Water solvent is more environmentally benign than mineral spirit solvent. Water solvent paint, varnish, stain and even lacquer products are available.

Pigment: The primary purpose of pigment in a coating is to provide colour and hiding ability, but some pigments are used to make sanding easier, control gloss level or simply act as a filler. Colour pigments give paint colour and opacity. Those dispersed by the tinting machines used in paint stores allow colour matching and mixing to produce any conceivable colour for both water- and solvent-based products.

Extender pigments are used to control the gloss of a coating. Gloss is the ability of a coating to reflect light. Generally, the higher the gloss of paint coating, the more washable and wear-resistant it is. Terms such as flat, satin, eggshell, semi-gloss and gloss describe gloss levels ranging from none to high. Since these terms

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do differ from one manufacturer to another, it is advisable to test a sample to make sure it has the desired reflectance.

Pigment also provides resistance to ultraviolet light. For this reason, paint lasts longer in outdoor exposures than stain or varnish. Rust-inhibiting pigments are used in conjunction with other pigments in metal primers to provide corrosion protection.

Resin: Resin is the film-forming ingredient that binds the pigment particles together after the paint has dried and gives physical characteristics such as adhesion and durability. Alkyd, latex and polyurethane are the resins used most frequently in coatings. Nitrocellulose is used most often for lacquer.

As the resin content increases, gloss and durability increase, but the ability of a coating to conceal imperfections decreases. For this reason, a high resin content coating would be the desired option where a lot of wear is anticipated, and a low resin content coating is advisable where flaws must be masked in a prepared surface such as gypsum board (drywall).

TYPES OF COATINGS

Paint

Paint is a coating that provides solid colour. The vast majority of residential-quality paints use alkyd or latex as their principal resin ingredients. Properties such as gloss, sheen, hardness, durability (including ability to be scrubbed without burnishing) and hiding ability are attained by adjusting the pigment/resin ratio.

The suitability of paint for exterior or interior application is determined by the chemical composition of the resin. Resin for exterior paint provides the elasticity to accommodate temperature and dimensional changes, and permeability to allow moisture movement without blistering the paint.

Sealers and primers are specially formulated to seal the grain in wood, or the surface of interior finishes such as drywall or plaster. They also prepare surfaces to accept paints, stains or varnishes.

Varnish and polyurethane

Varnish is a clear coating used as a topcoat over natural or stained wood for interior trim and architectural woodwork. It also has some exterior applications. Varnish is like paint but, because it is used as a clear finish, lacks hiding pigment. Most varnishes contain a resin combining alkyd with polyurethane. Water-reducible polyurethane is also available.

Stain

Stain is a coating with a high solvent content that causes colouring to be absorbed into the cell openings of wood surfaces. The degree to which a stain penetrates can be adjusted for specific applications. Although some stains penetrate to the extent that they leave no surface residue, most penetrate but leave some surface coating.

Stains are specially formulated to meet the specific requirements of interior and exterior uses. For exterior applications, stain is usually used alone but, in some instances, it may be top-coated with exterior quality varnish. When used alone, stain will alter the colour of the wood and provide a degree of protection from sun and water.

For interior applications, stain is used to alter the colour of wood and to accent grain and texture. A transparent topcoat is usually applied to seal the surface.

Lacquer

Lacquer is a fast-drying, protective top-coating used for fine finishing of architectural woodwork and furniture. It is normally used as a transparent finish, like varnish, to display the wood grain, but is also available in solid colours.

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Alkyd and Latex Coatings

Most paints, varnishes and stains used for the interior and exterior protection of walls, trim and other general purposes can be categorized generally as having either an alkyd or a latex resin base.

Alkyd coatings: Alkyd (oil) resins are used for the manufacture of general purpose paint, varnish, and stain. Alkyd paints containing a large amount of linseed oil give paints flexibility properties, which are important when they are used as exterior primers and paints.

Increasing the amount of alkyd and reducing the amount of linseed oil results in a hard interior/exterior enamel desirable for high-wear surfaces. Mixing alkyd and polyurethane resins further increases the hardness, which produces a polyurethane enamel. Enamel paint has a high degree of durability and therefore a fairly high gloss.

Latex coatings: Latex formulations contain latex as the resin, water as the solvent, and pigment such as titanium dioxide, extender pigments and colour pigments similar to those found in alkyd paints. Latex is used as the resin for paint, varnish and solid stains, but not for semi-transparent stains.

Latex resin is comprised of small spheres of plastic material suspended in a water solvent. As the paint dries, the spheres coalesce to form a film that covers the painted surface. The amount of resistance the finished surface has to abrasion from wear and scrubbing depends on the extent to which the pigment is covered by latex. As the latex resin content increases relative to the pigment, the gloss and durability increase, but the hiding power of the coating to conceal subsurface irregularities decreases.

Exterior and interior latex coatings differ in the type of latex used for the resin. Acrylic latex is the most used resin for exterior products. More economical PVA latex is commonly used for interior applications. For high quality interior paint, a blend of PVA and acrylic or straight acrylic is used.

Acrylic has better adhesion qualities than PVA. Acrylic latex paint would therefore be better for coating over alkyd paint than PVA resin latex.

Comparison of Alkyd and Latex

Most alkyd paints contain some vegetable oils such as linseed oil that have a tendency to yellow with time. Because latex coatings do not contain any oil, they have better gloss and colour retention.

Latex coatings dry faster and give less noxious odour than alkyd coatings and cleanup is done with water rather than the spirit or oil based solvents use for alkyd paints.

Flat latex paint tends to be more durable on exterior surfaces than alkyd finishes because the latex is permeable and allows the moisture content of wood to adjust rather than blister the paint. This is not the case for gloss latex paints that have a permeability similar to alkyds.

Alkyd coatings are still preferred for trim such as doors, frames and baseboards because they are harder, and flow better, thereby leaving fewer brush marks than latex coatings.

Because latex coatings are more environmentally benign than oil-based products, their use is encouraged.

APPLICATION

Proper surface preparation is essential to a successful coating finish. The application temperature is critical. Apply at temperatures above 10 °C (50°F) to surfaces that are dry, clean and dust free.

If latex paint is applied at a low temperature, proper film formation will not occur, making it susceptible to peeling. At low temperatures, alkyd paint dries too slowly and is susceptible to damage.

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Exterior Coatings

The durability of exterior coatings depends on whether the coating permits the movement of moisture, thereby avoiding blistering, and excludes the ultraviolet portion of sunlight, which causes the coating to deteriorate.

Wood products treated with water-borne wood preservatives can be coated using the same products and techniques as for untreated materials. As is the case with all wood products used in exterior applications, coating performance will be best if the moisture content of the underlying material is 19 per cent or less.

Primer provides some early protection and ensures adhesion between wood and topcoats. Prime surfaces for painting as quickly as possible after installation. As wood weathers, it takes on a grey appearance that can seriously affect adhesion of paint. Sand it off before priming.

Use alkyd paints for doors and trim where durability is needed, and latex paints for wood cladding to allow moisture movement and minimize the potential for blistering.

Varnish made for exterior use contains no colour pigment and has only limited ability to screen ultraviolet light. This means varnish is a high-maintenance coating for exterior applications with 4 or 5 coats required initially and annual coatings afterward.

Interior Coatings

Interior surfaces are painted to provide a pleasing appearance and to protect them from damage by moisture that is prevalent in the kitchen, bathroom and laundry rooms. Painted surfaces are also easier to clean.

Wall and ceiling gypsum board finishes are painted. Doors, trim, and interior millwork may be painted, stained or varnished.

To prevent running or sagging, varnish should not be applied in thick coats. Two thin coats, with light sanding and sufficient drying time between, are adequate for most residential applications. Items such as stair treads and handrails may warrant a third coat.

When performing interior painting, provide sufficient ventilation and lighting. Solvent-based paints and cleaners should be stored outside the living space. Dispose of all rags, paints, stains and thinners in an appropriate manner, usually at special depots for toxic wastes.

In all cases, follow the manufacturer's application instructions to attain proper finish appearance and performance.

SUSTAINABLE HOUSING INSIGHT

Healthy Indoor Environment

- Use water-based low VOC paint, stain and varnish.
- The fumes from oil-based paint, stain and varnish are flammable and containers should be stored away from sources of heat and flame.
- Store products outside the living space.

Affordability

- Paint, stain and varnish are low-cost finishes that can be easily changed without damage to materials.
- Exterior paint, stain and varnish must be periodically inspected and repaired to protect the house from deterioration and prevent costly replacement.

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CHAPTER 25
Eavestroughs and Downspouts



Eavestroughs and downspouts are not required by the NBC but are recommended because they direct roof water away from the house, resulting in reduced groundwater adjacent to the foundation. However, in sub-zero temperatures, they can impede removal of roof water and contribute to ice-damming problems (see Figure 100 in Chapter 12).

Metal eavestroughs are available in continuous, one-piece lengths or in segments that are joined and sealed on-site. Fittings such as inside and outside corners, downspout connectors and elbows are available in sizes and angles to suit installation requirements. Plastic materials are also used for eavestroughs and downspouts.

Install eavestroughs after the exterior finish is complete. Mount them on the fascia board as close as possible to the shingle overhang, with a slight slope toward the downspouts.

Metal brackets fitted inside the trough are used to attach eavestroughs. Corrosion-resistant spikes 150 mm (6 in.) long and spaced about 750 mm (30 in.) apart may be used. A metal spacer tube is placed between the interior surfaces of the eavestrough, and the spike is driven through the eavestrough and the spacer into the fascia board and supports.

Downspouts may be rectangular or round. Those made from metal are usually rectangular and corrugated for added strength. The corrugated patterns are also less likely to burst when plugged with ice.

Goosenecks, composed of elbows and short sections of downspout piping, are used to bring the downspout in line with the wall.

Downspouts are fastened to the wall with straps and hooks. At least two hooks or straps should be used with each 3 m (10 ft.) length of downspout.

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Where downspouts are not connected to a storm sewer, an elbow with an extension or a splash block is used to direct the water away from the foundation wall and to avoid erosion. The final grading of the lot should ensure positive drainage away from the building.

SUSTAINABLE HOUSING INSIGHT

Healthy Indoor Environment

- Eavestroughs and downspouts should collect rainwater and direct it away from the foundation walls, which will help to keep the basement dry.

Environmental Responsibility

- Connect downspouts to a storage container such as a rain barrel or cistern, and use this water for watering lawns.

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CHAPTER 26
Decks, Porches and Balconies



Decks, porches and balconies must be designed to carry snow and occupant loads, braced to ensure lateral stability and supported by a solid foundation. They must also be equipped with adequate guards and constructed to resist exposure to water. They may be free-standing or attached to a building.

LOADS AND SIZING OF FRAMING MEMBERS

A 1.9 kPa (40 psf) live snow load and 0.5 kPa (10 psf) dead load are the minimum design loads for sizing wood members for outdoor decks in Canada. If specified roof snow loads in a given area exceed 1.9 kPa (40 psf), the snow load must be used in the deck design. For the sizing of deck joists and beams, refer to Tables 43 and 44 (Appendix A). Posts should be a minimum of 140 × 140 mm (6 × 6 in. nominal) unless calculations show that lesser sizes are adequate. They should be wide enough to fully support all beam plies.

Decks, porches and balconies over 600 mm (24 in.) and less than 1800 mm (71 in.) above the finished ground level are required to have guards at least 900 mm (36 in.) high. Decks higher than 1800 mm (71 in.) must have guards at least 1070 mm (42 in.) high.

Figure 175 shows a common arrangement for a deck foundation, framing and guard. Outdoor decks differ from standard floor construction in that individual deck planks can carry the entire load—there is no subfloor to distribute the load. For this reason, it is important to ensure that the decking is thick enough and adequately supported to withstand the anticipated loads. Wood decking should be at least 32 mm (1¼ in.) thick if supported at 400 mm (16 in.) centres and at least 38 mm

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(2 in. nominal) thick if supported at 600 mm (24 in.) centres. Common widths are 89 and 140 mm (4 and 6 in.).

Low-level decks must be built so that the bottoms of the deck joists are at least 150 mm (6 in.) above the ground to prevent moisture being transferred to the decking from grass or ground cover. Wood materials should be pressure treated or made from durable species like eastern or western cedar.

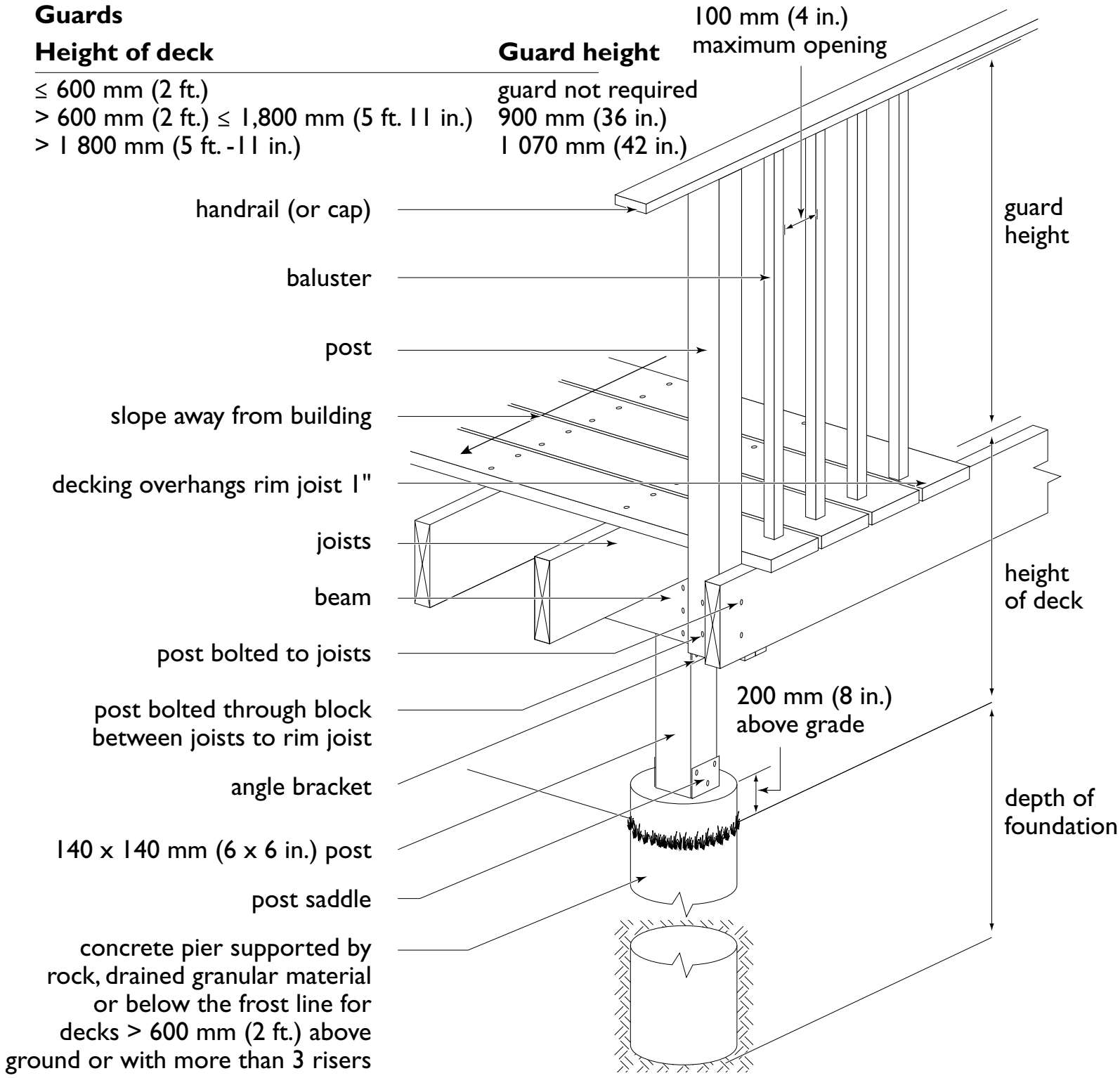
All deck planks should be oriented so that the ends of the annual rings on the ends of the planks face down. Thus, any cupping that takes place will drain rather than puddle. Provide a 3 mm (⅛ in.) space between the deck planks to permit drainage and drying.

Because decks, balconies, verandas and similar platforms support people, they are considered to be parts of buildings. Usually, pier-type columns are used to support decks.

175 Wood deck detail

Guards

Height of deck	Guard height
≤ 600 mm (2 ft.)	guard not required
> 600 mm (2 ft.) ≤ 1,800 mm (5 ft. 11 in.)	900 mm (36 in.)
> 1 800 mm (5 ft. -11 in.)	1 070 mm (42 in.)



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If the underside of the joists of decks or other accessible exterior platforms is located more than 600 mm (24 in.) above the ground, the foundation must be below frost level so that movement does not cause drainage to be directed into the house.

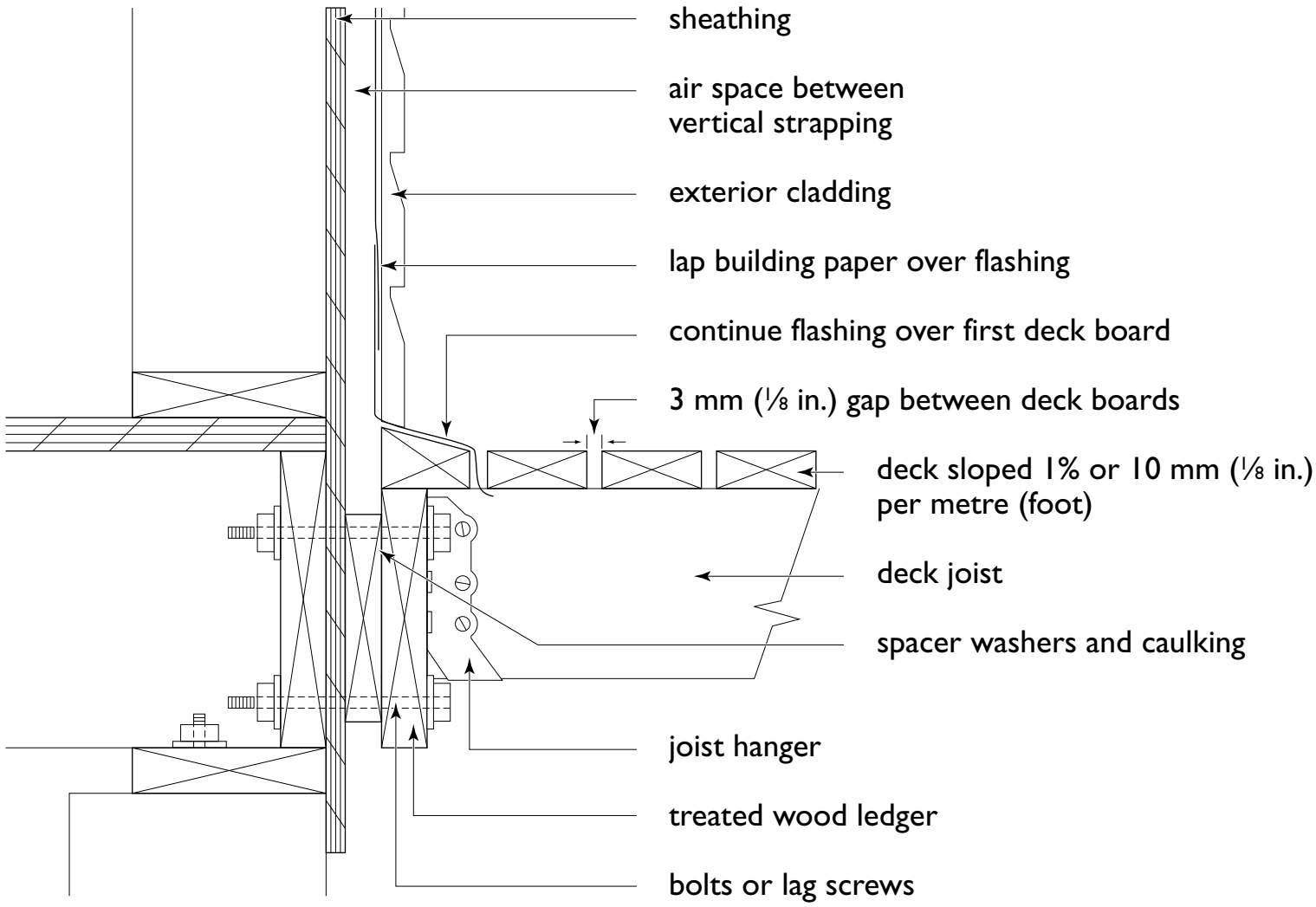
If the joists are more than 600 mm (24 in.) above the ground or support a superstructure such as a canopy, the piers must be braced.

Special attention is required when decks are bolted to the building envelope. The surface of the deck should be located at least 19 mm (¾ in.) below the floor level of the building and should slope a minimum of one per cent away from the building to remove rain and snowmelt. Decks attached directly to the sides of buildings with siding should have flashing installed behind the siding and lapped over the header joist or ledger (Figure 176). Alternatively, use other means such as wood blocking for special-purpose deck hangers for the ledger to provide a drainage space between the decking and the siding.

Foundations for decks and other accessible exterior platforms need not be below the frost level if the deck or platform is not more than one storey, is 55 m^2 (590 sq. ft.) or less in area does not support a roof, and its movement will not affect the structure to which it is attached.

Where these conditions are met and a shallow foundation is constructed, there must be means for levelling the structure. Access must be provided by either a passageway below at least 600 mm (24 in.) high or with removable decking.

176 Deck connection to house



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SUSTAINABLE HOUSING INSIGHT

Environmental Responsibility

- When treated wood is used, use fasteners that are resistant to treatment chemicals. Stainless steel fasteners are recommended for treated wood.
- Consider using wood composite decking, steps, handrails and balusters, which have superior resistance to weather and require less maintenance than wood.

Affordability

- To postpone replacement cost, choose materials that will be durable and easy to maintain outdoors.

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CHAPTER 27
Garages and Carports



As built-in or attached garages and carports are considered part of the dwelling unit to which they are attached, they have essentially the same structural requirements. This also applies to garages that are separated from a house by a breezeway. The footings for garages and carports must be below frost as required for the rest of the house (see Chapter 7).

A parking structure is considered to be a carport if more than 60 per cent of its perimeter wall area is open. Certain requirements apply only to garages and not to carports. For example, garages are required to have features to prevent them from exposing the remainder of the building to exhaust fumes, whereas carports are considered to be naturally vented due to the open perimeter.

GARAGES

Garages can be attached or detached. Built-in garages with living accommodation over the garage area are common in two-storey houses. In an attached garage, a complete air barrier is required in walls and ceiling separating the garage from occupied spaces. Doors separating a garage from the house are required to be weatherstripped and be self-closing to keep garage exhaust and vapours from contaminating living areas. The operation of motor vehicles in garages is a potential source of carbon monoxide (CO), a colourless, odourless gas that can accumulate in lethal concentrations in enclosed spaces without occupants being aware of it. If a garage is heated, the heating system should be separate from the house heating system to reduce the risk of garage fumes entering the house.

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A garage should be long and wide enough to leave space to walk around the stored vehicle. This requires at least 5.6 m (18 ft. 4 in.) between the inside face of the front and rear walls. Additional length may be required to accommodate storage or a work area.

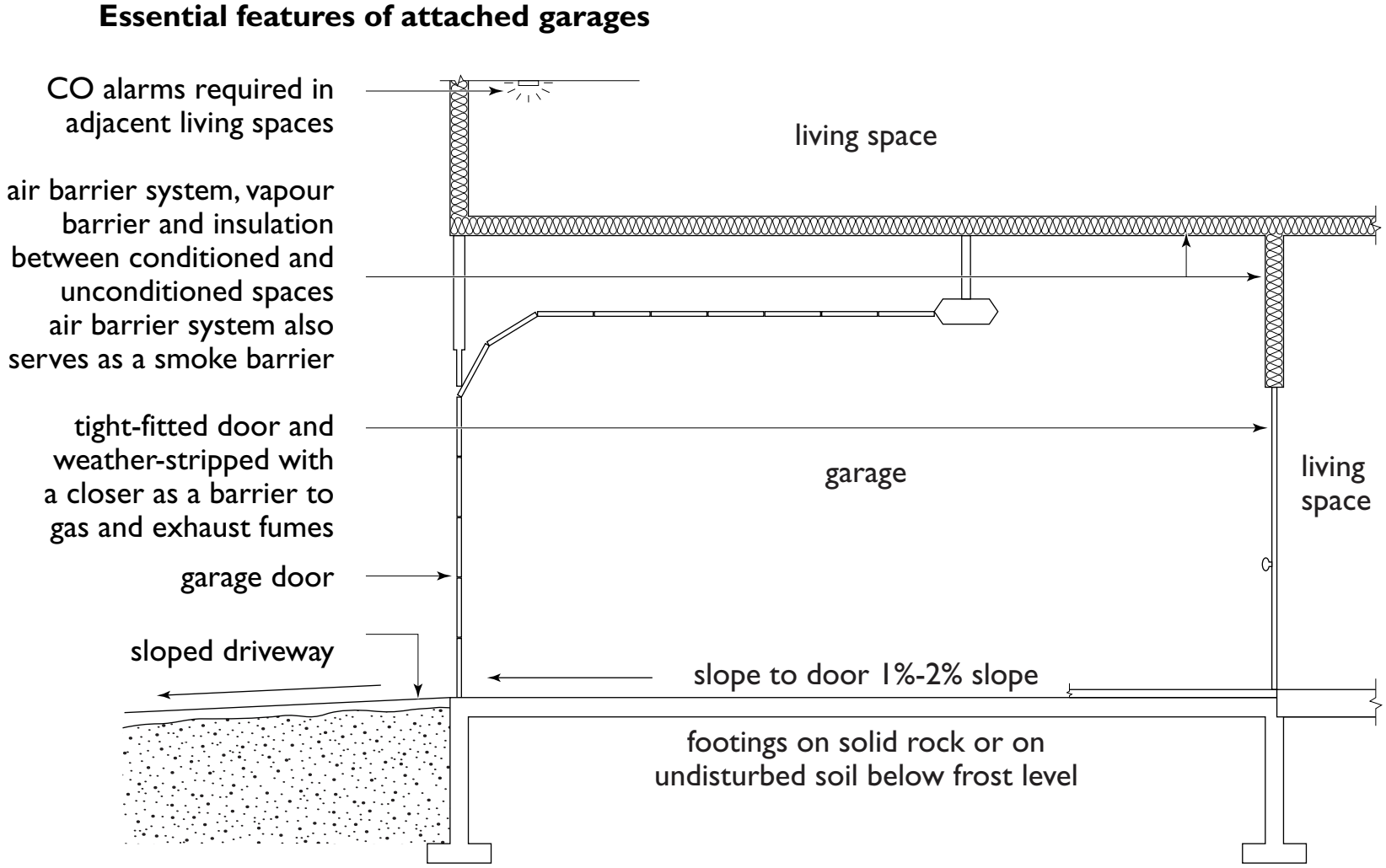
The clear width should be at least 3.05 m (10 ft.) and 3.5 m (11 ft. 6 in.) or more is better so that doors on either side of a vehicle can be opened freely. A two-car garage should be at least 5.56 m (18 ft. 4 in.) wide.

The framing and exterior finish of the garage's sidewalls and roof are similar to that of the house. Interior finish is largely a matter of choice. For single dwellings, a fire separation is not required between the garage and the house, but there must be a smoke and an air barrier in the separating walls to ensure fumes do not enter the living area. The essential features of garages are shown in Figure 177.

Every bedroom that shares a wall or floor with a garage or an attic space that abuts a garage must be protected by a CO alarm located either in the bedroom or not more than 5 m (16 ft.) (measured along hallways) from the bedroom door.

Common walls between the house and the garage must be insulated and fitted with air barriers and vapour barriers. If the garage is to be heated, the walls and ceiling should include insulation and an air barrier and should be covered to protect the barrier from damage.

177 Essential features of attached garages



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Electrical and mechanical systems that connect between a garage and a living area must be designed to keep fumes and exhaust from entering the house.

There are many types of doors for garages. The sectional overhead door is the most common. It has rollers at each section fitted into a track up each side of the door and along the ceiling. It also has a counterbalance spring to ease the operation of the door. These doors are usually fitted with automatic openers.

CARPORTS

Carport roofs are usually supported by posts located on top of concrete piers. Piers should be at least 190 × 190 mm (8 × 8 in.). Cylindrical piers are often used for this purpose. The base of the pier should be sufficiently large to ensure that the safe bearing pressure for the soil is not exceeded and far enough below grade to prevent frost heaving.

Where wood posts are used, the concrete piers should extend at least 150 mm (6 in.) above the ground to protect the posts from ground moisture. Anchor posts securely to both piers and roof framing to resist wind uplift.

SUSTAINABLE HOUSING INSIGHT

Healthy Indoor Environment

- Attached garages are required to have an airtight barrier and weather-stripped, self-closing doors between them and living spaces. Carbon monoxide (CO) detectors are required for adjacent bedrooms.

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CHAPTER 28
Surface Drainage, Driveways and Walkways



Site planning and grading must be considered at the initial planning stage (see Chapter 2). To create a successful landscape plan, the needs for surface drainage, driveways and walkways must be assessed. Driveways and walkways should be made of materials in character with the house and yard.

SURFACE DRAINAGE

Consider drainage in the initial planning stage to remove rain and snowmelt from the site, and give consideration to the location of the house on a property, its elevation relative to the site and utilities.

Establish a surface drainage pattern that will drain the entire lot and direct water away from the house (see Figure 3 in Chapter 2). Driveways and walkways should help drainage, not interfere with it. If a house uses well water, all surface drainage must be directed away from the well to avoid contaminating the water supply.

Slope all surfaces away from the foundation walls at least 5 per cent, and provide a 10 per cent slope for the first 2 m (6 ft. 6 in.) to ensure a positive slope after foundation backfill settles. Impermeable surfaces adjacent to the house, such as driveways, should have a slope of at least 2 per cent.

Build a swale (a gently sloping ditch) where the drainage slope around the house meets a reverse slope. For example, if a lot slopes up from the front to the rear, the swale should be located at the sides of the house so that the surface water flows along the swale, around the house, and out toward the street or roadside ditch (see Figure 3 in Chapter 2).

DRIVEWAYS

A driveway should be at least 2.4 m (8 ft.) wide and 3 m (10 ft.) wide when it also serves as a walkway. It should have a slope suitable for traction in winter conditions, provide good visibility at the street intersection and be

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graded so that water will not accumulate on the surface. The suggested maximum gradient along the length is 5 per cent with a cross slope of 2 per cent.

Common surfacing materials for driveways are concrete, asphalt and interlocking pavers. Proprietary systems are available that will support vehicle loads but allow water to dissipate and allow grass or ground cover to grow. Gravel surfacing is often used for rural driveways.

An area to be paved must be graded to a uniform smooth surface and be well compacted. Provide gravel or crushed stone at least 100 mm (4 in.) thick after compaction. Asphalt should be at least 40 mm (1½ in.) thick and concrete at least 100 mm (4 in.) deep.

Concrete placing, finishing and curing should be carried out as described in Chapter 7.

Place control joints in concrete driveways 3 to 3.5 m (10 to 12 ft.) apart. Use 6 to 12 mm (¼ to ½ in.) thick pre-moulded joint filler to isolate the concrete surface from curbs, the garage floor and the house foundation wall.

WALKWAYS

Cast-in-place concrete, interlocking pavers and flagstones are commonly used for walkways. They should be built on a well-compacted base with a slight slope to drain surface water. The recommended maximum gradient for a walkway along its length is 5 per cent with a maximum cross-slope of 2 per cent. Concrete walks should be at least 100 mm (4 in.) thick. Locate control joints spaced about 1.5 times the walkway width.

Interlocking pavers and flagstones should be placed over a compacted levelling bed of sand or stone dust.

SUSTAINABLE HOUSING INSIGHT

Healthy Indoor Environment

- Good drainage away from the foundation helps prevent indoor quality-related moisture problems.

Environmental Responsibility

- Use porous paving materials wherever possible to allow storm water to be absorbed in the ground.

RELATED PUBLICATIONS

Landscape Guide for Canadian Homes,
Canada Mortgage and Housing Corporation (publication no. 63523)

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CHAPTER 29
Maintenance



A house built with suitable material and construction details will require far less maintenance than one that is not. While modern materials have reduced maintenance requirements, some maintenance can be expected, even during the first year of occupancy.

For example, settling may occur in the ground around the foundation, which can cause surface water to pond against the basement or foundation wall. This should be corrected by placing additional fill material to restore a proper slope to carry water away from the foundation.

Regular maintenance will reduce repair and replacement costs, and increase service life and resale value. Provide new buyers with a maintenance manual that outlines operating and maintenance instructions, particularly for mechanical systems.

SUSTAINABLE HOUSING INSIGHT

Affordability

- Build to minimize upkeep
- Perform required maintenance to prolong service life.

RELATED PUBLICATIONS

Maintenance Matters (bulletins),
Homeowner Protection Office, Branch of BC Housing

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Table 1
Conversion factors

Framing terms		
	Metric - dimension	Imperial - nominal (unplaned) dimensions
Lumber	38 x 38 mm	2 x 2 in.
	38 x 89 mm	2 x 4 in.
	38 x 140 mm	2 x 6 in.
	38 x 184 mm	2 x 8 in.
	38 x 235 mm	2 x 10 in.
	38 x 286 mm	2 x 12 in.
Panels	600 x 2,400 mm	2 x 8 ft.
	1,200 x 2,400 mm	4 x 8 ft.
Spacings	300 mm	12 in. O.C.
	400 mm	16 in. O.C.
	600 mm	24 in. O.C.
Units of Measure		
°C	x 1.8 + 32 =	°F
kg	x 2.205 =	lb
kPa	x 0.1450 =	lbf/in^2 (psi)
kPa	x 20.88 =	lbf/ft^2
L	x 0.2200 =	gal (imp.)
L/s	x 13.20 =	gal/min (gmp)
lx	x 0.09290 =	ft-candle
m	x 3.281 =	ft
m^2	x 10.76 =	ft^2
m^3	x 35.31 =	ft^3
mm	x 0.03937 =	in.
m^3/h	x 0.5886	ft^3/min (cfm)
m/s	x 196.8 =	ft/min
MJ	x 947.8 =	Btu
N	x 0.2248	lbf
Watts	x 3.412 =	Btu/h
ng/(Pa.s.m^2)	x 0.0174	Perms
Pa	x 0.004014 =	in. of water

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Table 2
Concrete mixes (by volume)

Concrete Strength	Cement (part)	Water (not more than)	Sand (parts)	Coarse Aggregate
2,200 psi (15 MPa)	1	20 L (4.4 imp. gal.) per 40 kg (88 lb.) bag of cement	2	4 parts up to 50 mm (2 in.) in size
	1	20 L (4.4 imp. gal.) per 40 kg(88 lb.) bag of cement	-	6 parts pit run gravel
3,000 psi (20 MPa)	1	18 L (4.0 imp. gal.) per 40 kg(88 lb.) bag of cement	1¾	3 parts up to 40 mm (1½ in.) in size
	1	18 L (4.0 imp. gal.) per 40 kg (88 lb.) bag of cement	-	4¾ parts pit run gravel

Note to Table 2

1. For higher strength concretes, use commercial suppliers to ensure strength and air entrainement requirements are met

Table 3
Minimum depths of foundations

Type of Soil	Foundations containing heated basement or crawl space		Foundations containing no heated space	
	Good soil drainage to at least the depth of frost penetration	Poor soil drainage	Good soil drainage to at least the depth of frost penetration	Poor soil drainage
Clay or soils not clearly defined	1.2 m (4 ft.)	1.2 m (4 ft.)	1.2 m (4 ft.) but not less than the depth of frost penetration	1.2 m (4 ft.) but not less than the depth of frost penetration
Silt	No limit	No limit	Below the depth of frost penetration	Below the depth of frost penetration
Coarse grained soils	No limit	No limit	No limit	Below the depth of frost penetration
Rock	No limit	No limit	No limit	No limit

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Table 4
Minimum footing sizes (Length of supported joists 4.9 m [16 ft.] or less) (Design floor load 2.4 kN/m^2 [50 lb./ft.^{2}] maximum)

No. of Floors Supported	Minimum Widths of Strip Footings, mm (in.)		Minimum Area of Column Footings[1], m^2 (sq. ft.)
	Supporting Exterior Walls	Supporting Interior Walls	
1	250 (10)[2]	200 (8)[3]	0.4 (4.3)
2	350 (14)[2]	350 (14)[3]	0.75 (8)
3	450 (18)[2]	500 (20)[3]	1.0 (11)

Notes to Table 4

1. Sizes are based on columns spaced 3 m (9 ft., 10 in.) (on centre). For other column spacings, footing areas must be adjusted in proportion to the distance between columns.
2. For each storey of masonry veneer over wood-frame construction, footing widths must be increased by 65 mm (2½ in.). For each storey of masonry construction other than foundation walls, the footing width must be increased by 130 mm (5⅛ in.).
3. For each storey of masonry supported by the footing, the footing width must be increased by 100 mm (4 in.).

Table 5
Minimum thickness of foundation walls

Type of Foundation Wall	Minimum Wall Thickness, mm (in.)	Maximum Height of Exterior Finish Grade Above Basement Floor or Inside Grade, m (ft.–in.)	
		Foundation Wall Laterally Unsupported at the Top[1 to 4]	Foundation Wall Laterally Supported at the Top[1 to 4]
Solid concrete, 15 MPa (2,200 psi) minimum strength	150 (6)	0.80 (2–7)	1.50 (4–11)
	200 (8)	1.20 (3–11)	2.15 (7–0)
	250 (10)	1.40 (4–7)	2.30 (7–6)
	300 (12)	1.50 (4–11)	2.30 (7–6)
Solid concrete, 20 MPa (2,900 psi) minimum strength	150 (6)	0.80 (2–7)	1.80 (5–10)
	200 (8)	1.20 (3–11)	2.30 (7–6)
	250 (10)	1.40 (4–7)	2.30 (7–6)
	300 (12)	1.50 (4–11)	2.30 (7–6)
Unit masonry	140 (5½)	0.60 (1–11)	0.80 (2–7)
	240 (9⅞)	1.20 (3–11)	1.80 (5–10)
	290 (11⅞)	1.40 (4–7)	2.20 (7–2)

Notes to Table 5

1. Foundation walls are considered laterally supported at the top if the floor joists are embedded in the top of the foundation walls, or if the floor system is anchored to the top of the foundation walls with anchor bolts, in which case the joists may run either parallel or perpendicular to the foundation wall.
2. When a foundation wall contains an opening of more than 1.2 m (3 ft.–11 in.) in length or openings in more than 25 per cent of its length, the portion of the wall beneath such openings is considered laterally unsupported unless the wall around the opening is reinforced to withstand the earth pressure.
3. When the length of solid wall between windows is less than the average length of the windows, the combined length of such windows is considered a single opening.
4. When foundation walls support solid masonry walls, the foundation wall is considered laterally supported by the first floor.

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Table 6
Mortar mix proportions (by volume)

Permissible Use of Mortar	Portland Cement	Masonry Cement (Type H)	Lime	Aggregate
All locations[1]	½ to 1	1	—	Not less than 2¼ and not more than 3 times the sum of the volumes of the cement and lime
	1	—	¼ to ½	
All locations[1], except foundation walls and piers	—	1	—	
	1	—	½ to 1¼	
All locations, except loadbearing walls of hollow units	1	—	1¼ to 2½	
All non-loadbearing partitions and all loadbearing walls of solid units except foundation walls	1	—	2¼ to 4	
	—	—	1	

Note to Table 6

1. Must not be used for sand-lime brick or concrete brick.

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Table 7
Dimension lumber – grades and uses

Sizes, mm (in.)	Grades	Common Grade Mix[1]	Principal Uses	Grade Category
38 to 89 mm (2 to 4 in.) thick; 38 to 89 mm (2 to 4 in.) wide	Select structural No. 1 and No. 2	No. 2 and better (No. 2 & Btr.)	Most common; used in most construction. Shows high strength, stiffness and good appearance. Preferred for trusses, rafters and roof joists.	Structural light framing
	No. 3[3]	—	Used in construction where high strength and appearance are not important, such as studs in non-loadbearing walls.	
	Construction[3] Standard[3]	Standard and better (Std. & Btr.)	Most common, used in general framing work. Has less strength than No. 2 and better structural light framing, but is stronger and allows longer spans than No. 3.	Light framing
	Utility[2]	—	Used most economically where high strength is not important, such as studs and plates in partition walls, blocking and bracing.	
	Economy[2]	—	Used in temporary or low-cost construction where strength and appearance are not important.	
38 to 89 mm (2 to 4 in.) thick; 114 mm (5 in.) and wider	Select Structural No. 1 and No. 2	No. 2 & Btr.	Most common; used in most construction where high strength and stiffness are desired such as floor joists, roof joists and rafters.	Structural joists and planks
	No. 3[3]	—	Used in general construction where strength is not important.	
	Economy[2]	—	Used in temporary or low-cost construction where strength and appearance are not important.	
38 to 89 mm (2 to 4 in.) thick; 38 mm (2 in.) and wider	Stud[3]	—	Most common; special purpose grade intended for all stud uses, including bearing walls	Stud
	Economy stud[2]	—	Used in temporary or low-cost construction where strength and appearance are not important.	

Notes to Table 7

1. For ease in grade sorting at the mill, the higher grades are combined and sold as a grade mix. Pieces of lumber in the grade mix are still individually grade stamped.
2. Except for the utility and economy grades, all grades are stress graded, which means specified strengths have been assigned and span tables calculated.
3. Construction, Standard, Stud and No. 3 Grades are typically used in designs that are not composed of 3 or more essentially parallel members spaced on 600 mm (24 in.) centres or less, so arranged or connected to mutually support loading.

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Table 8
Sizes for dimension lumber and boards

	Metric Equivalents, mm		Metric Nomenclature, mm	Nominal Sizes, in.	Actual Sizes, in.	
	Dry	Green			Dry	Green
Dimension Lumber	38 x 38	40 x 40	38 x 38	2 x 2	1½ x 1½	1⁹⁄₁₆ x 1⁹⁄₁₆
	64	65	64	3	2½	2⁹⁄₁₆
	89	90	89	4	3½	3⁹⁄₁₆
	140	143	140	6	5½	5⅝
	184	190	184	8	7¼	7½
	235	241	235	10	9¼	9½
	286	292	286	12	11¼	11½
	64 x 64	65 x 65	64 x 64	3 x 3, etc.	2½ x 2½	2⁹⁄₁₆ x 2⁹⁄₁₆
	89 x 89	90 x 90	89 x 89	4 x 4, etc.	3½ x 3½	3⁹⁄₁₆ x 3⁹⁄₁₆
Boards	19 x 38	21 x 40	19 x 38	1 x 2	¾ x 1½	¹³⁄₁₆ x 1⁹⁄₁₆
	64	65	64	3	2½	2⁹⁄₁₆
	89	90	89	4	3½	3⁹⁄₁₆
	114	117	114	5	4½	4⅝
	140	143	140	6	5½	5⅝
	184	190	184	8	7¼	7½
	235	241	235	10	9¼	9½
	286	292	286	12	11¼	11½
	25 x 38	26 x 40	25 x 38	1¼ x 2, etc.	1 x 1½	1³²⁄₃₂ x 1⁹⁄₁₆
	32 x 38	33 x 40	32 x 38	1½ x 2, etc.	1¼ x 1½	1⁹⁄₃₂ x 1⁹⁄₁₆

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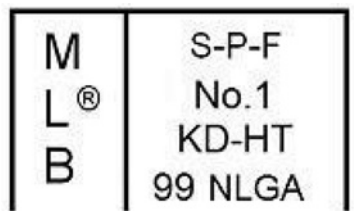
Table 9
Facsimiles of lumber grade marks approved for use in Canada

A.F.P.A® 00 S-P-F NLGA KD-HT 1	**Alberta Forest Products Association** 900, 10707 100 Avenue Edmonton, Alberta T5J 3M1 Tel: 780-452-2841 Email: info@albertaforestproducts.ca Website: www.albertaforestproducts.ca
CMSA® No 1 KD-HT NLGA 100 S–P–F	**Canadian Mill Services Association** #200, 601-6th Street New Westminster, British Columbia V3L 3C1 Tel: 604-523-1288 Email: info@canserve.org Website: www.canserve.org
CMSA® 100 HT	
CSI No.1 00 KD-HT NLGA D FIR-L (N)	**Canadian Softwood Inspection Agency Inc.** Brookswood RPO P.O. Box 61599 Langley, British Columbia V3A 8C8 Tel: 604-535-6192 Email: info@canadiansoftwood.com Website: www.canadiansoftwood.com
CFPA® 26 S-P-F KD-HT 2 NLGA	**Central Forest Products Association** c/o Alberta Forest Products Association (see above for contact info)
COFI® KD-HT 00 1 NLGA S – P – F	**Council of Forest Industries** 1501-700 West Pender Street Pender Place, Business Building Vancouver British Columbia V6C 1G8 Tel: 604-684-0211 Email: info@cofi.org Website: www.cofi.org
ILMA® KD-HT 00 1 NLGA S – P – F	
5 No. 2 KD-HT S-P-F NLGA	**Macdonald Inspection Service** 211-1548 Johnston Road White Rock, British Columbia V4B 3Z8 Tel: 604-535-6192 Website: www.gradestamp.com

Continued on p. 271

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Table 9 (continued)
Facsimiles of lumber grade marks approved for use in Canada

	**Maritime Lumber Bureau** P.O. Box 459 Amherst, Nova Scotia B4H 4A1 Tel: 902-667-3889 Website: www.mlb.ca
	**Newfoundland and Labrador Lumber Producers Association** P.O. Box 8 Glovertown Newfoundland and Labrador A0G 2L0 Email: nllpa@personainternet.com Tel: 709-533-2206
	**Ontario Forest Industries Association** (Home of CLA Grading and Inspection) 8 King Street East, Suite 1704 Toronto, Ontario M5C 1C3 Tel: 416-368-6188 Email: info@ofia.com Website: www.ofia.com
	**Ontario Lumber Manufacturers Agency** 244 Viau Road Noelville, Ontario P0M 2N0 Tel: 705-618-3403 Email: info@olma.ca Website: www.olma.ca
	**Pacific Lumber Inspection Bureau** P.O. Box 19118 4th Avenue Postal Outlet Vancouver, British Columbia V6K 4R8 Tel: 604-732-1782 Email: info@plib.org Website: www.plib.org
	**Québec Forest Industry Council** 1175, avenue Lavigerie, bureau 200 Québec City, Quebec G1V 4P1 Tel: 418-657-7916 Email: info@QFIC.g.ca Website: www.qfic.qc.ca

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Table 10
Commercial species of lumber

Commercial Species Group Designation	Grade Stamp Identification	Species in Combination	Wood Characteristics
Spruce – Pine – Fir	S – P – F	Spruce (all species except coast sitka spruce), lodgepole pine, jack pine, alpine fir, balsam fir	Woods of similar characteristics. They work easily, take paint easily and hold nails well. Generally white to pale yellow in colour.
Douglas Fir – Larch	D. Fir – L	Douglas fir, Western larch	High degree of hardness and good resistance to decay. Good nail holding, gluing and painting qualities. Colour ranges from reddish-brown to yellowish white.
Hem – Fir	Hem – Fir	Pacific coast hemlock, amabilis fir	They work easily, take paint well and hold nails well. Good gluing characteristics. Colour range pale yellow-brown to white.
Northern Species	North	Western red cedar	Wood with exceptional resistance to decay. Moderate in strength. High in appearance qualities, it works easily and takes fine finishes. Colour varies from reddish-brown heartwood to light sapwood.
	North	Red pine, ponderosa pine	Fairly strong and easy-to-work woods that take a good finish and hold nails and screws well. Moderately durable, they season with little checking or cupping. Sapwood is a pale yellow colour; heartwood pale brown to reddish tinge.
		Western white pine, eastern white pine	Softest of the Canadian pines, they work and finish exceptionally well. Not as strong as most pines but do not tend to split or splinter. Good nail holding properties. Low shrinkage, better than all other Canadian species except the cedars. Take stains, paints and varnishes well. Colour of sapwood almost white; heartwood creamy white to light straw brown.
		Trembling aspen, largetooth aspen, balsam poplar	Light woods of moderate strength, they work easily, finish well and hold nails well. Generally light in colour, varying from almost white to greyish white.

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Table 11
Effective thermal resistance of assemblies in buildings with a heat-recovery ventilator

Climate Zone Heating-degree days	Heating degree-days of building location,[1] in celsius degree-days					
	Zone 4 <3000	Zone 5 3000 - 3999	Zone 6 4000 - 4999	Zone 7A 5000 - 5999	Zone 7B 6000 - 6999	Zone 8 >7000
Typical Locations	Vancouver, BC	Kamloops, BC Kelowna, BC Toronto, ON	Prince Rupert, BC Lethbridge, BC Ottawa, ON Montreal, QC Halifax, NS	Calgary, AB Regina, SK Winnipeg, MB Quebec City, QC Edmundston, NB	Cold Lake, AB Whitehorse, YK	NWT and Nunavut
	Minimum Effective Thermal Resistance RSI m²•K/W (R ft²•°F•h/Btu)					
Building assembly above ground						
Ceilings below attics	6.91 (39.2)	6.91 (39.2)	8.67 (49.2)	8.67 (49.2)	10.43 (59.22)	10.43 (59.22)
Cathedral ceilings and flat roofs	4.67 (26.5)	4.67 (26.5)	4.67 (26.5)	5.02 (28.5)	5.02 (28.5)	5.02 (28.5)
Walls[2]	2.78 (15.8)	2.97 (16.9)	2.97 (16.9)	2.97 (16.9)	3.08 (17.5)	3.08 (17.5)
Floors over unheated spaces	4.67 (26.5)	4.67 (26.5)	4.67 (26.5)	5.02 (28.5)	5.02 (28.5)	5.02 (28.5)
Building assembly below grade or in contact with the ground[1]						
Foundation walls	1.99 (11.3)	2.98 (16.9)	2.98 (16.9)	2.98 (16.9)	2.98 (16.9)	2.98 (16.9)
Unheated floors[3] • below frost line[4, 5] • above frost line[5]	Uninsulated 1.96 (11.1)	Uninsulated 1.96 (11.1)	Uninsulated 1.96 (11.1)	Uninsulated 1.96 (11.1)	Uninsulated 1.96 (11.1)	Uninsulated 1.96 (11.1)
Heated and unheated floors on permafrost	n/a	n/a	n/a	n/a	4.44 (25.2)	4.44 (25.2)
Heated floors[6]	2.32 (13.2)	2.32 (13.2)	2.32 (13.2)	2.84 (16.1)	2.84 (16.1)	2.84 (16.1)
Slabs-on-grade with an integral footing[6]	1.96 (11.1)	1.96 (11.1)	1.96 (11.1)	2.84 (16.1)	2.84 (16.1)	3.72 (21.1)

Notes to Table 11

1. See NBC 1.1.3.1.
2. See NBC 9.36.2.8.(3) for requirements concerning the above-ground portion of foundation walls.
3. Does not apply to below-grade floors over heated crawl spaces.
4. Typically applies to floors-on-ground in full-height basements.
5. Refers to undisturbed frost line before house is constructed.
6. See NBC 9.25.2.3.(5) for requirement on placement of insulation. The design of slabs-on-grade with an integral footing is addressed in NBC Part 4 (see Article 9.16.1.2.).

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Table 12
Effective thermal resistance of assemblies in buildings without a heat recovery ventilator

Climate Zone Heating-degree days	Heating degree-days of building location,[1] in celsius degree-days					
	Zone 4 <3000	Zone 5 3000 - 3999	Zone 6 4000 - 4999	Zone 7A 5000 - 5999	Zone 7B 6000 - 6999	Zone 8 >7000
Typical Locations	Vancouver, BC	Kamloops, BC Kelowna, BC Toronto, ON	Prince Rupert, BC Lethbridge, BC Ottawa, ON Montreal, QC Halifax, NS	Calgary, AB Regina, SK Winnipeg, MB Quebec City, QC Edmundston, NB	Cold Lake, AB Whitehorse, YK	NWT and Nunavut
	Minimum Effective Thermal Resistance RSI m²•K/W (R ft²•°F•h/Btu)					
Building assembly above ground						
Ceilings below attics	6.91 (39.2)	8.67 (49.2)	8.67 (49.2)	10.43 (59.2)	10.43 (59.2)	10.43 (59.2)
Cathedral ceilings and flat roofs	4.67 (26.5)	4.67 (26.5)	4.67 (26.5)	5.02 (28.5)	5.02 (28.5)	5.02 (28.5)
Walls[2]	2.78 (15.8)	3.08 (17.5)	3.08 (17.5)	3.08 (17.5)	3.85 (21.9)	3.85 (21.9)
Floors over unheated spaces	4.67 (26.5)	4.67 (26.5)	4.67 (26.5)	5.02 (28.5)	5.02 (28.5)	5.02 (28.5)
Building assembly below grade or in contact with the ground[1]						
Foundation walls	1.99 (11.3)	2.98 (16.9)	2.98 (16.9)	3.46 (19.6)	3.46 (19.6)	3.97 (22.5)
Unheated floors[3] • below frost line[4, 5] • above frost line[5]	Uninsulated 1.96 (11.1)	Uninsulated 1.96 (11.1)	Uninsulated 1.96 (11.1)	Uninsulated 1.96 (11.1)	Uninsulated 1.96 (11.1)	Uninsulated 1.96 (11.1)
Heated and unheated floors on permafrost	n/a	n/a	n/a	n/a	4.44 (25.2)	4.44 (25.2)
Heated floors[6]	2.32 (13.2)	2.32 (13.2)	2.32 (13.2)	2.84 (16.1)	2.84 (16.1)	2.84 (16.1)
Slabs-on-grade with an integral footing[6]	1.96 (11.1)	1.96 (11.1)	1.96 (11.1)	3.72 (21.1)	3.72 (21.1)	4.59 (26.1)

Notes to Table 12

1. See NBC 1.1.3.1.
2. See NBC 9.36.2.8.(3) for requirements concerning the above-ground portion of foundation walls.
3. Does not apply to below-grade floors over heated crawl spaces.
4. Typically applies to floors-on-ground in full-height basements.
5. Refers to undisturbed frost line before house is constructed.
6. See NBC 9.25.2.3.(5) for requirement on placement of insulation. The design of slabs-on-grade with an integral footing is addressed in NBC Part 4 (see Article 9.16.1.2.).

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Table 13
Required thermal characteristics of windows, doors and skylights

Climate Zone Heating-degree days		**Heating degree-days of building location,[1] in celsius degree-days**					
		Zone 4 <3000	Zone 5 3000 - 3999	Zone 6 4000 - 4999	Zone 7A 5000 - 5999	Zone 7B 6000 - 6999	Zone 8 >7000
Typical Locations		Vancouver, BC	Kamloops, BC Kelowna, BC Toronto, ON	Prince Rupert, BC Lethbridge, BC Ottawa, ON Montreal, QC Halifax, NS	Calgary, AB Regina, SK Winnipeg, MB Quebec City, QC Edmundston, NB	Cold Lake, AB Whitehorse, YK	NWT and Nunavut
Thermal Characteristics	Windows and Doors[2]	**Maximum U-value, W/(m²•K)**					
		1.80	1.80	1.60	1.60	1.40	1.40
		Minimum Energy Rating					
		21	21	25	25	29	29
	Skylights	**Maximum Overall Thermal Transmittance**					
		2.90	2.90	2.70	2.70	2.40	2.40

Notes to Table 13

1. See NBC 1.1.3.1.
2. Except skylights and glass block assemblies

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Table 14
Comparison of typical window thermal efficiencies

Thermal performance of a typical casement window with low conductivity edge seal

	Aluminum frame with thermal break				Wood or vinyl frame				Fibreglass frame			
	RSI	R	U	ER	RSI	R	U	ER	RSI	R	U	ER
Double glazed clear with air fill	0.28	1.59	0.62	0.6	0.36	2.04	0.49	15.1	0.42	2.38	0.42	21.0
Double glazed low-E with air fill	0.35	1.99	0.50	7.3	0.47	2.67	0.37	22.9	0.55	3.12	0.32	28.5
Double glazed low-E with argon	0.37	2.10	0.48	11.0	0.51	2.90	0.34	26.7	0.61	3.46	0.29	32.0
Triple glazed clear with air fill	0.35	1.99	0.50	7.3	0.50	2.84	0.35	28.2	0.56	3.18	0.31	29.2
Triple glazed low-E with air fill	0.39	2.21	0.45	12.1	0.60	3.41	0.29	30.5	0.68	3.86	0.26	33.8
Triple glazed low-E with argon	0.41	2.33	0.43	14.8	0.65	3.69	0.27	33.2	0.75	4.25	0.24	34.6

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Table 15
Maximum spans for built-up floor beams supporting not more than one floor[1, 2]

Commercial Designation	Grade	Supported Length,[5, 6] m / ft.	Maximum Span, m (ft.–in.)[3, 4] Size of Built-up Beam, mm (in.) 38 x 184 2 x 8 3-ply	38 x 184 2 x 8 4-ply	38 x 184 2 x 8 5-ply	38 x 235 2 x 10 3-ply	38 x 235 2 x 10 4-ply	38 x 235 2 x 10 5-ply	38 x 286 2 x 12 3-ply	38 x 286 2 x 12 4-ply	38 x 286 2 x 12 5-ply
Douglas Fir – Larch	No. 1 and No. 2	2.4	2.97	3.42	3.82	3.63	4.19	4.68	4.21	4.86	5.43
		8	9–8	11–2	12–6	11–10	13–8	15–3	13–8	15–10	17–8
		3.0	2.65	3.06	3.42	3.24	3.75	4.19	3.76	4.35	4.86
		10	8–8	10–0	11–2	10–7	12–2	13–8	12–3	14–2	15–10
		3.6	2.42	2.80	3.13	2.96	3.42	3.82	3.44	3.97	4.44
		12	7–11	9–1	10–2	9–8	11–2	12–5	11–2	12–11	14–5
		4.2	2.24	2.59	2.89	2.74	3.17	3.54	3.18	3.67	4.11
		14	7–4	8–5	9–5	8–11	10–4	11–6	10–4	11–11	13–4
		4.8	2.10	2.42	2.71	2.56	2.96	3.31	2.98	3.44	3.84
		16	6–10	7–11	8–10	8–4	9–8	10–9	9–8	11–2	12–6
		5.4	1.98	2.28	2.55	2.42	2.79	3.12	2.81	3.24	3.62
		18	6–5	7–5	8–4	7–10	9–1	10–2	9–2	10–7	11–9
		6.0	1.88	2.17	2.42	2.29	2.65	2.96	2.66	3.07	3.44
		20	6–1	7–1	7–11	7–6	8–7	9–8	8–8	10–0	11–2
Hem – Fir	No. 1 and No. 2	2.4	3.11	3.55	3.82	3.80	4.39	4.88	4.41	5.10	5.70
		8	10–1	11–7	12–6	12–5	14–4	15–11	14–4	16–07	18–7
		3.0	2.78	3.21	3.55	3.40	3.93	4.39	3.95	4.56	5.10
		10	9–1	10–5	11–7	11–1	12–9	14–4	12–10	14–10	16–7
		3.6	2.54	2.93	3.28	3.11	3.59	4.01	3.60	4.16	4.65
		12	8–3	9–7	10–8	10–1	11–8	13–1	11–9	13–7	15–2
		4.2	2.35	2.72	3.04	2.88	3.32	3.71	3.34	3.85	4.31
		14	7–8	8–10	9–11	9–4	10–10	12–1	10–10	12–6	14–0
		4.8	2.20	2.54	2.84	2.69	3.11	3.47	3.12	3.60	4.03
		16	7–2	8–3	9–3	8–9	10–1	11–4	10–2	11–9	13–1
		5.4	2.07	2.39	2.68	2.54	2.93	3.27	2.94	3.40	3.80
		18	6–9	7–10	8–9	8–3	9–6	10–8	9–7	11–1	12–4
		6.0	1.97	2.27	2.54	2.41	2.78	3.11	2.79	3.22	3.60
		20	6–5	7–5	8–3	7–10	9–0	10–1	9–1	10–6	11–9
Spruce – Pine – Fir	No. 1 and No. 2	2.4	3.07	3.38	3.64	3.92	4.32	4.65	4.57	5.25	5.59
		8	10–0	11–0	11–11	12–10	14–1	15–2	14–11	17–2	18–3
		3.0	2.85	3.14	3.38	3.52	4.01	4.32	4.09	4.72	5.25
		10	9–4	10–3	11–0	11–6	13–1	14–1	13–4	15–4	17–2
		3.6	2.63	2.95	3.18	3.22	3.71	4.06	3.73	4.31	4.82
		12	8–7	9–8	10–5	10–6	12–1	13–3	12–2	14–0	15–8
		4.2	2.44	2.80	3.02	2.98	3.44	3.84	3.46	3.99	4.46
		14	7–11	9–2	9–10	9–8	11–2	12–6	11–3	13–0	14–6
		4.8	2.28	2.63	2.89	2.79	3.22	3.60	3.23	3.73	4.17
		16	7–5	8–7	9–5	9–1	10–6	11–8	10–6	12–2	13–7
		5.4	2.15	2.48	2.77	2.63	3.03	3.39	3.05	3.52	3.93
		18	7–0	8–1	9–0	8–7	9–10	11–0	9–11	11–5	12–10
		6.0	2.04	2.35	2.63	2.49	2.88	3.22	2.89	3.34	3.73
		20	6–8	7–8	8–7	8–1	9–4	10–6	9–5	10–10	12–2

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Table 15 (continued)
Maximum spans for built-up floor beams supporting not more than one floor[1, 2]

Commercial Designation	Grade	Supported Length,[5, 6] m	Maximum Span, m (ft.–in.)[3, 4]								
			Size of Built-up Beam, mm (in.)								
			38 x 184			38 x 235			38 x 286		
			2 x 8			2 x 10			2 x 12		
		ft.	3-ply	4-ply	5-ply	3-ply	4-ply	5-ply	3-ply	4-ply	5-ply
Northern Species	No. 1 and No. 2	2.4	2.59	2.99	3.29	3.16	3.65	4.08	3.67	4.24	4.74
		8	8–5	9–9	10–9	10–3	11–11	13–3	11–11	13–9	15–5
		3.0	2.31	2.67	2.99	2.83	3.27	3.65	3.28	3.79	4.24
		10	7–6	8–8	9–9	9–2	10–8	11–11	10–8	12–4	13–9
		3.6	2.11	2.44	2.73	2.58	2.98	3.33	3.00	3.46	3.87
		12	6–10	7–11	8–10	8–5	9–8	10–10	9–9	11–3	12–7
		4.2	1.95	2.26	2.52	2.39	2.76	3.09	2.77	3.20	3.58
		14	6–4	7–4	8–3	7–9	9–0	10–1	9–0	10–5	11–8
		4.8	1.83	2.11	2.36	2.24	2.58	2.89	2.59	3.00	3.35
		16	5–11	6–10	7–8	7–3	8–5	9–5	8–5	9–9	10–11
		5.4	1.72	1.99	2.23	2.11	2.43	2.72	2.45	2.82	3.16
		18	5–7	6–6	7–3	6–10	7–11	8–10	8–0	9–2	10–3
		6.0	1.64	1.89	2.11	2.00	2.31	2.58	2.32	2.68	3.00
		20	5–4	6–2	6–10	6–6	7–6	8–5	7–7	8–9	9–9

Notes to Table 15

1. Spans apply only where the floors serve residential areas.
2. When the floors have a concrete topping of not more than 51 mm (2 in.), the spans must be multiplied by 0.8.
3. Spans are clear spans between supports. For total span, add two bearing lengths.
4. 3-ply beams with supported lengths greater than 4.2 m (13 ft.–8 in.) require 114 mm (4½ in.) of bearing. All other beams require 76 mm (3 in.) bearing.
5. Supported length means half the sum of the joist spans on both sides of the beam.
6. Straight interpolation may be used for other supported lengths.

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Table 16
Maximum spans for built-up floor beams supporting not more than two floors[1, 2]

Commercial Designation	Grade	Supported Length, m[5, 6]	Maximum Span, m (ft.–in.)[3, 4]								
			Size of Built-up Beam, mm (in.)								
			38 x 184			38 x 235			38 x 286		
			2 x 8			2 x 10			2 x 12		
		ft	3-ply	4-ply	5-ply	3-ply	4-ply	5-ply	3-ply	4-ply	5-ply
Douglas Fir – Larch	No. 1 and No. 2	2.4	2.22	2.56	2.87	2.72	3.14	3.51	3.15	3.64	4.07
		8	7–3	8–4	9–4	8–10	10–2	11–5	10–3	11–10	13–3
		3.0	1.99	2.29	2.56	2.43	2.80	3.14	2.82	3.25	3.64
		10	6–6	7–6	8–4	7–11	9–2	10–2	9–2	10–7	11–10
		3.6	1.81	2.09	2.34	2.22	2.56	2.86	2.57	2.97	3.32
		12	5–11	6–10	7–7	7–3	8–4	9–4	8–4	9–8	10–10
		4.2	1.68	1.94	2.17	2.05	2.37	2.65	2.38	2.75	3.07
		14	5–6	6–4	7–1	6–8	7–9	8–7	7–9	8–11	10–0
		4.8	1.57	1.81	2.03	1.92	2.22	2.48	2.23	2.57	2.88
		16	5–1	5–11	6–7	6–3	7–3	8–1	7–3	8–4	9–4
		5.4	1.48	1.71	1.91	1.81	2.09	2.34	2.10	2.43	2.71
		18	4–10	5–7	6–3	5–11	6–10	7–7	6–10	7–11	8–10
		6.0	1.40	1.62	1.81	1.72	1.98	2.22	1.99	2.30	2.57
		20	4–7	5–3	5–11	5–7	6–5	7–3	6–6	7–6	8–4
Hem – Fir	No. 1 and No. 2	2.4	2.33	2.69	3.01	2.85	3.29	3.68	3.30	3.82	4.27
		8	7–7	8–9	9–9	9–3	10–8	12–0	10–9	12–5	13–11
		3.0	2.08	2.41	2.69	2.55	2.94	3.29	2.96	3.41	3.82
		10	6–9	7–10	8–9	8–3	9–7	10–8	9–7	11–1	12–5
		3.6	1.90	2.20	2.45	2.33	2.68	3.00	2.70	3.12	3.48
		12	6–2	7–2	8–0	7–7	8–9	9–9	8–9	10–2	11–4
		4.2	1.76	2.03	2.27	2.15	2.49	2.78	2.50	2.88	3.22
		14	5–9	6–7	7–5	7–0	8–1	9–1	8–2	9–5	10–6
		4.8	1.65	1.90	2.13	2.01	2.33	2.60	2.30	2.70	3.02
		16	5–4	6–2	6–11	6–7	7–7	8–6	7–6	8–9	9–10
		5.4	1.55	1.79	2.00	1.86	2.19	2.45	2.11	2.54	2.84
		18	5–1	5–10	6–6	6–0	7–2	8–0	6–10	8–3	9–3
		6.0	1.44	1.70	1.90	1.72	2.08	2.33	1.96	2.41	2.70
		20	4–8	5–6	6–2	5–7	6–9	7–7	6–4	7–10	8–9
Spruce – Pine – Fir	No. 1 and No. 2	2.4	2.41	2.79	3.03	2.95	3.41	3.81	3.42	3.95	4.42
		8	7–10	9–1	9–11	9–7	11–1	12–5	11–2	12–10	14–5
		3.0	2.16	2.49	2.79	2.64	3.05	3.41	3.06	3.53	3.95
		10	7–0	8–1	9–1	8–7	9–11	11–1	10–0	11–6	12–10
		3.6	1.97	2.27	2.54	2.41	2.78	3.11	2.79	3.23	3.61
		12	6–5	7–5	8–3	7–10	9–1	10–1	9–1	10–6	10–9
		4.2	1.82	2.11	2.35	2.23	2.57	2.88	2.59	2.99	3.34
		14	5–11	6–10	7–8	7–3	8–5	9–4	8–5	9–9	10–10
		4.8	1.71	1.97	2.20	2.09	2.41	2.69	2.42	2.79	3.12
		16	5–7	6–5	7–2	6–9	7–10	8–9	7–11	9–1	10–2
		5.4	1.61	1.86	2.08	1.97	2.27	2.54	2.28	2.63	2.95
		18	5–3	6–1	6–9	6–5	7–5	8–3	7–5	8–7	9–7
		6.0	1.53	1.76	1.97	1.86	2.15	2.41	2.11	2.50	2.79
		20	5–0	5–9	6–5	6–0	7–0	7–10	6–10	8–2	9–1

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Table 16 (continued)
Maximum spans for built-up floor beams supporting not more than two floors[1, 2]

Commercial Designation	Grade	Supported Length, m[5, 6]	Maximum Span, m (ft.–in.)[3, 4]								
			Size of Built-up Beam, mm (in.)								
			38 x 184			38 x 235			38 x 286		
			2 x 8			2 x 10			2 x 12		
		ft	3-ply	4-ply	5-ply	3-ply	4-ply	5-ply	3-ply	4-ply	5-ply
Northern Species	No. 1 and No. 2	2.4	1.94	2.24	2.50	2.37	2.73	3.06	2.75	3.17	3.55
		8	6–4	7–3	8–2	7–8	8–11	9–11	8–11	10–4	11–6
		3.0	1.73	2.00	2.24	2.12	2.44	2.73	2.46	2.84	3.17
		10	5–8	6–6	7–3	6–11	7–11	8–11	8–0	9–3	10–4
		3.6	1.58	1.83	2.04	1.93	2.23	2.50	2.24	2.59	2.90
		12	5–2	5–11	6–8	6–3	7–3	8–1	7–4	8–5	9–5
		4.2	1.46	1.69	1.89	1.79	2.07	2.31	2.08	2.40	2.68
		14	4–9	5–6	6–2	5–10	6–9	7–6	6–9	7–10	8–9
		4.8	1.37	1.58	1.77	1.67	1.93	2.16	1.94	2.24	2.51
		16	4–5	5–2	5–9	5–5	6–3	7–0	6–4	7–4	8–2
		5.4	1.29	1.49	1.67	1.58	1.82	2.04	1.83	2.11	2.36
		18	4–2	4–10	5–5	5–2	5–11	6–8	6–0	6–11	7–8
		6.0	1.22	1.41	1.58	1.50	1.73	1.93	1.74	2.01	2.24
		20	4–0	4–7	5–2	4–10	5–8	6–3	5–8	6–6	7–4

Notes to Table 16

1. Spans apply only where the floors serve residential areas.
2. When the floors have a concrete topping of not more than 51 mm (2 in.), the spans must be multiplied by 0.8.
3. Spans are clear spans between supports. For total span, add two bearing lengths.
4. 3-ply beams with supported lengths greater than 4.2 m (13 ft.–8 in.) require 114 mm (4½ in.) of bearing. All other beams require 76 mm (3 in.) bearing.
5. Supported length means half the sum of the joist spans on both sides of the beam.
6. Straight interpolation may be used for other supported lengths.

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Table 17
Maximum spans for built-up floor beams supporting not more than three floors[1, 2]

Commercial Designation	Grade	Supported Length, m[5, 6]	Maximum Span, m (ft.–in.)[3, 4]								
			Size of Built-up Beam, mm (in.)								
			38 x 184			38 x 235			38 x 286		
			2 x 8			2 x 10			2 x 12		
		ft.	3-ply	4-ply	5-ply	3-ply	4-ply	5-ply	3-ply	4-ply	5-ply
Douglas Fir – Larch	No. 1 and No. 2	2.4	1.85	2.14	2.39	2.26	2.61	2.92	2.63	3.03	3.39
		8	6–0	6–11	7–9	7–4	8–6	9–6	8–7	9–10	11–0
		3.0	1.66	1.91	2.14	2.02	2.34	2.61	2.35	2.71	3.03
		10	5–5	6–3	6–11	6–7	7–7	8–6	7–8	8–10	9–10
		3.6	1.51	1.74	1.95	1.85	2.13	2.39	2.14	2.48	2.77
		12	4–11	5–8	6–4	6–0	6–11	7–9	7–0	8–1	9–0
		4.2	1.40	1.62	1.81	1.71	1.98	2.21	1.99	2.29	2.56
		14	4–7	5–3	5–11	5–7	6–5	7–2	6–6	7–6	8–4
		4.8	1.31	1.51	1.69	1.60	1.85	2.07	1.86	2.14	2.40
		16	4–3	4–11	5–6	5–3	6–0	6–9	6–1	7–0	7–10
		5.4	1.23	1.42	1.59	1.51	1.74	1.95	1.75	2.02	2.26
		18	4–0	4–8	5–2	4–11	5–8	6–4	5–8	6–7	7–4
		6.0	1.17	1.35	1.51	1.43	1.65	1.85	1.66	1.92	2.14
		20	3–10	4–5	4–11	4–8	5–5	6–0	5–5	6–3	7–0
Hem – Fir	No. 1 and No. 2	2.4	1.94	2.24	2.51	2.37	2.74	3.06	2.75	3.18	3.56
		8	6–4	7–4	8–2	7–9	8–11	10–0	9–0	10–4	11–7
		3.0	1.74	2.00	2.24	2.12	2.45	2.74	2.46	2.84	3.18
		10	5–8	6–6	7–4	6–11	8–0	8–11	8–0	9–3	10–4
		3.6	1.58	1.83	2.05	1.92	2.24	2.50	2.18	2.60	2.90
		12	5–2	5–11	6–8	6–3	7–3	8–2	7–1	8–5	9–5
		4.2	1.43	1.69	1.89	1.71	2.07	2.32	1.95	2.40	2.69
		14	4–8	5–6	6–2	5–7	6–9	7–6	6–4	7–10	8–9
		4.8	1.30	1.58	1.77	1.56	1.92	2.17	1.77	2.18	2.51
		16	4–2	5–2	5–9	5–1	6–3	7–1	5–9	7–1	8–2
		5.4	1.19	1.47	1.67	1.44	1.76	2.04	1.64	2.00	2.35
		18	3–10	4–9	5–5	4–8	5–8	6–8	5–4	6–6	7–8
		6.0	1.11	1.36	1.58	1.34	1.63	1.92	1.53	1.85	2.18
		20	3–7	4–5	5–2	4–4	5–3	6–3	5–0	6–0	7–1
Spruce – Pine – Fir	No. 1 and No. 2	2.4	2.01	2.32	2.60	2.46	2.84	3.17	2.85	3.29	3.68
		8	6–7	7–7	8–5	8–0	9–3	10–4	9–3	10–9	12–0
		3.0	1.80	2.08	2.32	2.20	2.54	2.84	2.55	2.95	3.29
		10	5–10	6–9	7–7	7–2	8–3	9–3	8–4	9–7	10–9
		3.6	1.64	1.90	2.12	2.01	2.32	2.59	2.33	2.69	3.01
		12	5–4	6–2	6–11	6–6	7–7	8–5	7–7	8–9	9–9
		4.2	1.52	1.75	1.96	1.85	2.15	2.40	2.10	2.49	2.78
		14	4–11	5–9	6–5	6–0	7–0	7–10	6–10	8–1	9–1
		4.8	1.40	1.64	1.84	1.68	2.01	2.24	1.91	2.33	2.60
		16	4–6	5–4	6–0	5–5	6–6	7–4	6–2	7–7	8–6
		5.4	1.28	1.55	1.73	1.54	1.89	2.12	1.76	2.16	2.46
		18	4–2	5–0	5–8	5–0	6–2	6–11	5–9	7–0	8–0
		6.0	1.19	1.47	1.64	1.44	1.76	2.01	1.64	2.00	2.33
		20	3–10	4–9	5–4	4–8	5–8	6–6	5–4	6–6	7–7

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Table 17 (continued)
Maximum spans for built-up floor beams supporting not more than three floors[1, 2]

Commercial Designation	Grade	Supported Length, m[5, 6]	Maximum Span, m (ft.–in.)[3, 4]								
			Size of Built-up Beam, mm (in.)								
			38 x 184			38 x 235			38 x 286		
			2 x 8			2 x 10			2 x 12		
		ft.	3-ply	4-ply	5-ply	3-ply	4-ply	5-ply	3-ply	4-ply	5-ply
Northern Species	No. 1 and No. 2	2.4	1.61	1.86	2.08	1.97	2.28	2.55	2.29	2.64	2.96
		8	5–3	6–1	6–9	6–5	7–5	8–3	7–5	8–7	9–7
		3.0	1.44	1.67	1.86	1.76	2.04	2.28	2.05	2.36	2.64
		10	4–8	5–5	6–1	5–9	6–8	7–5	6–8	7–8	8–7
		3.6	1.32	1.52	1.70	1.61	1.86	2.08	1.87	2.16	2.41
		12	4–3	4–11	5–6	5–3	6–1	6–9	6–1	7–0	7–10
		4.2	1.22	1.41	1.57	1.49	1.72	1.93	1.73	2.00	2.23
		14	4–0	4–7	5–1	4–10	5–7	6–3	5–8	6–6	7–3
		4.8	1.14	1.32	1.47	1.40	1.61	1.80	1.62	1.87	2.09
		16	3–9	4–3	4–10	4–6	5–3	5–10	5–3	6–1	6–10
		5.4	1.08	1.24	1.39	1.32	1.52	1.70	1.53	1.76	1.97
		18	3–6	4–1	4–6	4–3	4–11	5–6	5–0	5–9	6–5
		6.0	1.02	1.18	1.32	1.25	1.44	1.61	1.45	1.67	1.87
		20	3–4	3–10	4–3	4–1	4–8	5–3	4–9	5–5	6–1

Notes to Table 17

1. Spans apply only where the floors serve residential areas.
2. When the floors have a concrete topping of not more than 51 mm (2 in.), the spans must be multiplied by 0.8.
3. Spans are clear spans between supports. For total span, add two bearing lengths.
4. 3-ply beams with supported lengths greater than 4.2 m (13 ft.–8 in.) require 114 mm (4½ in.) of bearing. All other beams require 76 mm (3 in.) bearing.
5. Supported length means half the sum of the joist spans on both sides of the beam.
6. Straight interpolation may be used for other supported lengths.

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Table 18
Spans for steel floor beams

Section	Supported Joist Length, m (ft.), (half the sum of joist spans for both sides of the beam)													
	2.4 m	7 ft. 10 in.	3 m	9 ft. 9 in.	3.6 m	11 ft. 9 in.	4.2 m	13 ft. 9 in.	4.8 m	15 ft. 8 in.	5.4 m	17 ft. 8 in.	6.0 m	19 ft. 11 in.
	One storey supported													
W150 x 22	5.5	18-0	5.2	17-1	4.9	16-1	4.8	15-8	4.6	15-1	4.5	14-9	4.3	14-1
W200 x 21	6.5	21-3	6.2	20-3	5.9	19-5	5.7	18-8	5.4	17-8	5.1	16-8	4.9	16-1
W200 x 27	7.3	23-10	6.9	22-7	6.6	21-7	6.3	20-8	6.1	20-0	5.9	19-4	5.8	19-0
W200 x 31	7.8	25-7	7.4	24-3	7.1	23-3	6.8	22-3	6.6	21-7	6.4	21-0	6.2	20-3
W250 x 24	8.1	26-7	7.6	24-10	7.3	23-10	7.0	23-0	6.6	21-7	6.2	20-3	5.9	19-4
W250 x 33	9.2	30-2	8.7	28-6	8.3	27-2	8.0	26-2	7.7	25-3	7.5	24-7	7.3	23-10
W250 x 39	10.0	32-9	9.4	30-9	9.0	29-6	8.6	28-2	8.4	27-7	8.1	26-7	7.9	25-10
W310 x 31	10.4	34-1	9.8	32-1	9.4	30-9	8.9	29-2	8.4	27-7	8.0	26-2	7.6	24-10
W310 x 39	11.4	37-4	10.7	35-1	10.0	32-9	9.8	32-1	9.5	31-2	9.2	30-2	9.0	29-6
	Two storeys supported													
W150 x 22	4.9	16-1	4.4	14-3	4.1	13-3	3.8	12-6	3.5	12-6	3.4	11-2	3.2	10-6
W200 x 21	5.6	18-4	5.1	16-8	4.6	15-1	4.3	14-1	4.1	13-4	3.8	12-6	3.7	12-1
W200 x 27	6.4	21-0	6.1	20-0	5.6	18-4	5.3	17-4	4.9	16-1	4.7	15-4	4.4	14-4
W200 x 31	6.9	22-7	6.5	21-3	6.2	20-3	5.8	19-0	5.4	17-8	5.1	16-8	4.9	16-1
W250 x 24	6.8	22-3	6.1	20-0	5.6	18-4	5.2	17-1	4.9	16-1	4.6	15-1	4.4	14-4
W250 x 33	8.2	26-10	7.7	25-3	7.0	23-0	6.5	21-3	6.1	20-0	5.8	19-0	5.5	18-0
W250 x 39	8.8	28-10	8.3	27-2	7.8	25-7	7.2	23-7	6.8	22-3	6.4	21-0	6.1	20-0
W310 x 31	8.7	28-6	7.8	25-7	7.2	23-7	6.7	22-0	6.2	20-3	5.9	19-4	5.6	18-4
W310 x 39	10.0	32-9	9.3	30-6	8.5	27-10	7.9	25-10	7.4	24-3	7.0	23-0	6.7	22-0

Note to Table 18

1. The section information provides the beam depth and weight in metric units. For example, a W150 x 22 beam is 150 mm (6 in.) deep and weighs 22 kg. per metre (14.8 lbs. per foot)

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Table 19
Maximum spans for glue-laminated floor beams – 20f-E grade[1]

Number of Floors Supported	Beam Width, mm (in.)	Supported Length, m[6,7]	Maximum Span, m (ft.–in.)[2 to 5] Beam Depth, mm (in.) 228	266	304	342	380	418	456
		ft	9	10½	12	13½	15	16½	18
1	80 (3)	2.4	4.32	5.04	5.76	6.48	7.20	7.92	8.64
		8	14–1	16–5	18–9	21–1	23–5	25–9	28–2
		3.0	3.87	4.51	5.15	5.80	6.44	7.09	7.73
		10	12–7	14–8	16–9	18–10	21–0	23–1	25–2
		3.6	3.53	4.12	4.70	5.29	5.88	6.47	7.06
		12	11–6	13–5	15–4	17–3	19–2	21–1	23–0
		4.2	3.27	3.81	4.36	4.90	5.44	5.99	6.53
		14	10–8	12–5	14–2	15–11	17–9	19–6	21–3
		4.8	3.06	3.57	4.07	4.58	5.09	5.60	6.11
		16	9–11	11–7	13–3	14–11	16–7	18–3	19–11
		5.4	2.88	3.36	3.84	4.32	4.80	5.28	5.76
		18	9–5	10–11	12–6	14–1	15–8	17–2	18–9
		6.0	2.73	3.19	3.64	4.10	4.56	5.01	5.47
		20	8–11	10–5	11–10	13–4	14–10	16–4	17–10
1	130 (5)	2.4	5.51	6.43	7.35	8.26	9.18	10.10	11.02
		8	17–11	20–11	23–11	26–11	29–11	32–11	35–10
		3.0	4.93	5.75	6.57	7.39	8.21	9.03	9.86
		10	16–0	18–9	21–5	24–1	26–9	29–5	32–1
		3.6	4.50	5.25	6.00	6.75	7.50	8.25	9.00
		12	14–8	17–1	19–6	22–0	24–5	26–10	29–3
		4.2	4.16	4.86	5.55	6.25	6.94	7.64	8.33
		14	13–7	15–10	18–1	20–4	22–7	24–10	27–1
		4.8	3.90	4.54	5.19	5.84	6.49	7.14	7.79
		16	12–8	14–10	16–11	19–0	21–2	23–3	25–4
		5.4	3.67	4.28	4.90	5.51	6.12	6.73	7.35
		18	11–11	13–11	15–11	17–11	19–11	21–11	23–11
		6.0	3.48	4.07	4.65	5.23	5.81	6.39	6.97
		20	11–4	13–3	15–1	17–0	18–11	20–10	22–8
2	80 (3)	2.4	3.28	3.83	4.37	4.92	5.47	6.01	6.56
		8	10–8	12–5	14–3	16–0	17–9	19–7	21–4
		3.0	2.93	3.42	3.91	4.40	4.89	5.38	5.87
		10	9–7	11–2	12–9	14–4	15–11	17–6	19–1
		3.6	2.68	3.12	3.57	4.02	4.46	4.91	5.36
		12	8–9	10–2	11–7	13–1	14–6	16–0	17–5
		4.2	2.48	2.89	3.31	3.72	4.13	4.54	4.96
		14	8–1	9–5	10–9	12–1	13–5	14–10	16–2
		4.8	2.32	2.71	3.09	3.48	3.86	4.25	4.64
		16	7–7	8–10	10–1	11–4	12–7	13–10	15–1
		5.4	2.19	2.55	2.91	3.28	3.64	4.01	4.37
		18	7–1	8–4	9–6	10–8	11–10	13–1	14–3
		6.0	2.07	2.42	2.77	3.11	3.46	3.80	4.15
		20	6–9	7–11	9–0	10–2	11–3	12–5	13–6

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Table 19 (continued)
Maximum spans for glue-laminated floor beams – 20f-E grade[1]

Number of Floors Supported	Beam Width, mm (in.)	Supported Length, m[6, 7]	Maximum Span, m (ft.–in.)[2 to 5] Beam Depth, mm (in.) 228	266	304	342	380	418	456
		ft	9	10½	12	13½	15	16½	18
2	130 (5)	2.4	4.18	4.88	5.57	6.27	6.97	7.66	8.36
		8	13–7	15–10	18–2	20–5	22–8	24–11	27–3
		3.0	3.74	4.36	4.99	5.61	6.23	6.85	7.48
		10	12–2	14–2	16–3	18–3	20–3	22–4	24–4
		3.6	3.41	3.98	4.55	5.12	5.69	6.26	6.83
		12	11–1	13–0	14–10	16–8	18–6	20–4	22–3
		4.2	3.16	3.69	4.21	4.74	5.27	5.79	6.32
		14	10–3	12–0	13–9	15–5	17–2	18–10	20–7
		4.8	2.96	3.45	3.94	4.43	4.93	5.42	5.91
		16	9–7	11–3	12–10	14–5	16–0	17–8	19–3
		5.4	2.79	3.25	3.72	4.18	4.64	5.11	5.57
		18	9–1	10–7	12–1	13–7	15–1	16–8	18–2
		6.0	2.64	3.08	3.53	3.97	4.41	4.85	5.29
		20	8–7	10–0	11–6	12–11	14–4	15–9	17–3
3	80 (3)	2.4	2.75	3.21	3.66	4.12	4.58	5.04	5.50
		8	8–11	10–5	11–11	13–5	14–11	16–5	17–11
		3.0	2.46	2.87	3.28	3.69	4.10	4.51	4.92
		10	8–0	9–4	10–8	12–0	13–4	14–8	16–0
		3.6	2.24	2.62	2.99	3.37	3.74	4.11	4.49
		12	7–4	8–6	9–9	10–11	12–2	13–5	14–7
		4.2	2.08	2.42	2.77	3.12	3.46	3.81	4.15
		14	6–9	7–11	9–0	10–2	11–3	12–5	13–6
		4.8	1.94	2.27	2.59	2.91	3.24	3.56	3.89
		16	6–4	7–5	8–5	9–6	10–6	11–7	12–8
		5.4	1.83	2.14	2.44	2.75	3.05	3.36	3.66
		18	6–0	6–11	7–11	8–11	9–11	10–11	11–11
		6.0	1.74	2.03	2.32	2.61	2.90	3.19	3.48
		20	5–8	6–7	7–7	8–6	9–5	10–4	11–4
3	130 (5)	2.4	3.50	4.09	4.67	5.25	5.84	6.42	7.01
		8	11–5	13–4	15–2	17–1	19–0	20–11	22–10
		3.0	3.13	3.66	4.18	4.70	5.22	5.74	6.27
		10	10–2	11–11	13–7	15–4	17–0	18–8	20–5
		3.6	2.86	3.34	3.81	4.29	4.77	5.24	5.72
		12	9–4	10–10	12–5	14–0	15–6	17–1	18–7
		4.2	2.65	3.09	3.53	3.97	4.41	4.85	5.30
		14	8–7	10–1	11–6	12–11	14–4	15–10	17–3
		4.8	2.48	2.89	3.30	3.72	4.13	4.54	4.95
		16	8–1	9–5	10–9	12–1	13–5	14–9	16–1
		5.4	2.34	2.72	3.11	3.50	3.89	4.28	4.67
		18	7–7	8–10	10–2	11–5	12–8	13–11	15–2
		6.0	2.22	2.58	2.95	3.32	3.69	4.06	4.43
		20	7–3	8–5	9–7	10–10	12–0	13–3	14–5

Notes to Table 19

1. Spans apply only where the floors serve residential areas.
2. Spans are valid for glue-laminated timber conforming to CAN/CSA-O122-M and CAN/CSA-O177-M.
3. Spans are clear spans between supports. For total span, add two bearing lengths.
4. Provide a minimum bearing length of 89 mm (3½ in.).
5. Top edge of beam assumed to be fully laterally supported by joists.
6. Supported length means half the sum of the joist spans on both sides of the beam.
7. Straight interpolation may be used for other supported lengths

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Table 20
Maximum spans for floor joists – general cases[1, 2]

Commercial Designation	Grade	Joist Size, mm	Maximum Span, m (ft.–in.) Joist Spacing, mm (in.) With Strapping 300	With Strapping 400	With Strapping 600	With Bridging 300	With Bridging 400	With Bridging 600	With Strapping and Bridging 300	With Strapping and Bridging 400	With Strapping and Bridging 600
		in.	12	16	24	12	16	24	12	16	24
Douglas fir – larch (includes Douglas fir and western larch)	No. 1 and No. 2	38 x 140	3.09	2.91	2.62	3.29	2.99	2.62	3.29	2.99	2.62
		2 x 6	10–2	9–7	8–7	10–10	9–10	8–7	10–10	9–10	8–7
		38 x 184	3.71	3.53	3.36	4.00	3.76	3.44	4.19	3.90	3.44
		2 x 8	12–2	11–7	11–0	13–1	12–4	11–3	13–9	12–10	11–3
		38 x 235	4.38	4.16	3.96	4.66	4.38	4.11	4.84	4.51	4.20
		2 x 10	14–4	13–8	13–0	15–3	14–4	13–6	15–10	14–10	13–10
		38 x 286	4.99	4.75	4.52	5.26	4.94	4.65	5.43	5.06	4.72
		2 x 12	16–5	15–7	14–10	17–2	16–2	15–3	17–10	16–7	15–6
Hem – fir (includes western hemlock and amabilis fir)	No. 1 and No. 2	38 x 140	3.09	2.91	2.62	3.29	2.99	2.62	3.29	2.99	2.62
		2 x 6	10-2	9–7	8–7	10–10	9–10	8–7	10–10	9–10	8–7
		38 x 184	3.71	3.53	3.36	4.00	3.76	3.44	4.19	3.90	3.44
		2 x 8	12–2	11–7	11–0	13–1	12–4	11–3	13–9	12–10	11–3
		38 x 235	4.38	4.16	3.96	4.66	4.38	4.11	4.84	4.51	4.20
		2 x 10	14–4	13–8	13–0	15–3	14–4	13–6	15–10	14–10	13–10
		38 x 286	4.99	4.75	4.52	5.26	4.94	4.65	5.43	5.06	4.72
		2 x 12	16–5	15–7	14–10	17–2	16–2	15–3	17–10	16–7	15–6
Spruce, pine, or fir (includes spruce [all species except coast sitka spruce], jack pine, lodgepole pine, balsam fir and alpine fir)	No. 1 and No. 2	38 x 140	2.92	2.71	2.49	3.14	2.85	2.49	3.14	2.85	2.49
		2 x 6	9–7	8–11	8–2	10–4	9–4	8–2	10–4	9–4	8–2
		38 x 184	3.54	3.36	3.20	3.81	3.58	3.27	3.99	3.72	3.27
		2 x 8	11–7	11–0	10–6	12–5	11–9	10–9	13–1	12–2	10–9
		38 x 235	4.17	3.96	3.77	4.44	4.17	3.92	4.60	4.29	4.00
		2 x 10	13–8	13–0	12–4	14–6	13–8	12–10	15–1	14–1	13–2
		38 x 286	4.75	4.52	4.30	5.01	4.71	4.42	5.17	4.82	4.49
		2 x 12	15–7	14–10	14–1	16–4	15–5	14–6	17–0	15–10	14–9
Northern species (includes any Canadian species covered by the NLGA Standard Grading Rules)	No. 1 and No. 2	38 x 140	2.51	2.33	2.16	2.83	2.57	2.25	2.83	2.57	2.25
		2 x 6	8–3	7–8	7–1	9–3	8–5	7–5	9–4	8–5	7–5
		38 x 184	3.19	3.04	2.84	3.44	3.23	2.96	3.60	3.36	2.96
		2 x 8	10–6	10–0	9–4	11–3	10–7	9–8	11–10	11–0	9–8
		38 x 235	3.76	3.58	3.41	4.01	3.77	3.54	4.16	3.88	3.62
		2 x 10	12–4	11–9	11–2	13–1	12–4	11–7	13–8	12–9	11–10
		38 x 286	4.29	4.08	3.88	4.53	4.25	4.00	4.67	4.35	4.06
		2 x 12	14–1	13–5	12–9	14–9	13–11	13–1	15–4	14–4	13–4

Note to Table 20

1. Spans apply only where the floors serve residential areas.
2. Subfloor must comply with minimum requirements from Tables 18 and 19.

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Table 21
Maximum spans for floor joists – special cases[1, 2]

Commercial Designation	Grade	Joist Size, mm / in.	Maximum Span, m (ft.–in.)								
			Joists with ceilings attached to Wood Furring						Joists with concrete topping		
			Joist Spacing, mm (in.)						Joist Spacing, mm (in.)		
			Without Bridging			With Bridging			With or Without Bridging[3]		
			300	400	600	300	400	600	300	400	600
			12	16	24	12	16	24	12	16	24
Douglas fir – larch (includes Douglas fir and western larch)	No. 1 and No. 2	38 x 140	3.29	2.99	2.62	3.29	2.99	2.62	3.29	2.99	2.55
		2 x 6	10-10	9-10	8-7	10-10	9-10	8-7	10-10	9-10	8-5
		38 x 184	4.06	3.83	3.44	4.33	3.93	3.44	4.33	3.81	3.11
		2 x 8	13-4	12-7	11-3	14-2	12-11	11-3	14-2	12-6	10-2
		38 x 235	4.78	4.50	4.11	5.24	4.98	4.31	5.37	4.65	3.80
		2 x 10	15-8	14-9	13-6	17-2	16-4	14-2	17-8	15-3	12-6
		38 x 286	5.44	5.12	4.68	5.93	5.64	5.00	6.24	5.40	4.41
		2 x 12	17-10	16-10	15-4	19-5	18-6	16-5	20-6	17-9	14-6
Hem – fir (includes western hemlock and amabilis fir)	No. 1 and No. 2	38 x 140	3.29	2.99	2.62	3.29	2.99	2.62	3.29	2.99	2.62
		2 x 6	10-10	9-10	8-7	10-10	9-10	8-7	10-10	9-10	8-7
		38 x 184	4.06	3.83	3.44	4.33	3.93	3.44	4.33	3.93	3.26
		2 x 8	13-4	12-7	11-3	14-2	12-11	11-3	14-2	12-11	10-8
		38 x 235	4.78	4.50	4.11	5.24	4.98	4.39	5.53	4.88	3.99
		2 x 10	15-8	14-9	13-6	17-2	16-4	14-5	18-2	16-0	13-1
		38 x 286	5.44	5.12	4.68	5.93	5.64	5.25	6.54	5.66	4.63
		2 x 12	17-10	16-10	15-4	19-5	18-6	17-3	21-6	18-7	15-2
Spruce, pine, or fir (includes spruce [all species except coast sitka spruce], jack pine, lodgepole pine, balsam fir and alpine fir)	No. 1 and No. 2	38 x 140	3.14	2.85	2.49	3.14	2.85	2.49	3.14	2.85	2.49
		2 x 6	10-4	9-4	8-2	10-4	9-4	8-2	10-4	9-4	8-2
		38 x 184	3.87	3.64	3.27	4.12	3.75	3.27	4.12	3.75	3.27
		2 x 8	12-8	11-11	10-9	13-6	12-4	10-9	13-6	12-4	10-9
		38 x 235	4.55	4.28	3.91	4.99	4.75	4.18	5.27	4.79	4.13
		2 x 10	14-11	14-1	12-10	16-4	15-7	13-9	17-3	15-8	13-7
		38 x 286	5.18	4.88	4.46	5.65	5.37	5.06	6.23	5.81	4.79
		2 x 12	17-0	16-0	14-7	18-6	17-7	16-7	20-5	19-1	15-9
Northern species (includes any Canadian species covered by the NLGA Standard Grading Rules)	No. 1 and No. 2	38 x 140	2.83	2.57	2.25	2.83	2.57	2.25	2.83	2.57	2.23
		2 x 6	9-4	8-5	7-5	9-4	8-5	7-5	9-4	8-5	7-4
		38 x 184	3.50	3.29	2.96	3.72	3.38	2.96	3.72	3.32	2.71
		2 x 8	11-6	10-10	9-8	12-3	11-1	9-8	12-3	10-11	8-11
		38 x 235	4.11	3.87	3.54	4.51	4.29	3.76	4.69	4.06	3.31
		2 x 10	13-6	12-8	11-7	14-9	14-1	12-4	15-4	13-4	10-10
		38 x 286	4.68	4.40	4.03	5.10	4.85	4.36	5.44	4.71	3.84
		2 x 12	15-4	14-5	13-2	16-9	15-11	14-4	17-10	15-5	12-7

Notes to Table 21

1. Spans apply only where the floors serve residential areas.
2. Subfloor must comply with minimum requirements from Tables 18 and 19.
3. No bridging is assumed for spans for floor joists with concrete topping.

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Table 22
Minimum thickness of subflooring

	Minimum Subflooring Thickness, mm (in.), for Maximum Joist Spacing at		
	400 (16)	500 (20)	600 (24)
Plywood and OSB, O-2 grade	15.5 (5/8)	15.5 (5/8)	18.5 (23/32)
OSB, O-1 grade, and waferboard, R-1 Grade	15.9 (5/8)	15.9 (5/8)	19.0 (3/4)
Particleboard	15.9 (5/8)	19.0 (3/4)	25.4 (1)
Panel mark (performance-rated panels) sub-floor only	1F16	1F20	1F24
Panel mark (performance-rated panels) sub-floor and underlay	2F16	2F20	2F24
Lumber	17.0 (11/16)	19.0 (3/4)	19.0 (3/4)

Table 23
Sheathing and subfloor attachment

	Minimum Length of Fasteners for Sheathing and Subfloor Attachment, mm (in.)				
Element	Common or Spiral Nails	Ring Thread Nails or Screws	Roofing Nails	Staples	Minimum No. or Maximum Spacing of Fasteners
Plywood, OSB or waferboard up to 10 mm (3/8 in.) thick	51 (2)	45 (1 3/4)	N/A	38 (1 1/2)	150 mm (6 in.) o.c. along edges and 300 mm (12 in.) o.c. along intermediate supports
Plywood, OSB or waferboard 10 mm (3/8 in.) to 20 mm (13/16 in.) thick	51 (2)	45 (1 3/4)	N/A	51 (2)	
Plywood, OSB or waferboard over 20 mm (13/16 in.) thick	57 (2 1/4)	51 (2)	N/A	N/A	
Fibreboard sheathing up to 13 mm (1/2 in.) thick	N/A	N/A	44 (1 3/4)	28 (1 1/8)	
Gypsum sheathing up to 13mm (1/2 in.) thick	N/A	N/A	44 (1 3/4)	N/A	
Board lumber 184 mm (8 in.) or less wide	51 (2)	45 (1 3/4)	N/A	51 (2)	2 per support
Board lumber more than 184 mm (8 in.) wide	51 (2)	45 (1 3/4)	N/A	51 (2)	3 per support

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Table 24
Nailing for framing[1]

Construction Detail	Minimum Length of Nails, mm (in.)		Minimum Number or Maximum Spacing of Nails
Floor joist to plate – toe nail	82	(3¼)	2
Wood or metal strapping to underside of floor joists	57	(2¼)	2
Cross bridging to joists	57	(2¼)	2 at each end
Double header or trimmer joists	76	(3)	300 mm (12 in.) (o.c.)
Floor joist to stud (balloon construction)	76	(3)	2
Ledger strip to wood beam	82	(3¼)	2 per joist
Joist to joist splice (See Table 29)	76	(3)	2 at each end
Tail joist to adjacent header joist (end nailed) around openings	82 101	(3¼) (4)	5 3
Each header joist to adjacent trimmer joist (end nailed) around openings	82 101	(3¼) (4)	5 3
Stud to wall plate (each end) toe nail or end nail	63 82	(2½) (3¼)	4 2
Doubled studs at openings, or studs at walls or wall intersections and corners	76	(3)	750 mm (30 in.) (o.c.)
Doubled top wall plates	76	(3)	600 mm (24 in.) (o.c.)
Bottom wall plate or sole plate to joists or blocking (exterior walls)[1]	82	(3¼)	400 mm (16 in.) (o.c)
Interior walls to framing or subflooring	82	(3¼)	600 mm (24 in.) (o.c.)
Horizontal members over openings in non-loadbearing walls – each end	82	(3¼)	2
Lintels to studs	82	(3¼)	2 at each end
Ceiling joist to plate – toe nail each end	82	(3¼)	2
Roof rafter, roof truss or roof joist to plate – toe nail	82	(3¼)	3

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Table 24 (continued)
Nailing for framing[1]

Construction Detail	Minimum Length of Nails, mm (in.)		Minimum Number or Maximum Spacing of Nails
Rafter plate to each ceiling joist	101	(4)	2
Rafter to joist (with ridge supported)	76	(3)	3
Rafter to joist (with ridge unsupported)	76	(3)	See Table 30
Gusset plate to each rafter at peak	57	(2¼)	4
Rafter to ridge board – toe nail – end nail	82	(3¼)	3
Collar tie to rafter – each end	76	(3)	3
Collar tie lateral support to each collar tie	57	(2¼)	2
Jack rafter to hip or valley rafter	82	(3¼)	2
Roof strut to rafter	76	(3)	3
Roof strut to loadbearing wall – toe nail	82	(3¼)	2
38 mm x 140 mm (2 in. x 6 in.) or less plank decking to support	82	(3¼)	2
Plank decking wider than 38 mm x 140 mm (2 in. x 6 in.) to support	82	(3¼)	3
38 mm (2 in.) edge laid plank decking to support (toe nail)	76	(3)	1
38 mm (2 in.) edge laid plank to each other	76	(3)	450 mm (18 in.) (o.c.)

Note to Table 24

1. Where the bottom wall plate or sole plate of an exterior wall is not nailed to joists or blocking, the exterior wall is permitted to be fastened to the floor framing by plywood, OSB, or waferboard sheathing that extends down over the floor framing and is fastened to that framing by nails or staples. The wall can also be fastened by tying the wall framing to the floor framing with galvanized strips that are 50 mm (2 in.) wide, 0.41 mm (0.016 in.) in thickness or more, spaced not more than 1.2 m (48 in.) apart and fastened at each end with at least two 63 mm (2½ in.) nails.

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Table 25
Size and spacing of studs

Type of Wall	Supported Loads (including dead loads)	Minimum Stud Size mm (in.)	Maximum Stud Spacing, mm (in.)	Maximum Unsupported Height m (ft.–in.)
Interior	No load	38 x 38 (2 x 2) 38 x 89 (2 x 4) flat[1]	400 (16) 400 (16)	2.4 (8–0) 3.6 (11–10)
	Attic not accessible by a stairway	38 x 64 (2 x 3) 38 x 64 (2 x 3) flat[1] 38 x 89 (2 x 4) 38 x 89 (2 x 4) flat[1]	600 (24) 400 (16) 600 (24) 400 (16)	3.0 (9–10) 2.4 (8–0) 3.6 (11–10) 2.4 (8–0)
	Attic accessible by a stairway plus one floor Roof load plus one floor Attic not accessible by a stairway plus two floors	38 x 89 (2 x 4)	400 (16)	3.6 (11–10)
	Roof load Attic accessible by a stairway Attic not accessible by a stairway plus one floor	38 x 64 (2 x 3) 38 x 89 (2 x 4)	400 (16) 600 (24)	2.4 (8–0) 3.6 (11–10)
	Attic accessible by a stairway plus two floors Roof load plus two floors	38 x 89 (2 x 4) 38 x 140 (2 x 6)	300 (12) 400 (16)	3.6 (11–10) 4.2 (13–9)
	Attic accessible by a stairway plus three floors	38 x 140 (2 x 6)	300 (12)	4.2 (13–9)
Exterior	Roof with or without attic storage	38 x 64 (2 x 3) 38 x 89 (2 x 4)	400 (16) 600 (24)	2.4 (8–0) 3.0 (9–10)
	Roof with or without attic storage plus one floor	38 x 89 (2 x 4) 38 x 140 (2 x 6)	400 (16) 600 (24)	3.0 (9–10) 3.0 (9–10)
	Roof with or without attic storage plus two floors	38 x 89 (2 x 4) 38 x 140 (2 x 6)	300 (12) 400 (16)	3.0 (9–10) 3.6 (11–10)
	Roof with or without attic storage plus three floors	38 x 140 (2 x 6)	300 (12)	1.8 (6–0)

Note to Table 25

1. Studs on the flat are permitted to be used in gable ends of roofs that contain only unfinished space or in non-loadbearing interior walls within the limits described in the National Building Code of Canada. Studs supporting only a load from an attic not accessible from a stairway are permitted to be placed on the flat, in accordance with this table, if they are clad on not less than one side with plywood, OSB, or waferboard sheathing fastened to the face of the studs with a structural adhesive, and if the portion of the roof supported by the studs does not exceed 2.1 m (6 ft.–10 in.) in width.

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Table 26
Maximum spans for spruce, pine or fir lintels – No. 1 or No. 2 grade – non-structural sheathing[7]

Lintel Supporting	Lintel Size, mm / in.[4]	Maximum Span, m (ft.–in.)[2,3] — Exterior Walls — Specified Snow Load, kPa (psf)[6] 1.0 (20.9)	1.5 (31.3)	2.0 (41.8)	2.5 (52.2)	3.0 (62.7)	Interior Walls
	2-ply						
Limited attic storage and ceiling	2-38 x 89	This area intentionally left blank					1.27
	2-2 x 4						4–2
	2-38 x 140						1.93
	2-2 x 6						6–4
	2-38 x 184						2.35
	2-2 x 8						7–9
	2-38 x 235						2.88
	2-2 x 10						9–5
	2-38 x 286						3.34
	2-2 x 12						11–0
Lintel Supporting Roof and ceiling only (tributary width 0.6 m (2 ft.))[6]	2-38 x 89	2.55	2.23	2.02	1.88	1.77	1.88
	2-2 x 4	8-4	7-4	6-8	6-2	5-10	6-2
	2-38 x 140	4.01	3.50	3.18	2.96	2.78	2.96
	2-2 x 6	13-2	11-6	10-5	9-8	9-2	9-8
	2-38 x 184	5.27	4.61	4.18	3.88	3.66	3.88
	2-2 x 8	17-4	15-1	13-9	12-9	12-0	12-9
	2-38 x 235	6.37	5.76	5.34	4.96	4.67	4.96
	2-2 x 10	20-11	18-11	17-6	16-3	15-4	16-3
	2-38 x 286	7.38	6.67	6.21	5.87	5.61	5.87
	2-2 x 12	24-3	21-11	20-4	19-3	18-5	19-3
Lintel Supporting Roof and ceiling only (tributary width 4.9 m (16 ft. 0 in.))[1]	2-38 x 89	1.27	1.11	1.01	0.93	0.87	0.93
	2-2 x 4	4-2	3-8	3-4	3-1	2-10	3-1
	2-38 x 140	1.93	1.66	1.48	1.35	1.25	1.35
	2-2 x 6	6-4	5-5	4-10	4-5	4-1	4-5
	2-38 x 184	2.35	2.02	1.80	1.64	1.52	1.64
	2-2 x 8	7-9	6-8	5-11	5-5	5-0	5-5
	2-38 x 235	2.88	2.47	2.20	2.01	1.84	2.01
	2-2 x 10	9-5	8-1	7-3	6-7	6-1	6-7
	2-38 x 286	3.34	2.87	2.56	2.33	2.09	2.33
	2-2 x 12	11-0	9-5	8-5	7-8	6-10	7-8
Lintel Supporting Roof, ceiling and 1 storey[1,2,5]	2-38 x 89	1.05	0.96	0.89	0.84	0.79	0.74
	2-2 x 4	3-5	3-2	2-11	2-9	2-7	2-5
	2-38 x 140	1.49	1.37	1.27	1.19	1.13	1.02
	2-2 x 6	4-11	4-6	4-2	3-11	3-8	3-4
	2-38 x 184	1.82	1.67	1.55	1.44	1.33	1.20
	2-2 x 8	6-0	5-6	5-1	4-9	4-4	3-11
	2-38 x 235	2.22	2.04	1.89	1.73	1.59	1.45
	2-2 x 10	7-3	6-8	6-2	5-8	5-3	4-9
	2-38 x 286	2.58	2.36	2.15	1.96	1.81	1.66
	2-2 x 12	8-5	7-9	7-1	6-5	5-11	5-5

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Table 26 (continued)
Maximum spans for spruce, pine or fir lintels – No. 1 or No. 2 grade – non-structural sheathing[7]

Lintel Supporting	Lintel Size, mm / in.[4]	Maximum Span, m (ft.–in.)[2,3] Exterior Walls Specified Snow Load, kPa (psf)[6] 1.0 (20.9)	1.5 (31.3)	2.0 (41.8)	2.5 (52.2)	3.0 (62.7)	Interior Walls
	2-ply						
Lintel Supporting Roof ceiling and 2 storeys[1,2,5]	2-38 x 89	0.94	0.88	0.83	0.79	0.76	0.64
	2-2 x 4	3-1	2-11	2-9	2-7	2-6	2-1
	2-38 x 140	1.34	1.26	1.19	1.13	1.06	0.88
	2-2 x 6	4-5	4-2	3-11	3-8	3-6	2-11
	2-38 x 184	1.63	1.53	1.44	1.33	1.25	1.05
	2-2 x 8	5-4	5-0	4-9	4-4	4-1	3-5
	2-38 x 235	1.99	1.87	1.72	1.60	1.50	1.27
	2-2 x 10	6-6	6-2	5-8	5-3	4-11	4-2
	2-38 x 286	2.31	2.12	1.96	1.82	1.71	1.45
	2-2 x 12	7-7	6-11	6-5	6-0	5-7	4-9
Lintel Supporting Roof ceiling and 3 storeys[1,2,5]	2-38 x 89	0.88	0.83	0.80	0.77	0.74	0.59
	2-2 x 4	2-11	2-9	2-7	2-6	2-5	1-11
	2-38 x 140	1.25	1.19	1.14	1.08	1.02	0.81
	2-2 x 6	4-1	3-11	3-9	3-7	3-4	2-8
	2-38 x 184	1.52	1.44	1.35	1.27	1.21	0.97
	2-2 x 8	5-0	4-9	4-5	4-2	3-11	3-2
	2-38 x 235	1.86	1.73	1.62	1.53	1.45	1.17
	2-2 x 10	6-1	5-8	5-4	5-0	4-9	3-10
	2-38 x 286	2.11	1.96	1.84	1.74	1.66	1.35
	2-2 x 12	6-11	6-5	6-1	5-9	5-5	4-5

Notes to Table 26

1. Lintel spans are calculated based on a maximum floor joist, roof joist or rafter span of 4.9 m (16 ft.–0 in.) and a maximum roof truss span of 9.8 m (32 ft.–0 in.). Lintel spans may be increased by 5 per cent if rafter and joist spans are no greater than 4.3 m (14 ft.–1 in.), and roof truss spans are no greater than 8.6 m (28 ft.–3 in.). Spans may be increased by 10 per cent if rafter and joist spans are no greater than 3.7 m (12 ft.–2 in.), and roof truss spans are no greater than 7.4 m (24 ft.–3 in.).
2. If floor joists span the full width of the building without support, lintel spans shall be reduced by 15 per cent for "Roof, ceiling and 1 storey", by 20 per cent for "Roof, ceiling and 2 storeys" and by 25 per cent for "Roof, ceiling and 3 storeys".
3. For ends of lintels fully supported by walls, provide minimum 38 mm (1½ in.) of bearing for lintel spans up to 3 m (10 ft.), or minimum 76 mm (3 in.) of bearing for lintel spans greater than 3 m (10 ft.).
4. A single piece of 89 mm (3½ in.) thick lumber may be used in lieu of 2 pieces of 38 mm (1½ in.) thick lumber on edge.
5. Spans apply only where the floors serve residential areas.
6. Spans for 0.6 m (2 ft.) tributary width are calculated for lintels in end walls that support only a 0.6 m (2 ft.) width of roof and ceiling, but do not support roof joists, roof rafters or roof trusses.
7. When structural sheathing is used, lintel spans may be increased by 15 per cent. Structural sheathing consists of a minimum 9.5 mm (⅜ in.) thick structural panel conforming to CSA O121, CSA O151, CSA O437 or CSA O325 fastened with at least two rows of fasteners conforming to Table 20 to the exterior face of the lintel, and a single row to the top plates and studs.

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Table 27
Maximum spans for built-up ridge beams and lintels supporting roof and ceiling only. No. 1 or No. 2 grade

Commercial Designation	Lintel Size, mm		Maximum Span, m (ft.–in.)[1, 2, 3]				
			Specified Snow Load, kPa (psf)				
			1.0	1.5	2.0	2.5	3.0
	in.		20.9	31.3	41.8	52.2	62.7
Spruce, pine, or fir (includes Spruce [all species except Coast Sitka Spruce], Jack Pine, Lodgepole Pine, Balsam Fir and Alpine Fir)	38 x 184	3-ply	2.88	2.48	2.21	2.01	1.86
	2 x 8		9–6	8–2	7–3	6–7	6–1
		4-ply	3.30	2.86	2.55	2.32	2.14
			10–10	9–5	8–4	7–7	7–0
		5-ply	3.55	3.10	2.82	2.59	2.40
			11–8	10–2	9–3	8–6	7–10
	38 x 235	3-ply	3.53	3.03	2.70	2.46	2.27
	2 x 10		11–7	9–11	8–10	8–1	7–5
		4-ply	4.07	3.50	3.12	2.84	2.62
			13–4	11–6	10–3	9–4	8–7
		5-ply	4.54	3.91	3.43	3.17	2.93
			14–11	12–10	11–5	10–5	9–7
	38 x 286	3-ply	4.09	3.52	3.13	2.85	2.63
	2 x 12		13–9	11–6	10–3	9–4	8–8
		4-ply	4.72	4.06	3.62	3.29	3.04
			15–6	13–4	11–10	10–10	10–0
		5-ply	5.28	4.54	4.04	3.68	3.40
			17–4	14–11	13–3	12–1	11–2

Notes to Table 27

1. Beam and lintel spans are calculated based on a maximum supported length of 4.9 m (16 ft.–0 in.). Spans may be increased by 5 per cent for supported lengths not more than 4.3 m (14 ft.–1 in.), by 10 per cent for supported lengths not more than 3.7 m (12 ft.–2 in.) and by 25 per cent for supported lengths not more than 2.4 m (7 ft.–10 in.).
2. For ridge beams, supported length means half the sum of the rafter, joist or truss span on both sides of the beam. For lintels, supported length means half the sum of truss, roof joist or rafter spans supported by the lintel plus the length of the overhang beyond the lintel.
3. Provide minimum 76 mm (3 in.) bearing.

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Table 28
Minimum thickness of wall sheathing

Type of Sheathing	Minimum Thickness, mm (in.) With Supports 400 (16) o.c.	With Supports 500 (20) o.c.	With Supports 600 (24) o.c.	Material Standards
Structural				
Fibreboard (insulating)	9.5 (3/8)	-	11.1 (7/16)	CAN/CSA-A247
Gypsum sheathing	9.5 (3/8)	-	12.7 (1/2)	CAN/CSA-A82.27-M
Plywood (exterior type)	6.0 (1/4)	-	7.5 (5/16)	CSA O121-M CSA O151-M CSA O153-M
OSB, O-1 grade, and waferboard, R-1 grade	6.35 (1/4)	-	7.9 (5/16)	CSA O437.0
Panel mark (performance-rated panels)	W16	W20	W24	CSA O325.0
Lumber	17.0 (11/16)	-	17.0 (11/16)	See Table 7
Mineral fibre, rigid board, type 2	25 (1)	-	25 (1)	CSA A101-M
OSB, O-2 grade	6.0 (1/4)	-	7.5 (5/16)	CSA O437.0
Phenolic, faced	25 (1)	-	25 (1)	CAN/CGSB-51.25-M
Non-Structural				
Expanded polystyrene (Types 1 and 2)	38 (1 1/2)		38 (1 1/2)	CAN/CGSB-51.20-M
Expanded polystyrene (Types 3 and 4)	25 (1)		25 (1)	CAN/CGSB-51.20-M
Urethane and isocyanurate (Types 1, 2 and 4)	38 (1 1/2)		38 (1 1/2)	CGSB 51-GP-21M
Urethane and isocyanurate (Type 3)	25 (1)		25 (1)	CGSB 51-GP-21M
Urethane and isocyanurate (Types 1 and 2), faced	25 (1)		25 (1)	CAN/CGSB-51.26-M

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Table 29
Maximum spans for roof joists – specified roof snow loads 1.0 to 2.0 kPa (20.9 to 41.8 psf)

			Maximum Span, m (ft.–in.)								
			Specified Snow Load, kPa (psf)[1]								
			1.0 (20.9)			1.5 (31.3)			2.0 (41.8)		
		Joist Size, mm	Joist Spacing, mm (in.)			Joist Spacing, mm (in.)			Joist Spacing, mm (in.)		
			300	400	600	300	400	600	300	400	600
Commercial Designation	Grade	in.	12	16	24	12	16	24	12	16	24
Douglas fir – larch (includes Douglas fir and western larch)	No. 1 and No. 2	38 x 89	2.59	2.36	2.06	2.27	2.06	1.80	2.06	1.87	1.63
		2 x 4	8–6	7–9	6–9	7–5	6–9	5–11	6–9	6–2	5–4
		38 x 140	4.08	3.71	3.24	3.57	3.24	2.83	3.24	2.94	2.57
		2 x 6	13–5	12–2	10–8	11–8	10–8	9–3	10–8	9–8	8–5
		38 x 184	5.36	4.87	4.26	4.69	4.26	3.72	4.26	3.87	3.38
		2 x 8	17–7	16–0	14–0	15–4	14–0	12–2	14–0	12–8	11–1
		38 x 235	6.85	6.22	5.44	5.98	5.44	4.74	5.44	4.94	4.22
		2 x 10	22–6	20–5	17–10	19–8	17–10	15–7	17–10	16–2	13–10
		38 x 286	8.34	7.57	6.40	7.28	6.62	5.50	6.62	6.00	4.90
		2 x 12	27–4	24–10	21–0	23–11	21–9	18–1	21–9	19–8	16–1
Hem – fir (includes western hemlock and amabilis fir)	No. 1 and No. 2	38 x 89	2.59	2.36	2.06	2.27	2.06	1.80	2.06	1.87	1.63
		2 x 4	8–6	7–9	6–9	7–5	6–9	5–11	6–9	6–2	5–4
		38 x 140	4.08	3.71	3.24	3.57	3.24	2.83	3.24	2.94	2.57
		2 x 6	13–5	12–2	10–8	11–8	10–8	9–3	10–8	9–8	8–5
		38 x 184	5.36	4.87	4.26	4.69	4.26	3.72	4.26	3.87	3.38
		2 x 8	17–7	16–0	14–0	15–4	14–0	12–2	14–0	12–8	11–1
		38 x 235	6.85	6.22	5.44	5.98	5.44	4.75	5.44	4.94	4.32
		2 x 10	22–6	20–5	17–10	19–8	17–10	15–7	17–10	16–2	14–2
		38 x 286	8.34	7.57	6.62	7.28	6.62	5.77	6.62	6.01	5.25
		2 x 12	27–4	24–10	21–9	23–11	21–9	18–11	21–9	19–9	16–10

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Table 29 (continued)
Maximum spans for roof joists – specified roof snow loads 1.0 to 2.0 kPa (20.9 to 41.8 psf)

			Maximum Span, m (ft.–in.)								
			Specified Snow Load, kPa (psf)[1]								
			1.0 (20.9)			1.5 (31.3)			2.0 (41.8)		
		Joist Size, mm	Joist Spacing, mm (in.)			Joist Spacing, mm (in.)			Joist Spacing, mm (in.)		
			300	400	600	300	400	600	300	400	600
Commercial Designation	Grade	in.	12	16	24	12	16	24	12	16	24
Spruce, pine, or fir (includes spruce [all species except coast sitka spruce], jack pine, lodgepole pine, balsam fir and alpine fir)	No. 1 and No. 2	38 x 89	2.47	2.24	1.96	2.16	1.96	1.71	1.96	1.78	1.56
		2 x 4	8–1	7–4	6–5	7–1	6–5	5–7	6–5	5–10	5–1
		38 x 140	3.89	3.53	3.08	3.40	3.08	2.69	3.08	2.80	2.45
		2 x 6	12–9	11–7	10–1	11–2	10–1	8–10	10–1	9–2	8–0
		38 x 184	5.11	4.64	4.05	4.46	4.05	3.54	4.05	3.68	3.22
		2 x 8	16–9	15–3	13–4	14–8	13–4	11–7	13–4	12–1	10–7
		38 x 35	6.52	5.93	5.18	5.70	5.18	4.52	5.18	4.70	4.11
		2 x 10	21–5	19–5	17–0	18–8	17–0	14–10	17–0	15–5	13–6
		38 x 286	7.94	7.21	6.30	6.94	6.30	5.50	6.30	5.73	5.00
		2 x 12	26–1	23–8	20–8	22–9	20–8	18–1	20–8	18–9	16–5
Northern species (includes any Canadian species covered by the NLGA Standard Grading Rules)	No. 1 and No. 2	38 x 89	2.23	2.03	1.77	1.95	1.77	1.55	1.77	1.61	1.41
		2 x 4	7–4	6–8	5–10	6–5	5–10	5–1	5–10	5–3	4–7
		38 x 140	3.51	3.19	2.79	3.07	2.79	2.43	2.79	2.53	2.21
		2 x 6	11–6	10–6	9–2	10–1	9–2	8–0	9–2	8–4	7–3
		38 x 184	4.61	4.19	3.66	4.03	3.66	3.20	3.66	3.33	2.91
		2 x 8	15–2	13–9	12–0	13–3	12–0	10–6	12–0	10–11	9–6
		38 x 235	5.89	5.35	4.68	5.15	4.68	4.09	4.68	4.25	3.68
		2 x 10	19–4	17–7	15–4	16–11	15–4	13–5	15–4	13–11	12–1
		38 x 286	7.17	6.52	5.58	6.26	5.69	4.80	5.69	5.17	4.27
		2 x 12	23–6	21–5	18–4	20–7	18–8	15–9	18–8	17–0	14–0

Note to Table 29

1. To determine the specified snow load in your location, contact your municipal building department.

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Table 30
Maximum spans for roof joists – specified roof snow loads 2.5 and 3.0 kPa (52.2 and 62.7 psf)

			Maximum Span, m (ft.–in.)					
			Specified Snow Load, kPa (psf)[1]					
			2.5 (52.2)			3.0 (62.7)		
		Joist Size, mm	Joist Spacing, mm (in.)			Joist Spacing, mm (in.)		
			300	400	600	300	400	600
Commercial Designation	Grade	in.	12	16	24	12	16	24
Douglas fir – larch (includes Douglas fir and western larch)	No. 1 and No. 2	38 x 89	1.91	1.74	1.52	1.80	1.63	1.43
		2 x 4	6–3	5–8	5–0	5–11	5–4	4–8
		38 x 140	3.01	2.73	2.39	2.83	2.57	2.25
		2 x 6	9–10	9–0	7–10	9–3	8–5	7–4
		38 x 184	3.95	3.59	3.14	3.72	3.38	2.90
		2 x 8	13–0	11–9	10–3	12–2	11–1	9–6
		38 x 235	5.05	4.59	3.84	4.75	4.32	3.55
		2 x 10	16–7	15–1	12–7	15–7	14–2	11–8
		38 x 286	6.14	5.46	4.46	5.78	5.05	4.12
		2 x 12	20–2	17–11	14–8	19–0	16–7	13–6
Hem – fir (includes western hemlock and amabilis fir)	No. 1 and No. 2	38 x 89	1.91	1.74	1.52	1.80	1.63	1.43
		2 x 4	6–3	5–8	5–0	5–11	5–4	4–8
		38 x 140	3.01	2.73	2.39	2.83	2.57	2.25
		2 x 6	9–10	9–0	7–10	9–3	8–5	7–4
		38 x 184	3.95	3.59	3.14	3.72	3.38	2.95
		2 x 8	13–0	11–9	10–3	12–2	11–1	9–8
		38 x 235	5.05	4.59	4.01	4.75	4.32	3.72
		2 x 10	16–7	15–1	13–2	15–7	14–2	12–3
		38 x 286	6.14	5.58	4.68	5.78	5.25	4.32
		2 x 12	20–2	18–4	15–4	19–0	17–3	14–2

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Table 30 (continued)
Maximum spans for roof joists – specified roof snow loads 2.5 and 3.0 kPa (52.2 and 62.7 psf)

			Maximum Span, m (ft.–in.)					
			Specified Snow Load, kPa (psf)[1]					
			2.5 (52.2)			3.0 (62.7)		
		Joist Size, mm	Joist Spacing, mm (in.)			Joist Spacing, mm (in.)		
			300	400	600	300	400	600
Commercial Designation	Grade	in.	12	16	24	12	16	24
Spruce, pine, or fir (includes spruce [all species except coast sitka spruce], jack pine, lodgepole pine, balsam fir and alpine fir)	No. 1 and No. 2	38 x 89	1.82	1.65	1.44	1.71	1.56	1.36
		2 x 4	6–0	5–5	4–9	5–7	5–1	4–6
		38 x 140	2.86	2.60	2.27	2.69	2.45	2.14
		2 x 6	9–5	8–6	7–5	8–10	8–0	7–0
		38 x 184	3.76	3.42	2.99	3.54	3.22	2.81
		2 x 8	12–4	11–3	9–10	11–7	10–7	9–3
		38 x 235	4.81	4.37	3.82	4.52	4.11	3.59
		2 x 10	15–9	14–4	12–6	14–10	13–6	11–9
		38 x 286	5.85	5.31	4.64	5.50	5.00	4.37
		2 x 12	19–2	17–5	15–3	18–1	16–5	14–4
Northern species (includes any Canadian species covered by the NLGA Standard Grading Rules)	No. 1 and No. 2	38 x 89	1.64	1.49	1.31	1.55	1.41	1.23
		2 x 4	5–5	4–11	4–3	5–1	4–7	4–0
		38 x 140	2.59	2.35	2.05	2.43	2.21	1.93
		2 x 6	8–6	7–9	6–9	8–0	7–3	6–4
		38 x 184	3.40	3.09	2.70	3.20	2.91	2.53
		2 x 8	11–2	10–2	8–10	10–6	9–6	8–4
		38 x 235	4.34	3.94	3.35	4.09	3.71	3.10
		2 x 10	14–3	12–11	11–0	13–5	12–2	10–2
		38 x 286	5.28	4.76	3.89	4.97	4.40	3.59
		2 x 12	17–4	15–7	12–9	16–4	14–5	11–9

Note to Table 30

1. To determine the specified snow load in your location, contact your municipal building department.

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Table 31
Maximum spans for roof rafters – specified roof snow loads 1.0 to 2.0 kPa (20.9 to 41.8 psf)

			Maximum Span, m (ft.–in.)								
			Specified Snow Load, kPa (psf)[1]								
			1.0 (20.9)			1.5 (31.3)			2.0 (41.8)		
		Rafter Size, mm	Rafter Spacing, mm (in.)			Rafter Spacing, mm (in.)			Rafter Spacing, mm (in.)		
			300	400	600	300	400	600	300	400	600
Commercial Designation	Grade	in.	12	16	24	12	16	24	12	16	24
Douglas fir – larch (includes Douglas fir and western larch)	No. 1 and No. 2	38 x 89	3.27	2.97	2.59	2.86	2.59	2.27	2.59	2.36	2.06
		2 x 4	10–9	9–9	8–6	9–4	8–6	7–5	8–6	7–9	6–9
		38 x 140	5.14	4.67	3.95	4.49	4.08	3.34	4.08	3.60	2.94
		2 x 6	16–10	15–4	12–11	14–9	13–5	10–11	13–5	11–10	9–8
		38 x 184	6.76	5.88	4.80	5.74	4.97	4.06	5.06	4.38	3.58
		2 x 8	22–2	19–4	15–9	18–10	16–4	13–4	16–7	14–5	11–9
		38 x 235	8.30	7.19	5.87	7.02	6.08	4.96	6.19	5.36	4.38
		2 x 10	27–3	23–7	19–3	23–0	19–11	16–3	20–4	17–7	14–4
		38 x 286	9.63	8.34	6.81	8.14	7.05	5.76	7.18	6.22	5.08
		2 x 12	31–7	27–5	22–4	26–9	23–2	18–11	23–7	20–5	16–8
Hem – fir (includes western hemlock and amabilis fir)	No. 1 and No. 2	38 x 89	3.27	2.97	2.59	2.86	2.59	2.27	2.59	2.36	2.06
		2 x 4	10–9	9–9	8–6	9–4	8–6	7–5	8–6	7–9	6–9
		38 x 140	5.14	4.67	4.08	4.49	4.08	3.50	4.08	3.71	3.08
		2 x 6	16–10	15–4	13–5	14–9	13–5	11–6	13–5	12–2	10–1
		38 x 184	6.76	6.14	5.04	5.90	5.21	4.26	5.31	4.60	3.75
		2 x 8	22–2	20–2	16–6	19–4	17–1	14–0	17–5	15–1	12–4
		38 x 235	8.63	7.54	6.16	7.36	6.37	5.20	6.49	5.62	4.59
		2 x 10	28–4	24–9	20–2	24–2	20–11	17–1	21–4	18–5	15–1
		38 x 286	10.11	8.75	7.15	8.54	7.40	6.04	7.53	6.52	5.33
		2 x 12	33–2	28–9	23–5	28–0	24–3	19–10	24–9	21–5	17–6

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Table 31 (continued)
Maximum spans for roof rafters – specified roof snow loads 1.0 to 2.0 kPa (20.9 to 41.8 psf)

			Maximum Span, m (ft.–in.)								
			Specified Snow Load, kPa (psf)[1]								
			1.0 (20.9)			1.5 (31.3)			2.0 (41.8)		
		Rafter Size, mm	Rafter Spacing, mm (in.)			Rafter Spacing, mm (in.)			Rafter Spacing, mm (in.)		
			300	400	600	300	400	600	300	400	600
Commercial Designation	Grade	in.	12	16	24	12	16	24	12	16	24
Spruce, pine, or fir (includes spruce [all species except coast sitka spruce], jack pine, lodgepole pine, balsam fir and alpine fir)	No. 1 and No. 2	38 x 89	3.11	2.83	2.47	2.72	2.47	2.16	2.47	2.24	1.96
		2 x 4	10–3	9–3	8–1	8–11	8–1	7–1	8–1	7–4	6–5
		38 x 140	4.90	4.45	3.89	4.28	3.89	3.40	3.89	3.53	3.08
		2 x 6	16–1	14–7	12–9	14–0	12–9	11–2	12–9	11–7	10–1
		38 x 184	6.44	5.85	5.11	5.62	5.11	4.41	5.11	4.64	3.89
		2 x 8	21–1	19–2	16–9	18–5	16–9	14–6	16–9	15–3	12–9
		38 x 235	8.22	7.47	6.38	7.18	6.52	5.39	6.52	5.82	4.75
		2 x 10	27–0	24–6	20–11	23–7	21–5	17–8	21–5	19–1	15–7
		38 x 286	10.00	9.06	7.40	8.74	7.66	6.25	7.80	6.76	5.52
		2 x 12	32–10	29–9	24–3	28–8	25–2	20–6	25–7	22–2	18–1
Northern species (includes any Canadian species covered by the NLGA Standard Grading Rules)	No. 1 and No. 2	38 x 89	2.81	2.55	2.23	2.46	2.23	1.95	2.23	2.03	1.77
		2 x 4	9–3	8–5	7–4	8–1	7–4	6–5	7–4	6–8	5–10
		38 x 140	4.42	4.02	3.44	3.86	3.51	2.91	3.51	3.14	2.56
		2 x 6	14–6	13–2	11–3	12–8	11–6	9–6	11–6	10–4	8–5
		38 x 184	5.81	5.13	4.19	5.00	4.33	3.54	4.41	3.82	3.12
		2 x 8	19–1	16–10	13–9	16–5	14–3	11–7	14–6	12–6	10–3
		38 x 235	7.24	6.27	5.12	6.12	5.30	4.33	5.40	4.67	3.82
		2 x 10	23–9	20–7	16–10	20–1	17–5	14–2	17–8	15–4	12–6
		38 x 286	8.40	7.27	5.94	7.10	6.15	5.02	6.26	5.42	4.43
		2 x 12	27–7	23–10	19–6	23–3	20–2	16–6	20–6	17–9	14–6

Note to Table 31

1. To determine the specified snow load in your location, contact your municipal building department.

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Table 32
Maximum spans for roof rafters – specified roof snow loads 2.5 and 3.0 kPa (52.2 and 62.7 psf)

			Maximum Span, m (ft.–in.)					
			Specified Snow Load, kPa (psf)[1]					
			2.5 (52.2)			3.0 (62.7)		
		Rafter Size, mm	Rafter Spacing, mm (in.)			Rafter Spacing, mm (in.)		
			300	400	600	300	400	600
Commercial Designation	Grade	in.	12	16	24	12	16	24
Douglas fir – larch (includes Douglas fir and western larch)	No. 1 and No. 2	38 x 89	2.41	2.19	1.86	2.27	2.06	1.71
		2 x 4	7–11	7–2	6–1	7–5	6–9	5–7
		38 x 140	3.76	3.26	2.66	3.46	3.00	2.45
		2 x 6	12–4	10–8	8–9	11–4	9–10	8–0
		38 x 184	4.58	3.96	3.24	4.21	3.65	2.98
		2 x 8	15–0	13–0	10–7	13–10	12–0	9–9
		38 x 235	5.60	4.85	3.96	5.15	4.46	3.64
		2 x 10	18–4	15–11	13–0	16–11	14–8	11–11
		38 x 286	6.50	5.63	4.59	5.98	5.17	4.23
		2 x 12	21–4	18–5	15–1	19–7	17–0	13–10
Hem – fir (includes western hemlock and amabilis fir)	No. 1 and No. 2	38 x 89	2.41	2.19	1.91	2.27	2.06	1.80
		2 x 4	7–11	7–2	6–3	7–5	6–9	5–11
		38 x 140	3.79	3.42	2.79	3.57	3.14	2.57
		2 x 6	12–5	11–3	9–2	11–8	10–4	8–5
		38 x 184	4.80	4.16	3.40	4.42	3.83	3.12
		2 x 8	15–9	13–8	11–2	14–6	12–7	10–3
		38 x 235	5.87	5.08	4.15	5.40	4.68	3.82
		2 x 10	19–3	16–8	13–7	17–9	15–4	12–6
		38 x 286	6.81	5.90	4.82	6.27	5.43	4.43
		2 x 12	22–4	19–4	15–10	20–7	17–10	14–6

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Table 32 (continued)
Maximum spans for roof rafters – specified roof snow loads 2.5 and 3.0 kPa (52.2 and 62.7 psf)

			Maximum Span, m (ft.–in.)					
			Specified Snow Load, kPa (psf)[1]					
			2.5 (52.2)			3.0 (62.7)		
		Rafter Size, mm	Rafter Spacing, mm (in.)			Rafter Spacing, mm (in.)		
			300	400	600	300	400	600
Commercial Designation	Grade	in.	12	16	24	12	16	24
Spruce, pine, or fir (includes spruce [all species except coast sitka spruce], jack pine, lodgepole pine, balsam fir and alpine fir)	No. 1 and No. 2	38 x 89	2.29	2.08	1.82	2.16	1.96	1.71
		2 x 4	7–6	6–10	6–0	7–1	6–5	5–7
		38 x 140	3.61	3.28	2.86	3.40	3.08	2.66
		2 x 6	11–10	10–9	9–5	11–2	10–1	8–9
		38 x 184	4.74	4.31	3.52	4.46	3.96	3.23
		2 x 8	15–7	14–2	11–6	14–8	13–0	10–7
		38 x 235	6.06	5.27	4.30	5.59	4.84	3.96
		2 x 10	19–10	17–3	14–1	18–4	15–11	13–0
		38 x 286	7.06	6.11	4.99	6.49	5.62	4.59
		2 x 12	23–2	20–1	16–4	21–4	18–5	15–1
Northern species (includes any Canadian species covered by the NLGA Standard Grading Rules)	No. 1 and No. 2	38 x 89	2.07	1.88	1.62	1.95	1.77	1.49
		2 x 4	6–10	6–2	5–4	6–5	5–10	4–11
		38 x 140	3.26	2.84	2.32	3.02	2.61	2.13
		2 x 6	10–8	9–4	7–7	9–11	8–7	7–0
		38 x 184	3.99	3.46	2.82	3.67	3.18	2.60
		2 x 8	13–1	11–4	9–3	12–1	10–5	8–6
		38 x 235	4.88	4.23	3.45	4.49	3.89	3.17
		2 x 10	16–0	13–10	11–4	14–9	12–9	10–5
		38 x 286	5.66	4.90	4.00	5.21	4.51	3.68
		2 x 12	18–7	16–1	13–2	17–1	14–10	12–1

Note to Table 32

1. To determine the specified snow load in your location, contact your municipal building department.

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Table 33
Maximum spans for ceiling joists – attic not accessible by a stairway

Commercial Designation	Grade	Joist Size, mm (in.)		Maximum Span, m (ft.–in.) Joist Spacing, mm (in.) 300	(12)	400	(16)	600	(24)
Douglas fir – larch (includes Douglas fir and western larch)	No. 1 and No. 2	38 x 89	(2 x 4)	3.27	(10–9)	2.97	(9–9)	2.59	(8–6)
		38 x 140	(2 x 6)	5.14	(16–10)	4.67	(15–4)	4.08	(13–5)
		38 x 184	(2 x 8)	6.76	(22–2)	6.14	(20–2)	5.36	(17–7)
		38 x 235	(2 x 10)	8.63	(28–4)	7.84	(25–9)	6.85	(22–6)
		38 x 286	(2 x 12)	10.50	(34–5)	9.54	(31–3)	8.34	(27–4)
Hem – fir (includes western hemlock and amabilis fir)	No. 1 and No. 2	38 x 89	(2 x 4)	3.27	(10–9)	2.97	(9–9)	2.59	(8–6)
		38 x 140	(2 x 6)	5.14	(16–10)	4.67	(15–4)	4.08	(13–5)
		38 x 184	(2 x 8)	6.76	(22–2)	6.14	(20–2)	5.36	(17–7)
		38 x 235	(2 x 10)	8.63	(28–4)	7.84	(25–9)	6.85	(22–6)
		38 x 286	(2 x 12)	10.50	(34–5)	9.54	(31–3)	8.34	(27–4)
Spruce, pine, or fir (includes spruce [all species except coast sitka spruce], jack pine, lodgepole pine, balsam fir and alpine fir)	No. 1 and No. 2	38 x 89	(2 x 4)	3.11	(10–3)	2.83	(9–3)	2.47	(8–1)
		38 x 140	(2 x 6)	4.90	(16–1)	4.45	(14–7)	3.89	(12–9)
		38 x 184	(2 x 8)	6.44	(21–1)	5.85	(19–2)	5.11	(16–9)
		38 x 235	(2 x 10)	8.22	(27–0)	7.47	(24–6)	6.52	(21–5)
		38 x 286	(2 x 12)	10.00	(32–10)	9.09	(29–10)	7.94	(26–1)
Northern Species (includes any Canadian species covered by the NLGA Standard Grading Rules)	No. 1 and No. 2	38 x 89	(2 x 4)	2.81	(9–3)	2.55	(8–5)	2.23	(7–4)
		38 x 140	(2 x 6)	4.42	(14–6)	4.02	(13–2)	3.51	(11–6)
		38 x 184	(2 x 8)	5.81	(19–1)	5.28	(17–4)	4.61	(15–2)
		38 x 235	(2 x 10)	7.42	(24–4)	6.74	(22–2)	5.89	(19–4)
		38 x 286	(2 x 12)	9.03	(29–8)	8.21	(26–11)	7.17	(23–6)

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Table 34
Minimum rafter-to-joist nailing[1, 2]

		Rafter Tied to Every Joist						Rafter Tied to Joist Every 1.2 m (3 ft., 11 in.)					
		Building Width up to						Building Width up to					
		8 m (26 ft., 3 in.)			9.8 m (32 ft., 2 in.)			8 m (26 ft., 3 in.)			9.8 m (32 ft., 2 in.)		
		Roof Snow Load, kPa (psf)[3]											
Roof Slope	Rafter Spacing, mm (in.)	1 (20) or less	1.5 (30)	2.0 (40) or more	1 (20) or less	1.5 (30)	2.0 (40) or more	1 (20) or less	1.5 (30)	2.0 (40) or more	1 (20) or less	1.5 (30)	2.0 (40) or more
1:3	400 (16)	4	5	6	5	7	8	11	–	–	–	–	–
	600 (24)	6	8	9	8	–	–	11	–	–	–	–	–
1:2.4	400 (16)	4	4	5	5	6	7	7	10	–	9	–	–
	600 (24)	5	7	8	7	9	11	7	10	–	–	–	–
1:2	400 (16)	4	4	4	4	4	5	6	8	9	8	–	–
	600 (24)	4	5	6	5	7	8	6	8	9	8	–	–
1:1.71	400 (16)	4	4	4	4	4	4	5	7	8	7	9	11
	600 (24)	4	4	5	5	6	7	5	7	8	7	9	11
1:1.33	400 (16)	4	4	4	4	4	4	4	5	6	5	6	7
	600 (24)	4	4	4	4	4	5	4	5	6	5	6	7
1:1	400 (16)	4	4	4	4	4	4	4	4	4	4	4	5
	600 (24)	4	4	4	4	4	4	4	4	4	4	4	5

Notes to Table 34

1. Nails not less than 79 mm (3⅛ in.).
2. Ceiling joists must be fastened together with at least one more nail per joist splice than required for the rafter-to-joist connection.
3. To determine the specified snow load in your location, contact your municipal building department.

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Table 35
Minimum thickness of roof sheathing for sloping roofs[1]

		Sheathing Thickness, mm (in.), for Truss or Rafter Spacing at			
		300 (12)	400 (16)	500 (20)	600 (24)
Plywood and OSB, O-2 grade	Supported[2] edges	7.5 (5/16)	7.5 (5/16)		9.5 (3/8)
	Unsupported edges	7.5 (5/16)	9.5 (3/8)		12.7 (1/2)
OSB, O-1 grade and waferboard R-1 grade	Supported edges	9.5 (3/8)	9.5 (3/8)		11.1 (7/16)
	Unsupported edges	9.5 (3/8)	11.1 (7/16)		12.7 (1/2)
Panel mark (performance-rated panels)	Supported[2] edges	-	1R16	1R20	1R24
Panel mark (performance-rated panels)	Unsupported edges	-	2R16	2R20	2R24
Lumber[3]		17 (11/16)	17 (11/16)		19 (3/4)

Notes for Table 35

1. The thickness of sheathing for flat roofs used as walking decks is the same as for subfloors (see Table 18).
2. Supported edges between panels by means of H clips or minimum 38 mm x 38 mm (2 in. x 2 in.) blocking between trusses or rafters.
3. For eastern white pine and red pine, minimum lumber grade is No. 4 common. For all other species, the minimum grades shall be standard or No. 3 common.

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Table 36
Roofing types and slope limits for roofs

Type of Roofing	Slope	
	Minimum	Maximum
Built-up roofing		
Asphalt base (graveled)	1 in 50	1 in 4
Asphalt base (without gravel)	1 in 25	1 in 2
Coal-tar base (graveled)	1 in 50	1 in 25
Cold process	1 in 25	1 in 1.33
Asphalt shingles		
Normal Application	1 in 3	No limit
Low slope application	1 in 6	No limit
Roll roofing		
Smooth and mineral surfaced	1 in 4	No limit
480 mm (19 in.) wide selvage asphalt roofing	1 in 6	No limit
Cold application felt	1 in 50	1 in 1.33
Wood shingles	1 in 4	No limit
Handsplit shakes	1 in 3	No limit
Asbestos-cement corrugated sheets	1 in 4	No limit
Corrugated metal roofing	1 in 4	No limit
Sheet metal shingles	1 in 4	No limit
Slate shingles	1 in 2	No limit
Clay tile	1 in 2	No limit
Glass fibre reinforced polyester roofing panels	1 in 4	No limit

Table 37
Exposure and thickness of wood shingles and machine-grooved shakes – walls

Shake or Shingle Length, mm (in.)	Maximum Exposure, mm (in.)		Minimum Butt Thickness, mm (in.)
	Single Coursing	Double Coursing	
400 (16)	190 (7½)	305 (12)	10 (⅜)
450 (18)	216 (8½)	356 (14)	11 (⁷⁄₁₆)
600 (24)	292 (11½)	406 (16)	13 (½)

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Table 38
Stapling table, mm (in.)

A)	Asphalt shingles to wood decks 1. 1.6 mm (16 gauge) thick, 22.2 (7/8) long, 11.1 (7/16) crown Corrosion resistant ⅓ more staples than the number of nails required 2. 1.6 mm (16 gauge) thick, 19 (3/4) long, 25.4 (1) crown Corrosion resistant Equivalent to number of nails required
B)	Cedar shingles to wood decks 1.6 mm (16 gauge) thick, 28.6 (1 1/8) long, 9.5 (3/8) crown Corrosion resistant
C)	Gypsum plaster lath, 9.5 (3/8) thick 1.6 mm (16 gauge) thick, 25.4 (1) long, 19 (3/4) crown Gypsum plaster lath, 9.5 (3/8) thick 1.6 mm (16 gauge) thick, 28.6 (1 1/8) long, 19 (3/4) crown
D)	7.5 and 9.5 (5/16 and 3/8) plywood wall sheathing 1.6 mm (16 gauge) thick, 38.1 (1 1/2) long, 9.5 (3/8) crown
E)	9.5 (3/8) plywood roof sheathing 1.6 mm (16 gauge) thick, 38.1 (1 1/2) long, 9.5 (3/8) crown
F)	11.1 and 12.7 (7/16 and 1/2) fibreboard wall sheathing 1.6 mm (16 gauge) thick, 38.1 (1 1/2) long, 9.5 (3/8) crown
G)	6.4 (1/4) underlayment 1.2 mm (18 gauge) thick, 28.6 (1 1/8) long, 9.5 (3/8) crown
H)	7.9 and 9.5 (5/16 and 3/8) hardboard underlayment 1.2 mm (18 gauge) thick, 28.6 (1 1/8) long, 7.9 (5/16) crown
I)	Metal plaster lath 2 mm (14 gauge) thick, 38.1 (1 1/2) long, 19 (3/4) crown

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Table 39
Stucco mixes (by volume)

Portland Cement	Masonry Cement, Type H	Lime	Aggregate
1 1	– 1	¼ to 1 1	3¼ to 4 parts per part of cementitious material

Table 40
Minimum thickness of flashing materials

Material	Minimum Thickness, mm (in.)			
	Roof Flashing	Wall Flashing		
		Cladding	Above-Grade Masonry	
			Exposed	Concealed
Aluminum	0.48 (0.019)	0.48 (0.019)	0.48 (0.019)	–
Copper	0.46 (0.018)	0.46 (0.018)	0.36 (0.014)	0.36 (0.014)
Copper or aluminum laminated to felt or kraft paper	–	–	–	0.05 (0.002)
Galvanized steel	0.33 (0.013)	0.33 (0.013)	0.33 (0.013)	0.33 (0.013)
Lead sheet	1.73 (0.068)	1.73 (0.068)	1.73 (0.068)	1.73 (0.068)
Polyethylene	–	–	–	0.50 (0.02)
Roll roofing, types	–	–	–	Standard
Zinc	0.35 (0.014)	0.35 (0.014)	0.35 (0.014)	0.35 (0.014)
Vinyl	–	1.02 (0.04)	–	–

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Table 41
Dimensions for wood-strip flooring

Type of Flooring	Maximum Joist Spacing, mm (in.)	Minimum Thickness of Flooring, mm (in.)	
		With Subfloor	No Subfloor
Matched hardwood (interior use only)	400 (16) 600 (24)	7.9 (5/16) 7.9 (5/16)	19.0 (3/4) 33.3 (1 5/16)
Matched softwood (interior or exterior use)	400 (16) 600 (24)	19.0 (3/4) 19.0 (3/4)	19.0 (3/4) 31.7 (1 1/4)
Square edge softwood (exterior use only)	400 (16) 600 (24)	– –	25.4 (1) 38.1 (1 1/2)

Table 42
Nailing of wood-strip flooring

Finish Floor Thickness, mm (in.)	Minimum Length of Flooring Nails, mm (in.)	Maximum Spacing of Flooring Nails, mm (in.)
7.9 (5/16)	38 (1 1/2)	200 (8)
11.1 (7/16)	51 (2)	300 (12)
19.0 (3/4)	57 (2 1/4)	400 (16)
25.4 (1)	63 (2 1/2)	400 (16)
31.7 (1 1/4)	70 (2 3/4)	600 (24)
38.1 (1 1/2)	83 (3 1/4)	600 (24)

Note to Table 42

1. Staples are permitted to be used to fasten wood strip flooring not more than 7.9 mm (5/16 in.) in thickness provided the staples are not less than 29 mm (1 3/16 in.) long with a shank diameter of 1.19 mm (0.047 in.) and a width of 4.7 mm (3/16 in.) crowns.

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Table 43
Built-up beams for exterior decks (lumber not incised)

	Post Spacing m	Number and Size of Plys mm (in.) Joist Span 2.4	2.7	3.0	3.3	3.7	4.3
	ft.	8	9	10	11	12	14
D.Fir-L	1.2	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 184
	4	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 8
	1.8	1-38 x 184	1-38 x 184	1-38 x 235	1-38 x 235	1-38 x 235	2-38 x 184
	6	1-2 x 8	1-2 x 8	1-2 x 10	1-2 x 10	1-2 x 10	2-2 x 8
	2.4	2-38 x 184	2-38 x 184	2-38 x 184	2-38 x 184	2-38 x 235	2-38 x 235
	8	2-2 x 8	2-2 x 8	2-2 x 8	2-2 x 8	2-2 x 10	2-2 x 10
Hem-Fir	1.2	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 140
	4	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 6
	1.8	1-38 x 184	1-38 x 184	1-38 x 184	1-38 x 235	1-38 x 235	1-38 x 235
	6	1-2 x 8	1-2 x 8	1-2 x 8	1-2 x 10	1-2 x 10	1-2 x 10
	2.4	1-38 x 235	2-38 x 184	2-38 x 184	2-38 x 184	2-38 x 184	2-38 x 235
	8	1-2 x 10	2-2 x 8	2-2 x 8	2-2 x 8	2-2 x 8	2-2 x 10
S-P-F	1.2	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 140
	4	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 6
	1.8	1-38 x 184	1-38 x 184	1-38 x 184	1-38 x 235	1-38 x 235	1-38 x 235
	6	1-2 x 8	1-2 x 8	1-2 x 8	1-2 x 10	1-2 x 10	1-2 x 10
	2.4	1-38 x 235	2-38 x 184	2-38 x 184	2-38 x 184	2-38 x 184	2-38 x 235
	8	1-2 x 10	2-2 x 8	2-2 x 8	2-2 x 8	2-2 x 8	2-2 x 10
Northern Species	1.2	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 184	1-38 x 184	1-38 x 184
	4	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 8	1-2 x 8	1-2 x 8
	1.8	1-38 x 235	1-38 x 235	1-38 x 235	2-38 x 184	2-38 x 184	2-38 x 184
	6	1-2 x 10	1-2 x 10	1-2 x 10	2-2 x 8	2-2 x 8	2-2 x 8
	2.4	2-38 x 184	2-38 x 235	2-38 x 235	2-38 x 235	2-38 x 235	2-38 x 286
	8	2-2 x 8	1-2 x 10	1-2 x 10	1-2 x 10	1-2 x 10	2-2 x 12

Continued on p. 312

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Table 43 (continued)
Built-up beams for exterior decks (lumber incised)

	Post Spacing	Number and Size of Plys mm (in.)					
		Joist Span					
	m	2.4	2.7	3.0	3.3	3.7	4.3
	ft.	8	9	10	11	12	14
D.Fir-L	1.2	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 184	1-38 x 184
	4	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 8	1-2 x 8
	1.8	1-38 x 235	1-38 x 235	1-38 x 235	1-38 x 235	2-38 x 184	2-38 x 184
	6	1-2 x 10	1-2 x 10	1-2 x 10	1-2 x 10	2-2 x 8	2-2 x 8
	2.4	2-38 x 184	2-38 x 184	2-38 x 235	2-38 x 235	2-38 x 235	2-38 x 235
	8	2-2 x 8	2-2 x 8	2-2 x 10	2-2 x 10	2-2 x 10	2-2 x 10
Hem-Fir	1.2	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 184
	4	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 8
	1.8	1-38 x 184	1-38 x 235	1-38 x 235	1-38 x 235	1-38 x 235	2-38 x 184
	6	1-2 x 8	1-2 x 10	1-2 x 10	1-2 x 10	1-2 x 10	2-2 x 8
	2.4	2-38 x 184	2-38 x 184	2-38 x 184	2-38 x 235	2-38 x 235	2-38 x 235
	8	2-2 x 8	2-2 x 8	2-2 x 8	2-2 x 10	2-2 x 10	2-2 x 10
S-P-F	1.2	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 140	1-38 x 184
	4	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 6	1-2 x 8
	1.8	1-38 x 184	1-38 x 184	1-38 x 235	1-38 x 235	1-38 x 235	2-38 x 184
	6	1-2 x 8	1-2 x 8	1-2 x 10	1-2 x 10	1-2 x 10	2-2 x 8
	2.4	2-38 x 184	2-38 x 184	2-38 x 184	2-38 x 184	2-38 x 235	2-38 x 235
	8	2-2 x 8	2-2 x 8	2-2 x 8	2-2 x 8	2-2 x 10	2-2 x 10
Northern Species	1.2	1-38 x 140	1-38 x 140	1-38 x 184	1-38 x 184	1-38 x 184	1-38 x 235
	4	1-2 x 6	1-2 x 6	1-2 x 8	1-2 x 8	1-2 x 8	1-2 x 10
	1.8	1-38 x 235	2-38 x 184	2-38 x 184	2-38 x 184	2-38 x 184	2-38 x 235
	6	1-2 x 10	2-2 x 8	2-2 x 8	2-2 x 8	2-2 x 8	2-2 x 10
	2.4	2-38 x 235	2-38 x 235	2-38 x 235	2-38 x 235	2-38 x 286	2-38 x 286
	8	2-2 x 10	2-2 x 10	2-2 x 10	2-2 x 10	2-2 x 12	2-2 x 12

Notes to Table 43

1. Incising is knife cutting the surface of wood to help perservatives penetrate the wood.
2. Design based on 2001 CAN/CSA O86.
3. Live load = 40 psf (1.9 kPa), Dead load = 10 psf (0.5 kPa).
4. Lumber No. 2 and Better grade, pressure treated, wet service.
5. Beam selection is for a beam on the edge of a deck. Double the number of plys for middle beams supporting joists on both sides.
6. Nail-laminate the beams to act as a single member (see Columns and Beams).

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Table 44
Joists for exterior decks

		Joist span, m (ft.–in.)			
		Joists not incised		Joists incised	
	Joist Size	Joist spacing, mm (in.)			
	mm	400	600	400	600
	in.	16	24	16	24
Douglas fir - larch (includes Douglas fir and western larch)	38 x 140	2.9	2.3	2.6	2.2
	2 x 6	9-6	7-6	8-6	7-2
	38 x 184	3.5	2.8	3.2	2.6
	2 x 8	11-6	9.2	10-6	8-6
	38 x 235	4.3	3.5	3.9	3.2
	2 x 10	14-1	11-6	12-9	10-6
Hem - fir (includes western hemlock and amabilis fir)	38 x 140	2.9	2.5	2.8	2.3
	2 x 6	9-6	8-2	9-2	7-6
	38 x 184	3.7	3.0	3.4	2.7
	2 x 8	12-1	9-9	11-2	8-10
	38 x 235	4.3	3.6	4.1	3.4
	2 x 10	14-1	11-9	13-4	11-2
Spruce, pine, or fir (includes spruce [all species except coast sitka spruce], jack pine, lodgeploe pine, balsam fir and alpine fir)	38 x 140	2.8	2.4	2.7	2.3
	2 x 6	9-2	7-10	8-10	7-6
	38 x 184	3.7	3.1	3.5	2.8
	2 x 8	12-1	10-2	11-6	9-2
	38 x 235	4.3	3.8	4.3	3.5
	2 x 10	14-1	12-6	14-1	11-6
Northern Species (includes any Canadian species covered by the NLGA Standard Grading Rules	38 x 140	2.5	2.0	2.3	1.9
	2 x 6	8-2	6-7	7-6	6-2
	38 x 184	3.0	2.5	2.8	2.3
	2 x 8	9-9	8-2	9-2	7-6
	38 x 235	3.7	3.0	3.4	2.8
	2 x 10	12-1	9-9	11-2	9-2

Notes to Table 44

1. Incising is knife cutting the surface of wood to help perservatives penetrate the wood.
2. Design based on 2001 CAN / CSA O86
3. Live load + 1.9 kPa (40 psf), Dead load = 0.5 kPa (10 psf).
4. Lumber No. 2 and Better grade, pressure treated, wet service conditions.

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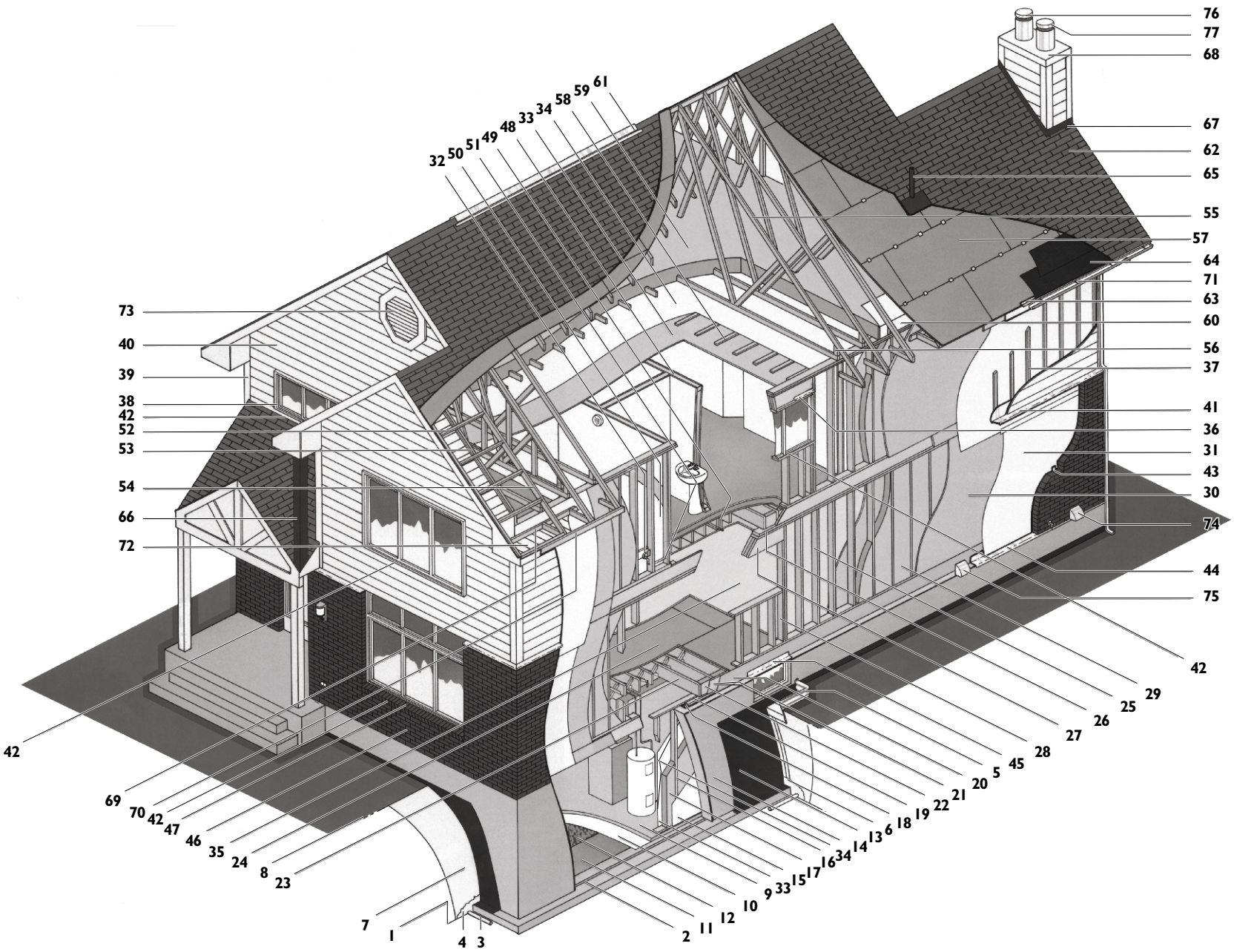
APPENDIX B

Cutaway View of a Wood-frame House



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APPENDIX B
Cutaway View of a Wood-frame House



Foundation Excavation

1. Excavation to solid rock or below the depth of frost penetration
2. Concrete footing with key
3. Perforated perimeter drain tile
4. Crushed stone with soil filter cloth over
5. Galvanized steel basement window well
6. Vertical drain to drain tile
7. Clean free-draining backfill material
8. Slope ground for surface drainage

Basement Floor

9. Concrete floor slab
10. Polyethylene dampproofing
11. Rigid insulation
12. Crushed stone

Foundation Wall and Sill

13. Bituminous dampproofing to exterior side of foundation wall
14. Concrete foundation wall
15. Rigid insulation to interior side of foundation wall
16. Wood-framing
17. Batt insulation
18. Closed-cell foam sill gasket
19. Sill plate attached to concrete wall with anchor bolts

Floor Platforms and Headers

20. Rigid insulation to exterior side of rim joist
21. Rim joist
22. Batt insulation
23. Floor joists with cross bridging or blocking
24. Tongue-and-groove plywood or OSB subflooring

Continued on p. 315

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APPENDIX B
Cutaway View of a Wood-frame House

(Continued)

Exterior Wall Framing
25. Wood stud framing
26. Double top plate, cross-lapped at corners
27. Lintel, double wood headers with insulated cavity
28. Jack stud bearing under lintel
29. Batt insulation
30. Plywood or OSB wall sheathing
31. Spunbonded polyolefin weather resistive barrier
32. Electric receptacles and switches penetrating air barrier on exterior walls and ceilings mounted in airtight, moulded plastic boxes

Interior Finishes
33. Gypsum board interior finish on walls and ceilings
34. Polyethylene air barrier/vapour retarder, lapped and sealed at all joints
35. Floor finish (carpet, hardwood, resilient flooring or ceramic tile)

Siding Finish and Trim
36. Drip cap flashing with end dams over window head
37. Vertical wood strapping, aligned over studs; 25 mm (1 in.) air space at butt joints
38. J-trim under soffit and around window moulding
39. Prefinished wood trim
40. Prefinished siding (hardboard, wood, vinyl or aluminum)
41. Brick cap flashing
42. Sill flashing with end dams

Brick
43. Metal brick ties
44. Brick sill flashing
45. Steel angle brick lintel
46. Brick veneer
47. Brick sill

Partition Walls
48. Partition wall framing
49. Double floor joist under partition wall
50. Polyethylene vapour retarder to continue across partitions at intersections with exterior wall and ceiling
51. Seal holes through partition studs for electric wiring at exterior wall joint

Roof and Ceiling Framing
52. Wood ladder framing to extend roof overhang at gable
53. Prefabricated gable-end roof truss shortened to receive gable end soffit ladder framing
54. Prefabricated roof truss
55. Prefabricated roof truss
56. Truss heel to accommodate insulation without compression
57. Plywood or OSB roof sheathing with metal "H" clips or blocking at joints
58. Ceiling wood strapping
59. Insulation
60. Insulation baffle to retain insulation and maintain vent space of at least 63 mm (2½ in.)

Roof Finishes
61. Prefinished metal ridge vent
62. Roofing shingles
63. Prefinished metal drip edge
64. Self-sealing composite eave protection
65. ABS plastic plumbing vent stack with neoprene rubber roof collar on vent stack
66. Prefinished metal valley flashing
67. Prefinished metal flashing at chimney to roof joints
68. Prefinished metal chimney capping

Fascia and Soffit
69. Wood blocking for truss soffit
70. Wood fascia plate
71. Prefinished aluminum fascia cladding
72. Perforated vented aluminum soffit with J-trim on wall
73. Gable end roof vent

Ventilation and Mechanical Equipment
74. Exhaust air vent hood with screen and insulated duct from central exhaust air system or heat recovery ventilator (HRV)
75. Fresh air supply vent hood with screen and insulated duct to central fresh air system or HRV
76. Insulated double wall stainless steel fireplace chimney flue with rain cap from prefabricated, zero clearance, fireplace
77. Double wall stainless steel furnace flue with rain cap

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APPENDIX C
Alternative Text



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APPENDIX C
Alternative Text

CHAPTER 1 – IMPORTANT GENERAL INFORMATION

Figure 1
Principles of sustainable housing

No additional alt text

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CHAPTER 2 – PLANNING, DESIGN AND CONSTRUCTION

Figure 2
Approval, permits and inspection processes for new houses

The approval, permits and inspection processes for new houses occur over three stages; pre-construction, construction, and post-construction. Pre-construction processes may include:

1. planning, zoning and environmental approvals;
2. site plan, working drawings and specifications
3. building permit, plumbing permit, heating permit, electrical permit, utility permit for gas or propane, health unit permit for wells and septic systems

Construction processes may include inspection for:

1. excavation and footings
2. sewers, drains, water services and underground plumbing
3. electrical services
4. pre-backfill
5. plumbing, heating and electrical rough-in
6. framing
7. insulation, air barrier and vapour barrier
8. pre-occupancy
9. final plumbing, heating and electrical work

Post-construction processes may include:

1. completion inspection for the interior and exterior
2. Certificate of Occupancy

Figure 3
Site drainage

Two views of a house in the middle of a lot. The first shows the land sloping from the back to the front of the lot, with surface water captured in perimeter drain tile and directed to the storm sewer at the street at the front of the lot. The second shows the lot with the ground sloping away from the house, with surface drainage to the storm sewer at the street and to the catch basin at the back of the lot.

Figure 4
Sample single house construction schedule

Subsequent to drawings, financing and the necessary permits* being in place, the minimum construction timing for an average house may be approximately 16 weeks, with a typical sequence as follows:

1. building layout a portion of a week
2. excavation and footings a portion of a week
3. foundation and drainage one week
4. backfill and framing, including flashing and roofing, two weeks
5. doors and windows one week, after which the building can be considered closed and secure
6. plumbing, heating and electrical rough-in two weeks
7. insulation, air and vapour barriers two weeks
8. exterior finishes two weeks
9. interior finishes two weeks
10. paint, cabinets and fixtures one week
11. landscaping one week

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CHAPTER 4 – LUMBER AND OTHER WOOD PRODUCTS

Figure 5
Examples of engineered wood products

Three types of engineered joists. Each joist type includes a top and bottom wooden member, termed a chord, such as a 38 x 89 mm (2 x 4 in.) on the flat, or LVL. The truss types differ by the members which separate these chords. The first shows a metal web joist, where metal strips, mounted on each side of the chords, span on the diagonal from one chord to the other in a continuous metal ribbon the extent of the joist. The second shows a wood web joist, where pieces of wood, the same width as the chords, span diagonally from the inside of one chord to the inside of the other, continuously along the length of the joist, and are attached to the chords with nailing plates. The third shows a wood I-joist, where a thin sheet of plywood or OSB spans between the inside of one chord to the inside of the other.

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CHAPTER 5 – FUNCTIONS OF THE BUILDING ENVELOPE: WATER, AIR, VAPOUR AND HEAT CONTROL

Figure 6
Examples of air leakage locations

No additional alt text

Figure 7
Carrying the air barrier around a rim joist at a floor intersection

No additional alt text

Figure 8
Placement of air barrier over joist headers

No additional alt text

Figure 9
Air barrier and moisture management details at window head

Shown are the following from the framing sheathing and window out to the siding:

- A weather resistive barrier (WRB) extending from the top of the window frame up a sufficient distance to extend above the head flashing. The WRB also extends a minimum 100 mm (4 in.) both sides of the window
- the exterior window trim is installed over the WRB
- head flashing with end dams is installed above the exterior window head trim and extends a minimum 100 mm (4 in.) beyond both sides of the window, greater if required to cover the window trim
- the WRB on the exterior sheathing is lapped over the head flashing
- the wood furring between the WRB and siding to create a drainage space for shredding water is installed over the WRB
- the siding is installed over the furring

Figure 10
Air barrier and moisture management details at window sill

Shown are the following from the framing sheathing and window out to the siding:

- prior to installation of the window in the rough opening, a sub-sill flashing is installed on the strip of weather resistive barrier (WRB) that has been installed on the rough opening sill, extending down the wall
- the window is installed
- a weather resistive barrier (WRB) on the exterior sheathing is lapped under the sub-sill flashing
- a sill flashing with end dams is installed under the window sill
- the wood furring for the drainage space between the WRB and siding is installed over the WRB
- the sill trim is installed over the WRB or over the wood furring as per design drawings, and under the sill flashing
- the siding is installed

Figure 11
Window in highly insulated wall

Shown are the following from interior to exterior:

- Foil-faced, self-adhered membrane applied to rough framing sill, extending from under the window frame to the outside face of the window sill
- Window shims to level window
- Backer rod and sealant, or spray foam, to connect wall air barrier to window
- Stud cavity with glass fibre (batt) insulation
- Sheathing
- Sheathing membrane (air and water barrier)
- Exterior insulation
- Sill flashing with end dams
- Exterior wood trim
- Cladding (any type)

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APPENDIX C
Alternative Text

Figure 12
Polyethylene strips at end of partition and over top wall plates to provide continuity of the air barrier

No additional alt text

Figure 13
Installation of polyethylene sheet strips in interior wall framing

No additional alt text

Figure 14
Combined air barrier/vapour barrier

The polyethylene can be either stapled to the studs and plates with seams lapped at least 100 mm (4 in.) or attached to the studs and plates with a continuous bead of acoustical sealant. The air barrier / vapour barrier consists of 0.15 mm (6 mil) polyethylene.

Figure 15
Concrete wall with rigid insulation on outer face

No additional alt text

Figure 16
Concrete wall insulated with rigid insulation and batts

No additional alt text

Figure 17
Insulated concrete form foundation wall

No additional alt text

Figure 18
Location of thermal insulation

No additional alt text

Figure 19
Double-wall framing construction

No additional alt text

Figure 20
Typical 38 x 140 mm (2 x 6 in.) wall

Shown are the following from interior to exterior:

- 12.7 mm (½ in.) drywall on the interior
- polyethylene sheet
- wood framing- studs and sheathing
- insulation between studs
- sheathing membrane (air barrier)
- Furring strips for air space
- Horizontal siding on the exterior

Figure 21
Brick veneer cladding with insulation in the framing space and outboard

Shown are the following from interior to exterior:

- 12.7 mm (½ in.) gypsum board on the interior
- Polyethylene sheet
- 38 x 140 mm (2 x 6 in.) studs
- Batt insulation between studs
- sheathing
- Rigid insulation sheathing
- Sheathing membrane (air barrier)
- 25 mm (1 in.) air space
- 100 mm (4 in.) clay brick on the exterior

Figure 22
Siding with insulation in the framing space and outboard

Shown are the following from interior to exterior:

- 12.7 mm (½ in.) gypsum board interior
- Polyethylene sheet
- 38 x 89 mm (2 x 4 in.) framing
- Batt insulation between studs
- Expanded polystyrene nailed to studs
- Sheathing membrane (air barrier)
- Vertical wood furring creating air space
  Horizontal siding attached to studs

Note: Bracing required in walls at corners

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Figure 23
Floor over unheated crawl space insulated with friction-fit batts

No additional alt text

Figure 24
Eave details to avoid blocking ventilation

Shown are the following from interior to exterior:

- Raised-heel truss with batt or loose-fill insulation on the ceiling. Includes view of perforated soffit.
- Ordinary truss heel joint with air ventilation baffle between the truss members at the plane of building envelope extending up the underside of the roof sheathing with a minimum 25 mm (1 in.) continuous air space above the baffle. Includes view of perforated soffit.

Figure 25
Insulating joist-type roof ceiling between the ceiling and sheathing

Shown are the following from interior to exterior:

- Gypsum board on interior of ceiling
- Air and vapour barrier
- Roof joists
- Insulation batts between roof joists
- Cross-members which provide a recommended 89 mm (3½ in.) ventilation space
- Perforated soffit and prefinished fascia outboard of exterior wall
- Roof sheathing

Figure 26
Alternative method of insulating joist-type roof ceiling between the ceiling and sheathing

Shown are the following from interior to exterior:

- Ceiling
- Air and vapour barrier
- Wood I joists with holes in the upper portion of the web for cross ventilation
- Insulation batts between roof joists
- Baffles between joists at the plane of the wall building envelope to contain insulation in proper area
- Roof sheathing
- Perforated soffit and prefinished fascia outboard of exterior wall

Figure 27
Insulation of a flat joist-type roof ceiling above the sheathing

Shown are the following from interior to exterior:

- 12.7 mm (½ in.) gypsum board ceiling
- Wood roof joists
- Vapour barrier (only required for vapour permeable insulation)
- 9.5 mm (⅜ in.) plywood sheathing (not used as a walking deck
- Type 4 expanded polypropylene insulation
- Built-up roofing membrane
- 40 mm (1½ in.) crushed stone or gravel

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CHAPTER 6 – LOCATION AND EXCAVATION

Figure 28
Establishing the lines of the house

There are two figures, A and B. The components of figure A are:

- A rectangle indicating location of outside of foundation wall, including corners.
- A wooden framework of stakes and horizontal boards, termed a batter board, on the outside of each corner

Figure B is described in the alternative text for Figure 30

Figure 29
Finish grade sloped for drainage

No additional alt text

Figure 30
Method of setting batter boards and establishing corners for excavation

No additional alt text

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CHAPTER 7 – FOOTINGS, FOUNDATIONS AND SLABS

Figure 31
Size of footings

No additional alt text

Figure 32
Steel column supported on steel bearing plate resting on footings

In addition to what is included in the adjacent text:

- Concrete footing is placed on the bearing soil or compacted granular material
- The surface of the footing is set so that it will be level with the bottom of the concrete floor slab
- The portion of the steel column encased by the floor slab is wrapped with a layer of sheathing membrane or polyethylene to break the bond between the column and slab

Figure 33
Wood column supported on concrete footings

In addition to what is included in the adjacent text:

- Concrete footing is placed on the bearing soil or compacted granular material
- The surface of the footing is set so that it is level with the bottom of the concrete floor slab
- The portion of the wood column encased by the floor slab is wrapped with a layer of polyethylene

Figure 34
Fabric form footing and ICF foundation wall

In addition to what is included in the adjacent text:

- The fabric also prevents concrete water from entering the water table and eliminates ground water entry

Figure 35
Stepped footings

No additional alt text

Figure 36
Adjusting foundation thickness to accommodate insulation and masonry veneer

No additional alt text

Figure 37
Concrete formwork and combination form ties

No additional alt text

Figure 38
Framing for a basement window

No additional alt text

Figure 39
Notches or beam pockets in foundation walls

Shown are the following:

- Foundation wall
- Notch or pocket for beam
- Wood beam raised 38 mm (1½ in.) to be level with sill plate
- Top of steel beam to be level with top of foundation wall
- 90 mm (3½ in.) minimum bearing
- Steel bearing plate
- Separate wood beams installed less than 150 mm (6 in.) above grade from concrete with damp-proofing material, such as 0.15 mm (6 mil) polyethylene

Figure 40
Method of anchoring floor system to concrete walls, showing anchor bolt for wood sill

No additional alt text

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Figure 41
Typical floor slab/wall isolation joint

Detail showing a vertical cross-section detail at a concrete foundation wall, footing and floor slab intersection. Polyethylene sheet is installed between the concrete floor slab and the underlying crushed gravel layer and between the concrete floor slab edge and the adjacent foundation wall. Joint filler seals the top of the gap between the floor slab and the foundation wall.

Figure 42
Control joint in basement wall

Shown are the following:

- Vertical 19 x 19 mm (¾ x ¾ in.) strips of wood bevelled on two sides are nailed opposite one another on the inside faces of the form with the narrow 12 mm (½ in.) side facing in.
- The resulting outside control joint is caulked

Note: The combined thickness of the outer and inner strips should equal approximately one-fifth of the wall thickness. This example is for a 200 mm (8 in.) thick foundation wall, the strips could each be 19 mm (¾ in.) thick

Figure 43
Insulating concrete form foundation

Shown are the following

- The interior face of the ICF, covered with gypsum board
- The ICF with sill plate
- The portion of the exterior face of the ICF that is above grade with a parging finish

Figure 44
Concrete blocks for foundation construction

Shown are the following:

- Various block types including: 1) stretcher, 2) corner, 3) 2 types of beam or lintel, 4) sash and 5) Solid top
- With the exception of one type of beam or lintel, block types are rectangular solids with hollow spaces. The exception is the one type of beam or lintel which is U-shaped to accept a beam or lintel
- Sash blocks have hollow spaces which extend from the top to the bottom of the block.
- Solid top blocks have hollow spaces which are on the lower half of the block

Figure 45
Concrete block wall

No additional alt text

Figure 46
Certification mark for preserved wood foundation wood and plywood

Certification mark showing:

- The company name and logo
- The name of the inspection agency
- CSA 0322, the standard under which the material is qualified
- The type of preservative used
- A four digit number, the first two indicating the treating plant and the second two the year of treatment
- PWF, i.e. the use approved for the material

Figure 47
Preservative-treated wood foundations

Four figures, A to D, are presented.

A. Foundation with concrete floor slab and wood footings showing:

- An excavation that exceeds the intended outside dimensions of the foundation wall by at least 300 mm (12 in.)
- A minimum 125 mm (5 in.) gravel bed placed on the bearing soil throughout the excavation
- A polyethylene sheet on the gravel bed extending over the footing plate and up the exterior face of the treated plywood to grade when latter installed, stopping at grade
- Treated wall footing plates which define the dimensions of the foundation wall placed on the gravel
- Treated screed boards placed vertically on the inside edge of the footing plate
- A concrete slab to the screed boards
- Treated wall plate on the footing plate
- Treated wall stud
- Treated exterior plywood
- A framing strap attaching first floor joist network to foundation top plates and stud

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- 38 x 89 mm (2 x 4 in.) treated blocking placed between the studs (backing at panel joint)
- A treated plywood cover attached to the exterior plywood at grade level
- Free draining backfill, installed in the excavation against the exterior wall
- A finished grade, sloped a minimum 1 in 12 away from the foundation

B. Foundation with wood sleeper showing:

- An excavation that exceeds the intended outside dimensions of the foundation wall by at least 300 mm (12 in.)
- A minimum 125 mm (5 in.) gravel bed
- Treated footing plates which define the dimensions of the foundation wall placed on the gravel
- A polyethylene sheet on the gravel bed extending over the footing plate and up the exterior face of the treated plywood to grade when installed
- Treated wood sleepers the same thickness as the treated footing plate, placed on the polyethylene sheet
- A pressure treated wall, placed on the footing plate such that a bearing surface is available on the interior of the footing plates
- Pressure treated joists installed on the sleepers and the bearing surface on the interior of the footing plates
- A treated subfloor

C. Foundation with suspended wood floor showing:

- An excavation that exceeds the intended outside dimensions of the foundation wall by at least 300 mm (12 in.)
- A minimum 125 mm (5 in.) gravel bed
- Treated footing plates which define the dimensions of the foundation wall placed on the gravel
- A polyethylene sheet on the gravel bed extending over the footing plate and up the exterior face of the treated plywood to grade when latter installed
- A pressure treated wood exterior wall
- A pressure treated wood interior wall, placed on the interior treated footing plates positioned on the vapour barrier.
- Floor joists, placed on the interior walls and on 38 x 140 mm (2 x 6 in.) ledgers attached to the inside face of the exterior walls
- A subfloor attached to the joist network

D. Foundation on concrete strip footing showing:

- The dimensions of the excavation exceed the intended outside dimensions of the foundation wall by at least 300 mm (12 in.)
- Strip footing, with 60 mm (2½ in.) minimum diameter tubes to facilitate water passages placed 1.2 m (4 ft.) on centre at the bottom of
- Gravel bed on the bearing soil continuously throughout the excavation except where the strip footing is positioned. The top of the gravel bed is at the same elevation as the top of the footing
- A polyethylene sheet is laid on the gravel bed extending over the top of the concrete footing and up the exterior face of the treated plywood to grade when latter installed
- The pressure treated exterior wall placed and fastened on the centre of the footing.
- A screed is attached to the inside face of the exterior wall. The top of the screed defines the top of the concrete slab
- The concrete slab

Figure 48
Location of control joints

Control joints around column footings may be omitted if column footings are below floor level and the column is wrapped with two layers of sheathing membrane or joint filler to break the bond

Figure 49
Independent concrete floor slab and foundation wall

No additional alt text

Figure 50
Drain pipe at foundation wall

No additional alt text

Figure 51
Window well at basement wall

No additional alt text

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CHAPTER 9 – FLOOR FRAMING

Figure 52
Built-up wood beam

In addition to what is included in the adjacent text:

- The damp-proofing material could be 0.155 mm (2 mil) polypropylene

Figure 53
Joists supported on top of wood beam

In addition to what is included in the adjacent text:

- Toenail the joists to the wood beams with at least 2-80 mm (3½ in.) nails

Figure 54
Joists supported on ledger strips nailed to beam

In addition to what is included in the adjacent text:

- Where the joists contact the beam, the tops of opposite joists, which sit above the top of the beams, are attached to one another with a 38 x 38 x 600 mm (2 x 2 x 24 in.) splice. The splice is flush with the top of the joists and there is a minimum 13 mm (½ in.) space between the top of the beam and underside of the splice. The splice is nailed to each of the opposing joists with two 82 mm (3¼ in.) nails

Figure 55
Joists framed into a steel beam

No additional alt text

Figure 56
Sill-plate method used in platform construction

In addition to what is included in the adjacent text:

- A mortar levelling bed can be used between the top of the foundation wall and underside of the foam gasket
- The minimum distance from finished grade to top of foundation wall is 150 mm (6 in.) for a masonry finish and 200 mm (8 in.) for stucco and sidings

Figure 57
Floor joists supported on a ledge formed in the foundation wall

In addition to what is included in the text:

- The minimum distance from finished grade to top of foundation wall is 200 mm (8 in.)
- The joist network sill plate, header and joists sit on the top of the ledge on the inside of the concrete foundation. The sill plate is anchored to the foundation with anchor bolts and the rim joist separated from the concrete face by a 12 mm (½ in.) airspace if untreated.
- The top of the subfloor on the joist network is level with the bottom of the wall plate;

Figure 58
Floor joists supported on a ledge formed in the foundation wall

In addition to what is included in the adjacent text:

- The minimum distance from finished grade to top of foundation wall is 150 mm (6 in.)
- The joist network sill plate, header and joists, and subfloor sit on the top of the ledge on the inside of the concrete foundation. The sill plate is anchored to the foundation and the joist header separated from the concrete face by a 12 mm (½ in.) airspace if untreated
- The exterior wall framing sits on top of the sub-floor
- Base flashing is placed on the top of the foundation, extending up the wall sheathing as well as outboard of the foundation
- A sheathing membrane extends down the wall sheathing and laps over the portion of the base flashing that extends up the wall
- The brick veneer is attached to the wall framing

Figure 59
Floor joists embedded in the top of the foundation wall

No additional alt text

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Figure 60
Masonry support using joist-embedded method of floor framing

- Rather than the header joist being positioned at the outside face of the concrete formwork, as was the case in the above Figure, it is placed near the centre of the concrete formwork, creating a ledger on the outside face of the concrete once the concrete is placed
- The exterior wall framing sits on top of the sub-floor
- Base flashing is placed on the top of the foundation, extending up the wall sheathing as well as outboard of the foundation
- A sheathing membrane extends down the wall sheathing and laps over the portion of the base flashing that extends up the wall
- The brick veneer, which is above the ledger, is attached to the wall framing

Figure 61
Principles for wood I-joist installation

- Prior to installation, wood joists must be properly handled and stored on site
- The span distance must be correct for the joists being used and there must be adequate bearing length on supports (e.g. a foundation wall sill plate)
- Rim framing is required to transfer continuous wall loads
- Safe installation practices include the use of temporary bracing across multiple top chords prior to installation of sub-floor sheathing
- Placement and sizing of holes in web must be correct
- All wood I-joist cantilevers require engineering
- Web stiffeners (where required) and squash blocks transfer floor loads

Figure 62
Load transfer requirements for wood I-joists

- Rim framing transfers exterior wall loads around the I-joists to the wall below
- Blocking transfers interior wall loads around I-joists to the wall or beam below
- Squash blocks are used to transfer point loads from columns or framing around doors and windows from one floor to the next without loading the I-joists
- Web stiffeners may be required if the load on the joist exceeds the design capacity of the joist without web stiffeners

Figure 63
Floor framing

- The floor joists are typically parallel to one another and to two opposite sides of the foundation and perpendicular to the other two sides of the foundation
- Cross-bridging and blocking between the joists, and strapping on the underside of the joists helps stiffen the floor assembly and distribute floor loads
- At least two edges on subfloor panel edges are flat – these butt together and are joined over joists
- The subfloor is nailed or screwed to joists (field-gluing will help improve floor performance)

Figure 64
Framing for floor openings where double headers and double trimmers are used

The following sequence is used, with the joist pieces assembled in a fashion so that the inside faces of the first trimmers and inside faces of the second headers define the width and length respectively of the floor opening:

- The first trimmers on each side of each header are nailed to the first headers
- The first headers are nailed to the tail joists
- The second headers are nailed to the first headers
- The first trimmers are nailed to the second headers
- The second trimmers are nailed to the first trimmers
- Note that joist hangers may be required as an alternative to end nailing the first headers into the tail joists

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APPENDIX C
Alternative Text

Figure 65
Floor framing at projections

No additional alt text

Figure 66
Basement beam and first floor joist framing

No additional alt text

Figure 67
Floor joists bearing on beam and foundation wall

No additional alt text

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CHAPTER 10 – WALL FRAMING

Figure 68
Wall framing used with platform construction

Further wood-frame wall details include:

- The studs can be toe-nailed to the bottom plate or, if the wall has been assembled lying on the subfloor, end nailed through the bottom plate to the joists or header joist
- Cripple, or trimmer, studs extend from the horizontal plate defining the bottom of a window rough opening to the bottom plate.

Figure 69
Multiple stud arrangements at an exterior corner

Three arrangements are:

1. A three corner stud. One wall ends with a stud in the conventional orientation. A second stud is nailed to the inside face of that stud such that it is at right angles to the stud and flush with the inside corner, and extends the length of the stud. The end of the second wall, with a conventional stud, is brought together with the first wall and nailed.
2. A two corner stud. Both walls end with a conventional stud. The two walls are brought together, with the face of one stud against the side of the other, and nailed. Gypsum board clips attach the sheets of drywall on each side of the corner.
3. The third drawing provides an isometric view of the three corner stud arrangement in 1 above.

Figure 70
Multiple stud arrangements at the intersection of an interior partition with an exterior wall

Four possible arrangements are:

1. The interior partition intersects with the exterior wall close to but not on, an exterior wall stud. A second stud is installed adjacent to and at right angles to that exterior wall stud flush with inside face of the framing. The end stud of the partition wall is then nailed to the second stud. If the vapour barrier has not been installed on the inside surface of the exterior wall, a strip of polyethylene sufficient to span between adjacent exterior wall studs is fastened to that face of the partition wall which is nailed to the exterior wall.
2. The interior partition intersects with the exterior wall in the central area of the stud cavity. Horizontal blocking is installed in the cavity, spanning from the inside face of one stud to the inside face of the adjacent stud. The end stud of the partition wall is then nailed to the blocking. If the vapour barrier has not been installed on the inside surface of the exterior wall, a strip of polyethylene sufficient to span between adjacent exterior wall studs is fastened to that face of the partition wall which is nailed to the blocking.
3. The interior partition intersects with an exterior wall stud, and the vapour barrier and drywall have been installed. The end stud of the partition wall is nailed through the drywall (and vapour barrier) to the exterior wall stud.
4. The interior partition intersects with the exterior wall partially on an exterior wall stud. A second stud is installed in the exterior wall a small distance from the first stud such that the partition wall end stud also intersects with the second stud. The space between the exterior wall studs is insulated. The end stud of the partition wall is then nailed to the second stud. If the vapour barrier has not been installed on the inside surface of the exterior wall, a strip of polyethylene sufficient to span between adjacent exterior wall studs is fastened to that face of the partition wall which is nailed to the exterior wall.

Figure 71
Support for ceiling finish where ceiling joists run parallel to a partition

- A 38 x 140 mm (2 x 6 in.) plate is centred on and nailed to the top surface of the 38 x 89 mm (2 x 4 in.) top plate such that it extends over each side of the top plate

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- If the partition is on the top floor, a strip of vapour barrier is installed between the two plates
- 38 x 89 mm (2 x 4 in.) blocking is installed which spans between the joists on either side of the wall location. The bottom of the blocking is installed at sufficient height above the underside of the joists, in order to be flush with the top of the 38 x 140 mm (2 x 6 in.) plate.
- The plate is nailed to the blocking

Figure 72
End-wall framing and nailing support for interior finish for platform construction

- A nailing plate such as a 38 x 89 mm (2 x 4) on the flat is nailed to the top of the exterior wall top plate such that a portion is inboard of the top plate thereby providing a nailing surface for the attachment of the ceiling interior finish

Figure 73
Braced wall bands and panels

No additional alt text

Figure 74
Wall framing using balloon construction method

No additional alt text

Figure 75
Structural insulated panel system (SIPS)

No additional alt text

Figure 76
Platform framing

No additional alt text

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CHAPTER 11 - CEILING AND ROOF FRAMING

Figure 77
L-shaped trussed roof

Two images of a particular roof configuration are shown.

1. One is the plan (aerial) view of the roof which is comprised of two gable roofs that join forming an L in plan view. The ridge of one roof section originates from a location on the ridge of the other (main) section. The intersecting roof planes result in two valleys on the roof.
2. A cut-away view of the L-shaped roof shows:
   - Portions of the roof sheathing
   - Common trusses on both the main and intersecting roofs
   - Valley trusses, which are smaller trusses placed on the roof sheathing of the main roof that form the part of the truss network for the intersecting roof overlying the main roof
   - A girder truss, which is a stronger truss within the intersecting roof truss network. This truss is placed on the double top plates of the main roof to provide additional support.

Figure 78
Raised heel truss roof provides depth for insulation

No additional alt text

Figure 79
Types of prefabricated roof trusses

No additional alt text

Figure 80
Temporary bracing of roof trusses

In addition to what is included in the text:

- Gable ends are normally sheathed prior to the installation of the end braces

Figure 81
Permanent bracing of roof trusses

One approach for permanently bracing gable roof trusses is as follows:

- Pairs of diagonal braces, originating at the mid- point of the gable end top chord span the underside of several trusses, with one brace extending to the base of the top chord abover the exterior wall, and the other to the top chord along the ridge. This is duplicated on the other plane of the roof and repeated at approximately 6m (20 ft.) intervals as required by the truss manufacturer.
- Lateral bracing extends from the underside of the mid-point of a truss web at one end of the roof to the other on both roof planes.
- The bracing is 38 x 89 mm (2 x 4 in.) or as required by truss manufacturer.

Figure 82
Types of pitched roofs

Six roofs are shown: a gable, a gable dormer, a shed dormer and a hip roof:

- A flat roof is one that is flat or pitched just enough to provide drainage.
- A monolith roof has a single plane with a moderately sloping surface.
- A gable roof is a ridged roof that has only two planes. the gable is the triangular portion of the building wall at each end of the roof.
- A hip roof is one which rises by inclined planes from all four sides of a building which intersect at a centre point or ridge. The intersections of adjacent roof planes are terms hips.
- A gambrel roof is similar to a gable roof but has its two roof planes broken by an obtuse angles, so that the lower slope on each is steeper than the adjacent upper slope.
- A mansard roof is similar to a hip roof but has its four roof planes broken by an obtuse angle, so that the lower slope on each is steeper than the adjacent upper slope.

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Figure 83
Roof framing and attachment

In addition to what is included in the text:

- For a gable roof, a ridge board provides the bearing surface for the top of each rafter.
- When required, framing, termed collar ties, horizontally spans between the upper portions of a pair of gable roof rafters, providing an intermediate support for the rafter pairs
- When required, a framing member laid flat on top of, at right angles to and spanning several collar ties can be installed to prevent lateral deflection of the collar ties

Figure 84
Rafter heel supported on a rafter plate

No additional alt text

Figure 85
Doubled ceiling joists and stub joists used where a hip rafter reduces clear span space near the end wall

No additional alt text

Figure 86
Rafter heel supported on a load-bearing wall

No additional alt text

Figure 87
Framing at a valley

No additional alt text

Figure 88
Typical dormer framing

No additional alt text

Figure 89
Wide projection at gable end supported by "lookout" rafters

No additional alt text

Figure 90
Narrow projection at gable end

No additional alt text

Figure 91
Typical construction of a low-slope roof with overhang

No additional alt text

Figure 92
Soffit roof ventilation

In addition to what is included in the text:

- The ventilation air flows through up the perforated soffit, into the area between the baffle restraining the insulation and the roof sheathing and then up toward the top of the attic space

Figure 93
High-level roof ventilation

Two types of vents are shown:

- A ridge vent, which is slightly raised above the ridge, runs the length of the ridge, and facilitates the outflow of the ventilation air by means of the negative pressure from airflow (wind) over the roof
- A gable vent, which is mounted at the top of the gable wall

Figure 94
Ceiling joists

No additional alt text

Figure 95
Roof rafters

No additional alt text

Figure 96
Roof joists

No additional alt text

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CHAPTER 12 – ROOF SHEATHING AND COVERINGS

Figure 97
Application of structural wood-panel roof sheathing

In addition to what is included in the text:

- Nails through edges of plywood or OSB onto supporting members (roof trusses, joists or rafters) to be placed at 150 mm (6 in.) on centre
- Nails through long side of plywood or OSB onto supporting members to be placed at 300 mm (12 in.) on centre

Figure 98
Installation of wood-board roof sheathing

No additional alt text

Figure 99
Roof sheathing detail at a valley and at a chimney opening

No additional alt text

Figure 100
Eave protection

In addition to what is included in the text:

- The minimum 900 mm (36 in.) eave protection up the roof is measured along the slope of the roof
- The minimum 300 mm (12 in.) inside the inner face of the exterior wall is measured horizontally

Figure 101
Application of asphalt shingles

No additional alt text

Figure 102
Installation of wood shingles

No additional alt text

Figure 103
Installation of hand-split shakes

No additional alt text

Figure 104
Finish at ridge and hips

No additional alt text

Figure 105
Built-up roof

No additional alt text

Figure 106
Sheet metal roofing

Nailing strips support the metal roofing in the 7 images shown:

1. Sheet metal pieces on a roof plane, with the upper piece lapping over the lower piece
2. An eave starter, a narrow piece of sheet metal, is installed at the eave. A full sheet metal piece is installed over top, extending up the roof
3. In a valley, the sheet metal pieces are cut at the angle necessary to fit the valley and are installed over the valley flashing. The sheet metal pieces cover the upper portion of each side of the valley flashing, leaving the centre portion of the flashing exposed
4. Sheet metal ridge caps fit over the two pieces at the top of the roof planes, i.e. at the ridge
5. Sheet metal ridge caps fit over the two pieces at the top of the roof planes, i.e. at the hip
6. Sheet metal end wall and roof plane pieces at an intersection are installed over flashing. The sheet metal pieces cover the edge of each side of the valley flashing, leaving a portion of the flashing exposed
7. Sheet metal side wall and roof plane pieces at an intersection are installed over flashing. The sheet metal pieces cover the edge of each side of the valley flashing, leaving the centre portion of the flashing exposed

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CHAPTER 13 – WALL SHEATHING AND EXTERIOR SURFACES

Figure 107
Vertical and horizontal application of panel-type sheathing

In addition to what is included in the text:

- Maintain a minimum distance of 10 mm (⅜ in.) between the edge of the sheathing and the nails

Figure 108
Lumber sheathing application

In addition to what is included in the text:

- For diagonal application lumber is at 45 degrees to the studs

Figure 109
Types of siding

No additional alt text

Figure 110
Horizontal siding

In addition to what is included in the text:

- A starter strip is installed on the inside face at the bottom of the lowest piece of horizontal siding to enable the lowest piece of siding to have the same angle relative to the sheathing as subsequent pieces
- An insect screen is installed at the bottom of the horizontal siding to enable drainage between the back of the horizontal siding and the sheathing membrane while preventing insects from accessing the drainage space

Figure 111
Siding installation

In addition to what is included in the text:

- Butt joints are made over the centre of stud if sheathing omitted
- Scribe siding tight against window openings

Figure 112
Outside-corner treatment of wood siding

No additional alt text

Figure 113
Masonry veneer support on foundation wall

No additional alt text

Figure 114
Support of masonry veneer on an ICF foundation

In addition to what is included in the text:

- The flare is created by narrowing the inside face of the outside insulation at the top of the wall, thereby thickening the concrete at the top of the wall

Figure 115
Basic exterior insulation and finish system (EIFS) components

No additional alt text

Figure 116
Components of an exterior insulation and finish system (EIFS)

From the inside of the wall system to the outside:

- A wood frame wall (conventional or optimum value engineering) with insulation and sheathing
- Water resistant barrier membrane (WRB)
- Insulation, with vertical drainage channels on the face adjacent to the WRB
- Base coat with mesh between the base coat and insulation
- Finish coat
- A two-stage joint, that extends through the finish coat, base coat with mesh and insulation, for pressure equalization and drainage at joints between panels

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CHAPTER 14 – FLASHING

Figure 117
Base flashing at roof penetration

Vertical cross section of a plumbing vent pipe penetrating a roof deck. A base flashing secured around the pipe, seals the pipe to the roof waterproofing membrane. A counter flashing is installed around the pipe over the top edge of the base to divert water over the base flashing thereby preventing water from leaking into the roof between the base flashing and pipe.

Figure 118
Base flashing at roof-wall junction

In addition to what is included in the text:

- A cant strip, a piece of lumber which in cross section is an isosceles triangle, is fastened at the intersection of the roof and wall, with one short side of the triangular piece against the wall and the other short side on the roof
- The base flashing, which is flexible, extends over the roof surface and is bent over the cant strip and up the wall.
- Metal counter flashing is installed, extending from the base of the cant strip, where it is folded over itself to elevate it above the base flashing, up the wall
- The built-up roofing is installed to a depth part way up the cant strip
- The wall sheathing paper is lapped over the counter flashing
- The wall siding is installed

Figure 119
Counter flashing

In addition to what is included in the text:

- A cant strip, a piece of lumber which in cross section is an isosceles triangle, is fastened at the intersection of the roof and wall, with one short side of the triangular piece against the wall and the other short side on the roof
- The base flashing, which is flexible, extends over the roof surface and is bent over the cant strip and up the wall.
- Metal counter flashing is installed, extending from the base of the cant strip, where it is folded over itself to elevate it above the base flashing, up the masonry to the mortar joint above the counter flashing where it is fit into a saw cut in the mortar
- The built-up roofing is installed to a depth part way up the cant strip
- The wall sheathing paper is lapped over the counter flashing
- The wall siding is installed

Figure 120
Through-wall flashing

In this case the flashing is located at the joist between two floors, with a wood frame wall and masonry cladding separated by a drainage cavity.

- The brick wall is laid to the elevation of the bottom of the joist network
- An L-bracket is installed against the sheathing paper at the location of the joist and extending out just above the existing brick wall
- A flashing is installed that fits under the sheathing paper on the plywood above the joist network, extends down onto the L-bracket, and extends slightly past the face of the brick cladding, terminating with a downward tilt
- Weep holes are placed in the lower coarse of the brick work to ensure drainage of any water in the drainage cavity

Figure 121
Through-wall flashing at foundation

In this case the flashing is located at the junction between the top of the concrete foundation wall and first floor joist network with a wood frame wall and masonry cladding separated by a drainage cavity.

- A flashing is installed that fits under the sheathing paper on the plywood above the joist network, extends down past the joist network and onto the top of the concrete foundation wall, and is bent at the outside edge of the concrete wall, terminating with a downward tilt.

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- The wall sheathing paper is lapped over the top of the flashing
- Weep holes are placed in the lower coarse of the brick work to ensure drainage of any water in the drainage cavity

Figure 122
Dampproof flashing

In addition to what is included in the text:

- Drip edges are cut on the underside of the coping out board of, and parallel to, the exterior and interior wall planes. These help prevent water from migrating by surface tension on the underside of the coping to the wall surfaces

Figure 123
Valley flashing

No additional alt text

Figure 124
Stepped flashing

No additional alt text

Figure 125
Flashing at wall intersection

The procedure is as follows:

- Masonry veneer wall and wood frame substrate are installed and pass through sloped roof deck.
- Install base flashing segment at intersection between brick courses and sloped roof deck, with the vertical leg of the flashing having a minimum height of 100 mm (4 in.) placed against the surface of the brick. The 100 mm (4 in.) horizontal leg of the flashing resting on the roof deck. A minimum 75 mm (3 in.) overlap is required between consecutive pieces of segmented base flashing installed in a ship-lapped manner, the upper flashing on top of the lower flashing. Roof shingles are interwoven with and overlap base flashing
- A counter flashing segment extends vertically from the base flashing, over the brick masonry course, across the air cavity and is mechanically fastened to the sheathing with flat head galvanized roofing nails at 300 mm (12”) o/c minimum, two per segment. The vertical portion of the counter flashing at the wall sheathing is a minimum 100 mm (4 in) in height. Ensure there is a minimum overlap of 100 mm (4 in.) between the vertical leg of the counter flashing and the underlying vertical leg of the base flashing. A minimum 75 mm (3 in) overlap is required between consecutive pieces of segmented counter flashing installed in a ship-lapped manner, the upper flashing on top of the lower counter flashing.
- The counter flashing segment is a single piece of metal shaped and folded such that a vertical rectangular portion sits against the sheathing, a rectangular portion sits flat and horizontally on the top of the brick, and a vertical trapezoidal portion fits against the outside surface of the brick with the lower edge following the slope of the roof. In addition, an end dam is formed at the upper end of the horizontal segment by folding up and connecting a flange to the upper vertical segment and soldering or applying sealant to the intersection of the flange and the portion that sits against the sheathing.
- Building paper or housewrap, installed on top of the wall sheathing, overlaps the vertical leg of the counter flashing a minimum of 100 mm (4 in.) measured from the leading edge of the counter flashing facing the lower roof level.

Figure 126
Chimney flashing

In addition to what is included in the text:

- The saddle is a sloping structure that helps drain potential any water that accumulates at the intersection of the upper side of the chimney and the roof above
- Prior to installation of the saddle, a rubberized asphalt sheet, cut so that the chimney fits through, is installed on the sheathing surrounding the chimney and up the slope behind the chimney to at least the height of the counter flashing

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CHAPTER 15 – WINDOWS, EXTERIOR DOORS AND SKYLIGHTS

Figure 127
Minimum dimensions for egress windows

No additional alt text

Figure 128
Common window types

In addition to what is included in the text:

- Hopper windows are hinged at the bottom and swing into the interior

Figure 129
Window terminology

In addition to what is included in the text:

- The sash holds the glass in the window and attaches to the window frame
- The sill is the horizontal member forming the bottom of the window frame

Figure 130
Sequence for window installation

A typical sequence for window installation is:

1. Slope the rough opening sub-sill to the exterior
2. Install sheathing membrane below opening
3. Install water impermeable (WI) membrane onto sub-sill and extending to lap down over the sheathing membrane
4. Install WI corner reinforcing membrane at each lower corner of the rough opening
5. Install WI membrane lapping over the reinforcing membrane at the lower corners and extending up the inside and exterior face of the vertical rough opening framing members
6. Install strips of vertical sheathing membrane, lapping over lower membrane and wrapping into the vertical rough opening framing members
7. Install horizontal sheathing membrane and wrap under rough opening header
8. Install shims, window and insulation, the latter between the window frame and the rough opening framing
9. Install head flashing
10. Install and lap wall sheathing membrane
11. Lap sheathing membrane above opening over head flashing
12. Install wood furring for drainage cavity
13. Install metal drip edge at sill
14. Install siding
15. Install backer rod and exterior and interior sealants

Figure 131
Window sill

Drip edge arrangements are shown for exterior cladding and for masonry. In both cases a water-impermeable membrane is placed over either a sloped sill or a horizontal sill with dams and the slope of the top of the sill is 6% away from the window.

For exterior cladding the sill should extended 25 mm (1 in.) beyond the cladding and the drip notch positioned 6 mm (¼ in.) beyond the outer face of the cladding.

For a masonry exterior the brick course immediately under the window sill, which is termed the masonry sill, is sloped away from the wall, is flush with the other courses at the drainage space face but extends past the outside plane of the other courses, and has a drip edge on the underside outboard of the other courses. The window sill should extend 25 mm (1 in.) beyond the inner face of the masonry wall, with the drip edge notch positioned 15 mm (⅝ in.) beyond the inner face of the masonry sill. The masonry sill also has a drip edge, positioned outboard of the outer face of the masonry wall below.

Figure 132
Window attachment

Always refer to manufacturer's instructions.
In general:

- The rough opening dimensions should be 25 mm (1 in.) larger than the outside of the window frame to provide a minimum 12.5 mm (½ in.) space between the window frame and opening on all sides

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- Shim at the jamb and sill junctions only and junctions of multiple units
- Attach window with wood screws through sides of window frame only

Figure 133
Pre-hung manufactured door

Pre-hung manufactured exterior doors typically include the following characteristics:

- The door with pre-drilled lockset holes
- Three hinges attaching the door to the hinge jamb
- A jamb comprised of a head jamb, two side jambs (a hinge jamb and a lock jamb) and a threshold

Exterior doors are to have water-impermeable sill membrane and flashing

Figure 134
Door hardware requirements

No additional alt text

Figure 135
Stepped flashing for skylight

- A rubberized asphalt sheet (self-sealing) surrounds the opening, extending up the roof slope to above the height of the top of the (future) saddle flashing and is turned up and over the curb of the skylight rough opening
- The pre-finished steel saddle is installed
- The roof shingles and pre-finished step siding at the skylight are installed

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CHAPTER 16 – EXTERIOR TRIM AND MILLWORK

Figure 136
Roof projection at eaves

No additional alt text

Figure 137
Eave and gable-end intersections (viewed from below)

No additional alt text

Figure 138
Section through doorframe at sill

In addition to what is included in the text, the doorsill should rest on a water-impermeable sill membrane.

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CHAPTER 17 – STAIRS

Figure 139
Stair detail

In addition to what is included in the text:

- The tread is the horizontal part of a step
- The riser is the vertical part of a step. It is placed at the back of the tread, or on the lower floor, and extends the height of the step to the underside of the next tread up or the top floor
- The run of a tread is the horizontal distance from the edge of the nosing of the tread above to the edge of the nosing of the tread in question
- The rise is the vertical distance from the top of one tread to the top of an adjacent tread
- The projection is the horizontal distance from the face of the riser to the leading edge of the tread above
- The leading edge (nosing) of the tread can be rounded or bevelled and extends 25 mm (1 in.) past the face of the riser below
- The effective tread depth is the minimum tread depth less 15 mm ($^{19}/_{32}$ in.)

Figure 140
Types of stair layouts

Stair layouts include:

- Straight
- A long L, where a landing is near the top of the flight of stairs, which turn 90 degrees
- A wide L, where a landing is close to the centre of the flight of stairs, which turn 90 degrees
- A narrow U, with a single landing and a 180 degree turn
- A double L, with two 90 degree turns (one made up of 30 degree winder treads) resulting in a 180 degree turn
- A wide U, with two landings, each with a 90 degree turn and separated by a short set of steps, resulting in a 180 degree turn.

Figure 141
Stairway design

- In addition to what is included in the text:
- The total run is the horizontal distance from the face of the bottom most riser to the face of the topmost riser
- The total rise is the distance from finish floor level to finish floor level
- The headroom is determined by measuring the vertical distance from a sloping line formed by the leading edge of the nosings (the "leading line") to the underside of the floor above. The minimum headroom is the smallest of these distances.

Figure 142
Stair components

No additional alt text

Figure 143
Basement stairs

In addition to what is included in the text:

- One approach is to utilize a cut-out stringer and attach to its exterior face a wide, finished board, 25 mm (1 in.) thick which conceals the ends of the treads

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CHAPTER 18 – CHIMNEYS, FLUES AND FIREPLACES

Figure 144
Chimney height above the ridge

No additional alt text

Figure 145
Installation of flue linings

In addition to what is included in the text:

- Sealant is placed between the flue and masonry chimney cap to prevent water entry between the flue and chimney
- The outside face of a flue liner must surrounded by a minimum 75 mm (3 in.) solid masonry

Figure 146
Fireplace terms

In addition to what is included in the text, the components of a wood-burning fireplace include:

- Firebrick on three sides of the fireplace above the hearth, the forth side being open to the room
- The throat at the top of the fireplace, which slopes from the back wall toward the front
- The damper, which is positioned above the throat, is typically closed when the fireplace is not in use and open when the fireplace is in use
- A smoke shelf, a ledge at the bottom of a smoke chamber, which deflects or breaks downdrafts from the chimney
- A smoke chamber, which is an enlarged area immediately above the smoke shelf and below the flue lining
- Flue lining, which extends to the top of the chimney
- The back hearth includes an opening to the ash dump

Figure 147
Factory-built fireplace

Components of the factory-built fireplace include:

- Nailing flanges for attaching the fireplace enclosure to the wood framing adjacent to, but not in contact with, the sides of the fireplace
- Metal standoffs, which ensure the proper distance between the top of the fireplace enclosure and the wood framing above
- A ventilated metal surround at the front of the fireplace enclosure
- At the ceiling penetration above the fireplace, the flue pipe penetrates a metal plate, termed a fire-stop spacer, which is attached to the subfloor. The adjacent insulation is held back a minimum 50 mm (2 in.) from the flue pipe
- At the roof, the flue penetrates the framed chimney box through a collar on a custom galvanized steel cap fitted over the chimney box.
- A narrow round collar, termed a storm collar, is fit over the flue above the steel cap
- Finally, a chimney cap is fit over the flue.

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CHAPTER 19 – PLUMBING, ELECTRICAL AND APPLIANCES

Figure 148
Example of notch limitations

No additional alt text

Figure 149
Maximum size of holes drilled in joists

No additional alt text

Figure 150
Notching studs for plumbing

No additional alt text

Figure 151
Kitchen and bathroom in proximity for minimum pipe length

- The kitchen and bathroom share a common wall on the main floor. A 140 mm (6 in.) stud wall is required if the soil stack continues to upper floors
- In the bathroom, the head of the bathtub, back of the toilet, and back of washbasin or vanity abut the same wall, thereby shortening the length of hot and cold water lines and waste lines required. The waste lines join in the centre of the wall, in this case behind the toilet, and descend to the basement where a cleanout is positioned
- The kitchen sink is positioned above the laundry tub in the basement and share a roof vent and soil (waste) stack to the basement, where a cleanout is positioned
- The waste disposal piping system is buried under the concrete slab and directed outside the building to the sanitary sewer. A floor drain, positioned in front of the basement laundry tubs, is connected to the system

Figure 152
Washbasin and bathtub fixtures

One of the two diagrams is a cross-section of a washbasin mounted on brackets fastened to blocking or the stud wall. The exposed drainage piping is usually chrome plated or brass and includes a trap. The drainage piping from the washbasin enters the stud wall where it is connected to a soil stack. Holes are drilled in the bottom plate of the wall and subflooring for hot and cold water piping.

The other diagram is a cross-section of a profile of a bathtub at the head end which abuts a wall. The subflooring is cut to receive the drain piping. The overflow and outlet connect to drainage pipe (including a trap) before joining the soil stack

Figure 153
Toilet fixture

The figure is a cross-section of a toilet and connecting waste pipes. The toilet is secured to the floor with a flange, which also serves to direct the waste to drainage piping under the floor which in turn connects to the soil stack in the wall. This stack also receives the waste from the washbasin and bathtub. The wall bottom plate and subflooring are cut to accommodate the stack.

Figure 154
Venting for plumbing

In addition to what is included in the text:

A rubber boot is placed over the pipe, onto the roof surface and integrated with the roofing material

Figure 155
Sealing a plumbing vent below an attic

- In order to support the pre-fabricated vent pipe flashing at the ceiling, wood blocking is installed between the ceiling framing on either side of the planed vent location
- Polyethylene air and vapour barrier is installed
- The prefabricated vent pipe and flashing is installed and the flashing sealed against the underside of the polyethylene

Figure 156
Framing for soil-stack pipes

No additional alt text

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Figure 157
Typical arrangement of service entrance

The overhead electrical 'lead' wires from the utility are routed down a vertical conduit. The conduit is fastened to the side of the house with conduit straps and is attached to the meter base using a conduit connector. The electrical lead wires are attached to the 'top' (service side) of the meter socket in the meter base. The electrical wires from the 'bottom' (house side) of the meter socket continue through conduit to a right angle entrance ell, at which point the conduit penetrates the building envelope. The conduit terminates at a connector to a service panel in the house.

Figure 158
Service entrance equipment

There are three images in this figure

One image provides information related to that in Figure 159:

- The overhead 3-wire 120-240V electrical 'lead' wires enter the conduit through a weather head
- The service height (height of the weather head) above grade must be in accordance with the electrical code requirements

A second image shows the distribution panel:

- The distribution panel has a capacity of 100 to 200 amps
- The service wires are bought to the main breaker located in the basement through a rigid conduit. The main breaker and distribution panel containing fuses for the branch circuits are mounted on a 12.7 mm (½ in.) plywood or OSB back-up panel

Service equipment must be grounded. A ground wire from the main entrance panel must be clamped to the water service entrance pipe below the shut-off valve. The pipe must be metallic.

Figure 159
Drilling of structural members for wiring

Four images are shown:

1. A cross-section of a ceiling including a surface mounted receptacle to which a pendant fitting is attached. The pendant fitting is recommended to reduce heat build-up.
2. A switch box on one side of a rough door opening. The switch box is nailed to the inside of the full height stud with two 100 mm (4 in.) nails.
3. When holes are drilled in studs for wires, and are closer than 30 mm (1¼ in.) to the edge of the stud, metal protection plates must be fixed to the edge.
4. Holes are drilled in studs, top plates and bottom plate to facilitate routing of electrical wiring. The switch box beside the door framing is located 1.4 m (4½ ft.) above the floor.

Figure 160
Typical electrical equipment

Typical electrical equipment includes:

- Octagonal boxes for use as junction boxes, with fixtures or with outlets
- Rectangular boxes for switches and outlets
- Duplex wall outlets and cover plate
- Toggle switch and cover plate
- Circuit breakers

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CHAPTER 20 – SPACE CONDITIONING SYSTEMS

Figure 161
Basement plan showing typical heating layout

In addition to what is included in the text:

- The oil storage tank is located in the basement. Oil feed and vent pipes penetrate the building envelope to the outside
- The copper tubing attaching the oil tank to the furnace burner is in a conduit encased in the concrete floor
- The supply duct for the kitchen can terminate in a grill mounted on the toe-space under the kitchen counter

Figure 162
Isometric view of forced-air heating system

In addition to what is included in the text:

- The clearance between combustible materials and heating appliances must be in accordance with manufacturer's instructions
- The furnace wiring is extended to an emergency switch box normally fixed to the underside of a floor joist at the bottom of basement stairs
- The wiring from the relay control box is extended to a thermostatic control outlet generally located 1.2 m (4 ft.) off the first floor level

Figure 163
Common types of heat recovery ventilators

In addition to what is included in the text:

- In both the plate heat exchanger and wheel heat exchanger types of exchangers, two fans, a supply and exhaust fan, move the air through the exchanger. Both are mounted on the 'out' side of the exchanger, i.e. the supply fan pulls in air from the outside and directs it to the exchanger and the exhaust fan takes air from the exchanger and exhausts it to the outside.

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CHAPTER 21 – INTERIOR WALL AND CEILING FINISHES

Figure 164
Application of drywall finish

In addition to what is included in the text:

- When the drywall sheets are applied vertically, nails are spaced 150-200 mm (6 to 8 in.) on centre

Figure 165
Finishing of gypsum board

In addition to what is included in the text:

- The tape for the inside corners is sharply folded along its length to ensure it fits flat against both faces at the corner

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CHAPTER 22 – FLOOR COVERINGS

Figure 166
Application of strip flooring

In addition to what is included in the text:

- The first strip of flooring is separated from the wall by a 6 mm (¼ in.) expansion space or as recommended by the flooring manufacturer
- When face-nailed and set, shoe mold will cover nail on first strip of flooring

Figure 167
Installation of ceramic tile floor

In addition to what is included in the text:

- When the ceramic tile is installed over a mortar setting bed, the thickness of the mortar, about 30 mm (1 3/16 in.), requires that the top of the joists supporting the subfloor under the mortar be lower than adjacent joists over which other flooring will be placed in order that the surfaces of the tile and of the other flooring be flush. A horizontal ledger strip, or cleat, is attached to the joist that supports the other flooring. The top of the cleat is mounted such that the ceramic tile (on top of the subfloor, concrete topping and mortar setting bed) will be at the desired height relevant to the adjacent flooring. The joists under the ceramic tile are not as deep as the joists under the adjacent flooring in order that the underside of all joists is in a plane.

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CHAPTER 23 – INTERIOR DOORS, FRAMES AND TRIM

Figure 168
Interior door frame showing typical connection between jamb and head

In addition to what is included in the text:

- A dado the thickness of the head material is cut in the jambs in the location required to accept the head material

Figure 169
Door frame and trim showing frame blind-nailed under doorstop

Use NULL alt tag

Figure 170
Suggested dimensions and location of hardware

In addition to what is included in the text:

- The suggested clearances between the door and jambs are 2 mm (1/16 in.) for the latch jam and head, and 1 mm (1/32 in.) for the hinge jam
- The suggested clearance between the bottom of the door and flooring is 19 mm (3/4 in.)
- The suggested distance from the top of the door to the top of the top hinge is 175 mm (7 in.) and from the bottom of the door to the bottom of the bottom hinge 275 mm (11 in.)

Figure 171
Door Installation

In addition to what is included in the text:

- The latch face of the door should have a slight bevel along its length. The bevel should slope in, i.e. material is removed from the edge of the door that is adjacent to the doorstop.

Figure 172
Base moulding

In addition to what is included in the text:

- The joints at the interior corners of baseboard can be mitred or coped. The interior corners of the shoe mould are typically mitred.

Figure 173
Kitchen cabinets

Kitchen design may include the following elements:

- Overhead wall cabinets including the typical wall cabinet with three shelves, possibly with a light valence under to illuminate a work surface, a corner wall cabinet with a door at 45 degrees to the cabinets on both sides, a cabinet above the refrigerator that is less in height than the typical wall cabinets in order to accommodate the refrigerator, a cabinet above the range / oven, also less in height than the typical wall cabinet in order to allow the installation of a range hood exhaust under the cabinet at an acceptable distance above the range.
- Base wall cabinets can include a typical two shelf unit, a corner unit, a drawer cabinet, a cabinet that accommodates a double sink, and a full height, 7 shelve pantry cabinet
- A dishwasher, located near the double sinks
- A backsplash
- An island, comprised of a base cabinet and bar counter.
- The island and base wall cabinets incorporate a toe space, an indentation of the face of the cabinets at the floor

Figure 174
Storage closets

In addition to what is included in the text, clothes closets may contain a unit of drawers, and racks.

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CHAPTER 26 – DECKS, PORCHES AND BALCONIES

Figure 175
Wood deck detail

In addition to what is included in the text:

- The 'height of deck' is the distance from the grade to the top of the decking surface
- For decks > 600 mm (2 ft.) above ground or with more than 3 risers, a concrete pier supported by rock, drained granular material of extending below the frost line is required. The concrete pier must extend a minimum 200 mm (8 in.) above grade
- Posts, which support the deck framing, are fastened to a post saddle attached to the concrete pier. The top of the posts should be at an elevation such that the finished deck surface slopes slightly away from the building
- Built-up beams rest on and are fastened to the top of the posts with angle brackets
- The joists are positioned on the beam and the decking laid at right angles to the joists, overhanging the rim joist 25 mm (1 in.)
- The railing posts are bolted to the joists and, where possible, also to the rim joists
- The handrail (or cap) is placed on the top of the railing posts, defining the guard height (the height from the top of deck to top of handrail)
- Vertical members termed balusters, spaced no more than a 100 mm (4 in.) apart edge to edge, are installed from the surface of the deck to the underside of the handrail

Figure 176
Deck connection to house

- If necessary, the exterior cladding on the house is carefully removed in the area where the deck will contact the house, and set aside.
- A rim joist, also termed a ledger, is installed at a height such that when the decking is installed, its surface will be at least 19 mm (¾ in.) below the elevation of the inside floor surface
- The ledger is bolted through spacers installed between the ledger and the building sheathing paper (to enable drainage), the building sheathing paper and sheathing to the interior rim joist. The area where the bolts penetrate the building sheathing paper is caulked.
- Deck joists are fastened to the ledger using metal deck hangers and sloped at 5 mm per metre (1/16 in. per foot) away from the house
- The decking is installed, with 6 mm (¼ in.) gaps between the boards
- The decking board adjacent to the wall of the house is cut on a bevel in cross-section so that the edge closest to the house is at the level of the inside floor, and the other edge (adjacent to the boards) is the same thickness as the rest of the deck boards. This would require cutting a board thicker than the rest
- Metal flashing is installed on the sheathing immediately above the deck and the building sheathing paper lapped over
- The flashing extends onto the bevelled face of the deck board closest to the wall and down through the gap between the first and second boards
- The vertical strapping and exterior cladding is installed, or re-installed. The bottom of the strapping and cladding is slightly above the flashing on the bevelled face

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CHAPTER 27 – GARAGES AND CARPORTS

Figure 177
Essential features of attached garages

In addition to what is included in the text:

- Footings must bear on solid rock or on undisturbed soil below frost level
- The surface of the garage floor must slope toward the garage door
- The driveway slopes away from the garage
- A minimum 50 mm (2 in.) concrete curb or airtight partition is required between the garage and living space
- An air barrier system, vapour barrier and insulation between the conditioned and unconditioned spaces are required. The air barrier functions as a smoke barrier

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APPENDIX B – CUTAWAY VIEW OF A WOOD-FRAME HOUSE

Cutaway View of a Wood-frame House

Specific features and activities related to the following house construction phases are discussed below– Foundation Excavation, Basement Floor, Foundation Wall and Sill, Floor Platforms and Headers, Exterior Wall Framing, Interior Finishes, Siding Finish and Trim, Brick, Partition Walls, Roof and Ceiling Framing, Roof Finishes, Fascia and Soffit, Ventilation and Mechanical Equipment.

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