Civil Engineering

SUPERVISION AND MANAGEMENT

Third Edition

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ARNOLD

A member of the Hodder Headline Group
LONDON • SYDNEY • AUCKLAND

Third edition published in Great Britain 1995 by Arnold,
a division of Hodder Headline PLC, 338 Euston Road, London
NW1 3BH

First published 1966
Second edition 1972. Reprinted 1975, 1978, 1980, 1984

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloguing in Publications Data
Available on request

ISBN-13: 978-1-4612-8451-2 e-ISBN-13: 978-1-4613-1153-9
DOI: 10.1007/978-1-4613-1153-9

Typeset in Times by Anneset, Weston-super-Mare, Avon

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Preface

This book covers methods adopted for undertaking the design and construction of civil engineering projects. The options for separate design and construction are compared with design and build projects, construction management, and management contracting. The salient differences are shown between the various conditions of contract used. The roles of the engineer, employer's project manager or his representative under different forms of contract are compared. Requirements for the production of contract documents, specifications, tendering procedures and choice of contractor are set out.

The engineer's powers and the duties of his resident engineer on the site of construction are considered in detail. Records, filing systems, programme and progress charts used by the resident engineer are illustrated, and advice is given on the handling of safety problems and difficult situations on site.

Problems of measurement and billing of quantities according to the civil engineering standard method are described. Correct procedures for setting rates for varied work, payment for method-related items, and handling claims for unforeseen conditions under ICE Clause 12 are given. Difficulties with delay claims and situations where the contractor submits quotations before undertaking varied work are discussed.

The approach is essentially practical throughout and covers many actual problems met on site, including measures that are advisable in relation to site surveys and investigations, construction of earthworks and pipelines, and the production and placing of concrete.

The authors acknowledge with thanks the assistance received from the consulting engineers Binnie & Partners, whose long experience of handling major civil engineering projects in the UK and abroad has been of great benefit to the authors. The views given in this book are, however, our own.

A C Twort
J Gordon Rees April 1995

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Methods of commissioning works

1.1 Introduction

Civil engineering structures rank among the great material works of man. Every such work is unique in the sense that it represents a specially designed effort to develop and use some portion of the earth's natural resources at some particular location. In this effort it is needful, first to conceive the aim of the intended works; second to design them in practical detail; third to construct them; and fourth to put them into working operation. This fourfold process may commonly last from two to ten years; it may use the labours of hundreds of people, the knowledge of dozens of specialists gained over many years, and incorporate the natural and manufactured products of scores of different trades. Until such time as the works are completed there must be a continuous resolve to pursue their construction to finality; and resources must be provided in the form of money, manpower, machines and materials to support this resolve throughout the periods of design and construction.

Owing to their unique nature, civil engineering works must be commissioned in advance of need; they are not purchasable ready made. As a result there must be a promoter who has defined his need for the works, has resolved to undertake them and agrees to pay for them, and who will own and operate them when complete. The promoter has to find the money to finance the scheme, either from his own resources or by borrowing money from others. This is the capital investment in the works. Only when the works are in operation can the promoter receive tangible proof that the capital works he has commissioned have produced the object he wants. Until then he must have faith in what his various expert advisers say can be done and what they estimate will be the cost of the project.

The main obligations of the promoter can thus be summarized:

- to define the nature and magnitude of the functions of the project;
- to satisfy himself that the intended project will serve his needs;

- to obtain any statutory or other powers necessary for construction and operation of the project including environmental approvals;
- to find the money to pay for the design and construction work;
- to take over the project when complete and operate it.

A promoter wishing to procure works has necessarily to make a number of decisions as to the methods he will adopt to see the project through from inception to completion. Among these decisions will be whether he can carry out the work with his existing resources, or to what extent he needs to call on outside expertise or assistance. He may also have to comply with the rules set by his own company or authority, and take into account a wide range of statutory and other legal requirements that his company or authority must comply with before the project can commence.

The promoter will also need to be quite certain that the intended project will fulfil his needs by the time, some years forward, when it is completed. To do this he may need market studies to ensure that he has correctly appraised the end result that the project should achieve. In addition he will need feasibility studies and analyses to satisfy himself that the intended project is engineeringly practicable, and financially acceptable.

1.2 Importance of feasibility studies

Feasibility studies must provide a promoter with assurances that:

- the intended project will meet his needs in the most satisfactory and economic manner;
- the project is technically feasible and will give the results intended;
- any powers needed to construct the project can be obtained; and
- the estimated cost of the project is acceptable.

The feasibility studies may need to be extensive, and it can be an advantage to a promoter if he employs an independent consulting engineer to check the technical feasibility and cost of the project. The consulting engineer should be able to bring to a project extensive design and construction experience in the type of work the promoter needs, and also provide a wide range of specialists, who are often needed to ensure a project's success. A promoter's staff may lack such experience, as many organizations require new works only infrequently, whereas a consultant is continuously engaged on new construction and should have an up-to-date knowledge of developing techniques. In addition, the consultant may be able from his experience to offer solutions that may not have occurred to the promoter, and can advise on the problems and difficulties that can arise during construction and need to be avoided as much as possible.

In the initial stages, the studies usually concentrate on various options for the location, design and layout of the project. Accompanying this work there will be data-gathering and analysis, followed by the development and costing of alternative layouts and designs, so that the promoter can be assisted to choose that which seems most suitable. There will follow further feasibility tests, which could include substantial site investigations and, if necessary on the very largest projects, some trial construction. The latter might include construction of some trial earthworks, sinking of test borings, or some trial tunnelling or excavation. Model tests of hydraulic structures may be required. In this process the value of an independent consultant possessed of the necessary skills will be that he uses only his independent professional judgement in deciding what will serve the promoter's interests best. Such a consultant will have no relationship with any commercial or other firm that could have an interest in favouring any particular kind of development.

It is important that the feasibility studies include a close examination of the promoter's needs and the data on which they are based. Many instances could be quoted where large sums of money have been saved on a project by carrying out, at an early stage, a critical examination of the basic data the promoter has relied upon. These data might not have been procured according to latest techniques or requirements and therefore might not be sufficiently accurate in the light of current knowledge. They have to be tested for accuracy, reliability, and correctness of interpretation. Inaccuracies in them or misinterpretations of them could lead to wasted expenditure, or problems in construction which are costly to overcome.

The acquisition of powers to construct a project is often a lengthy and specialized process. Powers to purchase land, gain access, alter public rights of way, abstract water, discharge waste, gain planning approval, meet environmental and other objections etc. will involve many approaches to outside bodies. Special procedures, including presenting the case for a project before a public inquiry or gaining parliamentary approval, may be necessary in the UK. For projects internationally funded it will be necessary to meet the extensive requirements of funding agencies such as the World Bank, Asian Development Bank, United Nations Fund, or European Community regulations. These are often highly complex matters to handle, and a consultant experienced in such work, together with legal, financial and economic advisers may be essential to give the assistance that a promoter requires. Usually it takes a minimum of two years on major projects to conduct feasibility studies and negotiate the powers required for construction; often it can take longer. Even on a small project these matters can seldom be completed in less than a year.

1.3 Overall approaches to design and construction

The traditional and still widespread approach to civil engineering projects is to undertake design and construction separately. For design, either the promoter uses his own staff, or he employs a firm of consulting engineers to do this for him. The design includes production of all drawings of the works required, together with a specification of the works and a contract for their construction. Civil engineering contractors are then invited to submit tenders, which state prices for constructing the works, and the promoter chooses the tender that he considers best: usually the lowest-priced one, but not always so.

Instead of using a contractor the promoter can adopt **direct labour construction**, meaning that he uses his own employees to construct the works. Much routine civil engineering work is carried out in this manner by local authorities and public utilities in respect of such matters as resurfacing roads, constructing minor roads, laying water mains and sewers. Direct labour construction was commonly also used on major projects in Britain during the nineteenth century; and was in regular use on all sizes of projects overseas up to the late 1950s. Usually the work was placed by the promoter under the charge of a consulting engineer. Although this approach is less common now, it is still used in undeveloped areas overseas and occasionally for special work in the UK, as occurred in the construction of some of the tidal defences work in eastern England in the 1980s.

During the past decade or so, a number of different approaches to design and construction began to become more widespread than previously. Civil engineering contractors, growing in size and experience, began more frequently to offer **turnkey** projects. A promoter would define his project requirements and the contractor would then design and construct the project. Sometimes a contractor, in association with a bank, would also offer to fund the cost of a project, the promoter repaying such cost over a number of years. Promoters also sought ways in which they could achieve either greater speed in construction or greater certainty of the final price. Growth in the complexity of projects, such as in the multiplicity of services now required for modern high-rise buildings, meant that contractors found their principal task became that of ordering and coordinating the many specialist contractors needed to provide these services. Hence **management contracting** came to the fore in different forms. The variety of these various new approaches, together with the traditional approaches still widely adopted, are considered below.

1.4 Options for design

A promoter may have sufficient staff to undertake design work 'in house'; or he may decide to do some work in house and let out other work in separate 'packages' to be done by others. For large schemes it may be appropriate to divide the whole project into 'design packages', which are let out to appropriately experienced consultants, with overall control exercised by the promoter's staff, assisted perhaps by a firm of consultants of wide experience to coordinate the work of other consultants. Irrespective of how much design work is let out to others, the promoter's own staff will have to maintain some controlling input to ensure that the project is staying on the lines laid down by the promoter, and to ensure that it stays within the financial targets set.

On many projects there is a need for specialist design inputs. In some cases specialist consultants may be brought in; in other cases specialist contractors or suppliers may be consulted at the design stage, especially when some patented or unique process is considered for use. In some situations it may be appropriate to employ a contractor to design and construct a discrete part of the works. Alternatively all design work can be passed to the contractor, and some advantages and disadvantages of this are discussed later. But it has to be noted that the placing of any design in the hands of the construction contractor has the inescapable effect of creating a break between the promoter and the designer. One result is that the promoter can no longer dictate his wishes freely to the designer, and the result may in some respects be works that do not fulfil the functions intended to the complete satisfaction of the promoter.

The following subsections cover the principal design options commonly adopted.

(a) Detailed design in-house or by a consultant

The whole of the design is completed in detail before tenders are sought for construction, except for matters such as details of concrete reinforcement, which are not necessary for tendering purposes. The balance of detailed drawings are supplied to the contractor awarded the contract as required by his programme. There may be elements of design left for the contractor or his subcontractors to undertake, such as heating, lighting and plumbing systems. Specialist designers may, however, be brought in for the design of such services and other special facilities.

(b) Outline designs provided with detailed design by others

The promoter or his consultant draws up outline designs and a specification of requirements. Detailed design is then carried out by a separate design firm appointed by the promoter. This sort of arrangement can be seen in some management contracts (*see* Section 1.5 below), where the management contractor coordinates both detailed design and the construction. The design can also be let out as separate packages dependent on the size of the project: for example, design of an industrial estate may be packaged into roads and drainage, water and sewerage, electricity supplies etc.

(c) Layout design by promoter; detailed design by contractor

The promoter specifies functions and supplies layout plans. The contractor then undertakes the detailed design before proceeding with construction. The design element may be relatively small, such as designing the final alignment and levels for a pipeline; or it may be fairly substantial, such as the structural and reinforced concrete design required for a water tower or service reservoir. Such design by a contractor is often used outside the UK but is less common within; it may offer some advantages in that the contractor may design to suit his construction methods and the equipment he has available. The disadvantages are that some control over the design is lost to the promoter, the design may tend to suit the contractor more than the promoter, and time may also be lost, as design cannot start until the contract is awarded. The contractor also has to take some design risk, for which he must increase his prices.

(d) Detailed design for civil works: M & E design by others

This method is widely used for projects that combine both civil and mechanical and electrical works. There are many such projects in the fields of hydro-power, drainage, waste treatment and water supply. The detailed design of the civil works is carried out by the promoter or his consultant, incorporating requirements to suit the M & E equipment being supplied. The M & E work is normally undertaken by specialist contractors, who produce detailed drawings of their plant conforming with the general layout drawings and the specifications they have received under their contract. Close liaison is needed between the civil works design team and the plant designers.

(e) Functional specification by promoter: design by contractor

This is similar to (c) above except that the promoter specifies only the functions the project is to perform and provides drawings showing the location of the intended works and a tentative layout for them. The contractor then proceeds to devise the full layout required followed by detailed design in accordance with the specification, which may set out the design standards required. This is the basic set-up for design and construct contracts where most of the design responsibility is held by the contractor.

1.5 Options for construction

A promoter may decide to construct minor or routine civil works with his own workforce, hiring from outside any special skills required. But for all large projects it is usual to use a civil engineering contractor.

Many projects include the installation of major items of plant and equipment, such as generating plant, pumps and motors, gates and valves etc. and process plant of all kinds. It is then necessary to decide whether separate contracts shall be placed for the supply and erection of such plant, or whether the civil contractor will be required to order such plant. However, if plant is on long delivery time, separate contracts for its supply may be essential to avoid delay. It may also be essential to order complicated process plant in advance, because the plant drawings are required before the civil works design can be completed.

Provided the promoter or his consultant organizes the separate contracts efficiently, and takes care to ensure that interface problems are all dealt with, this procedure can work well. The contract drawn up with the civil contractor must specify exactly what services he is to provide to the separate contractors, and how he is to be paid for them. An advantage is that the promoter has direct contact with such specialist contractors and suppliers. This facilitates settlement of details, promotes the quality of the work, can forestall potential delays, and makes it possible to accommodate minor changes of design with little difficulty. Also, it avoids the addition of an on-cost by the civil contractor for handling such contracts. The majority of all projects are managed on this basis, which is similar to design option (d) under Section 1.4 above.

Sometimes it is possible to make the main civil contractor responsible for the supply of all plant and equipment; but this can only be done for large projects whose construction takes long enough time not to be hindered by the delivery times that manufacturers require for their plant. The promoter or his engineer initially discusses with plant suppliers what they can supply, then requires the civil contractor to place orders in accordance with details that the promoter specifies, allowing the contractor to select from a short list of approved suppliers. This leaves the civil contractor with the responsibility for organizing the plant contracts and providing them with the services they require. This system can also work satisfactorily if the civil contractor is properly efficient, and if the plant output fulfils ancillary purposes rather than produces the main output of the project (*see* Section 2.9).

Occasionally, when the supplier of process plant exerts a dominating influence on the layout and detailed design of a project, he may be invited to employ a civil engineering contractor as subcontractor to construct the works to accommodate the plant. The plant supplier may then employ some firm to design the civil works, or else he may pass this also to the civil contractor. Although the procedure is possible and has been adopted successfully, some suppliers of M & E plant are specialist manufacturers and cannot or will not take on responsibility for organizing the associated civil works. On the other hand a number of firms have developed, often by joining of a plant manufacturer with a major civil engineering contractor, who will offer a complete design and construct package for special processes such as petrochemical or water treatment (*see* Section 1.6).

Where services such as electric wiring, heating, lighting or plumbing are required it is usual to leave these matters for the civil contractor to arrange using appropriate subcontractors of his choice. Such subcontractors can be to the approval of the promoter or his engineer. However, if the promoter nominates – that is, specifies – a named subcontractor whom the contractor must use, the promoter becomes responsible for any delay or difficulty that the subcontractor causes to the civil contractor. Hence, wherever possible, the use of nominated subcontractors is avoided.

The main methods for undertaking construction can now be listed.

(a) Direct labour construction

The promoter uses his own workforce to carry out work either in one exercise or as and when they are free from other duties. Clearly, this may be a cheaper way of producing work if free time is available, but of course delay in completion can occur. Construction is fully controlled by the promoter, and flexibility to alter work is assured. With no competition on prices and no tendered sum there is a risk that costs will be excessive unless tightly managed by the promoter.

An alternative is to employ a consulting engineer to take charge of construction. He hires the necessary labour and plant, and orders the necessary materials, using money provided by the promoter. This was often done in the past and the method is still occasionally used now. It was widely used overseas where no contractors of sufficient capability were available, and can still be used for the same reason now. Given a small team of engineers and some key skilled foremen to guide local labour under a resident engineer with strong managerial capacities, the work was often notably successful in keeping to time and budget.

(b) Separate contracts

The whole work is split into packages: perhaps even to the extent of separating various building processes, such as brickwork or carpentry. This procedure involves numerous contracts and high staff involvement in coordinating and managing inputs. ('Self-build' houses are often built in this manner in the UK.) The main usage nowadays is under management contracting, which is described in paragraph (f) below. In developing countries the method may be used because local contractors often only provide one type of trade work.

(c) Main civil works contract with separate specialist contracts

This has already been generally described: a main civil works contractor is appointed, and the promoter lets separate contracts for M & E work and other specialist plant. This is the traditional and still most widely used method of procurement, and that for which the main standard conditions of contract are written. The promoter appoints an 'Engineer' – either a senior member of his staff or a consultant – who manages and administers the contracts, ensuring liaison between contractors, delivery on time and settlement of interface requirements, and who checks that the specification for the civil works contract defines all the facilities that the civil contractor must supply to M & E and other contractors. Further comments on this approach are given in Section 2.9.

(d) All work put under one civil contractor

This has already been mentioned at the beginning of this section. It can only be used where delivery of M & E plant, and other manufactured items such as pipes and valves, is on sufficiently short delivery time not to impede the civil contractor's programme for construction.

(e) Construction management

This arrangement is similar to (c) but a separate manager is appointed by the promoter to organize the letting and supervision of the contracts. Design may be by the promoter's staff, or can be placed as a separate design package let by the promoter but supervised by the manager. A manager is used because of his greater experience and knowledge of construction than the promoter possesses, which should enable him to avoid or minimize some of the problems of interfaces between contractors. The disadvantages include the separation of design from construction supervision, and of course the extra fees needed to pay the manager and his staff.

(f) Management contracting

In all the previous methods mentioned the promoter himself lets contracts for construction. In management contracting the promoter appoints one contractor, who manages all the construction inputs by letting contracts himself. These **works contracts** are effectively subcontracts to the management contractor; many may be labour-only contracts, while others are for 'supply and erect' such as for a steel framework. The promoter may retain rights to approve or disapprove appointment of a works contractor. The promoter lets a separate design contract, which is also placed under the administrative charge of the management contractor. One advantage is that the management contractor, by controlling both the progress on design and the letting of contracts, can get construction started early before the complete design is finished. Also, some flexibility for modifications of design is possible, as the later works packages let can take such modifications into account.

The use of a management contractor is principally adopted for complex building constructions rather than for civil engineering works. The policy relieves the promoter of any responsibility for coordinating the various design elements, the letting of works contracts, and of managing the inputs of the many contractors used in the construction. However, the success of the management contractor in respect of speed depends upon his ability to get efficient subcontractors working for him. Some projects have been highly successful; but others have suffered disastrous delays. Another weakness is that if construction starts before designs are sufficiently complete, consequent design alterations or changes made by the promoter can result in delays and excessive cost overruns. This can result in a tangle of legal claims and counter-claims as each of the parties involved – the promoter, management contractor, designers and works contractors – tries to make others responsible for some or all of the cost overrun. The price risk to the promoter is in any case relatively high, since the terms of a typical management contract permit extra costs and risks to pass straight through from the works contractors to the promoter. Management contracting was initially much favoured for large building developments with associated civil engineering work, but there has been considerable debate concerning its merits in comparison with construction management (described under paragraph (e) above), and the number of jobs using the method has declined.[1,2]

1.6 Design and construct and other options

(a) Design and construct or 'turnkey' contracts

Under this arrangement the contractor both designs and constructs the required works. He may use subcontractors or consulting engineers to do the design, but has to take responsibility for their work. In some cases the promoter may stipulate design requirements, i.e. design processes and parameters to be used; and he may require the designers used by the contractor to be to his approval. In other cases, particularly 'turnkey' projects, the design may be left entirely to the contractor. The advantages to a promoter are that he does not have to brief and employ a designer, construction can start before designs are complete, and any subsequent construction changes found necessary are the contractor's responsibility. However, the promoter may still need to employ a consultant to check the contractor's design, and he may employ an inspector to watch the contractor's construction and report to him on any matters he should take up with the contractor. Also, the work of bidding is expensive, and contractors may refuse to bid if more than three or four are invited to tender.

A design and construct or turnkey contract is often for a lump sum, which is advantageous to a promoter as he gains the benefit of initial certainty of price. Also, he can have a clear idea of what he is going to get if a contractor is able to offer an 'off the shelf' design for a type of structure that he has previously built, which he can show to the promoter. But if the design has yet to be formulated and is for some original works, the promoter commits himself to a single large contract with most details left in the contractor's hands. The contractor's price will also tend to be high, as it must cover his design costs and the risks he takes in both design and construction. Obviously, the promoter's only real control over the end result and quality of work is his checking of the packages offered by tenderers before awarding the contract. This is not necessarily sufficient because, in the limited time available for tendering, the contractor cannot work out and submit all details of his design development nor specify the exact nature of everything he will supply. Thus the promoter can suffer disappointment at what he receives; and if he consequently wishes to make any changes these may be very costly or even impracticable.

An advantage claimed for design and construct contracts is that collaboration between design and construction staffs can foster innovative design, which reduces cost. But unless the tender period gives sufficient time for an innovative design to be fully worked out the contractor may consider it too risky to make any allowance for it in his tender. If, after tendering, the contractor finds the innovative design practicable, any saving accrues to himself. More reliably, collaboration between designer and constructor can reduce the contractor's costs by such measures as standardizing component dimensions, avoiding complicated formwork, tailoring dimensions to suit reuse of the contractor's equipment, and reusing parts of previous designs. In so far as the contractor foresees at tendering stage that some of these practices will be possible, he can cut his tender price – i.e. the promoter benefits – but once his tender is accepted, further savings benefit himself. Thus for relatively uncomplicated or traditional civil engineering work, or repeat structures of a kind that the contractor has done before, design and construct or turnkey contracts can give a promoter a satisfactory job at lowest price. This suits a promoter who is more interested in gaining the output from the works than in the details of their design, and wants the works operating as soon as possible for a fixed sum commitment.

(b) Design, build and operate (DBO) contracts

Under this type of contract the contractor is required to operate and maintain the works for a number of years after he has completed their construction. The contract is for a lump sum, a proportion of which is payable in stages during the operating period, or income may be derived from sales or charges: bridge tolls, for example. This provides an incentive for the contractor to adopt sufficient quality in design and construction to ensure that he experiences low maintenance and repair costs during the operating period. Clearly, the contractor has to add to his prices for the additional risks that he shoulders, and the employer must have powers to act if the contractor does not undertake repairs and maintenance properly. Contracts of this type have been proposed for road construction, where problems arising from faulty design or construction tend not to be revealed except under two or three years' trafficking. However, repairs or excessive maintenance could also arise from unforeseeable ground conditions, traffic accidents, or traffic loading exceeding that specified in the contract, so occasions for dispute could proliferate in the case of roads, unless these risks are clearly placed on the contractor. Sometimes DBO contracts have been let for projects that include process equipment, such as water or wastewater treatment equipment. It is then the quality of the equipment that is principally targeted, not that of the buildings, whose maintenance usually presents an insignificant risk.

A DBO contract reduces the promoter's need to check the contractor's work, and keeps the contractor available to undertake repairs during the operating period. The extra cost may, however, be high, and the promoter will not escape responsibility for some repairs if these are due to an inadequate job specification or occur after the operating period when the project reverts to operation by the promoter.

A DBO contract may be let on the basis that the contractor also finances the project, for which he would usually need to associate with a bank for provision of the necessary funds. The operating period is then long term, for 15 to 20 years or more, during which the promoter makes regular payments according to the terms of the contract entered. The UK government has proposed such contracts for certain new roads, the government repaying the contractor via 'shadow tolls' – regular payments, usually monthly, based on the number of vehicles logged as using the road according to a 'shadow tariff', i.e. price per car, lorry etc. The risks on the contractor (and his funding bank) are many and high, being dependent both upon the cost of design, construction and operation, and also on the income likely to be received from the shadow tolls. The promoter's risk is only that his payments may be higher than expected owing to having to pay a high premium for the risks upon contractor and bank, or traffic exceeding that expected.

(c) Engineer, procure and construct (EPC) contracts

An EPC contract is a form of design and construct contract under which a design engineer or firm of design consultants heads a team which includes an experienced contractor. The promoter specifies his project in outline which the team designs in detail in continued liaison with him. The EPC organisation arranges and manages construction, letting specialist work packages out as necessary to suitable subcontractors. The promoter pays the actual cost of the work plus a fee, subject to a guaranteed maximum price, or to a target cost with an arrangement for the sharing of savings or excess costs on the target.

(d) Partnering

This is the name given to an arrangement whereby a promoter and contractor agree to cooperate on future work. There are two types: **term (or full) partnering**, which covers an intention to carry out a series of projects together or for a given period; and **project-specific partnering**, i.e. cooperation for one job at a time. Under partnering the staffs of the promoter and the contractor work together in developing the design and methods of construction. There must, of course, be appreciation of each other's skills, and a mutual aim to achieve a satisfactory project. Partnering is not entirely an innovation and is similar to a cost plus fixed fee arrangement, often adopted for repair of a structure or construction of a difficult project where all the requirements cannot be known beforehand (*see* (d) in Section 1.7). The promoter's design staff and the contractor's staff work together to solve problems.

EU competition rules may limit partnering agreements if they extend over too long a period or appear to offend against free competition, and may require a promoter to seek partnership with a contractor through a competitive tendering process. When such competitive tendering is used, the advantage of basing a partnering agreement on past successful working together of the promoter and a contractor may be lost. Project-specific partnering (by competition) is reported as widely used in the US public sector. It is said to originate from 'a desire to achieve a commitment to total quality management' (TQM) – another new term for aiming to get the best in both design and construction. Other contractual arrangements can, of course, achieve TQM.

(e) 'Term' or 'serial' contracting

This comprises letting an ordinary construction contract for carrying out a series of works of an identical nature – resurfacing roads, for example – for a given period of usually a year, occasionally longer. The terms of the contract set payment and other conditions for a series of similar works, which are ordered from time to time as they are needed.

1.7 Payment for construction

Contract prices vary not only according to the cost of labour and materials etc., but also according to the degree of responsibility that the contract places on the contractor, the terms under which he will be paid, and the degree of financial risk that he has to shoulder. Risks not placed on the contractor will have to be held by the promoter. The promoter therefore has to choose what type of contractual arrangement he will offer tenderers. If he calls for a fixed lump sum bid he gets near-certainty of final price because he takes very few risks, but the price may be high. However, if he allows for some other kind of payment that reimburses the contractor for extra work in overcoming unforeseen troubles, the promoter will get a lower-priced job because he takes some of the risks upon himself. The following list indicates the various payment arrangements commonly adopted and the consequent effect of risk on prices.

(a) Rates-only contracts

In this arrangement tenderers quote only their rates per unit of work of different kinds. Usually the types of work listed comprise standard civil engineering operations, often of a repetitive nature, such as road maintenance work. Or rates-only may be quoted for work whose quantity cannot be precisely defined in advance, such as grouting work or the sinking of boreholes to find water.

In some overseas countries the government, or a local government or public utility, may publish its own standard rates for a range of civil engineering operations, many of them being for the provision of labour only as pipes, steelwork and steel reinforcement are often supplied by the authority. Then for any project a bill of quantities may be produced to show the amount of work required, and tenderers are invited to bid their percentage of the 'official rates' to be applied to such quantities. Owing to inflation and failure to update the official rates, percentages offered are usually well over 100%. However, because most of the risks are held by the promoting authority, prices are usually the lowest that can be obtained.

(b) Rates and prices for remeasurement contracts

This is the most widely used standard type of contract and includes a bill of quantities covering the work to be done. Against each item the tenderer quotes his rate. The payment to the contractor then comprises the measurement of the work actually done under each item multiplied by the rate quoted. This reduces the risk to the contractor of having to do more work than billed without any extra pay: consequently, his prices generally reflect what he thinks the job will cost him, with a relatively modest amount for contingencies and an appropriate margin for profit. Thus the promoter, shouldering some of the risks, should find that if no major difficulties are encountered the cost of the job will come as tendered. The promoter also has the advantage that if he decides that he wants something extra on the contract he pays for it and can have it. The usual conditions of contract (such as the ICE Conditions, *see* Section 2.2) also give guidance on what payment should be made if extra work occurs due to 'unforeseen conditions'.

(c) Lump sum contracts

If all the work can be well defined at the time of tender, a lump sum price from tenderers may be called for. This more often applies to small constructions, especially those that involve little below-ground work. A series of lump sums may be called for instead of a single sum; even in a bill of quantities contract certain items may be labelled 'lump sum' for pricing. Supply contracts for plant and machinery often comprise a series of lump sums for different items. When variations are called for by the promoter (or the engineer acting on his behalf), it is usual to call upon the contractor to quote his addition or deduction against one or other of his lump sums.

In some kinds of civil engineering work the lump sum payment method can pose serious risks upon a contractor, so he has to increase his price accordingly. This is particularly so for turnkey projects, where the contractor has to undertake detailed design as well as construction, and for any contracts that include a substantial amount of below-ground work. The promoter has to pay the contractor's additional price for taking on all risks, irrespective of whether they materialize or not. Also, the promoter cannot alter his requirements without paying a possibly high premium extra, because the fixed lump sum is only for the fixed amount of work defined in the contract. Usually, payments under lump sum contracts are made in instalments as set out in the contract according to stipulated stages of completion.

(d) Reimbursable contracts

Under a reimbursable contract the contractor is reimbursed his expenditure plus a fee to cover his head office overheads and profit. The fee can be a fixed percentage added to his expenditure, or a lump sum. The contractor has to produce records showing his expenditure on labour, materials and plant. The first two comprise records 'as paid', but payment for use of plant owned by the contractor has often to be prearranged according to some schedule. It is usual for all the contractor's accounts for the project to be audited. Under this arrangement a promoter virtually has to take all risks, including the risk that he will have to pay for the contractor's inefficiency. Also, the promoter has no certainty about the final cost. Promoters are therefore reluctant to adopt the method unless a fixed fee is paid (not a percentage on expenditure) and the contractor is known to be reliably efficient. However, this type of payment gives complete freedom to vary the work done, so it is useful for undertaking emergency work, or work whose nature and extent cannot be known adequately beforehand. It has the advantage to the promoter that his engineer and staff can work in close collaboration with the contractor's engineering staff and workforce. This can often make major contributions to the successful overcoming of difficult conditions or unusual problems at the lowest possible cost.

(e) Target contracts

These are usually reimbursable contracts as (d) above, but with an estimated **target cost** set for the contractor's expenditure, and a fixed fee for the contractor's head office overheads and profit. If the contractor's expenditure exceeds the target he has to bear a proportion of the excess; if his expenditure is less than target he receives a proportion of the difference as a bonus. Thus there is a financial incentive to the contractor to be efficient and save costs. However, a target can only be set if the work to be done can be reasonably well defined in advance so that it can be costed. Hence the method is not possible for emergency work, nor for work of such difficulty that it is not possible to determine in advance what methods will be needed etc. Typically, the method has been used for substantial tunnelling work: that is, work whose general magnitude and nature can be foreseen, but which may require a flexible approach when difficulties arising from bad ground are encountered *en route*. Defining the basis and elements of the target cost can be difficult, and a target may become increasingly irrelevant if it has to be continuously adjusted because the work cannot proceed as intended. If disputes arise between the promoter and contractor about how the target cost should be adjusted, the purpose of this type of contract is defeated.

(f) Price variation provisions

In times of inflation it may be preferable to include clauses within the contract that set out how the contractor is to be reimbursed his extra costs due to any inflation of prices after he has tendered. Without such a clause the contractor has to add a margin to his prices to cover expected inflation, so he runs a risk that he might not have allowed enough, while the promoter runs the risk that he might have to pay more than the actual inflation increase. Calculating extra costs due to inflation can be complicated and time-consuming for the contractor and the promoter's supervisory staff, so that often a formula using officially published indices of prices is used instead. The contract has to set out how such indices will be used (*see* Section 11.8).

(g) Payment terms

Most standard conditions of contract contain specific provisions for interim payments, and require payment of interest to the contractor if the promoter fails to pay on time. The timing of these interim payments as the work proceeds is of importance to both promoter and contractor. A contractor has to lay out large sums of money to get work started, especially on overseas jobs: hence the earlier he can receive substantial payments the less he has to borrow from his reserves or the bank. Thus his prices will reflect timing of payments to him: the earlier he can get payment the lower his price. On the other hand the earlier the promoter has to pay out money, the more he will have to pay on his borrowings; and he has to make a choice between two risks. If he pays out too much money at an early stage to an incompetent contractor, he may have difficulty in getting value for his money. If he pays out too little money he may force a contractor who is not in a strong financial position into further financial difficulties, resulting in the contractor being unable to complete the work.

(h) Bonus payments

Some contracts contain bonuses for completion of the works, or stages of it, on or before a time stipulated in the contract. Provided the times set are reasonably achievable and do not encourage the contractor to skimp work, they can be rewarding to both contractor and promoter. Early completion can reduce borrowing costs for the promoter, as he can put the completed works into production earlier and gain an income from their output. Early completion also suits the contractor, as his overheads extend over less time and his profit on the job thereby increases. The problem about bonuses is that, if unexpected conditions occur causing the contractor a delay not of his own making, there may be a dispute about how much extra time should be allowed him. Bonuses should therefore be a reasonable amount: not so large that they put the contractor on a win or lose situation in respect of his whole profit.

(i) 'Ex-contractual' payments

These are payments made by a promoter to a contractor that are not authorized by the contract. They are occasionally paid when a contractor has performed very much to the satisfaction of the promoter but has shouldered some extra cost clearly not attributable to his own actions, such as exceptionally bad weather or other misfortune outside his control. Only the promoter can decide to make an ex-contractual payment, not the engineer or other person acting on his behalf; and the promoter must himself have power to make the payment. Hence a private person or company may have such power, but a public authority will usually have no such power.

(j) Prepayments

An employer will rarely make an unconditional prepayment, that is, a down payment, to a contractor at the start of the contract. He can, however, make early payment to the contractor for provision of offices, laboratory, and transport for the engineer's staff on site etc. (*see* Section 10.10). These matters by no means cover the contractor's outgoings for his initial set-up, especially when the project is very large and overseas, so advance payments secured by a repayment bond are often allowed. On the Mangla project in Pakistan the contractor needed a vast amount of constructional plant. To ease the financial burden on the contractor the employer (in effect the government) agreed to purchase plant required by the contractor up to a value of 15 per cent of the contractor's tender price excluding contingencies. The employer recovered this expenditure by deducting it in instalments over the first 30 months' interim payments to the contractor under the contract. In this case the employer could obtain further security for his down payment by retaining ownership of the plant until paid for by the contractor.

1.8 Nature of risks and their effect on prices

In addition to risks mentioned in the preceding section, many other financial risks attend the construction of civil engineering works. Among those most commonly encountered are the following:

1. design errors, quantification errors;
2. design changes found necessary, or required by the promoter;
3. unforeseen physical conditions or artificial obstructions;
4. unforeseen price rises in labour, materials or plant;
5. theft or damage to materials or equipment on site;
6. weather conditions, including floods or excessive hot weather;
7. delay or inability to obtain materials or equipment required;
8. inability to get the amount or quality of labour required; or labour strikes;
9. errors in pricing by the contractor.

Some of these risks can be shouldered by the promoter, if he so desires, by incorporating the appropriate clauses in the conditions of contract. Risks 1, 2 and 3 are carried by the promoter under the ICE Conditions of Contract (*see* Section 2.2) for a bill of quantities contract; and risk 4 can be covered in respect of price increases due to inflation if a price variation clause is included in the contract. Against theft and damage (5) the contractor can insure the works, or the employer can.

Weather conditions (6) have traditionally been a contractor's risk, and this has posed many problems for contractors because the effect of inclement weather (mostly wet weather in the UK) can vary according to the type of work undertaken. Any form of roadwork or earthwork construction can be severely affected by wet weather, whereas much building work need not be so affected. In some cases involving river or sea defence work, failure to complete a crucial operation before winter conditions set in can cause several months' delay involving much expense. The ICE Conditions entitle a contractor to an extension of the contract period for 'exceptional adverse weather conditions' but do not authorize additional payment on account of it. The 'New Engineering Contract' referred to in Section 2.2 attempts to define 'exceptional weather conditions' as a basis for claim, but has not been long enough in operation to be tested over a wide range of circumstances.

Risks (7) and (8) – that is, inability to get materials or labour respectively – are usually shouldered by the contractor, mainly because they are matters difficult to define, and lie within the ability of the contractor to control. The promoter can assist problems of non-availability of materials by negotiating with the contractor what materials are acceptable as a substitute; but the promoter is seldom able to assist on labour problems.

Most contractors are well aware that design changes made by the promoter can have a disastrous effect on progress and costs. Many of the most acrimonious disputes over large claims arise from design changes during the course of construction, or failure to complete the design adequately before construction starts. The position of the promoter must, however, be appreciated because sometimes he is forced to make changes by circumstances over which he has no control. This more particularly applies to civil engineering works that incorporate process plant of any kind. Design and construction may take 3 or 4 years, but during this period the promoter can become aware of new processes invented, or new regulations likely to apply, or that his customers are changing their requirements. He cannot have works built that are 'out of date' as soon as they are completed, so he is forced to make design changes during the course of construction. To cope with this situation the promoter should not enter unsuitable contracts that do not give him power to adopt reasonable changes of design at reasonable cost.

Usually any requirement that the contractor should shoulder most of the risks arises because the promoter prefers to have a fixed financial commitment, which will not be exceeded. Alternatively a promoter may be under some financial constraint, such as a limited allocation of government funds, which he has no authority to exceed: hence he may not be able to consider any claims for extras presented by the contractor. Fixed expenditure constraints are often applied by overseas governments. This fixing of the price, and placing all or most of the risks on the contractor, can be expected to lead to generally high prices. Also, if unexpected circumstances occur that the contractor has not allowed for, he may tend to adopt 'short-cut' methods, which do not produce the most satisfactory work, or he may be forced to finish the work at a loss.

1.9 Summary of possible arrangements

Table 1.1 summarizes the main types of arrangements that are commonly adopted for design and construction of civil engineering projects, and gives some indication of their principal advantages and disadvantages. Such analyses tend to be subjective, being dependent to a large extent on the circumstances applying under any particular arrangement, and the experiences of those who have adopted one or other arrangement. The truth is that most types of arrangements can work well if the contractor's prices are adequate, he is efficient and treated fairly, and the promoter and his engineer provide adequate drawings of what is wanted and do not indulge in too many changes.

In making a choice the promoter must consider which type of arrangement and what contract conditions will best suit his plans. He has to consider his priorities and decide whether he is looking primarily for speed in construction, a firm price, cheapness, value for money, or quality of works constructed. Not all these can be achieved at the same time. The promoter who is able to plan well in advance so that he can define exactly what he wants and can give his designers adequate time to complete their work, will usually get best value for money. A contractor who tenders for works that have been designed in all essentials, and which are not subsequently altered, will usually be able to give a good price and fast construction. Time spent ensuring adequate site investigations, full working out of the best designs, and careful production of contract documents, is the best guarantee that construction of a project will be trouble-free, on time, and to budget.

Table 1.1a

Comparison of different methods of project promotion

Advantages	*Disadvantages*
— SEPARATE DESIGN AND CONSTRUCTION: CONVENTIONAL ARRANGEMENT —	
Designer can be chosen to suit nature of works	More interface checking required between contractors
Works are designed to suit promoter's requirements	Promoter has to employ both designer and contractor
Competitive tenders for construction obtained on clearly defined package	Contractor has minimal input to design
Promoter not committed to project until designs complete	
Direct control over quality of work possible	
— DESIGN AND CONSTRUCT COMBINED CONTRACT —	
Possibility of reduced time to completion if construction can start before designs completed	Comparison of tenders difficult
Fewer contract interfaces	Suitable tenderers may be limited
Contractor's expertise can be used	Very careful specification of promoter's requirements needed to control results
Works or plant performance can be guaranteed	Promoter committed to works before they are designed
Firm price at an early stage	Variations difficult to make and evaluate
More risks can be passed to the contractor	Design and quality chosen to suit contractor

The wide variety of arrangements that can be adopted for obtaining design and construction is reflected in wide-ranging differences between the legal conditions under which contracts are drawn up for construction, or for design and construction. Among them a number of standard forms to meet different circumstances have developed by experience over the years. These are discussed in the next chapter.

1.10 Initial cost estimate for a project

At an early stage a promoter will naturally want to know the probable cost of his intended project. No realistic figure is usually possible until a feasibility study of it has been completed; before that only an 'order of magnitude' figure can normally be quoted. Nevertheless, the engineer must take every care to provide a reasonable estimate, to do which he needs to derive the cost by more than one method.

Three main methods of producing these 'budget' estimates are possible:

- by reference to the cost of similar projects;

Table 1.1b

Comparison of different methods of payment

Advantages	*Disadvantages*
— REMEASUREMENT —	
Greater certainty in pricing Project cost known with reasonable certainty Facilitates valuation of variations	Detailed bills of quantities needed Promoter must meet extra costs due to changes Work done has to be measured
— LUMP SUM —	
Firm price known early Financial bids easily evaluated Payment terms simple	Bid risks high hence prices may be high Long tender time required Variations difficult to value and agree
— REIMBURSABLE with FIXED FEE —	
Reduced documentation for tender Short tender time Variations easily evaluated Cost of project can be controlled Methods of construction can be controlled by designer Design can be altered during construction	Bid evaluation difficult Price competition minimal Checking and auditing contractor's costs necessary No firm final cost Contractor has no financial incentive to minimize costs Risk of inefficient contractor
— REIMBURSABLE with TARGET COST —	
As for Reimbursable with Fixed Fee with following changes:	
Contractor has financial motive to be efficient Contractor shoulders some proportion of cost exceeding target	Target difficult to define initially Target may need changing owing to changes in work required Disputes possible about fair target

- by sketch layout and component costing;
- by use of cost curves if available.

The first assumes that a record is available of the cost of past projects undertaken by the engineer and other costs taken from the technical press. Such costs should be accompanied by data such as project size, project components and distinctive features, dates of construction, and whether the price includes land, legal and engineering costs. Inflation factors have to be applied to update the costs. By comparing the principal features of the proposed project with those for which past costs are available, a probable order of magnitude total cost may be derived.

The second method is the most reliable. Even before a feasibility study is undertaken it should be possible to sketch out the proposed project on some notional site if the actual site is not yet decided, so that the layout and sizes of the various components required can be judged (*see* Section 1.11). The components can be roughly sized so that their possible cost can be estimated by comparison with price data held for similar structures. This procedure can also reveal costs for items that might otherwise have been missed.

The third method using published cost curves is not necessarily reliable because the data on which such curves are based are seldom available. Virtually every civil engineering project has some unique feature, so that overall costs expressed per unit of size or output can vary greatly. However, plotting the estimated costs derived from the previous methods on the cost curve can indicate whether the estimates are in the realm of possibility, or depart so far from the cost curve that they need re-examination.

While any of the above methods will involve uncertainty, they can be useful in comparing different options for a scheme. Care must be taken to ensure that they are costed on the same basis, or at least that further checks are carried out to achieve a reasonably fair comparison.

Inevitably the engineer must include substantial contingency sums in his project estimate at this stage to cover unforeseeable difficulties, and has to warn the promoter that his estimate is therefore subject to a plus or minus figure, often of substantial proportions. The promoter must, of course, be an optimist about his project because he often has the task of persuading his funders that the project is worth undertaking; so he may choose to quote only the lowest figure of cost because he fears the project might not otherwise be sanctioned. This is only natural, because it takes time for backers to evaluate the benefits of a project before accepting how much it will cost. The figure quoted by an engineer to his promoter must, of course, be the most realistic cost that he judges will apply; but the figure that the promoter chooses to quote publicly is a matter for him to decide.

1.11 Estimating the cost of a project at design stage

After a feasibility study has been completed and as the design is developed a more accurate estimate of cost is possible, based on cost parameters derived from an analysis of recent priced contracts for similar work. The designs should show the layout and sizes of component works required. For each such component it should be possible to make an approximate estimate of the quantities of the key structural operations required, such as bulk excavation, main concrete in framework and floors, wall areas, or roof areas. Examination of the priced contracts can then produce cost parameters that can be applied to the estimated quantities for the proposed structure. For example, the total concrete costs (inclusive of formwork, reinforcement, finishes, joints etc.) can be divided by the volume billed in framework and floors to give a parameter to apply to the proposed building. Similar all-in cost parameters can be analysed for all excavation (based on the bulk excavation volume); exterior walls and windows (based on area); roof (based on area) etc. Having produced a total cost for these principal items – e.g. excavation, concrete, walls and roof – all other costs for the building can be expressed as a percentage on their total.

Other structures are simpler to analyse. Pipeline costs can be expressed as per 100 mm diameter of pipe per metre laid, divided into supply and laying. Water tank unit costs can be derived for bulk excavation, concrete in walls, floor, columns and roof. Overall unit prices can also be developed for checking purposes, such as the cost of a building per m^3 volume; or of a tank per 1000 m^3 storage capacity.

Before the cost parameters are derived from previous priced contracts the following procedures are necessary.

- Preferably at least three priced contracts should be analysed. If possible, not all should be for the lowest tenders received; some should be the second or third lowest (if sensibly priced) to prevent underestimating.
- All preliminaries and overheads (*see* Sections 10.10 and 10.11) should be expressed as a percentage addition to the total of measured rates.
- If a tender is being analysed, general contingencies and dayworks should also be expressed as percentage additions, or shown separately. If a final account is being analysed, then all non-identifiable payments for extras, dayworks and claims should be included in the percentage on.
- Special costs for special circumstances should be separately noted, to decide whether they apply to the proposed project.
- Prices obtained should be brought up to a standard date by applying a suitable inflation factor. Good indicators of inflation are the dayworks rate for skilled tradesmen, and the prices for C25 grade concrete, reinforcement and formwork. In the UK, published indices for price fluctuation in construction costs are available (the Baxter indices), and overall price movements for different types of construction are tabulated by the Department of the Environment as Output Price Indices.[3]

The advantages of the method are that the costs are 'real' as tendered, on-costs are included, and the procedure facilitates checking of costs by different methods. The sum total cost derived needs checking. Often it is useful for two engineers to work separately so their results can be compared; or an estimator needs to explain his estimate to another, in which process he may be reminded of matters he has omitted.

During the design stage it may be found that a previous estimate appears too low; but it is important not to take over-hasty action in reporting this to the promoter. The problems causing the increase should be fully worked out first, and other aspects of design should be examined to see if they will also exceed the estimate or where, perhaps, some savings are possible. If an estimate must be increased it is better to do this only once, because a series of increased estimates may cause a promoter to lose confidence in any estimate provided to him. The estimated cost should be at current prices, leaving any inflation allowance for the promoter's financial advisers to add.

As the design nears completion more accurate estimates can be produced using, for instance, the actual quantities taken off for a tender with a bill of quantities. Such quantities can be priced either from historical data derived from priced contracts as indicated above, or from published databases of rates, or by compiling rates from basic costs for labour, plant and materials plus overheads.[4] In practice often a combination of these methods is required, with care needed to ensure that rates and prices are reasonable by checking a result obtained by one method against the result obtained by another.

1.12 Project cost control

It is during the design stage that measures to keep the cost of a project within a budget figure are most effective. All possible savings in design need to be sought, not only because this is manifestly in the interests of the promoter, but because there are sure to be some unforeseen extra costs that need to be offset by the savings. Alternative designs of layout or of parts of the works have often to be studied before the most economic solution is found: hence completion of all design before starting construction makes a major contribution to controlling project cost. The causes of extra cost, however, not only include the usual hazards when below-ground work is necessary, but also technical developments that occur during the three or four years that it takes to bring a project through from inception to completion. During this period there can be new types of process equipment available, new safety requirements, new construction techniques, and changes or additions to the promoter's needs due to changed market conditions or economic circumstances. The designer must keep aware of possible changes to the promoter's needs and other technical developments, and not so plan the works that possible additions or alterations are precluded or made unacceptably expensive.

If tenders are received that exceed the budget estimate by so large a sum that the promoter is unable to sanction the extra cost, means of cutting down the cost have to be sought. Generally speaking, down-sizing parts or the whole of the works is usually not as successful in reducing costs as omitting a part of the works. Reducing the output of some works or the size of a structure by 25 per cent, for instance, seldom results in more than 10 per cent saving of its cost, and can make restoration at a later date to the full output or size an expensive and uneconomic proposition. Down-sizing can also involve so much redesign that time is lost producing new drawings and also if re-tendering is necessary. If the promoter can find some part of the works that can be omitted, this is a more secure way of reducing the cost of a project, and it should be possible to negotiate such omission with the selected tenderer.

Under the contract for construction there will usually be contingency money held in reserve to meet unforeseen extras during construction. Often the amount is 5 or 10 per cent of the estimated cost of the known work; but for certain types of work, such as tunnelling, 15 per cent contingencies is sometimes adopted. As every engineer knows, the main aim is not to 'lose one's contingencies on Day 1'; that is, during the early stages of the job, when most troubles occur, one hopes not to spend too much of the contingency money. If a reasonable amount of the contingency money remains unspent at two-thirds of the way through a contract, there is a reasonable chance of not exceeding the contract sum. The means that should be adopted to keep a check on cost commitments during construction are discussed in Section 9.10.

References

1 *Construction Management Forum Report*. Reading: Centre for Strategic Studies in Construction, Reading University, January 1991.
2 Construction Industry Research & Information Association (CIRIA). *Roles, responsibilities and risk in management construction*. London: Science & Engineering Research Council, 1991.
3 Department of the Environment. *Monthly Bulletin of Indices*. London: HMSO.
4 *CESMM3 Price Database*. London: Thomas Telford. *Civil Engineering and Highways Works Price Book*. London: E & F N Spon. *Architects' and Builders' Price Book*. London: E & F N Spon. *Laxton's Building Price Book*. London: Kelly's Directories Ltd.

2

Contractual arrangements

2.1 Standard conditions of contract

Over a period of many years there have been introduced a large number of standard forms of conditions of contract. Sometimes these have been developed by particular industries or specialist suppliers, but conditions for more general use have been developed by the major engineering and building institutions, as well as by government and allied organizations. Use of these standard conditions is beneficial because they are familiar to contractors, give greater certainty in operation, and reduce the parties' exposure to risk. Such conditions are often produced by cooperation between contractors' and employers' organizations, with the advice of engineers and other professionals experienced in construction. The documents thus drawn up give a reasonable balance of risk between the parties. Their clauses are often interdependent: hence any alteration of them must be done with care, and is generally inadvisable because it may introduce uncertainties of interpretation. Some of the main standard conditions used for civil engineering projects are listed below, with an indication of their main provisions.

2.2 Conditions for civil engineering work

ICE Conditions of Contract for Works of Civil Engineering Construction

These, published by the Institution of Civil Engineers, are generally known as the **ICE Conditions**, and are the most widely used conditions for UK civil engineering work. They have a long history of satisfactory usage, the current series being first introduced in 1945. The latest edition is the 6th, published in 1991. A useful guide to the changes it made is the ICE publication *ICE Conditions of Contract: 5th* *and 6th Editions Compared*. The principal provisions of the 6th Edition are as follows.

- The contractor constructs the works according to the designs and details given in drawings and specifications provided by the employer.
- The contractor does not design any major permanent works, but may be required to design special items (such as bearing piles whose choice may depend on the equipment he owns) and heating and plumbing systems etc.
- An independent engineer, designated 'the Engineer', is appointed by the employer to supervise construction, ensure compliance with the contract, authorize variations, and decide payments due; but his decisions can be taken by the employer or contractor to conciliation procedures and/or arbitration.
- The contractor can claim extra payment and/or extension of time for overcoming unforeseen physical conditions, other than weather, which ' could ... not reasonably have been foreseen by an experienced contractor' (Clause 12).
- Payment is normally made by remeasurement of work done at rates tendered against items listed in bills of quantities, which can also include lump sums.

Successive editions of these conditions have been used on many different projects for half a century. A particular advantage they offer is that the interpretation of the provisions of the contract lies in the hands of a third person, the Engineer, who is independent and not a party to the contract, but is required to 'act impartially within the terms of the contract having regard to all the circumstances' (Clause 2(8)). This gives assurance to both parties that their interests and obligations under the contract will be dealt with fairly. Also, the contractor is paid for overcoming difficulties that he could not reasonably have foreseen. Both these matters reduce the contractor's risks, making it possible for him to bid his lowest economic price. This benefits the employer, who feels protected from paying more than he should do, and he does not have to pay out anything extra to cover unforeseen conditions if none occur. The ICE Conditions contain many other provisions that have stood the test of time. Properly drawn up and administered, a contract under these conditions appears fair to both parties, and the percentage of contracts ending in a dispute that goes to arbitration is very small.

ICE Conditions for Ground Investigation

These are based on the above-mentioned conditions, but allow for the investigative nature of the work and the need for reports and tests. A schedule of rates may be used instead of a bill of quantities (*see* Section 1.7(a)). The need for a maintenance period and for retention money is left to the drafter, and will depend on whether permanent works, such as measuring devices, are included.

ICE Minor Works Conditions

These are a shorter and rewritten form of the ICE Conditions for use on works that are fully defined at the tender stage and are generally of low value or short duration. Schedules are provided to enter the main contractual data. The conditions can be successfully used for larger works, but the standard ICE Conditions cover many more of the potential problems that could occur. Payment arrangements are left open, but are suitable for a single lump sum bid or priced bill of quantities.

ICE Design and Construct Conditions

These conditions were newly produced in 1992, so there is little experience of their working; though design and construct contracts are not new. The conditions repeat many of the ICE Conditions, but are written with the following principal differences:

- The contractor is required to undertake the design of some or all of the permanent works as well as undertaking construction of all the works.
- The employer sets out his required standards and performance objectives for both design and construction in a document entitled 'the Employer's Requirements'.
- An 'Employer's Representative' is appointed, who supervises construction on behalf of the employer. He has many duties similar to those of the Engineer under the ICE Conditions but, being a representative of the employer, he does not occupy a fully independent position.
- The employer can issue a Variation Order to vary his Requirements, in reply to which the contractor must submit a quotation for any extra cost in complying with same.
- Payment can be by means of tendered rates against bills of quantities, or by lump sum, or a mixture of both. However, care is needed if work is remeasured against billed rates, as the contractor could choose to adopt forms of design that suit the more profitable bill rates he has quoted.

Design and construct contracts are often used when the employer's main interest is to have some works built as soon as possible, and he need not, or does not wish to be concerned with the details of the design (*see* Section 1.6(a)). The contractor can therefore start construction as soon as he has enough design ready. But where a project offers a wide range of design options, a design and construct contract may not offer an employer the best service, because the options chosen by the contractor may tend to be those that suit his plant and workforce best, rather than the interests of the employer. However, if the 'Employer's Requirements' are sufficiently extensive and carefully specified, they can go a long way to ensuring coverage of all the employer's needs.

ICE: 'The New Engineering Contract' (NEC)

This is a novel form of contract introduced for consultation by a committee of the ICE in 1991 after extensive research, and then much revised in 1993. It is offered as an alternative to the ICE Conditions, but has not yet been proved by extensive experience. An NEC contract is formed from:

- contract data;
- the core clauses; and
- the option clauses.

The contract data define the documents accompanying the contract (e.g. drawings, specifications and schedules); the core clauses are included in all contracts; the main option clauses are for various types of contract, e.g. bill of quantities, target, cost reimbursement, or management, and there are secondary option clauses for things such as bonus, and price variation. A project manager appointed by the employer administers the contract for the employer, assisted by a supervisor on site. A separate adjudicator is appointed, to whom the contractor can take disputes with the project manager or the supervisor for adjudication. But if the employer or the contractor disagrees with the adjudicator's decision either can have the dispute referred to an arbitrator.

The contract attempts to overcome some old problems by several new approaches, but the latter may present some new difficulties. A list of sixteen Compensation Events is prescribed, any one of which entitles the contractor to claim extra payment or delay. They include the usual matters of claim, such as variation of work, and unforeseen conditions, but add unusual weather. The latter is defined as 'Weather recorded within a calendar month... at the place stated in the Contract Data which one of the weather measurements, when compared with the weather data, shows has occurred on average less frequently than once in ten years'. (A weather measurement could, for instance, be rainfall; the weather data are those supplied by the employer in the Contract Data.) This definition could give rise to problems of interpretation.

Another provision is that the contractor's claims when he experiences a compensation event take the form of quotations, which the project manager can accept, return for revision, or reject by advising he will make his own assessment in lieu. The problems with this approach are discussed in Section 12.12. Strict time limits of two weeks apply to stages of action and response by both contractor and project manager in respect of such quotations. These times are tight and may cause difficulties; failure of the project manager to reply within a specified time limit is itself a compensation event! This new contract has come under criticism from some construction lawyers and will need to show clear advantages in use if it is to be widely adopted, *see* Section 2.5. A revised edition is being prepared in 1995.

Table 2.1

Some FIDIC 4th Edition Conditions differing from those in the ICE Conditions 6th Edition

FIDIC Clause	*FIDIC 4th Edition*	*ICE 6th Edition*
2.3	Engineer can delegate any of his duties and powers to his Representative	2(4) Engineer cannot delegate certain matters to his Representative
4.1	Contractor cannot subcontract any part of works without prior consent of engineer	4(2) Contractor does not require con sent to subcontract any part of works
12.2	Engineer's decision on unforeseen conditions to be given after consultation with employer and contractor	12(5) Requirement to consult not stated
14.3	Contractor to provide estimated quarterly cash flow of payments to him according to his programme	14 No similar requirement
19.1	Contractor to take all reasonable steps to protect the environment on and off site	19(1) Not included
20.4	Employer's risks include any operation of the forces of nature against which an experienced contractor could not reasonably have expected to take precautions	20(2) Not stated
44.1	Extension of time given by engineer to be after due consultation with employer and contractor	44 Requirement to consult employer and contractor not stated; also, engineer must assess all delays
48.1	Engineer issues Taking Over Certificate	48(2) Engineer issues Certificate of Substantial Completion
49.1	Defects Liability Period	49(1) Defects Correction Period
51.1	Engineer can make any variation to works that is necessary or appropriate	51(1) Engineer can order a variation necessary or desirable for completion and/or improved functioning of the works
52.2	Engineer must consult employer and contractor before fixing new rates for varied work	52 Requirement to consult employer not stated

FIDIC 3rd and 4th Editions: 'Red Book'

These conditions are meant to apply to civil engineering work worldwide, and are published by the International Federation of Consulting Engineers (FIDIC). They take the same approach as the ICE Conditions, but with some variations and simplifications to allow for work outside the UK. Additions may cover local needs and different procedures for payment including payment in different currencies. The 4th Edition substantially revised the 3rd as a result of consultations

Table 2.1 cont.

52.3	If variations plus changes in quantities exceed 15% of the tendered contract sum (both excluding provisional sums, day-works and price variation) a sum can be added or deducted having regard to the contractor's site and overhead costs - based on amount in excess of 15% - after consulting employer and contractor - as agreed between engineer and contractor or - failing agreement as decided by the engineer	52 No similar provision
53.1	Contractor to send a copy of any notice of claim to employer	52(4) No requirement to send notice of claim to employer
53.5	Engineer's decision on contractor's claims to be taken after consultation with employer and contractor	52(4) Requirement to consult not stated
54.3 54.4	Employer to assist contractor get his equipment through customs and re-export it after use	Not applicable
57.1	Method of measurement not stated	57 ICE standard method to be used except where indicated to contrary
60.2 60.10	Interim payment certificates to be issued within 28 days and Employer to pay within further 28 days	60(2) Interim certificates and payment to be made within 28 days
67.1	Engineer must give decision on dispute between employer and contractor within 84 days	66(6) Engineer's decision to be given within one month if prior to substantial completion
67.2	Employer and contractor must endeavour to settle dispute amicably before arbitration proceedings start	66(6) No similar provisions but conciliation procedure is available
67.3	Arbitration is under the Rules of Conciliation and Arbitration of the International Chamber of Commerce	66(8) Arbitration procedure as ICE

within the international construction industry and with major international lending agencies. A comparison of the FIDIC 4th Edition conditions with those of the ICE 6th Edition is given in Table 2.1. An important FIDIC requirement is that the engineer is specifically required to consult with both the employer and the contractor before making a decision on a contractor's claim for additional payment or extension of the contract period. Another provision of importance is contained in Clause 52(3), which allows for adjustments to payment with respect to the contractor's overheads if the value of extra works ordered exceeds 15 per cent of the tendered sum excluding dayworks and provision money.

FIDIC Conditions of Contract for Design-Build and Turnkey projects – the 'Orange Book'– have recently been produced for discussion and are similar in many respects to the ICE Design and Construct Conditions.

Cost reimbursement conditions

Cost reimbursement contracts have long been used in civil engineering for emergency or repair work, or when conditions make it difficult to foresee all the work required or the methods that need to be adopted, such as in tunnelling. In such cases the conditions usually provide for the contractor to be responsible for constructing the works, but his proposed methods and expenditure are subject to the consent of the engineer, and his accounts are subject to audit. To simplify the financial accounting, cost reimbursement rates may be previously agreed for the contractor's use of his own plant, and for local site administration and miscellaneous expenditure. A fixed fee for the contractor's head office expenses and profit is agreed as a separate matter. Standard ICE or FIDIC conditions can readily be adapted as a basis of contract.

Employers tend to be reluctant to adopt a cost reimbursement approach because a firm final cost cannot be quoted, and there appears to be no money incentive for the contractor to be efficient. These objections can be overcome to some extent by adopting a target-cost formula, savings on the target cost or expenditure in excess being shared between employer and contractor in some preagreed manner. The target cost has to be precisely defined as to what it includes or excludes, and problems occur if the target has to be adjusted through encountering unforeseen difficulties. The contractor's accounts must be well kept and subject to audit. In the hands of a competent contractor, cost reimbursement contracts can overcome difficult construction problems with notable success at minimum cost. However, cost reimbursement contracts are not used for projects that can be detailed in advance.

2.3 Conditions for civil engineering or building work

GC/Works/1: Edition 3 (1991)

These are the **General Conditions of Government Contracts for Building and Civil Engineering Works** used by UK government departments. They are, in consequence, widely used and are available in a number of different forms: e.g. for payment by priced bills of quantities, lump sum, schedule of rates, or for design and construct. The contract is administered by a project manager or supervising officer, who may be given powers similar to those of the engineer under the ICE Conditions, but this depends on the policy of the government department concerned and the type of work undertaken. The employer (i.e. government department) takes on some powers exercised by the engineer under the ICE Conditions, including granting extension of time and deciding some payments to the contractor. Different departments may adopt different approaches in using the conditions, and new methods of contract administration have been tried out from time to time.

Joint Contracts Tribunal (JCT) Conditions

These are not intended or used for civil engineering work but are the most widely used conditions adopted in the building industry; they are described here to show the building industry's different approach. The **Joint Contracts Tribunal** comprises representatives of the RIBA, RICS, ACE, various building and specialist contractors' organizations and representatives of local authorities. A range of standard forms of conditions provides for different types of employer and for payment by lump sum or quantities. Usually an architect supervises construction and issues certificates for payment, but a civil engineer may carry out these duties for structural works. Quantity surveyors, advisory to the architect, draw up bills of quantities and produce valuations and estimates.

Unlike civil engineering work, items in the bills contain descriptions of what is required in addition to any specification included in the contract documents, and the work is to be carried out in accordance with the bills and the drawings. Much of the work is carried out by subcontractors appointed by the main contractor or subcontractors nominated by the employer through the architect. The need for nomination arises so that the architect can obtain exactly the finishes etc. he wishes to suit his designs. This tends to result in an increased possibility of disputes arising. A clerk of works may be appointed to supervise work on site for the employer, but with very limited powers under the contract. It is thus possible for there to be three separate appointments – architect, quantity surveyor and clerk of works – taking part in supervision, and this splitting of responsibilities and duties can lead to problems.

A management form of JCT Contract was introduced in 1987, under which the onus for carrying out the work is placed upon a management contractor: that is, a firm of builders or civil engineers whose primary input is to manage and coordinate the inputs of subcontractors.

2.4 Conditions mainly for plant and equipment supply

I Mech E Model Form A

This form, together with modifications that can be adopted (such as 'Form G' and a combined version called 'G90') is intended for contractor design, manufacture, supply and installation of mechanical, electrical and instrumentation plant of all sorts. The contract allows for definition of what is required in outline, the contractor being responsible for the design and manufacture or procurement. The total plant required for a project is often procured by issue of contracts covering separate specialities, such as pumps and motors, switchgear, or instrumentation, to suit the capabilities of tenderers. Provision for any associated civil works included in the contract is elementary: if they are required it is best that they should be included as a fully designed package that can be sublet. Payment terms are usually lump sum, but interim payments and some items of remeasure can be included. The terms provide for restricted liability of the contractor for defects other than during the first year of maintenance.

I Mech E MF/1 (a revision of I Mech E Model Form A)

This is for similar purposes as Model Form A but the terms have been modernized and improved, with revised and extended liability for defects and provision for performance tests. Payment terms have to be added.

FIDIC 2nd and 3rd Editions: 'Yellow Book'

These apply to mechanical, electrical, instrument and similar work, the provisions being similar to the I Mech E Form A conditions referred to above. The 3rd Edition is a substantially altered and improved version of the 2nd Edition. Again, it is intended for work worldwide, so it allows for additions to cover local needs.

I Chem E 'Red Book' Conditions

These conditions are primarily intended for process plant paid for on a lump sum basis, with interim progress payments as agreed. The contractor carries the main responsibility for design but must comply with any requirements set out in the contract. He arranges all procurement including any civil, mechanical, electrical and instrument work, and installs, sets to work, commissions and tests all plant. Performance tests are required to prove that the effectiveness of the plant is as specified in the contract. Provisions for dealing with claims and variations are not extensive; the expectation is that prior to the award of contract the parties will have agreed in detail the specific items of plant to be provided, so that little change is needed. The engineer is not fully independent, though required to be impartial in some actions; the purchaser is bound by the decisions made by the engineer and cannot dispute them in arbitration. Provision is made for an independent expert to be called in to decide some technical or valuation matters. As there is little allowance for unforeseen constructional problems, the conditions may not be suitable for associated civil engineering works.

I Chem E 'Green Book' Conditions

These conditions cover a cost-reimbursable contract for the provision of process plant. They can be used when the process or works have not been fully defined, so both purchaser and contractor may have design inputs; but the contractor is responsible for proper construction. The contract can be on the basis of cost plus a percentage fee (rarely used) or cost plus a fixed fee, or a target cost. Payment terms have to define which costs are reimbursable and which are covered by any lump sum payments. Payment is made on the basis of the estimated expenditure for the forthcoming month, subject to adjustment of the preceding month's payment according to the actual expenditure incurred. This amounts to payment in advance. A project manager administers the contract but he does not have a fully independent status, although he is required to act impartially in some matters. The purchaser is responsible for the actions of the project manager and cannot dispute his decisions. These I Chem E conditions have been used occasionally for certain civil engineering works, primarily because they form a framework on which to base a cost reimbursement contract (*see* end of Section 2.2 above), though they have to be extensively altered for civil engineering work.

2.5 A recent report on the UK construction industry: the Latham Report

A joint UK government and industry report on problems of conflict and litigation in the construction industry was published in mid-1994.[1] Most of its recommendations concern the production of guides and advice detailing how promoters should go about choosing and employing consultants, designers, specialists, project managers and contractors. It recommends that a **Construction Strategy Code of Practice** should be issued jointly by the DoE and a newly formed **Construction Clients' Forum**. It proposes that the DoE should hold a register of consultants undertaking public works; and a register of approved public works contractors and subcontractors, from which public authorities would be required to choose a contractor.

A key recommendation is that a new family of standard contracts should be developed, modelled on the ICE's New Engineering Contract (NEC: *see* Section 2.2 above) and providing for:

- the use of a Project Manager to be clearly defined as the employer's representative;
- the appointment of an Adjudicator to decide disputes, his decisions to be implemented immediately;
- the pre-pricing of variations by calling for quotations from the contractor before the varied work is ordered;
- the employer to pay money in advance into a trust account, sufficient to cover the next interim payment due and monies due to subcontractors.

It is proposed that the new standard contracts would eventually supersede other types of contract currently in use; and their key principles would later receive statutory backing in a Construction Contracts Bill laid before Parliament. In the meantime the report recommends that government should increasingly use the NEC in place of GC/Works/1, and that the JCT and ICE conditions should be modified to incorporate similar provisions to those in the NEC.

The report appears primarily directed towards solving problems in the building industry and makes no reference to the much lesser incidence of 'conflict and litigation' in civil engineering. As an indication of this the author of the report states that

> it does not seem to me to relate easily to reality on modern construction sites [to assume that] (a) design and construction are totally separated... (b) all design work will be fully planned by consultants and not subject to change once tender information has been sent out... and (c) the architect or engineer acting as contract administrator will also be accepted by the parties to the main contract as an impartial adjudicator between employer and contractor.

These views may be true of building work; they are not true in relation to civil engineering work, where many jobs are fully designed before tendering, and the engineer is widely accepted as capable of administering a contract impartially.

The proposal for a national register of contractors and subcontractors whom all public authorities will be required to use could meet with opposition. A further proposal that contractors be later classified 'with a "Star" system related to performance' seems unworkable. A contractor's performance can vary from one job to the next, and any two engineers may give quite different assessments of a contractor's ability.

The proposal that the employer should make advance payments into a trust fund poses many difficulties. For example, the amount that the employer puts into the fund to meet the next interim payment due to the contractor can be substantially less than the money that the contractor owes his subcontractors, so subcontractors are not fully protected. Many local authorities object to the proposal as being unnecessary in their case and likely to increase their costs unacceptably.

Substitution of the NEC type of contract for the well-tried ICE Conditions is unlikely be favoured by engineers and contractors in civil engineering, who have shown no widespread wish to abandon the ICE Conditions. The appointment of an adjudicator on every contract would tend to create a new profession of 'adjudication' – but this would amount to no more than reinstatement of the independent engineer under a new name, with the disadvantage that an adjudicator would deal only with disputes and have no day-to-day experience of running the contract. Other weaknesses of the NEC have been discussed in Section 2.2 above, and problems that the pre-pricing of variations can create are explained in Section 12.12 below.

A review of the civil engineering industry was also published by the Federation of Civil Engineering Contractors in early 1994.[2] It investigated similar problems to those considered by the Latham Report, such as the need to improve training of UK construction workers, achieve better productivity in the industry, devise more effective methods of prequalifying contractors, and apply criteria for the evaluation of tenders that take into account quality of service offered as well as tender price.

2.6 Roles of the key participants in a construction contract

A construction contract is made between two parties only: 'the Employer' and 'the Contractor'. Their roles are defined in the contract. However, because there is a need for day-to-day supervision of civil engineering construction, the two parties may agree that a third person should carry out such duties. This third person can have varying powers under the contract, and this is reflected in his designation. He can be designated 'the Engineer' under the contract; or he may be designated 'the Project Manager' or 'Employer's Representative', in both cases occupying a distinctly different position from 'the Engineer'. The roles of these participants are described briefly below; the use of a capital letter in their designation is discontinued except where necessary for clarity.

The **employer**, referred to as 'the purchaser' in some conditions of contract, initiates the process of acquiring the works. He sets down what he requires and specifies this in the tender documents, which he issues to firms of contractors to seek their offers to carry out the works. His obligations include ensuring that the works are legally acceptable and practical, and that the site for them is freely available. He may also need to arrange that associated needs, such as the supply of power, drainage and the like which he is providing, are available. Having set up these basic elements he must, above all, ensure that he can meet his obligation to pay the contractor in accordance with the contract. If any unresolved dispute occurs with the contractor, it is the employer who must decide what action to take; either to negotiate some settlement or, perhaps, take the dispute to arbitration or the courts.

The **contractor** takes on the obligation to construct the works. In his offer to the employer he puts himself forward as being able to build the works to the requirements set out in the tender documents. In order to do this he will have studied the documents and any geotechnical or other information provided or otherwise available, visited the site and checked the availability of such labour, plant and materials as may be needed. Once his offer is accepted and the contract is formed the contractor takes on the obligation of doing all and anything needed to complete the works in accordance with the contract, regardless of difficulties he may encounter. He is responsible for all work done by his subcontractors and suppliers, and any design work that the contract requires him to undertake.

The **engineer**, designated in the traditional form of contract under the ICE or FIDIC Conditions, has a role independent of the employer and the contractor. He is not a party to the contract; but he is named in it. Although he is appointed (and paid) by the employer, he has to supervise the construction of the works as an independent person, making sure they accord with the specified requirements. He also acts as an independent valuer of what should be paid to the contractor, and as a decider of issues arising in the course of construction. The engineer will normally be an experienced and qualified professional, whose knowledge and standing should be sufficient to assure both employer and contractor that the decisions he makes are likely to be satisfactory, and given independently and impartially. In the most widely used conditions of contract, decisions made by the engineer can be accepted by the parties to the contract; but, if either party should so choose, the engineer's decisions can be challenged and if need be taken to external arbitration. This ability to challenge the engineer's rulings can be seen as supporting the effectiveness of his role (*see* Sections 5.1, 5.2; 12.14, 12.15).

As mentioned in Section 2.5, the Latham Report queries whether the engineer is accepted by the employer and contractor as an impartial administrator of the contract. This view appears to result from the increased number of claims now submitted by contractors, which has led employers to believe that they must appoint their own representative or project manager (see below) to resist such claims. But in a fiercely competitive market, in which contractors' margins are cut to the minimum, it must be expected that contractors will seek to gain every extra that a contract appears to allow. However, if an employer uses an experienced engineer to produce efficient contract documents, and does not press for work to be started before designs are complete or alter the work after construction starts, he should not find himself liable to pay many claims. An independent engineer does not allow his decisions to be slanted in favour of one party or the other, as his continued employment depends on his reputation for fairness. This encourages contractors to submit keen prices, and gives both parties assurance that their positions are protected. A detailed discussion of the merits of appointing an independent engineer to administer the contract was presented by Ludlow and Rees in 1992.[3]

The **project manager**, or **employer's representative**, is usually designated under other forms of contract. He may carry out many similar duties as the engineer under the traditional form of contract, but he is not fully independent. The employer may give him powers to decide whether the quality of workmanship meets the contract requirements, but usually not the authority to make decisions about payment or major variations to the work without the prior assent of the employer. The specific content of the contract will define the limit of his powers to act independently. Decisions made by the project manager on matters that are subject to assent by the employer will commit the employer, who will not be able to dispute them. From the contractor's point of view, the project manager's decisions will be regarded as the employer's; so he may feel it necessary to increase his prices to cover the risk that the employer might tend to interpret the contract in his own favour. If the contractor is to offer his lowest prices he has to be assured that the terms of the contract will be interpreted impartially; for this reason an adjudicator may be appointed to whom the contractor can take his disputes with the project manager or employer's representative.

2.7 Contract documents

A contract is an agreement between two parties, which they intend to be legally binding with respect to the obligations of each party to the other and their liabilities. The contract thus binds the contractor to construct the works as defined, and the employer to pay for them in the manner and timing set out. As civil engineering works are often complex, involving the contractor in many hundreds of different operations using many different materials and manufactured items, and include employing a variety of specialists and machinery, the documents defining the contract are complex and comprehensive. The task of preparing them for tendering therefore warrants close attention to detail and uniformity of approach, so as to achieve a coherent set of documents, which forms an unambiguous and manageable contract. A typical set of contract documents will include the following.

- *Instructions to tenderers.* These tell the contractor where and when he must deliver his tender and what matters he must fill in to provide information on guarantees, bond, proposed methods for construction etc. The instructions may also inform him of items that will be supplied by the employer, and sources of materials that he should use (e.g. source of filling for earthworks construction).
- *General and particular conditions of contract.* The general conditions of contract may comprise any of the 'standard' forms of contract mentioned in Section 2.1. The particular conditions will comprise amendments or additions that the employer wishes to make to the standard conditions. Usually the standard conditions (which are available in printed form) are not reproduced in the tender documents, but they will be named, and it will be made clear in the particular conditions that they are to apply.
- *The specification.* This describes in words the works required, the quality of materials and workmanship to be used, and methods of testing to be adopted to ensure compliance. The specification usually starts with a description of the works to be constructed, followed by all relevant data concerning the site, access, past records of weather, etc. and availability of various services such as water supply and electric power. Further details are given in Sections 2.8–2.11 below.
- *Bill of quantities or schedule of prices.* These form an itemized list covering the works to be constructed, against each item of which the tenderer has to quote a price. A bill of quantities shows the number or quantity of each item and its unit of measure, the rate per unit of quantity quoted by the tenderer, and the consequent total price for that item. This permits remeasure according to the actual quantity done under each item. Some bills contain many hundreds of items, classified by trade or according to a standard method of measurement; other bills contain a smaller number of items (*see* Chapter 10). A schedule of prices may call for rates only, but can list provisional quantities that are estimated; that is, uncertain. They would be used, for instance, for a contract for sinking boreholes, items being provided for boring in stages of depth, the

total depth to which any hole has to be sunk not being known in advance.

- *Tender and appendices.* The tender sets out the formal wording, which comprises the tenderer's offer to undertake the contract, the tenderer having to enter the sum price that he offers. The appendices to tender will contain other matters that the tenderer confirms he accepts in making his offer, such as time for completion of the works, damages for failure to complete on time, minimum amount of insurances, and completion of bond. There may be other matters concerning the basis of his offer that he is required to supply, such as currency exchange rates (for overseas constructions), or sources of materials.
- *The contract drawings.* These should provide as complete a picture as possible of all the works to be built. They are each labelled 'Contract Drawing No. ...' The more complete the contract drawings are, the more accurately the contractor can price the work, and the less likelihood there is that variations and extra payments will be necessary. However, it is not necessary at tender stage to provide every detailed drawing that will ultimately be required (such as all concrete reinforcement drawings), so long as the contract drawings provided for tenderers show quite clearly what is required.

On small jobs all the foregoing documents may be combined in one volume; but on most jobs at least two and sometimes three volumes will be necessary. A tenderer is usually sent a second copy of the instructions to tenderers, bill of quantities, tender and appendices, so that he can keep one copy of what he has bid. Later, when a contractor is appointed, he is entitled under the ICE Conditions to receive four copies of the conditions of contract, specification and unpriced bill of quantities, together with as many sets of the contract drawings as are stipulated in the tender documents.

2.8 Writing specifications

In writing specifications care must be exercised to ensure consistency of requirements throughout and conformity with what is written in other documents. This consistency can be promoted if one person drafts all the documents or, where parts are written by others, one person carefully reads through the whole finished set of documents. An inconsistency in the documents can give rise to a major dispute under the contract, having a serious effect on its financial outcome. Some guiding principles are as follows:

- The layout and grouping of subjects should be logical. These need planning out beforehand.
- Requirements for each subject should be stated clearly, in logical order, and checked to see all aspects are covered.
- Language and punctuation should be checked to see that they cannot give rise to ambiguity.
- Legal terms and phrases should not be used.
- To define obligations the words 'shall' or 'must' (not 'should' or 'is to' etc.) should be used.

- Quality must be precisely defined, not described as 'best' etc.
- Brevity should be sought by keeping to essential matters.

It is not easy to achieve an error-free specification. It is of considerable assistance to copy **model clauses** that, by use and modification over many previous contracts, have proved satisfactory in their wording. However, copying whole texts from a previous specification, with modifications, must be done with care, as it can result in contradictory requirements. Entirely new material is quite difficult to write, and will almost certainly require more than one attempt to get it satisfactory.

The specification has to tell the contractor precisely:

- the extent of the work to be carried out;
- the quality and type of materials and workmanship required;
- the methods he is required to use, or may not use, to construct the works.

Under the first an informative description is given of what the contractor is to provide and of all special factors, limitations etc. applying. Under the second the detailed requirements are set out. The extent of detail adopted should relate to the quantity and importance of any particular type of work in relation to the works required. Thus the specification for concrete quality may be extensive where much structural concrete is to be placed; but it may be quite short if concrete is required only as bedding or thrust blocks to a pipeline. A 'tailormade' specification appropriate to the nature of the work in the contract should be the aim. Repetition of requirements should be avoided. If requirements appear in two places, ambiguity or conflict can be caused by differences of wording. Also, there is a danger that a late alteration changes one statement but fails to alter its repetition elsewhere.

The third of the items noted above needs careful consideration, as there may be dangers and liabilities involved in telling the contractor how to go about his work. Some methods may need to be specified, such as the requirements concerning the handling and placing of concrete, but these and similar matters should be specified under workmanship and materials. Other directions on method should be given only if essential for the design. For instance, if it is necessary to underpin or shore up an existing structure, the exact method used should not be specified for, if the contractor follows the method and damage ensues, the liability for damage may lie on the designer. Usually there is no need to specify a particular method, but there may be a need to rule out certain methods: for example, the contractor is not to use explosives.

Under the last item listed above it is important to avoid vague phraseology, such as requiring the contractor to provide 'matters, things and requisites of any kind', or 'materials of any sort or description'. Clause 8 of the ICE Conditions is sufficient to put on the contractor the obligation to do everything necessary to complete the works 'so far as the necessity for providing the same is specified or reasonably to be inferred from the contract'. Similarly, 'excavation in all materials' is an ineffectual phrase. The drafter might think it covers any rock encountered, but it does not if the geological data supplied with the contract or reasonably available to the contractor provide no evidence of the existence of rock. The definitions used in the Civil Engineering Standard Method of Measurement (*see* Section 10.3) should be followed and, if there is evidence that rock might be encountered, a definition of it is required as discussed in Section 10.7. The point must be borne in mind that a specification describes definitive requirements: that is, things the engineer envisages will be necessary. It is not meant to be another version of the conditions of contract.

2.9 Coordinating contracts for construction

In Chapter 1 different ways of carrying out construction work included the possibility of letting separate contracts, each suited to the type of work that specialist contractors are able to offer. This arrangement is common. Separate contracts for the supply of process plant and equipment give the engineer direct control over such contracts. This is often essential because:

- the performance of such plant may be the main function of the project;
- the layout, details, and space requirements for the plant must be known before civil designs can be undertaken;
- variations often require detailed discussion between the engineer and the supplier;
- the engineer is responsible for witnessing and approving all plant tests.

It may also be essential to place separate contracts for the supply of special pipes, valves and other materials because they take a long time to manufacture or, owing to economic conditions and changes in demand, they have gone into short supply and are on long delivery times. For overseas work, the time taken to manufacture, test and tranship plant may be such that it is essential to let these contracts well in advance of the intended start of civil construction.

An illustration of the coordinating work involved is shown in Fig. 2.1, which relates to construction of a water treatment works. It will be noted that the civil construction period of 20 months to substantial completion is relatively short. Hence, with the treatment plant taking 2 years to design, manufacture and deliver, and pipes and valves on 6 to 9 months delivery, separate contracts had to be let for these. Two precautions were taken. First, the treatment plant contractor was set a target date for delivery of his equipment some 3 months earlier than the date that it was expected the civil construction contract would be completed: enough to receive the equipment in order to give a safety margin for possible delays on the equipment. Second, the delivery dates for pipes and valves had been quoted in the civil contract as 2 to 3 months later than the actual delivery times promised by suppliers, also to give a safety margin. Hence, when the civil contractor tied his tender prices to being able to reach substantial completion 3 months earlier than had been expected and the contract conditions required (*see* Section 3.8), no problems arose, though, of course, the safety margins in hand were lost.

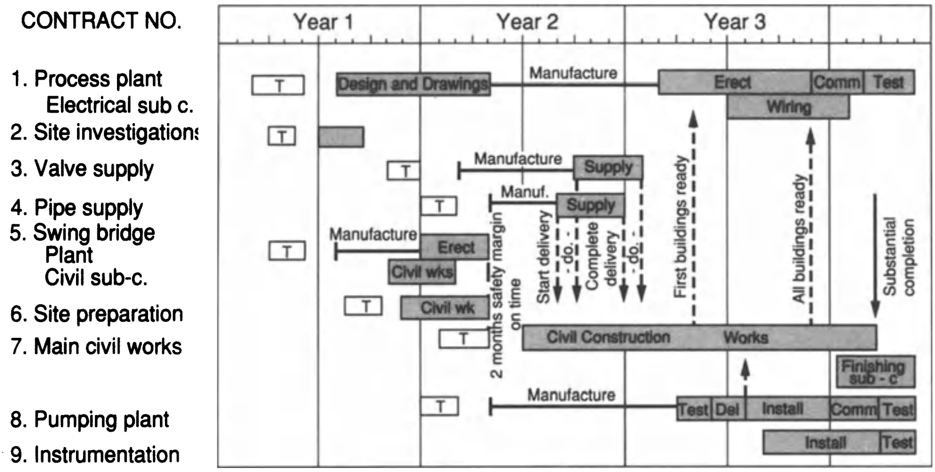


Fig. 2.1. Planning the coordination of contracts for a water supply project

On the massive Mangla dam project undertaken in Pakistan at a cost that would now be over £1 billion, the problem of how to coordinate the input of eight major plant suppliers for hydroelectric plant, gates and valves with the civil work, was solved by requiring the main civil contractor to take over the plant at the manufacturer's works after completion and testing to the satisfaction of the engineer. This left the civil contractor to organize transhipment of the plant to site and its erection by the plant supplier at a time to suit the civil works progress. Items in the civil contract reimbursed him for the cost of transhipment.

In the case shown in Fig. 2.1 and at Mangla a major contribution to speedy completion of each project was the letting of preliminary site preparation contracts, which can cover such matters as access roads and bridges, bulk excavation, the provision of electrical, water, and sewerage services to site, and housing for site personnel. Such contracts have the advantage that they can be let while design of the main works is still proceeding, but they must be completed before the main civil contract starts. Added advantages are that some trenches and other excavations can be left open for the main civil works tenderers to view, so minimizing the risk of claims for unforeseen ground conditions, and arrangements can be made to accept early deliveries of pipes, valves etc., which are put into store.

It is important that the contract documents for each plant supplier state precisely what each contractor is to do, and when and how each is allowed access to carry out his installation work. The interface requirements between plant contracts (such as matching of pipes and valves, cranes and equipment) must also receive particular attention, being subject to check and re-check after any variation. Sometimes the requirements of the employer have also to be precisely specified, such as when he can permit his existing works to be out of production for only a short time while new plant is connected in. Provision has also to be made requiring contractors to share the site with others, the main civil contractor usually being required to provide a number of services to other contractors, such as rights to use his canteen and toilets, common use of site roads, scaffolding, lifting gear, and the provision of electric power and light. These services must be adequately specified, and the method of paying the main contractor for them has to be stated and appropriate items provided in the bill of quantities.

Where, as is often the case, the main contractor has to offload and store another contractor's materials, questions of liability and responsibility arise if some defect in such materials is later discovered. The responsibility for offloading and safe storage may be put upon the main contractor, for which he is paid. But if it is not known when the defect occurred – i.e. during manufacture or delivery – or in mishandling when offloading or stored, a problem arises as to who is liable. For this reason thorough inspection of materials as they are offloaded is important. The resident engineer can help in this matter by sharing in the inspection, and watching that offloading is correctly done. The question of building in pipes for another contractor is also a frequent cause of trouble. The specification should state exactly what is required if the pipe is built in as the work proceeds, or if it has to be 'built in after', a hole being left for the purpose. The wording should make clear who is responsible for the correct setting of the pipe. Again, the resident engineer can help in this matter by checking the contractor's setting of the pipe before it is finally built in.

2.10 Specification of general requirements

In Sections 2.8 and 2.9 some problems of writing specifications have been mentioned. A specification usually comprises two distinct parts: (a) all the general requirements, and (b) the quality of workmanship and materials required. The first, or general requirements can usually be classified into four categories:

- scope of work and reference standards;
- drawings and documents;
- site details and data;
- completion and testing.

Under the first, the specification should provide a brief but reasonably comprehensive description of the works to be built. The elements making up the whole project should be mentioned, together with their principal sizes or, where relevant, outputs. (This is of assistance also to those who might wish to use the priced contract later for the purpose of analysing costs.) The services that the contractor is to provide may need description, particularly if he is to design any part of the works. The services that the employer and/or other contractors are to provide must be defined. Explanation should be given of the industry or national standards used on the project, and in what circumstances alternatives may be allowed.

The second section includes a list of the drawings accompanying the contract. It also specifies the drawings to be produced by the contractor for any designs he is to undertake or for explanation of his proposed methods of construction for the permanent or temporary works. Details of the drawings that the contractor is to submit may need to be specified in order that sufficient information is provided for the engineer to ascertain that the work to be constructed will comply with the specification and all safety measures required. The timing of submission of the contractor's drawings must be stated, together with the time allowed for the engineer to examine them and respond. Other documents to be produced by the contractor will be listed, such as test results and certificates for materials and items of plant, manufacturer's drawings, and maintenance and operation manuals. The form in which interim claims for payment are to be submitted may be specified (*see* Section 11.1).

The third section will contain much information about the site and relevant data, such as

- description of site and access, working areas;
- statutory requirements, such as work in public roads, Health and Safety at Work Act, Control of Pollution Act;
- water and power supplies available, sanitation, sewerage and solid waste disposal;
- contractor's offices;
- engineer's offices, attendance on engineer, vehicles for engineer, telephones;
- temporary fencing, site watching;
- setting-out data;
- geological and hydrological data.

The geological and hydrological data presented are of crucial contractual significance. The contractor has to base his prices on what is reasonably foreseeable: hence he must receive all data that have some relevance to what might be foreseeable. The ICE Conditions 6th Edition contain Clause 11, which states that the employer:

> shall be deemed to have made available to the contractor before the submission of the tender all information on the nature of the ground and sub-soil including hydrological conditions obtained by or on behalf of the employer from investigations undertaken relevant to the works.

This implies that all data 'relevant to the works' have to be supplied with the tender documents. Choice of this can present serious problems. There may be a large amount of such data, and they may be of variable reliability owing to use of different methods of procurement, testing samples etc. But to hold any data back on the basis of their doubtful validity would be dangerous; they could turn out to be highly relevant to troubles that the contractor might encounter. Yet to comment on the reliability of data, would be equally dangerous. Clause 11 states that 'interpretation' of the data is the contractor's responsibility. Therefore the data included in the tender documents must be chosen with care by the geotechnical engineer in charge of such investigations, and no interpretation or comment on such data should be given. However, factual descriptions of the methods used for obtaining data should be given, because this is relevant information that can indicate variations of data reliability. The dates when investigations took place and their exact location is also essential information.

The fourth section will define any requirements or restrictions in respect of the programme for construction and the completion of the contract, including details of sections of the works required to be completed early. If any bonus is to be allowed for completion of all or some part of the works by a given date, this will be described. Details will be given of all other contractors who will have rights to enter the site, what work they will undertake and when etc. (as Section 2.9). Lists of contractors supplying materials to be incorporated in the works will be given, together with expected times of delivery. Tests stipulated before work can be accepted will be detailed.

2.11 Specification for workmanship and materials

The second part of the specification will cover workmanship and materials, and will often be lengthy, perhaps comprising a volume or more on its own for a complex project. It is usual to specify a material and its associated workmanship together in the same section. If workmanship is described separately from materials there is a risk that some workmanship requirement may be overlooked by tenderers. The specification is divided into classes of work or trade. It is desirable to take these classes in the expected order of construction, as this helps to ensure that matters are not missed. However, the order of construction will probably not list trades in the same order as the ICE Standard Method for billing quantities (CESMM). In the latter, piling, tunnelling and engineering brickwork (Classes P, T, U respectively) come after softwood components (Class O) and miscellaneous metalwork (Class N). The best policy is to specify work in order of construction, indicating the appropriate CESMM class of work in each section heading. The bill of quantities should follow the CESMM classification because estimators may use computer software based on the ICE reference codes.

It is advisable to plan out subjects to be dealt with in the specification before detailed work on it starts. The order of subjects dealt with for a general civil engineering project might then be as follows:

1. demolition, site clearance;
2. excavation;
3. piling;
4. concrete:
   (a) *in situ*;
   (b) reinforcement;
   (c) formwork;
   (d) precast;
   (e) prestressed;
5. pipe-laying (might be put later);
6. steelwork (structural);
7. brickwork/blockwork/masonry;
8. roofing;

9. cladding (if special);
10. carpentry;
11. finishing trades (as necessary):
    (a) flooring;
    (b) plastering;
    (c) metalwork (e.g. windows, handrailing);
    (d) glazing;
    (e) joinery;
    (f) electrical;
    (g) plumbing;
    (h) painting;
12. roads; site restoration; fencing.

It is not advisable to use three or more levels of decimal numbering of sections, subsections and paragraphs such as '2.1.1', '2.1.2'. Only the section headings under each class of work need be numbered; subsections can be unnumbered and identified by a left-hand heading, and paragraphs are not numbered. This permits insertion of late additions without disturbing any numbering.

When drafting the specification, care should be taken to ensure coverage of all types of work that appear on the drawings. In civil engineering contracts the specification sets out all quality requirements, so these must be complete. The items in the bill of quantities only need sufficient description for the item to be identified for the purposes of payment. If an item in a bill of quantities appears with extra description that is not in the specification, this is a dangerous practice. The purpose of a bill of quantities is to define payments for the work, and a contractor might argue that the item with the added description is not part of the contract. (*See* Section 2.3, where it is noted that under JCT Conditions for building work the contrary practice applies.)

There have been differences of opinion among engineers as to the merits of **method** as against **performance** types of specification. A method specification for concrete quotes not only the materials and quantities of them to be used to make various grades of concrete but also the strengths and other physical characteristics to be achieved, together with requirements for handling and placing. A performance specification would stipulate only the strength and other physical characteristics to be achieved. This, it is said, leaves the contractor greater freedom to decide how he will achieve the performance criteria. However, opponents of performance specification point out that control by testing is only possible (in the case of concrete) 28 days after placing, and such tests may not provide sufficient proof that the structure will perform satisfactorily in the long term. If defects appear later, how is the contractor to be held responsible? Traditional method specification is therefore the usual practice adopted. It should be appreciated that many method specifications are based on long-standing practices that have proved satisfactory over many years of experience.

The specification ought to be precisely relevant to the work required. To include provisions that are inapplicable or irrelevant shows signs of a careless approach. When complex matters have to be specified it is best to avoid long and complicated sentences; short sentences are better. Occasional lists of requirements can aid clarity. The specification is a reference book which should be easy to consult. Inevitably large parts of it will cover such obvious requirements that they will not be read; for example, 'All formwork must be true to line and level'. Any unusual or special requirement should therefore not be tacked on to such standard material, or it will get missed. It should be put in as a separate paragraph, even if it comprises only a couple of lines, so that it stands alone.

As indicated in Section 2.8, when writing specifications much use is made of past work and experience. Many engineers and consultancy firms will have model clauses available for specifying materials in common use. Both 'short version' and 'comprehensive' model specification clauses may need to be drawn up for a given material, so that the appropriate model clause can be used, according to the amount and importance of that material in a job. Considerable use will be made of national standards, standard sizes or qualities of manufactured goods. But it should be noted that, although British or other national standards are often quoted, this may not be sufficient definition because many such standards cover various grades and qualities, and precise references may be needed. Permitted alternative national standards may need to be quoted also.

Use can be made of a trade-named product to specify a material required but, wherever possible, it is better to avoid restricting the contractor to just one product by adding after the named product the words 'or similar approved'. The problems caused by nominating one supplier are dealt with in Sections 9.2, 10.8 and 10.9, and it must be borne in mind that the practice could be contrary to EU competition rules.

Many sections of the civil engineering industry have their own approved technical specifications, which are meant to act as standards for their particular type of work. The UK Department of Transport has published extensive clauses covering all manner of roadwork in their Highways Specification. The water companies in the UK have published a Civil Engineering Specification for the Water Industry. These documents can give an important lead to the specifier, but should not be slavishly copied, but checked, amended and extended so as to relate concisely to the needs of each particular job.

It is wise to enquire of the employer whether he wishes any particular specifications or standard requirements to be adopted. This is important when work is undertaken for governments or public utilities overseas. They often have their own printed specification, departures from which may not be permissible as they might not be noticed or understood by local tenderers. The sanction of the employer might be needed before any addition or amendment could be made to such traditional specifications and, if allowed, may need to be put in a special section and carefully worded in simple English.

References

1 Latham, Sir Michael. *Constructing the team*. London: HMSO, July 1994.
2 *Strategic issues for civil engineering contractors*. Federation of Civil Engineering Contractors, March 1994.
3 Ludlow, MJ and Rees, JG. The engineer's role under FIDIC standard conditions of contract. *International Business Lawyer* 1992; November.

3

Tendering

3.1 Methods used for obtaining tenders

A promoter usually seeks bids or **tenders** from construction contractors on the basis of tender documents produced as described in the previous chapter. Tenders can be obtained in one of three ways: by open tendering, by selective tendering, or by negotiation.

Under **open tendering** the promoter advertises his proposed project, and permits as many contractors as are interested to apply for tender documents. Sometimes he calls for a deposit from applicants, the deposit being returned 'on receipt of a bona fide tender'. However, this method can be said to be wasteful of contractors' resources, as many may spend time preparing tenders to no effect. Also, knowing their chances of gaining the contract are small, contractors may not study the contract in detail to work out their minimum price, but simply quote a price that will be certain to bring them a profit if they win the contract.

Thus the promoter may be offered only a 'lottery of prices' and not necessarily the lowest price for which his project could be constructed. If he chooses the lowest tender he runs the risk that the tenderer has not studied the contract sufficiently to appraise the risks involved; or the tenderer might not have the technical or financial resources to undertake the work successfully. It is true that the promoter can check the resources and experience of the lowest bidder and reject his tender if the enquiry proves unsatisfactory; but several bids may be below the estimated cost of the job, and if such tenderers appear satisfactory and their bids are not far apart in value, it is difficult for the promoter to choose other than the lowest. The engineer advising the promoter may think that there is a risk that all such low bids could prove unsatisfactory, but he cannot advise the promoter what other bid to accept because he has no certainty of information.

Under **selective tendering** the promoter advertises his project and invites contractors to apply to be placed on a selected list of contractors who will be invited to bid for the project. Contractors applying are given a list of information that they should supply about themselves in order to 'prequalify'. The advantage to the promoter is that he can select only those contractors who have adequate experience, are financially sound, and have the resources and skills to do the work. Also, as only half a dozen or so contractors are selected, each contractor knows that he has a reasonable chance of gaining the contract and therefore has an incentive to study the tender documents thoroughly and put forward his keenest price. However, as contractors have all prequalified it is difficult to reject the lowest bid, even if it appears dubiously low unless it is due to some obvious mistake.

A problem with both open and selective tendering is that a contractor's circumstances can change after he has submitted his tender. He can make losses on other contracts, which affect his financial stability; or may be so successful at tendering that he does not have enough skilled staff or men to deal with all the work he wins. Neither method of tendering can therefore guarantee avoidance of troubles.

Negotiated tenders are obtained by the promoter inviting a contractor of his choice to submit prices for a project. Usually this is for specialized work or when particular equipment is needed as an extension of existing works, or for further work following a previous contract. Sometimes it can be used when there is a very tight deadline, or emergency works are necessary. A negotiated tender has a good chance of being satisfactory because, more often than not, it is based on previous satisfactory working together by the promoter and the contractor.

When invited to tender, the contractor submits his prices, and if there are any queries these are discussed and usually settled without difficulty. Thus mistakes in pricing can be reduced, so that both the engineer advising the promoter and the contractor are confident that the job should be completed to budget if no unforeseen troubles arise. However, negotiated tenders for public works are rare because the standing rules of public authorities do not normally permit them. But a private promoter or company not subject to restraints such as those mentioned in the next section can always negotiate a contract, and many do so, particularly for small jobs. However, even when a negotiated tender is adopted it is usual to prepare full contract documents so that the contract is on a sound basis. Production of the documents also means that they are available for open or selective tendering should a negotiated tender fail, or should the chosen contractor be unable to undertake the work.

3.2 Tendering requirements and EU rules

Civil engineering construction works and many other similar types of purchase form a large part of the annual expenditure of local and national government authorities and of the public services such as water, drainage, gas and electricity. Consequently, such authorities have long-standing rules concerning the procurement of tenders, designed to ensure that tenders are obtained openly in a manner that gives best value for taxpayer's money. The rules may stipulate the number of contractors to be prequalified under selective tendering according to the size of contract to be let, and penalties to be imposed if bribery or collusion by tenderers is discovered. In recent years competitive tendering has been introduced into local government, national health and other services in the UK, under which the promoter's own direct labour organization is required to bid in competition with outside contractors' offers in order to gain work.

Under some European Union Directives, rules have been set for tendering procedures for construction work, and also for the supply of goods and services, which members of the EU are obliged to follow. The rules vary according to the expected value of the contract and the type of service required. Most supply contracts for public works come under EU rules if they exceed a threshold value of 200 000 ECU (approximately £150 000); while construction contracts for the utilities (such as gas, water, drainage and electricity) come under control for contract values exceeding 5 million ECU (approximately £3.8 million). Limitations are applied to prevent splitting down work to avoid such rules. Some general features of the EU rules are as follows:

- *Procedure.* Open, restricted (i.e. selective) or negotiated tenders may be sought, but for negotiated tenders three tenderers must be preselected by an advertised procedure except in certain particular situations.
- *Advertising.* Work coming under the rules must be advertised annually, or for each contract individually, to permit tenderers to register their interest. If prequalification is not used, a contract notice advertisement must be issued. Minimum times are set for lists to remain open. After the award of a contract, an award notice must be issued.
- *Contract award criteria.* The criteria that are to be applied in awarding a contract must be set out. The choice may be the lowest tender, or that which is economically the most advantageous. In the latter case the factors that will be taken into account when judging tenders must be stated and adhered to.
- *Publicity.* All required notices must be published in the *Official Journal* of the EU, using standard formats.
- *Standards.* Standards must not be set in specifications in a manner that restricts trade between EU members. European standards, or national standards that implement such standards, take preference over any others.

The EU is not the only body setting rules for tendering. The major international lending authorities, such as the World Bank, Asian Development Fund, UNO, and WHO, also have rules to ensure that tenders are open to international contractors, or to contractors from countries funding a project, or to conform to some specific requirement. Individual countries often require that tendering procedures shall be so designed that either certain goods and services come only from inside the country, or maximum possible use is made of these. Limits may be set on the use of imported goods or services. On constructional contracts tenderers may be required to work in conjunction with local contractors, and the number of expatriates that the contractor employs in the country may be restricted.

3.3 Procedures under selective tendering

If a promoter is not subject to any of the restrictions outlined in the previous section, he may make a selected list of contractors from those who have served him satisfactorily in the past or those recommended to him. However, if competition is to be maintained, or EU rules or similar apply, then lists of potentially suitable tenderers should be compiled. These can be standing lists reviewed perhaps annually, or lists compiled for a specific project. Contractors wishing to be placed on a standing list may either answer the promoter's advertisements or apply direct to the promoter. This prequalification will usually seek to establish three categories of information about a contractor:

- The contractor's organization and resources: details of his ownership, details of staff available for the contract, and information concerning any special equipment or skills available for the particular type of work proposed.
- Experience and performance record: the experience the firm has of projects similar in type and size to the intended project, and what performance thereon was achieved. Some of this information may have to be obtained by asking the contractor to provide references from previous employers, the references being taken up. It is not always desirable to restrict the list to contractors who have done work of a similar kind and magnitude before, as this could unnecessarily restrict the choice of contractors and exclude competent contractors who have growing resources and skills.
- Financial standing. A contractor must be able to show that he has sufficient funding to carry out the proposed contract without overstretching his financial resources. The contractor may be asked for his turnover and recent financial history, and data with respect to his current financial commitments. Some of this information may be available from annual financial reports or other sources; but it may be important to check that all relevant data have been supplied. An accountant may be employed to enquire into these matters.

In order to collect the necessary data in an organized manner it is preferable for standard forms to be issued to contractors, otherwise comparison and analysis may be hindered. A format suitable for international tendering is available from FIDIC, and guidance is also given by the World Bank in their Standard Bidding Document. If the purpose of prequalification is the construction of a specific project, then applicants should be told the grounds on which their suitability will be assessed. Care is needed in defining these grounds. On the one hand, the criteria applied need to be sufficient to keep those qualifying to a reasonable number; on the other hand, they should not be so tight as to exclude potentially suitable contractors who just fail to meet one of the criteria applied.

For works of a value up to about £1 million, a list of six prequalified tenderers would usually be regarded as sufficient; for larger-value contracts it is seldom desirable or necessary to have more than eight prequalified contractors invited to bid. Where a standing list is maintained, this can be divided into lists of contractors best suited to certain kinds and magnitudes of work, but contractors should be given reasonable opportunity to change their listing on supplying additional information. Once a selected list has been produced and approved by the promoter, it is advisable that contractors on the list are approached individually shortly before sending out tender documents, asking them to confirm whether they are still interested in and capable of tendering. This is important if there is any substantial lapse of time between the prequalification of contractors and the sending out of tender documents. Contractors' commitments can change in a relatively short time. Those prequalifying should be informed of the expected timing of the issue of tender documents and start of construction, so that they can plan their tendering work and consider their response to other opportunities.

3.4 Issuing documents

There is a widespread tendency for promoters to want their civil engineering works designed and built in double-quick time. This pressure for speed often arises because of the unconscionable time it nowadays may take for a promoter to gain powers to construct his works. He may need to get planning consents, satisfy conservation and environmental interests, acquire land and wayleave rights, accommodate objectors, and go through the lengthy process of a public inquiry. The funding of international projects may also take some years to arrange. Commercial organizations tend to delay a project, then want it completed as fast as possible when market conditions are right. None of this can be avoided; but the pressure to undertake both design and construction in excessive haste needs to be resisted.

Starting construction before designs are complete, or before the promoter is sure what he wants, is a major cause of constructional problems, claims by contractors and of costs grossly exceeding original estimates. Hurriedly prepared documents, contract drawings incomplete before tendering, tender periods too short and a promoter who wants changes after construction has started, can lead to a legion of unforeseen problems, forced changes of design, multiple claims from a contractor and a job not completed any earlier than it would have been had proper time been allowed to get everything right before calling for tenders.

The three outstanding requirements for fast completion are:

- designs fully complete before tenders are called for;
- adequate tendering time for tenderers to prepare their bids;
- a promoter who makes no substantial changes to his requirements after construction has started.

Given good designs based on adequate site investigations, drawings providing all the details that a contractor needs, and no changes during construction, any competent and well-organized contractor can give fast construction. He can also give a good job. The quality of a job is all-important to a contractor's reputation. The cost of a job and how long it took may fade from a promoter's memory, but if

Plate 1a. The hydraulic model for the Ghazi Barotha hydro-power project, Pakistan, 1994

Plate 1b. Ground freezing to permit tunnelling through difficult ground subject to artesian water. Iver treatment works, Three Valleys Water Co., 1984

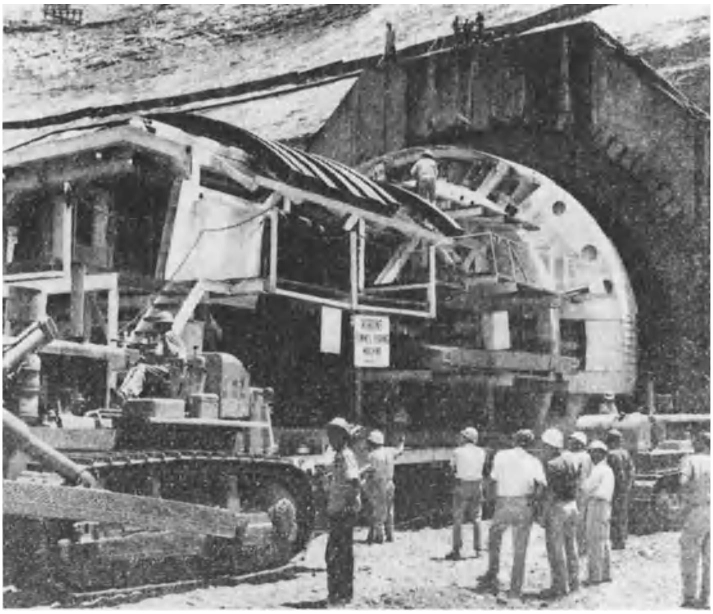


Plate 2a. An early use of a large tunnel mole for driving the 11.0 m diameter hydro-power supply tunnels on the Mangla dam project, Pakistan, 1963

Plate 2b. Tunnel excavation by hand may still be necessary in uncompacted materials requiring instant support. Corrugated steel bars are driven forward over a joist, wedged to slant upwards, so holding the roof material and permitting the next joist to be placed

Plate 3a. A Terex TS24C 552 kW twin-engined 36 m^3 capacity scraper for earth-moving. Terex Equipment Ltd, Motherwell, Scotland

Plate 3b. A Kato 160 kW tracked excavator, with 1.6 m^3 bucket. ACP Holdings, Leicester, UK

Plate 4a. An O & K RH40D 365 kW tracked excavator operating as a face shovel with 6 m^3 bucket. Orenstein & Koppel Ltd, Northampton, UK

Plate 4b. A Euclid R60 522 kW dump truck, 36 m^3 heaped capacity. VME Construction Equipment GB Ltd, Duxford, Cambridge, UK

the job is a poor one giving a series of after-troubles, it will be a continuing source of dissatisfaction to the promoter, which he will not forget.

Tender preparation and adjudication times need to be adequate; they should be programmed into a realistic timetable that gives sufficient time for the engineer and the contractor to carry out their duties. A contractor faced with a set of contract documents has to absorb much information, get many quotations, and consider all options. For a small job even four weeks' tendering time may fall short of his needs; for major projects up to three months' tendering time may be needed to ensure that tenderers have time to consider all their strategies and put their best price forward.

Not less than two sets of documents should be sent to each of the contractors on a selected list, and if a substantial amount of specialist input is specified, further copies of the parts of the documents covering these specialist requirements ought to be supplied. Promoters sometimes consider that tenderers should pay for all sets of documents they receive; this may be prudent when open tendering is adopted in order to prevent frivolous enquiries, the payment being returned to contractors who submit proper tenders. For selected tenderers, payment should be unnecessary except when a tenderer makes an unreasonable demand for extra copies. In whatever manner tender documents are sent to contractors, details of their dispatch should be logged, and each tenderer should acknowledge receipt. All drawings and specifications should eventually be returned to the promoter.

During the tendering period it may be necessary to issue amendments to tender documents. These may stem from errors and inconsistencies coming to light, queries raised by tenderers, or changed requirements by the promoter. Each amendment should be numbered, and a copy sent to every tenderer, with a request for him to acknowledge its receipt. If any query is raised by a tenderer (even by telephone) and the answer given to him provides him with additional or clarified information, this information must be confirmed in writing and the same information must be sent to all other tenderers; but the identity of the tenderer raising the query should not be disclosed.

Too many amendments should be avoided, as they can cause disruption to tenderers and may lead to requests for extension of the tendering time. Minor errors found in the specification or drawings should not be circulated; they should be noted for correction at a later stage. If the promoter requires some important change, careful consideration must be given as to whether tenderers should be advised of it, or whether the change should be held back to be dealt with when making the award of tender, or by issuing a variation order after the award of contract. Amendments should not be issued late in the tendering period. Requests received from contractors for extension of the tendering time can be avoided by giving adequate prior notice to selected contractors as to when tender documents will be issued, and giving sufficient tendering time. No extension of tendering time should be allowed if any tender has already been received, even though it remains unopened.

Sometimes **pre-tender meetings** are held, which all tenderers are invited to attend; they are usually addressed by the promoter, who wishes to clarify some special aspect of the proposed project or give information concerning some important query raised by a tenderer. Preferably such meetings should be avoided because they can provide opportunities that undermine the independent nature of competitive bids. However, visits to inspect sites will need to be paid by tenderers. If such site visits are made in the company of the promoter's engineer or one of his assistants, the engineer must be careful to provide only factual answers to queries raised. Should this provide a visiting tenderer with additional information, this will need to be sent out to all tenderers. It is better if the tenderer visiting is accompanied, if need be, by a guide who is not directly connected with the contract.

3.5 Considering tenders

Arrangements for return of tenders should be set out in the Instructions to Tenderers, giving both the place and latest time for receipt. Tenderers need to use secure means of delivery, and should receive a signed confirmation of delivery. It is usual to require tenders to be returned in sealed envelopes, marked only with the contract name and no means of identifying the name of the tenderer. Arrangements should be made to mark each tender envelope with the date and time of receipt, and for the safe storage of same until opening is authorized. Documents received after the closing time should be similarly marked and held unopened, until the promoter decides whether they can be considered valid or not. Obviously, common sense must be exercised; the promoter will not wish to have a genuine bid invalidated by conveyance mishaps outside the control of a tenderer, such as a postal strike, or aircraft delayed. Once tenders are opened, no late delivery of a tender can be considered.

Tenders for large projects are sometimes opened at a public ceremony, the name and total tendered price of each tenderer being announced. This has the advantage that everything is 'above board', so that practices that could distort straight price competition are precluded. Also, contractors gain immediate knowledge as to how they stand with respect to getting the contract. In other cases, such as in local government, the practice is for tenders to be opened by a senior official in the presence of the chairman of the appropriate committee and others according to the standing rules of the authority. A record is usually made of the tendered prices as opened, and signed by one or more of those present.

The tenders, when opened, are then usually passed to the promoter's engineer for examination. The first step is to mark all documents with the name of the tenderer and list them. This list should be given an independent check so as to be certain that, if a tenderer says one of his documents has been missed, the promoter's officials can show that it was not received. Once the list has been compiled, any document not returned by a contractor that should have been returned, is noted.

Some tenderers may attach qualifications to their tender, usually set out in their covering letter. Qualifications that simply refer to some minor interpretation of a statement in the documents can usually be left for later agreement. But some qualifications may deal with a matter of considerable importance that changes part, or all, of the basis of contract as set out in the contract documents. Some promoters have rules that require qualified offers of this kind to be rejected out of hand: if so, this should be made clear in the Instructions to Tenderers.

An offer that is qualified in some important respect may give a tenderer an unfair advantage over other tenderers. For instance, a qualification that tendered prices are subject to increase if rates of wages ruling at the time of tendering increase, would invalidate a tender if the contract documents contain no such provision. On the other hand, a tenderer may submit a more subtle qualification, such as 'Our prices are dependent upon being able to complete the contract within *X* months', where *X* months is less than the period for completion stated in the contract documents (*see* Section 3.8). A contractor can, of course, always submit an offer in accordance with the contract documents and add a second offer that proposes some reduction on the former offer if some qualifying condition is accepted.

Whether a qualified offer can be accepted or not depends upon the powers and restraints under which the promoter operates. A private person or company, subject to no restraint, can accept any tender. But a public authority or utility will be bound by standing rules and perhaps EU or other rules also; while a project funded by one of the international funding agencies may come under rules that preclude any qualification being accepted that could be inferred as granting a favour to one tenderer and not to others.

In some cases specific alternatives are allowed in the contract documents. These most often refer to methods of constructing major temporary works, such as cofferdams for bridge foundations, or river diversion works for construction of a dam. The contractor may be required to quote a price for following a design shown in the contract drawings, but be permitted to offer an alternative design of his own. The option has to be made fully clear in the contract documents, and full details of the tenderer's alternative design have to be provided.

Detailed consideration of tenders will usually start with an arithmetic check of the lowest three or four offers that are free of unacceptable qualifications. Any arithmetic errors found should be dealt with in a manner that is set out in the Instructions to Tenderers. Usually the unit rates quoted for items are taken as correct, and all consequent multiplications and additions are arithmetically corrected. Where this results in an alteration to the total tendered sum, either this altered sum is adopted, or the altered sum is brought back to the quoted tendered sum by inserting an **adjusting item**: the Instructions must state which. A reason for leaving the quoted tender sum unaltered is that the contractor's estimating staff work out the unit rates, whereas the contractor's directors personally look at the total sum to finally decide whether or not it is sufficient to cover the whole job.

The lowest three or four tenders are then checked for compliance with contract and other requirements, under the following headings.

- *Compliance:* conformity with instructions, completeness of entries, compliance with bond and insurance, absence of unacceptable qualifications etc.;

- *Technical:* conformity with specification, proposals for materials, use of subcontractors, temporary works proposed and methods of construction, intended programme etc.;
- *Organizational:* staff proposed, responsibilities held etc.;
- *Financial:* make-up of total price, amounts for items in Preliminaries, unit rates, exceptional prices, errors and omissions etc.

In addition, if open tendering has been adopted, details of tenderers' resources, past experience, financial and other data will need to be examined. This work will be conducted in parallel with the checking of prices described below.

3.6 Checking prices and comparing tenders

The engineer or consultant advising the promoter must bear in mind that his report on tenders should provide the factual results of his analysis of tenders. He may need to indicate what any particular finding implies; but he does not recommend which tender should be accepted unless the promoter requests this. Even so, the choice of contractor must be the promoter's, and not his adviser's. Sometimes it is necessary for the engineer or consultant to present an interim report on tenders. This can occur if there are many tenders, or complex issues need to be resolved concerning qualifications attached to tenders, or relating to the standing of tenderers if open tendering has been adopted.

While the lowest total tendered sum may be a major factor influencing choice, individual rates and prices must be examined to see whether relatively high or low rates entered could alter the ranking of tenders should certain quantities under remeasurement for payment come different from those in the bill of quantities. A contractor is entitled to set highly profitable rates for some items and non-profitable or loss rates for others. This can lead to problems if quantities are not as billed, or work has to be varied. The implication of such differences needs to be considered. Nevertheless, prices for the same type of work can vary widely from one contractor to another; in this connection sums entered by the contractor in the Preliminaries Bill must be taken into account (*see* Section 10.10). One tenderer may put large sums there for access, insurance, setting up, etc.; another may spread the cost of such items over all his unit rates, entering only a few relatively small sums in the Preliminaries Bill. Differences in rates can also arise from different materials or methods used, different appreciations of risk, and sometimes from simple error.

If the lowest tender appears impracticably low, the employer may agree that the engineer should interview the tenderer in the hope of elucidating whether this results from the tenderer's inexperience, over-optimism, or misunderstanding of the contract requirements. However, such a meeting can prove uninformative, leaving the problem still open as to whether such a tender should be accepted. If the lowest tender is the result of serious underpricing of a single major item or group of items, it may be necessary to confront the tenderer with this view. Acceptance of a tender that would put the contractor to a certain loss can lead to skimped work or the contractor failing to complete the works. To allow the tenderer to adjust his faulty price would not be permissible for a public authority but he can be allowed to withdraw his offer. However, a private employer is not precluded from bargaining with a tenderer to settle an adjusted price, or to agree upon some other solution such as offering a bonus to make up the underpriced item if the contractor completes the works early.

The chances of receiving an unrealistically low tender can be minimized by avoiding open tendering and giving selected prequalified tenderers adequate time to prepare bids. Before tenders are received the engineer can estimate what a fair bid price should be. However, under fiercely competitive conditions lower bids may be received; or if the work is of a type not favoured by contractors (for example, not offering reasonable amounts of rewarding work, too complicated, or located in an area posing labour or transport difficulties), the lowest bids can come much higher than expected. If a contractor expects that he will meet administrative problems, difficulty in getting permits, payments, materials, consents etc. and suffer from indecision or over-complicated authorizing systems run by the employer, he will add a premium to his prices. It must be realized that contractors pay as much attention to the competence of employers, as employers pay to the competence of contractors.

A further matter to be examined is the effect of a tenderer's pricing on the rate of payments to him during construction: that is, on the cash flow. A contractor may set his rates for early work high, such as rates for excavation and foundation concrete. Thus these, containing a large element of profit to him, will provide him with a good inflow of surplus cash at an early stage in the project. Similarly he may enter high prices in the Preliminaries Bill for early temporary works, such as provisions of offices. This pricing is of considerable financial benefit to a contractor, quickly reducing his start-up costs and borrowing needs; but it is also a disbenefit to the promoter who, often needing to borrow money to finance the capital expenditure on the project, has to pay interest thereon. Comparison of the rates of cash flow implied by different tenders may therefore need to be made to see their different financial effect on the promoter. If the interest on a promoter's borrowings is 'capitalized' – that is, not paid when due but added to his borrowings – this can magnify the effect of early cash disbursement on the promoter's costs, increasing the capital cost of the project to him. A further point is that a contractor who receives early money leaves the promoter at extra risk because, if the contractor gets into financial difficulties, much of the early money may not have been spent on permanent works of value to the promoter.

3.7 Choosing a tender

In order to resolve any mistakes or qualifications in tenders it is often necessary to hold a discussion with one or two of the tenderers. Such discussion must only take place with the knowledge of the promoter, and in accordance with any restrictions set by him. At this stage there is a strong possibility that tenderers will know the prices quoted by at least some others, so the negotiator must be alert to any attempt by a tenderer to adjust his price, so as to become the lowest or, if he is already the lowest, to reduce the gap between himself and the next lowest. A contractor has admitted that: 'It is always a great advantage to have the opportunity of taking a second look at one's tender when discussing it with a client'.

There has been a growing demand that tenders should be assessed on the basis of quality as well as price; the Latham report (*see* Section 2.5) emphasizes this. Any quality criteria to be applied must be stated in the documents. Quality assessment is of major importance under design and construct contracts where the contractor has control of design, the materials supplied, and the workmanship. For construction-only contracts the quality of the permanent works is already defined in the drawings and specification accompanying the tender documents, so it is the quality of the contractor's prospective performance that remains to be judged. This cannot be defined in measurable terms. Hence it is usual to judge a contractor's likely performance according to his reputation and experience, and on confidential reports from employers who have recently employed or are employing the contractor on their own work.

The final assessment of tenders must, of course, take into account any rules set out in the tender documents. The EU Directives, for instance, require the methods of comparing tenders to be described in the documents, and they must be adhered to. Failure to do so could entitle a disappointed tenderer to challenge the award of contract to another and claim compensation for the lost opportunity.

Having made all necessary comparisons of tenders, a decision must be made as to which tender should be recommended for acceptance, if the promoter requires this. Once tenders have been compared on a uniform basis, and all nonconformities and queries have been resolved, the question must be asked: is there any cogent reason for not recommending the lowest-ranked tenderer by price? Any reason put forward for this must be a real reason, such as clear evidence of a tenderer's financial problems or his lack of experience in some essential operation required under the contract. The report on tenders must be careful to present a balanced view, and not over- or understate the case for any tenderer. It is important not to 'mix fact with opinion'. The facts or evidence should form one statement; any comment thereon should form a separate statement. The 'facts', so far as they are known, should not be open to question, though they may comprise statements made by others, such as a bank report on a tenderer's financial status, or a referee's report. These problems of reportage are more likely to occur with open tendering. Under selective tendering, the competence of tenderers will already have been approved, so it is almost axiomatic that the lowest unqualified offer will be favoured.

3.8 Offer by a tenderer to complete early

A tenderer may state in his offer that his prices are dependent on being permitted to complete the works in a shorter time than the period for completion stated in the contract documents. This offer must be looked at with care because it implies that other separate contracts the employer may have let for supply of plant to be incorporated in the works must be speeded up also. Similarly, any nominated subcontractors must deliver earlier, and the engineer must be able to provide all outstanding design details according to the shorter programme. It is, of course, a benefit to an employer to have his works completed earlier: it can reduce his capital borrowing charges and enable him to gain an income from the works output earlier, though he must be able to accelerate his payments to the contractor. The question that arises, however, is whether the contractor's shorter time period should be substituted for the period for completion stated in the contract.

It is true that speedy construction can maximize a contractor's profit or permit him to offer a lower price, but this need not be his only motive. A contractor may say that he can complete a project three months early if he suspects the job is so liable to delay by other contractors, nominated subcontractors, extras, incompleteness of designs or unforeseen conditions, that he runs a small risk of having to abide by his promise. Indeed, if the contractor judges the position so, he may offer to complete the job 4, 5 or 6 months early, with even less likelihood of being held to his promise but with increased possibility of being able to claim extra payment for any delay caused him.

The question of adopting the contractor's shorter time as the contract period for completion needs careful consideration, and the position must be resolved clearly before award of the contract. The contractor might have second thoughts about his offer because he would become liable to liquidated damages if he did not complete in the time he offered. The employer might not favour it because any delay caused to the contractor would give a higher risk of an extension of time and would put the contractor in a stronger position to claim extra payment. If the contractor insists that his earlier completion time be adopted as the contract period, the employer may be entitled to reject the contractor's tender because it is a conditional offer not in line with the terms of tendering.

3.9 Procedure for accepting a tender

After the closing date for tenders, and if tenders have not been publicly opened, contractors will be anxious to discover where they stand: either to prepare themselves for holding discussions over their tender, or to divert their energies elsewhere if they find themselves unlikely to be offered the contract. If prices have not been arithmetically checked, it is inadvisable to give any information lest it turns out to be misleading. However, when the ranking of tenders has been checked, it should be possible to inform contractors enquiring if they are unlikely to succeed. Once a decision has been made by the promoter, all tenderers should be informed by a standard letter, stating the prices received but not identifying the tenderers who submitted them.

A **valid contract** must incorporate three basic elements:

- an offer (e.g. the tender) and its acceptance;
- consideration (i.e. the contractor undertakes to construct the works and the employer undertakes to pay him for them);
- an intent that the contract be legally binding (as evidenced in the contract documents).

During any negotiations the original tender may have been amended by interchange of letters. These letters must make clear what is the final amended tender offered and accepted. If the correspondence is not complete, and some condition or qualification remains unsettled, then a contract should not be formed and, in effect, there only exists an offer by one party and a different offer by the other. So a check must be applied to ensure that everything has been settled. Once this has been done and full agreement has been reached, then actual acceptance of a tender can take place.

In the case where a promoter is a person or private company the promoter can accept a tender by writing little more than: 'I accept your offer'. However, some corporations, and most statutory or other authorities, may be required by their constitution or standing rules to enter contracts above a certain value only by a **deed** or formal agreement, which has to be signed by an authorized person acting on behalf of the authority. Some authorities require the agreement to be **under seal**: that is, stamped with the corporate seal of the authority. Under any method, the acceptance must make clear what documents form the basis of contract.

Where a local authority can only enter a contract by means of a formal agreement, a typical letter from the Clerk of the authority to the contractor might be written as follows.

> Dear Sirs
>
> Contract No. 64
>
> for ....
> I am pleased to inform you that my Council has resolved to accept your tender dated 4 January 1994 for the above contract. The contract will comprise the following documents:
>
> (1) Volumes 1 and 2 of the printed documents containing the Tender, Conditions of Contract, Specification, Schedules and Bills of Quantities all as completed by you.
> (2) Contract Drawings Nos 1–45.
> (3) Tender Amendments Nos 1–3 inclusive.
> (4) The following communications:
> (a) Your covering letter of 4 January 1994 with enclosures 1–5 inclusive;
> (b) Our letter to you of 10 January 1994;
> (c) Your letter of 12 January 1994;

(d) This letter of acceptance.

The amended tender total is £123,456.00 as set out on the attached sheet.

A formal Agreement is being prepared and I shall be glad if you will advise me when you can call in to sign it.

Please now produce your Performance Bond and evidence of insurances as required under the contract.

Yours faithfully

Clerk to the Authority

If an authority empowers its chief executive to accept a tender on its behalf, or a company allows its Director to accept a tender, the letter can be a direct acceptance. However, if the authority or company is employing a consulting engineer to correspond with tenderers, then the consulting engineer usually has no authority to accept a tender, so he can only advise a tenderer that the authority or company has decided to accept his tender in terms similar to the above, or perhaps in the form 'On behalf of the...' or 'I am instructed by the... Council to inform you that your tender is accepted' etc.

Where acceptance of a tender is not possible for some time, for example because it requires agreement from government or from some international funding agency, a **Letter of Intent** can be issued by the promoter. This states the promoter's intention to sign a contract, and may therefore request the contractor to start on some aspect of the work. The Letter of Intent must state what work can be started, and how and what payment will be made for such work should the contract not be signed. There will also be a clause that provides for the Letter of Intent to become void upon signing of the contract. The contractor has to respond accepting the terms of the Letter of Intent. Usually the matter is discussed beforehand, so that the terms of the Letter of Intent are agreed before it is written. However, a Letter of Intent can prove to be full of legal pitfalls should anything go wrong, so it is best avoided. It can be useful, however, for authorizing a plant supply contractor to start producing designs and drawings of equipment he is to supply: that is, work that saves time but involves no large financial commitment.

A tender needs to be accepted within a reasonable time of its submission, otherwise a contractor may have grounds for withdrawing it. Sometimes the promoter stipulates for how long tenders are to remain open for acceptance, or a tenderer may state this in his offer. A contractor is put in a difficult position when there is an unexpected delay in accepting his offer because, although he does not wish to lose a job, the delay can cause his costs to rise if prices are inflating, or work that he hoped to undertake in two summers and a winter is delayed to take place during two winters and a summer.

3.10 Bond and insurance

In contracts for the construction of major civil engineering works it is usual to require the contractor to obtain a bond or security warrant that he will perform his obligations and complete the works in the contract. Such a bond is provided by a bank or an insurance company, who guarantee payment of an agreed sum or up to a given sum, say 10 per cent of the total tender value, if the contractor defaults on the contract. Normally a contractor can only get such a bond by lodging with the bondsman (i.e. guarantor) shares or securities of equal value to the bond, which he may not cash or dispose of without the bondsman's consent. The bond is thus a powerful hold on the contractor and also provides evidence that the contractor has some financial standing.

There is, however, criticism that a bond is too onerous on a contractor. It locks up his capital, and the fee he has to pay for it may be high. Also, it is pointed out that there are other holds on the contractor, such as retention money withheld from interim payments, plant and equipment that the contractor brings to site, and the fact that payments for work tend to lag at least one month behind the work done. If tenderers have prequalified, or if a proposed contractor's financial standing is not in doubt, it may be possible to dispense with bond, but the promoter has to consider this carefully. The extra cost of providing a bond (reflected in the tender price) may be outweighed by the protection that it gives to the promoter, especially in long-term contracts where the contractor's position can vary with time. If the contractor fails to complete, and another contractor has to be brought in, the expense to the promoter is usually high.

Insurance by the contractor is vitally important, and evidence that it has been obtained must be procured. Most contracts require the contractor to insure the works as they are built and until they are taken over by the promoter. Damage to the works is not rare, as construction sites are difficult to protect; so the works insurance must be sufficiently well worded to include various types and causes, not only for damage through accident, fire, flood and theft, but also for malicious damage done by persons known or unknown. Third-party insurances are also required, to indemnify the promoter against claims arising from the contractor's operations; and, by law, employees' insurances will be needed to cover the workforce. Third-party insurance is the principal insurance covering accidents to persons and their property, whether such persons are on site (authorized to be on site or not) or off site, in any case where the contractor's operations are held to be the cause. Subsidence or damage to adjacent property may need to be insured, and subcontractors must also take out insurance. The variety of risks and the number of parties involved who can have overlapping responsibilities makes insurance a complex matter on which specialist advice should be taken.

Publications giving guidance on tendering

Guidance on the preparation, submission and consideration of tenders for civil engineering contracts. London: Institution of Civil Engineers, 1983.
Tendering Procedure: Procedure for obtaining and evaluating tenders for civil engineering contracts. FIDIC, 1982.
Standard prequalification form for contractors. FIDIC.
UK Statutory Instruments implementing EU Directives:
The Public Supply Contracts Regulations 1991 (SI 2679)
The Public Works Contracts Regulations 1991 (SI 2680)
The Utilities Supply and Works Contracts Regulations 1992 (SI 3279)
The Public Services Contracts Regulations 1993 (SI 3228)

Note

Revised regulations regarding Public Supplies, and Consolidated Regulations for Utilities covering Works Contracts and Services, are to be brought in during 1995.

4

The contractor's site organization

4.1 Key site personnel for contractor

The key personnel employed by a contractor on a civil engineering construction site are:

- the agent, who is in charge;
- sub-agents and/or section engineers;
- the plant manager or site coordinator;
- the general foreman;
- the office manager.

On small jobs there may only be the agent and a section or site engineer. On large jobs the agent may be served by several sub-agents, one of whom may be appointed deputy agent; while sections of the job will have a section engineer and section foreman in charge of each. Sub-agents are directly responsible to the agent. The plant manager or site coordinator services all sections of the job. In the head office of the contractor will be a contracts manager (sometimes a director of the firm) who is responsible for head office services to the job and who decides overall policy for it. He may advise on technical problems in the execution of the contract, but he does not direct its day to day execution. He may frequently visit the site but he is not full time on site.

The foregoing personnel are not always men; increasing numbers of professionally qualified women now take part in civil engineering construction as agents, sub-agents and site engineers, and there have been woman contractors, agents and engineers for many years. In the following material it must therefore be borne in mind that the duties described would also be undertaken by women.

A good contractor keeps his site staff to a minimum to aid swift, economic construction. In order to achieve this he must employ the right type of senior personnel on site, who must act responsibly and be given the freedom to act on their own initiative. They must have quick communication with one another, and their levels and areas of responsibility must be clearly defined: hence the less complex the organization is, the better it will function. The contractor cannot afford to tolerate ineffectiveness in any of the responsible positions. In the early stages of a job, changes in key site personnel may take place that may seem swift and ruthless to the outsider. However, this must be so, because the key staff have to work together as a team, and each must be reliable in his field of work.

4.2 The agent

The agent is responsible for directing and controlling the whole of the construction work on site, and he (or she) will have wide powers to employ men, hire machinery and equipment, purchase materials, and employ subcontractors. His powers to do this without reference to his head office will depend on the size of the job, its nature and distance from head office (particularly for overseas work), the policy adopted by his firm and, of course, his standing within the firm.

An agent must display a considerable number of talents. He must not only be knowledgeable in the civil engineering arts of construction, but must be able to command men and be a good organizer and administrator. Furthermore, he needs a sound business sense, because his job is not only to get the works built properly in accordance with the contract but also to make a profit for the contractor. He should therefore be tough, practical, experienced, fair-minded, and energetic. In a number of cases his training will have consisted mainly of experience gained through many years of life on site, but most agents are now also professionally qualified, having had an academic engineering education in their early years. A good agent is probably the most secure guarantee an employer can have that his works will be built well. The obverse of this is that, if an agent is incompetent, then not even the combined pressure of the resident engineer and his staff can guarantee to make every detail of the job as good as it should be.

Some firms give their most experienced agents virtually complete charge of a job, both financial and engineering. This more often happens with the medium-sized 'family firm' of contractors, whose agent has been with them for many years. In a large contracting organization the agent will be reliant upon a number of services provided to him by his head office. These may include ordering of materials and supply of plant and equipment, payment of invoices, and production of monthly applications for payment, and programming. If the job is technically complex, the agent will look to his head office to provide drawings for temporary works such as bridges, cofferdams, complicated formwork, and foundations for tower cranes. At the head office of the contractor there may be appointed a project engineer to give technical assistance that the job requires.

The agent will give verbal instructions to his sub-agents and general foreman on the execution of work. He will also visit all parts of his job most days. Only occasionally will he call a meeting of his key personnel if some problem has to be discussed. Mostly the problems will be ones of progress, collating operations so that best use is made of skilled men and plant, deciding the order and manner in which jobs will be tackled etc. When things go wrong – and this is a frequent occurrence – the agent has to be informed immediately because all information centralizes upon him, and he has to decide what changes to make. He must take most decisions speedily, otherwise men may be left standing idle with no instructions.

Troubles usually come in two categories: either some construction operation reveals unexpected difficulty, or there are problems with labour, plant, or materials. Whenever any of these happens, the plan of work for the day may have to be changed, requiring the agent to issue new instructions. The agent has to 'carry in his head' not only his short-term strategy for, say, the next two or three days, but his medium-term strategy of what operations must be completed within the next few weeks. As in a game of chess, present moves have to be decided in terms of some overall strategy, the moves having to be rethought whenever circumstances change – especially the weather.

4.3 Sub-agents and section engineers

On large jobs the agent may delegate most of his office work and the organizing of services and materials for the job to his deputy agent. This gives the agent more time to concentrate on his main jobs of planning the constructional work, organizing and exerting his influence over the men, and dealing with construction problems. He will not expect to waste his time on clerical work. He finds out what is wanted and tells others what to do. When he has sub-agents in charge of different parts of the works he will monitor them, and advise them on how to get out of problems. The section engineers or sub-agents may undertake their own measurements of work done; alternatively a quantity surveyor may be employed to do this. Thus sub-agents' jobs vary, being sometimes partly administrative in support of the agent, and sometimes in charge of all work in a section.

On the section engineers and assistant engineers rests the main responsibility for seeing that the works are constructed to the right lines and levels. Initially there will be considerable work to do in site levelling, and setting out the main grid lines for the project. There will then be much detailed setting-out work to do, as required by the foremen on the works. Many temporary works may have to be planned, designed and set out, such as temporary access roads, power lines, water supply lines, drainage, concrete foundations for the batching plant and cranes, and so on. In addition it is normally the job of the section engineer to record progress, and to keep progress charts up to date on the wall of the agent's office.

Often a section engineer will be given full responsibility for day-to-day control of the construction work in his part of the works, giving instructions directly to gangers or any foreman under his control. He will be required to liaise with the agent and plant manager or site coordinator for the organization of materials, labour and plant to his section, which must fit in with the needs of other parts of the job. On small sites, a section engineer may virtually act as sub-agent as well, the two jobs merging into one when the job is not large enough to justify having both. Some firms expect their assistant engineers to take an active part in the executive control of the work so that they gain experience and training to become agents.

4.4 The plant manager or site coordinator

For sites in the UK and other developed countries there now exists a highly competitive plant hire industry, so that much of the plant used on site is hired and kept in maintenance by the hirer. Thus the previous role of the plant manager has tended to change into that of the site coordinator who keeps in contact with the needs of the section engineers and arranges plant hire, the flow of materials to site, and other matters. The introduction of portable radios and radio telephones has meant that changes can be organized rapidly according to changing circumstances on the site.

On remote or overseas construction sites a plant manager is often required, usually separately designated even on a small job. His job is to service and maintain plant in good condition and to have it available as required by the construction programme laid down by the agent. He needs to be kept advised of the agent's short- and long-term plans. Assisting him will be fitters and welders, and it will often be his job to maintain power supplies to the site including all electrical and heating supplies to the site offices. He often has to arrange for maintenance and repair work to be carried out by overtime or at weekends, to keep plant working productively. Maintenance is important because it can extend the working life of plant, thus reducing the contractor's costs (if he owns the plant). Also, plant breakdowns in the middle of an operation can severely disrupt progress and cause frustration and irritation among the men.

4.5 The general foreman

Changes in working practices and increased specialization have, over the years, eroded the role of the traditional general foreman. He still exists, usually with the smaller civil engineering firm. He then forms the agent's right-hand man for the execution of the work in the field, his explicit duty being to keep the work moving ahead daily as the agent has planned it. In the past he had much authority on site, and any junior engineer who got at cross-purposes with him could find his days on site numbered.

An experienced general foremen is often an astonishingly capable man, contributing most to changing a job from drawings of it to the real thing. Despite a lack of academic training, he would have an extensive knowledge of a wide range of crafts, and an instinctive feeling for the behaviour of soils and rocks that could unerringly lead him to judge that some foundation or fill material was 'no good' as soon as it was exposed, long before the resident engineer's tests proved it so. He would have a knowledge of what machines could do, and the basic principles of surveying and levelling. He was an all-round craftsman in the art of civil engineering construction, and many of the great constructions of the past owe their quality to the general foreman who took charge of their construction. Where he still exists, the professional engineer has much to learn from him and, if he is of the old-style type, he is one of the best guarantees that the work done on the job will be satisfactory.

However, as described in Section 4.10 below, more and more constructional work is nowadays undertaken by specialist firms acting as subcontractors or labour-only gangs to carry out specific trade work. These are self-organizing groups of workers under their own foreman or gang leader, so the contractor's sub-agent or section engineer may need to monitor them only as to the results they produce. However, the leaders of such subcontractors or gangs may, within their sphere, exhibit some of the same abilities as used to be exercised by the general foreman. With this increase of subcontracting and greater use of constructional plant, the role of the general foreman who used to take charge of all the work has diminished, but he still remains in existence as a key person on many sites.

4.6 The office manager and his staff

For large sites or when local labour is employed directly, there will usually be a need for an office manager in the contractor's site office. He keeps the clerical work going for the agent, sub-agent and section engineers. Where labour is taken on locally he will have to make up the paysheets and arrange for payment of the men. Through him may be ordered and organized all the miscellaneous requirements for the job: the 'consumables' such as picks and shovels, protective clothing, and small tools, minor repairs, fuel deliveries, electricity supplies and telephone. He will be in control of storekeepers, messengers, teaboys, staff car drivers and night watchmen. If he handles a considerable amount of cash there will probably be auditing checks of his work carried out by an accountant from the contractor's head office from time to time. On small projects he may order materials for the construction, as instructed by the agent, so will have to deal with the invoices for such materials, checking invoices against materials delivered, signing and sending them to head office for payment.

4.7 Skilled tradesmen and labourers

The skilled men include reinforcement fixers, steel erectors, concretors, formwork carpenters, bricklayers, pipe jointers, crane and machine operators, miners, and other trade specialists. Formerly, civil engineering contractors would have a small nucleus of experienced tradesmen in their permanent employment, and would place them as section foremen, getting additional tradesmen through the local employment office, or advertising for them. General labourers would be obtained from local sources. Quite often travelling gangs of formwork carpenters, steel erectors or reinforcement fixers would be taken on. Tunnelling work was almost always undertaken by an experienced gang under a leader, because the nature of tunnelling work demands close teamwork. Once a gang proved its worth, an agent would endeavour to use the same gang on his next job if he had similar work for them to do. Such gangs of tunnellers, formwork carpenters or steel fixers would be employed as a whole, so that if a dispute arose with the agent about pay or conditions and the agent would not meet their terms, they would leave *en bloc*, bringing the job to a standstill.

The problems of taking on staff at the job as described above, in which the contractor had to use such labour as was available, often of variable quality, led to different methods of staffing construction sites. Employment agencies grew up that could supply staff in various trades, giving an advantage to both the contractor and the men. To be successful an agency had to offer competent staff, and a competent tradesman registered with an agency was assisted in finding continuity of work. Groups of men could form gangs, offering to act as labour-only subcontractors for such jobs as fixing reinforcement; or they could widen their service by offering to supply as well as fix reinforcement. Thus subcontracting grew because it gave advantages to both parties; but at the same time it brought some new problems, which are discussed in more detail in Section 4.10 below.

There is still, of course, a need for some semi-skilled and unskilled workers on site. Although machines of a wide variety are now used on construction sites, semi-skilled labour is required for assisting in setting steel reinforcement and formwork, trimming formations, timbering excavations, compacting concrete etc. The occasional hand excavation is still required, and is skilled work, as any engineer will notice when he sees it done neatly and efficiently. Overseas in the less developed countries much manual labour is still used, not only because of low rates of pay and the cost or difficulty of getting machinery, but because it is the traditional way of undertaking construction, which suits the local economy and workpeople. In some countries women are widely used to undertake manual labour. If machines are brought in to do most of the work, this can deprive the local economy of a benefit: hence even the international contractor may use a considerable amount of local unskilled labour for his constructions overseas.

4.8 Accounting methods

While the agent may have wide authority on site, the large sums of money that he commits his firm to spending must come under the control of the contractor's head office. A normal procedure is to require the agent to make all major purchases by means of requests he puts in to his head office. For supply of materials in regular use a head office buyer may set up standard agreements with local suppliers within given areas. This system can only work sensibly, of course, if both head office and the site are in the same country. Otherwise the agent must decide from whom he wishes to obtain various materials, after getting alternative quotations from suppliers. The actual order to the supplier is then issued from the contractor's head office in response to a requisition from the agent stating all the details of the order. In this manner the agent does not have to handle payments himself. The materials clerk checks the supplier's invoice against the original order and the materials received sheets, forwarding the invoice to head office for payment.

The agent will nevertheless need to keep some cash locally, in a local bank account, for payments necessary in cash, such as for petrol for vehicles, a variety of consumables and for the wages of casual labour. Where payments are made direct to locally recruited staff, paysheets will have to be made up by the pay clerk on site. The basis of the paysheets are the time sheets sent in to the office manager by the men on site, the section foremen or gangers certifying the timesheets of men working under them. From time to time an accountant from head office will visit the site to audit the local paysheets and cash disbursements by the agent. On the larger sites a site accountant will be appointed.

The monthly returns of local expenditure sent by the agent to head office are added to head office payments to give the total expenditure on the job to date. Head office should keep the agent informed of this figure. More difficult is an assessment of the expenditure commitment on the job to date which includes the cost of materials, services, labour etc. ordered but not yet paid for. Cost accountants in head office may deal with this, but usually they analyse only recorded expenditure, which is not the same as the financial commitment. Hence a prudent agent may keep such an assessment going himself because of the importance to him of controlling the overall expenditure on the job to ensure a satisfactory final outcome to the contract. On overseas projects the large sums of money that have to be expended locally mean that a fully staffed accountant's office, under the charge of an experienced site accountant, will need to be set up.

Quantity surveyors to deal with measurement and the submission of monthly applications for payment are commonly employed by a contractor. These QSs, as they are widely called, may be based in head office visiting site, or they may be full time on site. To them the sub-agents or section engineers submit their monthly measurements and the QSs then make up the monthly statement, including – as all resident engineers know – the contractor's claims for extra payment. However, quantity surveyors are not always employed to do this work, as civil engineering quantities differ from building quantities (*see* Chapter 10), so the small contractor may use his engineers for this task or do it himself.

4.9 Providing constructional plant and equipment

It is usual for a contracting firm to have a plant depot at which is kept plant that the contractor owns, such as cranes, excavators, compressors and concrete mixers, and also many items of equipment, both major and minor, that have come back from individual jobs. The cost of running this depot, including major refurbishments of plant, will normally form a separate account within the contractor's accounting system. Sometimes a separate company may be set up to own and hire out this plant to jobs, the company being wholly owned by the contractor. Before the agent goes to site he will have agreed with the depot what plant and equipment is to be sent to his site.

The rates of charge to a job for such 'internal' hire of plant from the depot will normally be calculated to give enough return to the plant organization to cover plant depreciation, maintenance including major overhauls, administration costs and possibly some element of profit or return on investment. The cost of working repairs to plant is high, representing some 25 per cent or more of the normal commercial outside hire rate. The frequency of repairs is particularly high for mobile plant, where tracks may need frequent attention, and tyres may need renewal at high cost every few months. Wire ropes for cranes need constant renewal, and a stock of same has to be kept on site.

The rates for internal hire of plant to a job may be set high enough for a profit to be shown on the capital outlay: this profit, of course, goes back to the contractor. There is no actual cash transfer, but the head office accounts for a job will be debited with the hire cost of plant sent to the job, and also the cost of its transport to and from the job. In a typical arrangement the cost of plant hired would be debited weekly in accordance with a weekly return from the agent showing the plant he has on site, and the amount of time it has been worked. Rates of internal hire can vary according to the practice of the contractor. They can be low to provide a 'tax loss' or encourage agents to make use of the contractor's own plant; or high to return a profit and to prevent agents from 'hanging on' to plant in case they might need it. The site fitters are expected to carry out normal routine maintenance, the plant foreman or manager having to order spare parts required, which are then charged to the job. Major overhauls would be undertaken at the plant depot or at the maker's works and not charged to the job.

Depending on the contractor's strategy, the agent may also be permitted to hire plant from elsewhere: this will probably be necessary for some plant, as it is not economic for the contractor to buy enough plant to meet the maximum needs of all his jobs at one time. The advantage of outside hire is that an experienced driver may be hired with the plant, and the hirer will undertake all maintenance and running repairs from a local depot. The transport costs to site for hired plant may also be lower than that sent from the contractor's more distant depot. Sometimes a contractor may subcontract the work of excavation to an excavation subcontractor if there is a large amount to do. The subcontractor will provide all plant and drivers required and work to a fixed lump sum or unit rates for the measure of work done.

4.10 The contractor's use of subcontractors

Many civil engineering contractors now use subcontractors to do much of their work. Most conditions of contract permit a contractor to sublet work of a specialist nature; but the ICE Conditions of Contract have gone further and permit the contractor to subcontract any part of the work (but not the whole of the work), subject only to notifying the engineer of the work subcontracted and the name of the subcontractor appointed to undertake it. The contractor does not have to notify any labour-only subcontracts. The engineer has no rights in connection with such subcontracts except that he can require removal of a subcontractor who proves incompetent or negligent, or does not conform to safety requirements. Under FIDIC conditions for overseas work, subcontracting requires the engineer's prior sanction.

In building work there has long been a trend to pass the majority of work to specialists in the various trades, and the same has now occurred in civil engineering, where many operations are 'packaged up' and sublet. Thus excavation may be undertaken by an excavation subcontractor, formwork and reinforcement supplied and erected by others, and concreting undertaken by a fourth. The advantage to the contractor is that this reduces his staff and his capital outlay on plant and equipment; he can use subcontractors with proven experience and does not have to take on a range of temporary labour whose quality may be variable. The contractor retains responsibility for the quality and correctness of work and, of course, has to plan and coordinate the subcontract inputs required, together with supplying any necessary materials. As a consequence the contractor's main input to a project may be that of administering the subcontracts and controlling their financial outcome, so these tend to take priority over his management of the engineering problems that arise. Indeed there can be a tendency for the contractor to leave a subcontractor to solve any problems because they are seen as his risks under the subcontract. This can lead to exaggeration of difficulties as the various parties try to protect themselves against being responsible for any extra costs or delay.

As has been experienced widely in recent years, any default or presumed default by a subcontractor may result in the contractor withholding payment to him, giving rise to a dispute between them as to who is responsible. Late payment by contractors to subcontractors is a widespread source of complaint by subcontractors, but remedies are difficult to devise. The subcontracts are private contracts, whose terms are unknown to the engineer, so there is no power that he could be given to interfere in them. The engineer has only power to protect nominated subcontractors: that is, subcontractors he directs the contractor to use (*see* Section 10.8).

Suggestions have been made that a subcontractor should be entitled to interest on late payment by a contractor, but a subcontractor may not ask for interest if he fears that doing so might result in the contractor not giving him further work. The Latham Report (*see* Section 2.5) has no direct solution to the problem; its Recommendation 25 proposes that 'Standard Forms' of contract and subcontract should be recommended for use that contain a clause giving subcontractors the right of interest on late payments, deletion of this provision being designated as an 'unfair or invalid' practice under a proposed Construction Contracts Bill to be put before Parliament. Even if this proposal were adopted it might not be effective for the same reason as stated above.

The ICE has issued a Form of Subcontract 'designed for use in conjunction with the ICE General Conditions of Contract'. A contractor is, of course, not obliged to use this form but may use one of his own devising. However, the provisions of the ICE subcontract illustrate the many matters that such a subcontract has to cover. Apart from defining the work and the timing and duration of the subcontractor's input, the subcontract has to set out the division of risks as between contractor and subcontractor. The subcontract therefore defines procedures and methods of valuing variations made by the engineer or the contractor; sets out procedures for notification and payment for 'unforeseen conditions'; and stipulates requirements for insurances and so on. Many of the provisions are the same as the ICE conditions applying to the contractor, and are thus passed on to the subcontractor in respect of his work. The subcontractor is 'deemed to have full knowledge of the provisions of the main contract' and the contractor must give him a copy of it (without the prices) if the subcontractor requests it.

Of particular importance is Clause 3 of the ICE subcontract, which requires the subcontractor to indemnify the contractor 'against all claims, demands, proceedings, damages, costs and expenses made against or incurred by the contractor by reason of any breach by the subcontractor of the subcontract'. A subcontractor may find this clause unacceptable if the value of his subcontract is small and the indemnity has to cover tens of thousands of pounds because, for instance, his failure to complete some minor work or supply some goods on time could delay the whole job.

Neither the employer nor engineer has any rights or authority concerning a dispute between a contractor and his subcontractor. This sometimes results in defects in the work remaining unattended to while the contractor and subcontractor dispute who is responsible for them. Also, if a defect is found after a subcontractor has left site and he is believed or known to be responsible for it, the contractor may have difficulty in getting the subcontractor back to site to remedy it, or to pay for its repair. The contractor may therefore hold back full payment to the subcontractor for many months until a certificate of completion for the works is issued; this can be another occasion for dispute between contractor and subcontractor. The development of subcontracting in civil engineering has therefore brought both advantages and disadvantages. However, if the contractor is able to use subcontractors that he has worked with before and whose work he knows by past experience is satisfactory, it is not necessarily the case that any problems will arise.

4.11 Safety requirements

The **Health and Safety at Work etc. Act 1974** places a statutory obligation on all employers to safeguard their employees and all other persons affected by their operations. On a site the main obligation to comply lies on the contractor; but the employer and engineer are also responsible for the safety of their staffs and all persons they permit to visit the site. The Act incorporates and therefore continues to inforce previous safety acts, of which four sets of Regulations issued under the Factories Act 1961 comprise the principal general legislation applying specifically to construction sites. Only a brief resume can be given of their most widely applicable provisions.

Under the **Construction (General Provisions) Regulations 1961**, any contractor having more than twenty men employed on construction work must appoint an experienced person to act as Safety Supervisor on the site, charged with the duty of seeing that all safety regulations are met. His name must be entered on a copy of the Regulations (or official abstract thereof) which is exhibited on site, together with the telephone numbers of all local emergency services. The contractor is responsible for the safety of his employees and all other persons on site, such as subcontractors' staffs and visitors.

Daily inspections of excavations are required, and before every shift in the case of tunnels, working ends of trenches over 2 m deep, and the base of shafts. 'Thorough examinations' of excavations, tunnels, cofferdams or caissons must be conducted within 7 days prior to men starting work in them, and thereafter every 7 days and also after any fall of material, damage to supports etc. These thorough examinations must be conducted by a 'competent person' (that is, one experienced enough), who must file a written report in the prescribed form on the day of his examination. If the operation lasts less than 6 weeks, the examination can be made by the person in charge and his reports may be made weekly. Support is required to all excavations and earthworks where material is liable to fall more than 1.2 m so as to entrap or strike a person. Excavations more than 2 m deep must be fenced.

All excavations and enclosed or confined spaces in which men are to be employed must be adequately ventilated. No person is allowed to enter such space until the atmosphere has been tested by a competent person who is satisfied that no danger exists of a person being overcome by a toxic gas or lack of oxygen (*see* Section 5.8 for further details).

The **Construction (Lifting Operations) Regulations 1961** call for daily inspections of cranes, hoists etc., and thorough examinations and/or tests of such plant after erection or alteration, and at prescribed time intervals thereafter. Reports and certificates of thorough examination or test have to be produced in the prescribed form.

The **Construction (Working Places) Regulations 1966** primarily cover scaffolding, ladders, gangways etc. They are quite detailed. Scaffolding must be inspected within 7 days prior to use and weekly thereafter, written reports of these being put in a Scaffolding Register held on site. Ladders must be tied at the top, extend 1 m above the topmost landing, and be tied against swaying. Gangways must have 0.64 m minimum width for access only, 0.87 m if used also for stacking of materials. Guard rails and toe boards must be provided where a gangway is more than 2 m above ground.

The **Construction (Health and Welfare) Regulations 1966** set out requirements for first aid, shelters, washing and sanitary arrangements, the provisions varying with the number of men on site.

The wearing of hard hats became compulsory on most UK construction sites under the **Construction (Head Protection) Regulations 1989**. Hats to BS 5240 are taken to comply.

The **Personal Protective Equipment at Work Regulations 1992** came into force on 1 January 1993 and require employers to provide such equipment (e.g. safety harness etc.) to their employees and train them in their use. The regulations also apply to self-employed persons.

The Health and Safety Executive (HSE) employs inspectors who visit sites in the UK to examine safety measures taken by contractors. They have power to prohibit work on an operation until a statutory safety requirement is met. Under the **Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1985**, the contractor must report to the HSE any accident causing death or injury causing incapacity for more than 3 days, or which comprises a 'dangerous occurrence' on site, such as collapse of crane, explosion, etc.

4.12 New safety regulations

The **Construction (Design and Management) Regulations 1994** came into force on 31 March 1995 in response to EU Directive 92/57/EEC. They are often referred to as the 'CDM' or 'CONDAM' regulations. Their aim is to promote effective health and safety measures by placing certain duties on the client (i.e. promoter), designers and contractors involved in a project. The Health and Safety Executive (HSE) administers and enforces the regulations. The following are the principal requirements.

- The client has to appoint a planning supervisor and name the principal contractor and be reasonably satisfied that they, and also the designers, have adequate resources and competence to carry out their duties (Regs 6, 8, 9). He must provide the planning supervisor with any relevant information (Reg. 11) and ensure that information in any health and safety file delivered to him (see below) is kept available for inspection by persons needing to comply therewith (Reg. 12). The planning supervisor and principal contractor can be the same person, or the client himself can act as either or both (Reg. 6(6)).
- The planning supervisor has to notify the HSE of the intended project (Reg. 7) and ensure that a health and safety plan is prepared in respect of the project (Reg. 15(1)). He has to ensure that the designers pay adequate regard to health and safety matters (Reg. 14(a)(b)) and advise on the competence and adequacy of resources of designers and contractors (Reg. 14(c)). He ensures that a health and safety file is prepared for each structure (Reg. 14(d)), which includes relevant safety information and is kept up to date with any changes during construction (Reg. 14(e)). He must hand the file to the client on completion of the construction (Reg.14(f)).
- The designers have to ensure that any design 'includes among the design considerations adequate regard to the need (i) to avoid foreseeable risks' to health and safety; (ii) to 'combat at source [such] risks'; and (iii) to 'give priority to measures which will protect all persons carrying out construction work or

cleaning work at any time and all persons who may be affected by the work of such persons' (Reg. 13(2)(a)). Designers must also ensure that the design includes 'adequate information about any aspect of the project or structure or materials (including articles or substances) which might affect the health or safety of any person' (Reg. 13(2)(b)). The foregoing requirements are to be met 'to the extent that it is reasonable to expect the designer to address them at the time the design is prepared and to the extent that it is otherwise reasonably practicable to do so' (Reg. 13(3)).

- The principal contractor is required to comply with the health and safety plan and augment its provisions as necessary during construction (Regs 15(4) and 16(1)(e)). As principal contractor he has to coordinate the activities of all other contractors and subcontractors on the site and see that they comply with the health and safety plan (Regs 16 and 17). He must permit employees and self-employed persons to discuss and advise him on health or safety matters (Reg. 18). All contractors must comply with rules in the health and safety plan, and employers and self-employed persons must be informed of the contents of the plan or such part of it as is relevant to their work (Reg. 19).

Notifiable projects to which all the regulations apply are those where construction 'will be longer than 30 days or will involve more than 500 person days of construction work' (Reg. 2(4)). For 'domestic' work except demolition or housing estate development work (Regs 3(8) and 3(3)) and work involving less than five construction workers at any one time (Reg. 3(2)), the design requirements (13) only apply. 'Domestic' work is defined as work not carried out in connection with a client's trade, business or other undertaking (Reg. 2).

The hope is that the new regulations will promote better safety in construction. The production of a safety plan specifically required to identify risks should assist in this. But the designers' responsibilities for safety are unclear, as it may be difficult to decide how far designs must be modified to reduce hazards if this involves extra cost. Also, both the designers and the planning supervisor have responsibility for ensuring that any design pays 'adequate regard' to the need for health and safety measures (Regs 13(2) and 14(a)), so the question can arise as to who decides what measures are adequate. An Approved Code of Practice issued by the Health & Safety Executive endeavours to clarify these matters (see Further reading) and should be consulted.

The aim of widening responsibility for safe construction is laudable, as those who are in a position to reduce risks to health and safety can be considered as having some degree of responsibility for doing so. However, a person who suffers an accident may find increased difficulty in gaining compensation for his injuries because three parties share the responsibility for safety, and this may lead to increased litigation. One good consequence is that clients (i.e. employers) are checking the safety records and procedures of contractors before permitting them to tender. This will encourage all contractors to attain good standards of safety and safety training: a practice that many contractors of repute already follow. But a simple historical record of accidents is not necessarily a fair indication of a contractor's attention to safety, because of the wide variety of causes of accidents.

Many other Acts and Regulations remain in force relating to particular aspects of construction work: for example, the Mines and Quarries Act 1954; Work in Compressed Air Special Regulations 1958; and Diving Operations at Work Regulations 1961. The Health and Safety Executive (HSE) set up under the 1974 Act issues guidance booklets and Codes of Practice. These, together with other codes of practice issued by the British Standards Institution and other organizations, constitute a large body of safety advice, which needs to be followed. Listed below are some general guides, and some of the regulations or codes especially relevant to construction work.

Further reading

Health & Safety Executive publications (HSE Information Centre, Broad Lane, Sheffield S3 7HQ, UK)

Safety in construction work:

General site safety;

Excavations;

Scaffolding;

Demolitions.

Managing Construction for Health and Safety: Approved Code of Practice under the Construction (Design and Management) Regulations 1994.

Design for health and safety in construction.

A guide to managing health and safety in construction.

Health and safety for small construction firms.

Construction safety. Building Employers Confederation (formerly National Federation of Building Trade Employers).

Construction regulations handbook. Royal Society for Prevention of Accidents, The Priory, Queensway, Birmingham B4 6BS, 1982.

Regulations:

Health and Safety (First Aid) Regulations 1981;

Notification of Accidents and Dangerous Occurrences Regulations 1980;

Work in Compressed Air Special Regulations 1958 and 1960;

The Management of Health and Safety at Work Regulations 1992.

British Standard Codes of Practice:

CP 5531: 1988 *Safety in erecting structural frames;*

CP 5573: 1978 *Safety precautions in the construction of large diameter boreholes for piling and other purposes;*

CP 5607: 1988 *Safe use of explosives in the construction industry;*

CP 5974: 1990 *Temporarily installed suspended scaffolds and access equipment;*

CP 5975: 1982 *Falsework;*

CP 6031: 1981 *Earthworks;*

CP 6164: 1990 *Safety in tunnelling in the construction industry;*

CP 6187: 1982 *Demolition;*

CP 7121: 1989 *Safe use of cranes;*
CP 7212: 1989 *Safe use of construction hoists.*

Institution of Civil Engineers publications:
Safety in wells and boreholes;
Safety guide for men working in sewers or at sewage disposal works.

5

The engineer and his staff

5.1 The engineer's responsibilities for construction

The engineer under the ICE Conditions is employed by the employer, but is required to 'act impartially within the terms of the contract having regard to all the circumstances' (Clause 2(8)). The parties to the contract can thus look to the engineer to carry out the administrative duties required under the contract fairly, and to make the decisions that are necessary to allow the works to proceed to completion. The parties reserve to themselves, however, the right to challenge any opinions or decisions of the engineer should they so wish by taking the disputed matter to a conciliation procedure or arbitration for settlement.

As the parties have agreed that the engineer shall administer the contract, the employer cannot issue an instruction direct to the contractor; he can only request the engineer to do so. If the engineer has no power to issue the instruction, or thinks its issue would amount to an unfair administration of the contract, then the employer's request is a matter for him to negotiate with the contractor outside the terms of the contract. Occasions of this are relatively rare but, as an example, if the employer wants the contractor to stop working for a day so that he can bring a party of visitors on site to view the construction, he has to seek the contractor's agreement to this because the engineer usually has no power to order this.

The duties set out under the contract are extensive, and the engineer will find himself involved in depth in many aspects of the construction process: reviewing the quality of work, deciding liability in matters claimed, or assessing values of work done. Under the 6th Edition of the ICE Conditions the engineer's particular duties include the following:

- Clause 5: explaining any ambiguity in the contract documents;
- Clause 7: issuing any further drawings or details needed for construction;
- Clause 12: confirming or deciding on any actions to overcome unforeseen ground conditions should these be encountered;

- Clause 13: ensuring that the works are constructed in accordance with the contract;
- Clause 14: checking that the contractor's programme and his methods of constructing the works comply with any set needs and allow the work to be finished without harm to the permanent structures;
- Clause 36: testing or witnessing tests on materials either during manufacture or on the site, and (Clause 38) examining any work such as foundations which become covered as part of the construction;
- Clause 41: fixing the date for commencement of the work, and (Clause 40) ordering suspension of the work or part of it if this proves necessary;
- Clause 44: determining any extensions to the time allowed for completion of the works, and (Clause 48) certifying when completion has been achieved;
- Clause 51: ordering and (Clause 52) valuing variations to the works;
- Clause 52(4): keeping records of facts relating to any claims made by the contractor and deciding the amount, if any, of extra payments due as a result;
- Clauses 55–57: measuring and valuing the works constructed;
- Clause 60: considering the amounts of interim and final payments to the contractor and certifying those amounts as are in his opinion due;
- Clause 66: giving his decision on any disputes specifically referred to him; such decisions being subject to arbitration if not accepted by the parties.

In carrying out his duties the engineer will normally have assistants, both in his head office to provide services to the project and present matters to him for decision, and staff on the construction site to act as his eyes and ears and to record facts as construction progresses. The leader of his staff on site will normally be termed 'the Resident Engineer', whose duties and those of his staff are discussed later.

5.2 Limitations on the powers of the engineer

Under the ICE Conditions the engineer can only instruct a variation of the works that is 'in his opinion necessary for the completion of the works', or 'desirable for the completion and/or improved functioning of the works'. Thus the engineer cannot order matters that are, for instance, extraneous to the works or which add entirely new items; these are matters that the engineer must to refer to the employer, who will need to negotiate with the contractor his agreement to undertake the addition (*see* Section 12.3).

Although the engineer is given a wide range of duties and powers, he does not use them without reference to the parties to the contract, either of whom may wish to state his view on matters that the engineer is called upon to decide. The FIDIC Conditions, for instance (*see* Section 2.2), specifically call for such consultation by the engineer as part of the procedure that he must adopt before arriving at his decision.

If it becomes evident that the estimated final cost of the contract is approaching or is likely to exceed the contract sum, the engineer must forewarn the employer. The employer, such as a government or local government authority, may have no authority to spend more than the contract sum, or may need to go through a lengthy procedure to obtain sanction for any excess expenditure. In these circumstances the employer may need to negotiate with the contractor postponement or deletion of part of the works, and he may instruct the engineer not to issue any further variation orders involving extra cost without the employer's agreement.

If, on embarking on some contract for construction, the employer wishes to restrict the engineer's powers that would otherwise be exercisable under the conditions of contract, the specific powers that the employer reserves for himself must be stated in the contract documents issued to tenderers. Both the ICE Conditions Clause 2(1)(b) and the FIDIC 4th Edition Conditions require this. However, if the employer reserves too many powers for himself this could affect the basis of contract and reduce the benefit of having an independent engineer to administer it. The employer could find himself involved in many day-to-day decisions, and might become the effective administrator of the contract. This could result in tenderers taking a different attitude towards the contract, as a tenderer may only offer his lowest price if he is confident that an independent engineer will administer the contract.

However, an employer may sometimes wish to ensure that he is involved in or gives consent to proposals to vary the works that result in additional expenditure above some given limit, or which alter significantly some aspect of the structure or plant being provided. In practice, such restrictions are unlikely to detract from the engineer's independent position. The larger expenditures under variation orders usually arise from unforeseen conditions, which the engineer should in any case report to the employer, or from alterations or additions made by the employer himself. The engineer should, in any case, report regularly to the employer on the progress of the contract and any problems arising in order that the employer can submit his observations thereon, which the engineer must take into account when making his decisions.

5.3 The engineer's design responsibilities

Under the ICE Conditions the engineer has a duty to provide the contractor with the drawings and further instructions needed to carry out the works. This does not necessarily mean that the engineer is himself the designer; but if he is not, he may have less control over the production of this information, with a greater chance of delays and confusion arising. The engineer and, in particular, his resident engineer will thus need to keep a constant check on the progress of the work and liaise with the contractor and the designers to ensure that all information required is to hand in good time.

The drawings initially produced to accompany the traditional form of contract must be sufficient to allow tenderers to understand what has to be built, but they may not show every detail. The further details will have to be supplied as necessary by the engineer. The contractor will also need to produce further details to give his workmen directions, such as the arrangements for formwork and other temporary constructions. Where certain permanent works are to be designed by the contractor, then his drawings and design calculations need to be submitted to the engineer for approval, to ensure that they are suitable and adequate to produce the specified ends. Time must be allowed for this process, including time for adoption of any amendments that the engineer considers necessary.

Although the main aim of the designer will be to produce a structure that performs the intentions of the project, he will also need to bear in mind the manner in which it is to be built and the risks involved in building it that should be avoided or minimized wherever possible. By appropriate design it may be possible, for example, to avoid trenches of excessive depth and unsuitable lengths of reinforcement bars that would make access for concreting unnecessarily awkward. Safety in construction is a matter that, in the past, has often been seen as solely the responsibility of the contractor, but the CDM Regulations (*see* Sections 4.12 and 5.8) will make it a duty of the designer to take such matters into account in his designs, and to draw the attention of the contractor to any unusual details or methods of construction needed.

Once drawings have been passed to the site, the resident engineer will have to review them to check that they contain adequate information for the contractor to proceed, and to ensure that they remain suitable for the conditions actually exposed on the site. If further information is needed, the resident engineer may be able to provide this by his own site instructions, which clarify details or make minor variations, but he must ensure that any intended variation of importance is referred to the designer via the engineer for approval. In most projects, the consulting engineer who designed the works is also appointed the engineer for the construction. This has the advantage of maintaining consistency of approach throughout design and construction. If the resident engineer is appointed from the consultant's staff and has been involved in the design, or has been properly briefed on the design concepts, he will be able to draw the attention of the engineer to any site conditions that may adversely affect the permanent works as designed, or to any of the contractor's proposed methods of construction that may alter some design assumption.

In some cases overseas, however, it is the practice to consider construction an entirely separate matter from design. As a consequence the engineer or other person in charge of the construction may have had nothing to do with the design and has no guidance other than the drawings and specification supplied. This approach may not prove satisfactory if constructional difficulties are encountered or variations prove necessary, as the drawings and specification define only the works required and not the basis of their design. For some types of structure, such as dams, where the design for safety and durability is dependent upon the nature of the ground or materials revealed during construction, a responsible engineer or firm of consultants would not be prepared to undertake the design without also having rights to supervise construction.

5.4 The position held by the resident engineer

Although the engineer cannot relieve himself of the responsibility for administering the contract for construction, he can employ others to do part of the work for him, but he remains responsible for their actions. The ICE Conditions permit the appointment of an 'Engineer's representative' on site – commonly known as the **resident engineer** – to 'watch and supervise the construction and completion of the Works' (Clause 2(3)). The engineer can delegate to the resident engineer 'any of the duties and authorities vested in the Engineer' (Clause 2(4)) with certain exceptions, which are dealt with in Section 5.5 below.

The resident engineer therefore has to act at all times under the direction of the engineer, exercising only the powers delegated to him, and ensuring that he acts impartially as the engineer is required to act. He must remember that his actions may have consequential effects on the responsibilities and obligations of the engineer, and therefore in all cases of doubt as to the correctness of a proposed action he should first report to the engineer. He may make suggestions to the engineer, pointing out difficulties and advising on their overcoming. He is the professional engineer on the spot, able by his close connection with the work to anticipate site conditions and see when trouble is coming and report to and forewarn the engineer accordingly. It is not his job to take upon himself responsibilities and decisions that properly lie with the engineer. These obligations of the resident engineer apply even if, as happens occasionally, his salary is paid by the employer or he is a member of the employer's staff seconded to act as resident engineer on some new works. His authority derives from the engineer and his obligations lie solely to act on behalf of the engineer.

5.5 Powers and duties of the resident engineer

Under the ICE Conditions of Contract the name of the person appointed as resident engineer (that is, the Engineer's Representative on site) must be notified to the contractor (Clause 2(3)). Where the engineer authorizes the resident engineer to act on his behalf in regard to certain matters, they must be stated in writing and copied to the contractor (Clause 2(4)). The powers that the ICE Conditions do *not* permit the engineer to delegate to his resident engineer are:

- payment or extension of time for adverse physical conditions or artificial obstructions (i.e. Clause 12 claims);
- extensions of time for completion;
- agreements to accelerated working;
- issue of substantial completion certificates, defects correction certificate and final certificate for payment;
- notice that the contractor has abandoned or appears unable to complete the contract;
- issue of Notice of Dispute and the Engineer's Decision prior to conciliation or arbitration.

In addition it is often the case that the engineer does not delegate to a resident engineer in the UK power to:

- value variations or authorize payment for extra or altered work or for delay;
- issue interim payment certificates;
- approve the contractor's programme for construction.

The main purpose of the last three exclusions is to permit the engineer to check the validity of proposed extras on the contract and the rates or amounts paid for them. This checking would normally be done by the engineer's staff who also check the calculation of the interim payment certificates. However, if the site of construction is overseas the resident engineer may also be given powers to issue variation orders and interim payment certificates. In this case the resident engineer would normally have appropriate staff on site, so that variation orders and certificates of payment can go through a two-stage checking procedure before issue. The FIDIC conditions for overseas construction do not restrict the powers that the engineer can delegate to the resident engineer (*see* Section 2.2).

The usual powers and duties delegated to the resident engineer may contain most or all of the following:

- agreeing details of methods of construction; checking that appropriate instructions are given and any information required by the contractor is supplied in good time;
- ensuring that all materials and items to be supplied by the employer under other contracts which are to be incorporated in the works are ordered in good time;
- checking that materials and workmanship are satisfactory and as specified; issuing instructions for remedying faults therein;
- checking lines, levels, layout etc. of the works to ensure conformity with the drawings;
- issuing further instructions, drawings and clarifications of detail as are necessary to ensure satisfactory construction of the works;
- measuring the amount of work done, checking the contractor's interim statements and preparing them for submission to the engineer;
- undertaking all tests required and keeping records thereof;
- recording progress in detail; keeping a check on the estimated final total cost of the project;
- examining all claims from the contractor, preparing data relevant to such claims, sending to the contractor an initial response to every such claim;
- reviewing dayworks sheets, increases of prices, and all other matters requiring accountancy checking;
- checking the design of contractor's temporary works for compliance with safety regulations and satisfactory construction of permanent works;
- acting as the engineer's Safety Supervisor on site;
- reporting on all the foregoing to the engineer in the form he requires.

Plate 5a. A badly rutted formation, probably due to excessive moisture content of the fill

Plate 5b. It can be easier to get out of this sort of trouble than to decide whether the conditions could not reasonably have been foreseen by an experienced contractor' under Clause 12 of the ICE Conditions

Plate 6a. A problem for the designer under the Construction (Design and Management) Regulations 1994 who has to pay 'adequate regard to the need to avoid foreseeable risks' (see pp. 78–9). The designer may decide a stable berm must be cut into the hillside before the pipe trench is excavated

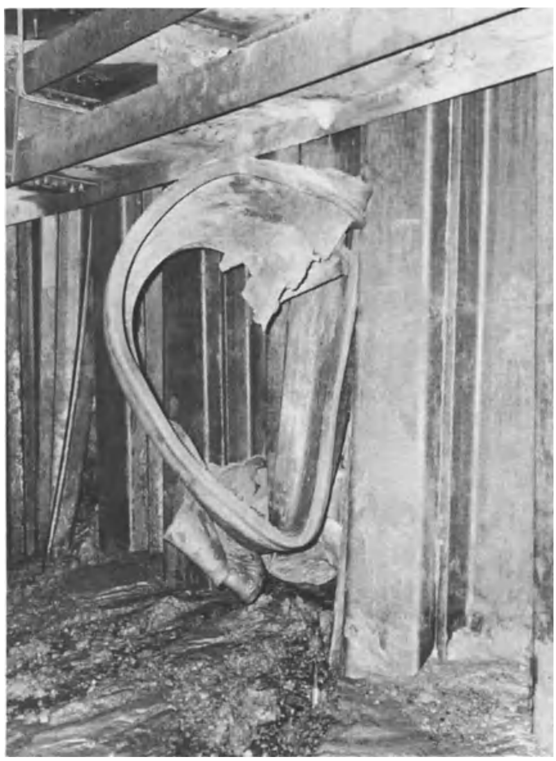


Plate 6b. Steel piling sometimes does not go where the civil engineer thinks it has – especially when he was not aware the ground contained boulders or other obstructions

Plate 7a. An unexpected hillside slip in shale. The question is whether it is sensible to place such risks on the contractor

Plate 7b. Erosion of a newly placed embankment by rainfall runoff from the formation above. This is likely to be a contractor's risk, as it is 'a condition due to weather conditions' under ICE Conditions Clause 12

Plate 8a. Accidents can only be prevented by always taking the proper precautions. The trench sides should have been supported, because no one could be certain they would stand unsupported

Plate 8b. Presumably somebody thought this trench was stable – and was proved wrong

5.6 Some problems of responsibility

If the engineer does not empower the resident engineer to issue instructions to vary the works, a contractor may ask what procedure he must follow to get sanction for some extra work. Or the contractor may take the view that the resident engineer's clarification of a detail actually varies the works, and may not be willing to proceed without the engineer's confirmation. Usually he will be told that he can accept the resident engineer's agreement or instruction on the matter, but if he is in doubt he can have the matter referred to the engineer. In practice, problems are unlikely to arise, because most 'extras' that arise are obviously necessary in order to complete the works, and the resident engineer should know what type of extra the engineer will approve. Also, the contractor is often not so much concerned with whether he should undertake some extra but how much he will be paid for it: a matter that he knows can be negotiated with the resident engineer but which is subject to agreement by the engineer when he issues a variation order.

Sometimes difficulty can occur if the contractor uses some material or method that the resident engineer approves, but which the engineer subsequently finds unsatisfactory. Wherever possible the engineer should support the resident engineer's decisions, or his site control is weakened. But if the resident engineer has made an error that the engineer feels he must rectify, he must do so as best he can, if necessary by agreeing some extra payment to the contractor for abortive work. However, if the engineer feels that the contractor has deliberately deviated from the specification or has taken advantage of some failure of the resident engineer to appreciate the consequences of the contractor's proposed change, he may decide to countermand the resident engineer's decision without agreeing any recompense to the contractor. Countermanding any decisions of the resident engineer should rarely ever be necessary, as the powers given to him should be chosen to match his level of experience, and he should be tutored before going to site on procedures that he should follow.

The resident engineer's chief technical duty is to watch and check that the quality of the workmanship and materials used complies with the specification. He may also have to take decisions affecting the design or outcome of the permanent works and, in these, he has to be careful to take the right action. Thus, if a foundation material appears doubtful, he should not approve it without first getting the opinion of the engineer or the engineer's geotechnical engineer on it. Negligence does not necessarily comprise making a wrong decision; but it does include not taking a prudent course of action that is possible. Thus not to refer a dubious foundation to the engineer's specialists could be taken as amounting to negligence if the foundation failed. The resident engineer should know the technical limitations of himself and his staff, and should not take decisions that ought properly to be referred to the engineer and his specialist staff.

5.7 Some important points to watch

Some important provisions of the ICE Conditions of Contract that need to be borne in mind by the resident engineer are as follows:

- All instructions to the contractor have either to be in writing or, if given orally, have to be confirmed in writing 'as soon as is possible under the circumstances' (Clause 2(6)(b)).
- If the contractor receives an oral instruction and confirms it in writing, and the engineer does not contradict such confirmation 'forthwith', then the confirmation is 'deemed an instruction in writing by the engineer' (Clause 2(6)(b)). These 'CVIs' as they are called can raise special difficulties for the resident engineer, and the problems of handling them are dealt with in detail in Sections 8.4 and 12.6.
- Although a resident engineer may not have been delegated powers to decide how much (if anything) should be paid against a contractor's claim for extra payment, he has powers to write to the contractor stating his views on the claim; and he should do so in each case so that the facts as he sees them are on record.
- There are numerous 'time clauses' in the conditions of contract: that is, clauses stipulating some time limit within which the engineer (and therefore probably the resident engineer also) must take action. An important instance is the requirement that the engineer must comment on the contractor's proposed programme within 21 days of its receipt, otherwise the engineer is deemed to have accepted it (Clause 14(2)). The same, in effect, applies to any part-programme or revised programme that the contractor supplies. Consequently if the engineer fails to comment within 21 days, the contractor's programme is deemed approved and anomalies may be introduced if the programme does not reflect the specified timing.
- The resident engineer has to ensure that the contractor receives all approvals, drawings, details and other information that he needs to construct the works, in good time; otherwise the contractor may claim for delay (Clause 7(4)).
- The resident engineer should not accept lower-grade materials or workmanship than that specified, even if the contractor offers a lower rate of charge than the bill rate for the specified material, unless the engineer agrees to this.
- The resident engineer must give immediate notice to the contractor when any defects in materials or workmanship are observed, because it may be very difficult to rectify a defective part of the work after it is completed. Hence inspections of quality should take place as soon as an operation is commenced, and as soon as material to be used in the permanent works is delivered to site.

5.8 The resident engineer's responsibilities for safety

The safety regulations applying to construction sites have been described in Sections 4.11 and 4.12, which mentioned that, under the proposed CDM Regulations, there must be a health and safety plan drawn up by the client's planning supervisor and extended by the 'principal contractor' to cover special or unusual aspects of the project. Primarily it is the responsibility of the contractor to comply with such a plan as needed for construction, and all safety regulations, as required by the ICE Conditions of Contract (Clauses 8(3), 15(1) and 19(1)).

The resident engineer will normally be appointed the engineer's Safety Manager on site. Hence he must ensure that his staff and any visitors he brings to site conform with all safety requirements. If the resident engineer shows visitors round the site, he should advise the agent that he wishes to do so, and should see that such visitors are accompanied when touring the site. Normally all formal visits by outside bodies to view the project should be agreed beforehand with the contractor or his agent.

Especial care is necessary when the resident engineer or any member of his staff need to enter manholes, shafts, wells and underground chambers. Such confined spaces can be highly dangerous through lack of oxygen, or the presence of toxic gases. Apart from other causes, toxic gases can be present in even a recently constructed manhole or shaft etc. due to gas seepage from the adjacent formation. A Safety Manual detailing the precautions to be followed should be in the hands of the resident engineer. All deep manholes, shafts etc. should be assumed potentially dangerous, the air quality therein being tested by a properly trained engineer using appropriate gas-detecting apparatus before any person is allowed to enter. A 'deep' manhole or shaft etc. cannot be exactly defined but it is prudent to take it as meaning any having a depth greater than the height of a man. In situations of possible danger a properly qualified and trained rescue team, equipped with all necessary safety and rescue equipment, should be present and be in charge of entry, ensuring that all the requirements of the Safety Manual are followed. Entry into sewers requires compliance with extensive safety measures because of the wide range of dangers from toxic or inflammable gases, dangerous liquids, flooding, and disease from contamination.

If the resident engineer notices a failure by the contractor to comply with a statutory safety regulation or any site safety rule, he should inform the agent or contractor's safety supervisor and request compliance. The resident engineer's request should, in the first instance, be verbal since the failure might not have come to the notice of the agent or safety supervisor. If the correct safety measures are not adopted within a reasonably short time, a written note should be sent to the agent confirming the requirement. If the contractor still does not comply, the resident engineer can instruct the contractor to comply, or warn him that he proposes to call in the health and safety inspector; but these extreme measures should not be adopted until all possible means of persuasion have failed. It would be impolitic of the resident engineer to contact the Health and Safety Inspectorate without first warning the contractor. Also, the resident engineer must be sure of his grounds, the lack of safety must relate to a matter of some importance, and it must be borne in mind that an HSE inspector might not be available to visit the site immediately.

A particular difficulty for the resident engineer occurs when he considers that the contractor is following an unsafe practice that, however, is not in contravention of a Construction Regulation. A frequent instance is when the contractor does not timber an excavation, whereas the resident engineer thinks he ought to. The Regulations state that support is required to all excavations *except*:

> where, having regard to the nature and slope of the sides of the excavation, shaft or earthwork and other circumstances, no fall or dislodgement of earth or other material so as to bury or trap a person employed or so as to strike a person employed from a height of more than 1.2 metres is liable to occur.

Obviously, different views can be held as to whether or not a fall is 'liable to occur'. The ICE Conditions of Contract do not say clearly that the contractor is to comply with the engineer's safety requirements, so the resident engineer has first to use persuasion. If this fails he may instruct the contractor to insert supports under general powers contained in the ICE Conditions (*see* Clauses 2(6), 13, 14(6) and (7)). The dilemma of the situation is that, with the supports inserted, no fall occurs, so there is no proof that the supports were necessary. Consequently the contractor may consider he is entitled to claim extra for 'complying with instructions'. But it is better to face a claim that could probably be resisted than see an accident happen. However, before issuing an instruction to timber, the resident engineer must examine the excavation and make a record of what he sees and any evidence to support his views. He should also listen to the opinions of others, including those of his staff; but if he still thinks the excavation requires supports because a fall is liable to occur he should instruct so. He has to bear in mind that he must protect the position of the engineer. If the resident engineer thinks an operation is unsafe but takes no action that is reasonably open to him to render that operation safe, then it would be difficult for him, and the engineer on whose behalf he works, to escape all responsibility should an accident occur.

5.9 Relationship between resident engineer and agent

The resident engineer must not be surprised to find that, on a new job, he is at first treated with considerable circumspection by the agent. He has to be, because one of the unknown factors that the contractor has yet to discover, which is of considerable importance to him, is what kind of resident engineer will be in charge. The agent will need to go carefully at first so that he can 'get the measure' of the man who can daily interfere with contractual work, and so that he can understand what are the special matters that concern the resident engineer, the methods of working that he will want adopted, and whether he will generally be easy or difficult to get on with. In like manner, the resident engineer will be waiting to observe how competent the agent is and what degree of trust can be placed upon him, so as to find out what degree of supervisory control will have to be exercised.

So far as the agent is concerned, he will want the resident engineer to be fair, reasonable, and understanding. He will want clear decisive instructions from the resident engineer, and he will want prompt answers to his requests for information. An agent must be given proper information and instructions before he does the work; not after, or when he is part way through. However, an agent will object to a resident engineer who is too keen on interfering in matters that should properly be handled by the contractor. Such a resident engineer may try to get in touch with subcontractors, or let such subcontractors approach him, without telling the agent what he is doing. Similarly, the over-keen resident engineer may be tempted to discuss the job with the foreman or gangers, a practice that is strictly not permissible for the resident engineer or any of his staff without the agent's permission.

If the resident engineer has any complaints, the agent will wish to be told about them personally, before they are passed to anyone else. It may be best if complaints are made to him verbally 'to his face', not first by a letter. A letter of complaint 'out of the blue' will seem unfair to the agent, because it gives him no opportunity to respond to it before it is 'put on record'. The verbal discussion should come first and, if necessary, the letter afterwards.

An especial nuisance to the agent is the resident engineer who is too meticulous and rigid in his views: who thinks it necessary to measure up every cubic yard of concrete to the third decimal place; or who insists that every word in the specification must be exactly and rigidly complied with, irrespective of the practical consequences to the job or the need to apply such conditions in every case. To be able to rely on one's own judgement and to have that judgement considered right and fair, by both the contractor and the engineer, should be the principal aim of every resident engineer. This judgement must be founded on engineering skill and knowledge, and a proper perception of the intentions laid down in the specification and drawings and the requirements of the design, tempered with a sense of justice and what is reasonable in the circumstances, and motivated by a desire to get the best end results.

5.10 Handling troubles

There will, of course, be times when troubles arise. When bad workmanship comes to light, or when quite unsuitable methods are being used, it is the resident engineer's duty to have the work rectified or the unsuitable methods stopped. This is easy to say, but not so easy to carry out in practice. Suppose, for example, it comes to the resident engineer's notice that a partly built wall is being built to a very inferior standard: the bricks are chipped (because they have been 'end-tipped' off a dumper), the joints are irregular, and the face is not uniformly plane. Now the first essential in such matters is that the bad workmanship ought to be discovered at an early stage. It is no use letting it carry on; nor is it of use to find the defects out when the structure is complete or nearly complete, or all the troubles and difficulties of trying to get things right will be magnified. The second essential is common sense: this is to keep one's temper, to refrain from accusing the contractor of fraud or incompetence, or from saying to the workmen, 'That has got to come down for a start'. Any one of these methods can be guaranteed to start things off with a row, which is not in the least helpful to anyone.

Instead, the resident engineer ought to ask the agent to come and look at the wall with him, indicating that he is unhappy about it. When they meet at the wall the wise resident engineer will say nothing, but will allow the agent to examine the wall for himself. One of two things will now happen: either the agent will make some admission of fault, or he will say, 'What's wrong with it then?' If the agent is ready to admit some fault, there is no doubt that with careful handling all will be made well. If, on the other hand, the agent asks what is wrong, the resident engineer must tell him clearly, saying not only what is wrong but what would be right in the circumstances, confining his remarks to the work itself. A discussion will then have to take place as to the possible remedies to be adopted and, in discussing remedies, the resident engineer will have to be flexible. His main aim must be to get the matter put right, but he must be prepared at the same time to accept any reasonable alternative for achieving this purpose. For instance, instead of pulling the wall down and rebuilding it, the agent might offer to plaster the wall, at his firm's expense, to a presentable appearance. If, however, no solution appears possible that the agent will accept, it is best to leave the matter over for the time being, either for another discussion after both parties have had more time to think about the problem, or for reference to the engineer for his decision. Leaving a decision over for a day is often a magic way of discovering the best answer to a problem.

There will be occasions for the resident engineer when he is not at all sure what he should do. Even the opinions of specialists may differ, and it may sometimes be very difficult for the resident engineer to decide whether or not he will accept some method proposed by the contractor's agent. The agent has to think up ways and means of doing things that are easiest and cheapest for him, which use the men and machines he has got, rather than the men and machines he would otherwise have to bring on site. He is therefore likely to propose methods that come as a surprise to the resident engineer, who has been schooled to think in terms of using the 'right' machines and 'right' methods for each particular job. He may therefore find himself in considerable doubt as to whether some novel method or short cut proposed by the agent will bring about the end result required, or whether it will result in some eventual harm to the quality or durability of the permanent works. The old-style general foreman was fertile in thinking up unusual methods of construction that saved him trouble, and not short of explanations as to why no possible harm could result.

The reasonable resident engineer will not wish to deprive the agent of opportunities for benefiting from his own skill, but he must not allow chances to be taken that might result in damage to the works. It is the quality of the work that it is his main duty to safeguard. If, therefore, he permits the agent to proceed on his proposed method he would be quite within his rights to forewarn the agent that, if any harm does result, then the contractor must make the harm good at his own expense. In coming to his decision, and if there is not time to discuss the matter with the engineer, he will be wise if he discusses the problem with his own inspectors and engineering staff, for on these difficult matters it is always useful and encouraging to have a consensus of opinion on one's side, and extra heads may point out further potential difficulties that may not at first have come to mind.

5.11 More difficult cases of trouble

In the preceding examples it is presupposed that the agent knows what good workmanship is, and that he and the resident engineer intend to work out their differences. There are, of course, more difficult cases where matters cannot be settled on site and have to be brought to the attention of the engineer. However, it is necessary to appreciate that the main preoccupation of both the engineer and contractor should be to see the work done properly and in good time. If the engineer and contractor get the impression that the resident engineer and agent are becoming too disputatious over matters not of primary importance, it may be that they will conclude – as a matter of expediency rather than justice – that one or the other of the two ought to moved off the job. Hence a word about matters that are often the cause of friction, and how to deal with them, might not be out of place.

One of the most difficult things for the resident engineer to tolerate is to stand by and see the agent make a mess of things. He sees the contractor's time and money being wasted, yet his suggestions for improvement are not accepted; he gets to hear, perhaps in a roundabout way, of complaints from the men about the way the job is run. He fears that all this is stacking up trouble for the future and does not know quite what to do about it. In the first instance the resident engineer must convey his opinions to the agent. But he cannot really do more than this until either the speed or quality of the work is manifestly suffering. He must bear in mind that some people are less efficient than others, that the way one man goes about a job is not necessarily the only way, and that probably all contractors have periods when they do not give a job their best attention. He must therefore wait for a while and see what happens.

When eventually he considers that there is a enough evidence for real complaint he must place the facts before the engineer, and the latter will make the necessary decision. The engineer may take the complaint up officially with the contractor. If this action brings no remedy the situation begins to be serious and must be handled all the more carefully. It is true that the engineer has the right to require withdrawal of an agent from site, but this is an extreme step, not to be taken until all else fails. It should only be done if there is positive proof that the job is being mismanaged by the agent, not because the agent is a difficult character, or is eccentric, or has odd ways of going about things.

If a job is running badly, the most persuasive information likely to lead the contractor to make the necessary changes is to inform him of any excessive amount of work that has had to be rejected as unsatisfactory, and to tell him of the probable loss on the job to date. This information must, of course, pass to the contractor via the engineer. It is not difficult to estimate a contractor's costs to a given date and to compare these with payments due, and if this calculation shows a loss to the contractor and its probable increase if the job continues to flounder on under the same leadership, then the resident engineer may be gratified to see how quickly a contractor can act when convinced of the need in financial terms.

The agent's side of the picture must not be forgotten. First and foremost, he will regard lack of appreciation of his difficulties as unreasonable. Second, the most certain way of losing the agent's respect and cooperation is to be 'continually reading the Specification at him' as if it were a holy writ, non-compliance with which is unthinkable. When the agent faces difficulties and is in need of help, it is up to the resident engineer to relax conditions that are not essential and to permit other ways round to the end result desired. An agent will never resent a call from the resident engineer for especial care with some operation, or for strict compliance with the specification in matters of importance, or for a top-class finish for those parts of the job that will remain permanently in view; but in return he will expect that there will be occasions where the strict letter of the specification is not appropriate and will not be called for by the resident engineer where compliance presents real difficulty.

The contractor who continuously submits claims for extra payment, and will not withdraw them despite many being obviously invalid, needs especial handling. The subject of claims themselves and how to deal with them is dealt with in detail in Chapter 12. The initial problem is how the resident engineer is to deal with such a contractor. In the first instance, however many claims are submitted, it is essential that the resident engineer 'keeps his cool'. He must give at least a first answer in writing to every such claim, but his answers must be factual and courteous, treating each as if it were a 'one-off' occasion. He must not be accusatory in his letters or show signs of irritation: he must let the facts stand. One of the reasons for this is that, if some dispute on claims eventually goes before an arbitrator, all the correspondence about each claim must be put before him. Thus the more the resident engineer's letters follow strict fact and are courteously worded, the more will his views about a claim have standing in the eyes of the arbitrator.

The chief defence against a disputatious contractor who submits many claims comprises the maintenance of extensive factual records in the resident engineer's office concerning every claim. The site diary, the weekly reports, the detailed daily reports of the inspectors, the copies of notes of instruction to the contractor, the minutes of meetings, the checked daywork sheets, and reports of tests: all are vital documents for ensuring that decisions on claims are supported by factual evidence. All must be filed in first-class order. When such claims come up for discussion at meetings with the contractor, the resident engineer's responses must be factual, firm and polite. It is best if the records of meetings on claims are drawn up by the resident engineer, at latest by the day after the meeting, and submitted to the contractor for agreement. Inevitably the submission by the contractor of many claims that are unreasonable, or his failure to come to a reasonable compromise on any, is bound to cause a degree of coolness between the resident engineer and the agent. Care must be taken not to let the situation decline into open hostility. The long-term outcome will not be unsatisfactory if the resident engineer is tough but polite, and keeps good records.

5.12 The resident engineer's staff

Except for the largest jobs, the resident engineer's staff on UK sites will be quite small. Two or three assistant engineers and two or three inspectors might be needed for a £25 million project in the UK; but much depends on the nature of the work. A clerk-typist, part or full time, is almost essential. There is usually a considerable amount of work for assistant engineers to do during the first one-third period of a project, tailing off thereafter. On large jobs a measurement engineer, or sometimes a quantity surveyor having experience of civil engineering work, may be needed to handle the checking of interim payments, dayworks sheets etc. This can be important because, if the resident engineer has only a couple of assistant engineers, he will not want to lose one on office work. A driver and suitable vehicle may be essential, because not all staff will have transport nor have vehicles suitable for getting about the site or carrying surveying equipment, concrete test cubes etc. Also, there may be frequent errands to be run, such as taking samples off site for testing. A chainman-cum-teaboy on the resident engineer's staff must not be forgotten, for his presence on even the smallest site can be a great asset. It is usual for the chainman, and the driver plus vehicle, to be provided by the contractor under the contract, and woe betide the drafter of the contract documents if he forgets to include provision of these in the specification.

Under the ICE Conditions the engineer or resident engineer must notify the contractor of 'the names, duties and scope of authority' of persons appointed to assist the resident engineer in his duties (Clause 2(5)). This must include the names of inspectors as well as assistant engineers, because the clause goes on to say that such assistants are not to have any authority to issue instructions save as 'may be necessary to enable them to carry out their duties and to secure their acceptance of materials and workmanship as being in accordance with the contract'. This clearly implies that they have power to accept or reject materials or workmanship. However, this must be done with tact and understanding.

It is insufficient to take the view that the resident engineer and his staff are present solely to ensure that the works conform to specification. Among other things they must assist the contractor in making a good job of the construction. On day-to-day problems the resident engineer should be able to inform the contractor of priorities in respect of materials and workmanship, the reason for these and where difficulties might lie ahead. When unexpected conditions occur, assistance must be given to find a solution that is not only necessary for the quality of the permanent works but is also that which the contractor feels he can do satisfactorily. The queries that the contractor raises must all be answered constructively, and, when reasonable help is asked for, it should be given. The main purpose of the contract is to give the employer the works he needs at a price guided by a fair interpretation of the terms of the contract; it is not intended as a basis for conflict.

The engineering assistants should be kept informed of problems on the job, so that their actions can be intelligently directed. This helps to avoid mistaken or conflicting instructions being given to the contractor. Young engineers on site for the first time need to be forewarned of some of the troubles they can fall into. A young engineer may be well aware that it is injudicious of him to give the general foreman 'an instruction'; he had better leave that to the resident engineer. But he may not be aware that a question that he innocently puts to a section foreman may well be (less innocently) translated into 'a complaint' that, travelling rapidly upwards, brings an irate agent into the resident engineer's office asking, 'What is this trouble your engineer is complaining about?' It all sounds rather difficult: but site life is rather a closed society, which seldom resists the temptation to 'put a newcomer in his place' to start with. However, once relationships are established and statuses are recognized, such troubles blow over.

Professionally qualified women civil engineers are increasingly employed on sites, and any idea that site is not a suitable environment for them is held only by the ignorant. Status on site is tied to evident competence and the ability to give clear instructions courteously: it has nothing to do with rank, gender, or colour. Construction sites under a good agent and a sensible resident engineer can provide an outstandingly valuable and enjoyable experience to an engineer in his or her career.

The inspector's job is primarily to be out on site watching the workmanship. Inspectors are usually older men, but this is no disadvantage because their practical experience is of particular value to the resident engineer, and also an advantage when having to deal with the contractor's workers. Persuasion, tact, tolerance, care in observation, and the ability to give firm direction are required. Not everyone possesses these qualities, and it is not really the job for a young man who can find it irksome to watch the work of others he sometimes feels he could do better himself. On overseas sites an inspector plays a much more positive role, often having to teach and demonstrate how work should be done. A good inspector can be an asset to a contractor. One agent admitted, 'I always welcome a good inspector: when he passes something I know it should be all right and it relieves me of a lot of worry'. One of the problems for the resident engineer is how to get hold of a 'good' inspector. Usually it is best done by recommendation from a resident engineer who has employed the inspector before. Many firms of consulting engineers keep good inspectors in continuous work, passing them from one job to another. If the resident engineer hears of one such 'coming free' and can gain his services he is lucky.

5.13 Quality assurance

A contractor may run a quality assurance system, and some employers may take this into consideration when making a list of selected contractors for tendering. Quality assurance (QA) as set out in BS 5750[1] is an administrative system for checking that the desired quality of a firm's output is achieved: it does not include a definition of quality itself. For example, a contractor may issue a design manual for formwork: this is his quality definition. His QA system may then stipulate that: the design manual is to be used; designers must have their designs checked by the firm's formwork specialist; the specialist must check and sign the design as approved; the signed design sheets must be filed, indexed and kept; the agent or his site engineer is to check and sign that the formwork is erected as designed; and the contractor's safety supervisor is to inspect and sign that the formwork erected is safe for use. A QA system can cover few or the whole range of a firm's operations, but to ensure that it meets the intended objectives (which have to be defined) it has to be **audited**. Audits can be carried out internally by a member of the firm, or by a client proposing to employ the firm, or by an independent authorized certifying body who can issue a certificate of approval.[2] In the last case the QA system is said to be **certified**. Repeat auditing is required from time to time.

A supplier may say he runs a QA scheme to BS 5750, but this has nothing to do with the standards that he adopts for his products, which need not conform to any British Standard. Also, a contractor can have a QA system but people may fail to follow it. A QA Manager can be appointed to see the system is operated; but he will not know when checkers have signed without actually checking, nor may he know when checks have been missed. The system can be difficult to apply at site level, where instructions are verbal, checks are visual, and much work is subcontracted or done by temporary labour. Thus a QA system can exist, but it may not be effective. A 1994 report on seven major projects for the UK Concrete Society gave many instances of defects observed in concrete design and construction despite QA systems being run.[3]

There has been extensive debate as to whether a contractor's QA scheme could permit reduction of the engineer's role in supervising the contract for construction, the idea being that the resident engineer would then only need to check that the contractor's QA checking system was being properly applied.[4,5] But under the ICE Conditions the engineer has a responsibility for ensuring that the quality of the work is as specified, and he cannot pass this duty to others. Even under ICE design and construct conditions and the ICE New Engineering Contract the employer's project manager has powers, and therefore implied duties, to ensure that work is satisfactory or defect-free. Such contracts would have to be radically reworded if sole reliance were to be placed on a contractor's QA system for quality of work done. Only under some kind of turnkey or simple purchase contract could reliance be placed on a contractor's QA system though, as mentioned under Section 1.6(a), even with that type of contract an employer may often appoint an inspector to watch over the contractor's work on his behalf. The presence of a good inspector gives the contractor, employer and engineer an assurance that the work is inspected and is satisfactory, and his cost to the job may be not be more than the increased price that a contractor might charge for running a QA system, and give a better guarantee of satisfactory workmanship.

5.14 Gifts and hospitality

At Christmas and other festive occasions, cheerful visitors may appear at the door of the resident engineer's office, wishing him and his staff the season's greetings and perhaps extending some gifts. Politely but firmly, without giving offence, the good wishes may be accepted but not the gifts. No doubt the gift is innocently intended: the contractor or an 'approved' subcontractor or supplier may be well pleased at the treatment he has received and wants to express his gratitude. But the engineer and all his staff occupy a position of trust, in which all parties involved in a contract – the employer, the contractor, his suppliers and subcontractors – expect to get fair treatment. To accept a gift from any of them, or any kind of pecuniary favour, might put in doubt the claim of the engineer and his staff to be impartial. It could be disastrous for the resident engineer (and for the contractor) if, having to give evidence on some unhappy dispute arising under the contract, the resident engineer has to admit under questioning that he accepted gifts from a contractor.

The question of accepting hospitality is a different matter. It is uncivil to refuse all invitations of this kind; courtesy demands that on the right occasion hospitality will be accepted, enjoyed and returned in the spirit it is given. The engineer's common sense will tell him when it is right: such as when a triumph on a job is to be celebrated; when personnel depart from the job; when troubles on the site need to be discussed in an 'off-the-job' atmosphere. As long as the giving and receiving of hospitality is conducted reasonably, these actions do much to promote friendly and willing cooperation on the site for the benefit of the job.

References

1 BS 5750 Part 1:1987 *Quality systems: Specification for design/development, production, installation and servicing* (equivalent standards are ISO 9001:1987 and EN 29001:1987).
2 The certifying bodies are monitored by the National Accreditation Council of Certifying Bodies (NACCB).
3 When quality takes a dive. *Construction News* 26 May 1994.
4 CIRIA calls for slashing of Engineer's role to aid QA. *New Civil Engineer* 11 June 1992.
5 Systems analysis. *Water and Environmental Management* October 1993.

6

Starting the construction work

6.1 Pre-commencement meeting and start-up arrangements

During the period when tenders were being considered, any discussions that were held will have been primarily directed towards clarifying uncertainties in tenders in order to select the best offer. Once an award of contract has been made, a further meeting is necessary to make preparations for starting the contract. Such a pre-commencement meeting will be attended by the employer or his key staff concerned, the engineer and his proposed resident engineer, and the contractor's manager and agent. This is to effect introductions and exchange information about the principal initial matters concerning each party. Items that may be covered by this meeting are as follows:

- Exchange of addresses, telephone numbers etc. and establishing agreed lines of communication (normally between engineer to head office of contractor, and from resident engineer to agent only).
- Clarifying the resident engineer's delegated powers, and setting out his proposed staffing and supervisory arrangements.
- The contractor's report on the agent's experience in the type of work involved, as his appointment must be approved by the engineer. The contractor's staffing and any particular needs for temporary works designs or special methods of construction proposed.
- Arrangements for provision of sets of contract documents to the contractor and indication of any further drawings that will be supplied (e.g. bar schedules).
- Progress by the contractor in obtaining bonds and insurance: especially important where early access to site is expected as this may not be permitted until bond and insurance are secured.
- The proposed date for commencement, which will be set by the engineer after taking the views of the contractor concerning his readiness to mobilize, and of

the employer concerning the readiness of the site for occupation.

- The programme for construction, which the contractor is to produce within 21 days of award of contract, and the consequent needs of the contractor in respect of further information and drawings to prevent occasioning delay.
- The contractor's health and safety plan, and how this will work in conjunction with any rules the employer may have set. This may need to take account of continued access to site which the employer may require for his own staff and protection of their safety.

Other matters that it might be important to consider include the siting of the resident engineer's offices, the services to be provided to him, and the printing of forms for monthly statements. This by no means exhausts the matters that may have to be discussed, and the first meeting may need to delegate to a further meeting consideration of certain matters in more detail.

The success of this meeting in establishing good working relationships can make an important contribution in setting the tone for subsequent cooperation.

6.2 The contractor's initial work

The contractor's agent will probably come to site with a small nucleus of permanent employees, and his main aim will be to get started on the actual work of construction as soon as possible. The contractor's head office should have already agreed with the engineer where the contractor's offices are to be sited, so the agent will have the first of these erected as soon as possible. He will have to visit the local employment office or employment agencies, if that has not already been done, to make arrangements for taking men on site. The agent will find it necessary to have some clerical assistance on site from the start; for preference his site coordinator and office manager will accompany him and will immediately start getting to site a wide variety of equipment, machinery and materials. Some of this will be sent out from the plant and equipment depot of the contractor's head office, but a large amount of supplementary equipment may be required from local sources. 'Consumables' will be required: a term meaning all those things – picks, shovels, tools, fuel, timber, office stationery, protective clothing, lighting equipment, temporary fencing, furniture, canteen equipment and a legion of other items – that are not plant nor large items of reusable equipment (such as steel shuttering), nor materials to go in the permanent work. A visit to the local bank manager may be necessary to make arrangements for withdrawing money for the payment of wages; and high up among the urgent tasks will be the need to arrange for telephone lines to site and postal deliveries.

At first it may be necessary to adopt a number of temporary measures to get the job started. Plant may have to be hired for the work of digging trenches to lay water supply and drainage, and a dozer for site clearance. A gang of men may have to be set fencing off the site area, another gang on making foundations for huts, and a third gang for offloading materials and equipment. A carpenter will be needed to take charge of hut erection; a site engineer will quickly be necessary for the setting out of levels and for producing sketches so as to direct the foremen and gangers what to do. It should not be more than a week before the agent and a nucleus of his staff have some kind of office in which to work and a store has been set up.

The agent will need to start arranging for delivery to site of some of the materials required for early incorporation in the works, particularly the aggregates proposed for concrete, or samples of ready-mix from local suppliers. Such samples will have to be made into cubes and tested. This sampling and testing can take a long time, so must be started early if good-quality concrete is required early on the job. The agent may visit – probably with the resident engineer – local suppliers of ready-mix concrete to observe their quality control and to discuss rates of supply and qualities of concrete required.

It depends on the location of the site, the standing of the agent, and the policy of the contractor, how far materials for use in the works are ordered by the agent or by the contractor's head office. The supply of major materials for which head office already possesses quotations would most probably be ordered by head office. But when the orders have been placed the agent will need to contact suppliers to advise them of quantities and times of delivery required. He will, no doubt, have to order some supplies locally, which he will do by telephone, covering agreed arrangements by issue of a confirmatory written order. He will probably seek to avoid entering long-term supply agreements with a new supplier for materials, unless this is essential, until he is confident that the supplier will not default on deliveries or on quality of materials supplied. Where a monopoly of supply exists, as in the case of cement, which is often available from only one local source, the contractor will be forced to make the best bargain he can, and in respect of quantity and rate of supply he may call upon the resident engineer to back him up in his request to the supplier.

The amount of civil engineering work taking place at any one time fluctuates with the economic climate so that, in periods of maximum activity, some material may get in short supply and be on a long delivery time, endangering the contractor's intended programme for construction. It sometimes requires the combined efforts of the agent and resident engineer to get satisfactory delivery in such matters, and early installation of services such as telephones, power lines, sewer connections and water supply. On overseas projects the procurement of local materials and the checking and steering of imported materials through customs often forms a major departmental function within the contractor's local organization.

6.3 The resident engineer's work

The engineer who finds himself newly appointed to take up the position of resident engineer and who has previously had little experience outside may well feel somewhat alarmed at the prospect before him. He has no doubt been told he 'will manage all right', but this seems small comfort as he thinks of all the things he doesn't know about the job and all the unknown questions likely to arise requiring an answer right away. He may also feel a little uneasy at the prospect of having to tell everyone what to do (instead of deciding action within a team), and may wonder how he is likely to match up to the contractor's agent, who appears a tough and forceful character considerably older than himself. However, the resident engineer is not expected to be able to solve every problem by himself, nor is it likely that problems of any engineering magnitude will be immediately encountered, for there are many organizational details to deal with first.

Work before going to site

The resident engineer should have spent some time before he goes to site examining the contract drawings and specifications, and there should have been an opportunity for him to have conversations with the designers. He should get to know how the job has been designed, so that he is able to make intelligent suggestions if the conditions revealed during the course of construction differ from those expected. He should make a file of all information that is basic to the job: soil test data on which the design has been based; levels; rainfall and runoff data; geological information; details of special materials or equipment to be incorporated in the job; lists and addresses of authorities and personnel who have been written to about the job, such as the local planning authority, the district road engineer, the local building surveyor, the employer and his directors or councillors and staff; a brief history of how the job came about and the dates and references of major decisions.

Perhaps considerably more than the above may be required. The compilation of this file of data can act as a check on the situation to date, so that a separate file of matters still outstanding to be dealt with by his head office can be made. Once the resident engineer is appointed, everyone previously connected with the job will tend to expect him to take responsibility for seeing that all site matters are done in due time and in the right order. Thus the programme of construction agreed between the contractor and the engineer will be one of the documents carefully studied by the resident engineer, so that he can check it in detail for its consequences.

The site office

One of the first things the resident engineer may have to decide is where he will have his office placed and what size and layout it should be. If there is any choice in the matter the office should be placed so that, from it, the main traffic in and out of the site can be observed. It is a mistake to choose a situation that overlooks the job but which does not have a view of the main entrance. Little worthwhile of the job can be seen from a distance, whereas even a distant view of the entrance will enable the engineer or his staff to notice a number of happenings: the delivery of materials, plant going off site, when callers are about to descend (especially the employer), and other matters.

The office itself can range from a simple hut to a veritable barracks, according to the size of the job. On a moderate-sized job where the resident engineer has two or three engineers to assist him he will need his own room, a drawing office, and a typing and filing room. In addition he will want a washroom, a small kitchen area where hot drinks can be made, and, separately, a room where wet clothes can be stripped off and hung up to dry. A small storeroom is invaluable for the storage of surveying and other equipment.

On many civil engineering jobs a soils and materials testing laboratory is necessary, and this is more conveniently placed near the resident engineer's offices than elsewhere. Outside the entrances to offices an essential item of equipment is a boot scraper, to prevent an excessive amount of mud finding its way into the offices. A small outside area of concrete with a hosepipe water supply and drain will be of much help in cleaning gumboots.

6.4 Early matters to discuss with the contractor

The question of an office and its siting having been settled with the contractor's agent, the next items to be discussed will almost certainly concern the laying on of services to the job: telephone, water supply, electric power, and drainage. The telephone is required as quickly as possible, and the telephone authority may need assistance in getting permission to run lines across private properties. The agent may ask the resident engineer to check the design of a water service line to the site and to approve proposals for hard standing for cars and the routing of access roads.

The question of drainage and sanitation may prove difficult to solve. The resident engineer has to watch that the contractual requirement to provide a 'small sewage treatment works' does not get whittled down to no more than a tank and a soakaway, or a tank and an overflow to a nearby ditch or river. This is the time to make sure that any sewage works proposed are of the right sort and are large enough to treat all the sewage from the maximum number of persons who will be employed on site plus an addition for visitors. If these sewage works are later found to be inadequate, it may prove easy to get promises for their enlargement from the contractor but considerably more difficult to get action if the contractor feels that, given a few more weeks, the number of men on the job will decline and the problem will solve itself.

The question of waste oil disposal from plant is a thorny one, and should be brought to the agent's notice. Discharge of used lubricating oil or waste diesel oil to public sewers may be forbidden; to discharge it through the site sewage works will probably ruin their proper functioning; and the discharge of even small quantities to a watercourse will almost certainly be detected by the National Rivers Authority, who will demand immediate rectification, and the contractor may be liable to a penalty and payment of compensation if damage has resulted.

The waste oil should be led to a pit and disposed of by tanker as the local sewerage authority advises.

The resident engineer will next need to know what part of the job the agent intends to tackle first, and from this may follow an immediate visit to that part of the site and a discussion as to the extent of the work required there and any necessary setting out that must precede it. The agent will need to know what are the local benchmarks that have been used for the original survey of the area, and, if these are some distance away, they may both agree that their staff should jointly arrange for a convenient benchmark and baseline to be set out near the job.

When the immediate working proposals have been agreed, the next topic is the programme as a whole, and this is the first of many discussions that will occur on that subject. Sometimes the agent wants more information from the resident engineer so that he can continue making his detailed plans, or he may have perceived some thorny problem ahead that he thinks might be avoided if the engineer would sanction some action not exactly in line with contract requirements. The resident engineer had best give only a guarded opinion if this is his first acquaintance with such a proposition.

In the early stages of the job the resident engineer must be wary of discussing matters of design with the contractor, or alterations in contract requirements. It is better to point out that the design of the works and the terms of the contract are the engineer's responsibility and any changes should be put to him. The resident engineer may find out later that there are very good reasons, which he did not at first appreciate, for the design being as shown on the drawings or for the requirements set out in the specification. Too early a desire to agree with a contractor can lead to later trouble. It is better not to make unnecessary promises for the future, which later may have to be broken as a result of increased understanding of the job.

6.5 Some early tasks for the resident engineer

At the end of the first day the resident engineer will no doubt find that he already has a number of tasks that will take up all his time during the next few days. It is likely that bulk excavations will have commenced or be about to commence. It will thus be imperative for the resident engineer to take levels of the natural ground over the site where the excavation is to take place, if these levels are not already available in sufficient detail. This is urgent work, for there will be no chance later of finding what the natural ground levels were, and the calculations for quantities of excavation would then be largely 'intelligent guesswork', or agreement will have to be sought on bill quantities, which may differ from the true quantity excavated. If the contractor has taken his own levels over the site and the resident engineer has let pass the opportunity of checking them, he will be in no position to argue against the contractor's figure for the excavation, even if this comes to substantially more than that shown in the bill of quantities. It may not be sufficient to rely on ground levels shown on the contract drawings, because these may be based on interpolation of published contoured maps of the area. Where such contours originate from aerial photography they can be a metre in error because they may reflect the top of vegetation rather than the soil level.

Another vital early task, particularly when working alongside existing structures or where site traffic passes close to properties, is to carry out and agree with the contractor the state of existing buildings and road surfaces etc. This is essential so that any claims for compensation for damage can be decided properly. In this survey, sets of photographs of existing cracks or damage, as well as general views, form an important part.

The question of disposal of excavated material will have to be considered. The resident engineer must see that all productive topsoil is stripped and stacked separately for later reuse. All amounts of soil should be so stacked, even that taken off areas for the site offices, as there is often a lack of soil at the end of the job.

The next task the resident engineer may need to do, if he has not done it already, is to check the delivery times for any equipment or materials to be supplied under other contracts or by the employer, such as for the supply of pipes and valves. On overseas jobs there may be many separate contracts for the supply of materials, such as steelwork and pipes. All these separate supply contracts have to be checked in detail to ensure that nothing has been missed.

6.6 Meeting the employer

Shortly after his arrival on site the resident engineer will see if the employer wishes to see him and will set aside a morning or afternoon for going over the site and discussing plans with him. It frequently happens that the employer or his representative does wish to keep contact with the job, but any observations of consequence that the employer makes, which might require some action, should be passed through to the engineer so that he may give the necessary directions. The employer may, for instance, be hoping that certain sections of the work can be completed and made use of by him before completion of the job as a whole; or he may want certain sections left for the time being because he may be having ideas of altering his requirements. Both these matters impinge directly upon the contractor's programme and could change the cost of the job. Therefore they have to be looked into by the engineer, who will first need a definite request from the employer to deal with the matter. If, of course, the employer is merely wanting to 'sound out' what is possible and how much it might cost, the resident engineer must give him a reasonable answer but make clear that the engineer must be involved before any decision is reached. One other matter the employer may raise is the traffic or noise created by the contractor, about which the employer has received complaints. The resident engineer may have to consider what reasonable requests he could put to the contractor that would reduce these complaints.

As some structures begin to take shape an employer can be expected to take more interest, and he may start making requests for minor additions once he or his operational staff see what the structure looks like. The resident engineer and engineer must expect this, and, if the contract has been wisely drawn up, it will allow for some flexibility of requirements in the later trades. Many finishes, and particularly colour schemes, are best left for the employer to choose. There is no point in an employer paying large sums for a project and not having some choice as to its final appearance. The resident engineer will therefore endeavour to meet reasonable requests of this type by the employer; but if some apparently extravagant extra is asked for he should be wary. He must remember that where the 'employer' comprises the council members of some public authority their views might not necessarily be the same as those of an officer acting on their behalf.

6.7 Setting up the clerical work

It will be necessary to set up a system for the handling of correspondence, filing, measurement of quantities and checking of contractor's interim payment applications, and for log sheets of all technical data. A typewriter or word processor will be an essential part of the equipment, even if the engineer has to get down to one-finger typing himself. A photocopying machine is essential. To check the contractor's interim payment application a printout calculator, as used by accountants, is useful. This prints out the figures added so that checking for arithmetic errors is made easier.

Petty cash must not be forgotten, and the recipe is 'enough but no more' because of the risk of break-ins. Petty cash never seems to balance (whatever accountants say) when the sum total of what it should be comprises a miscellany of stamps, a variety of small change, some crumpled notes, a bunch of folded receipts, and list of expenditure in practically everybody's handwriting. A deficit one week can become a surplus the next, and vice versa. If a deficit persists there is probably no criminal reason for it save human forgetfulness, and should the resident engineer make it up from his own pocket he will perceive the wisdom of not having too much petty cash.

7

Site surveys, investigations and layout

7.1 Site surveys

A detailed plan of existing ground levels on site is essential if excavation or earthwork filling quantities are to be accurately measured. The most convenient method for surveying and levelling small or moderately sized sites is to use spot levelling on a 20 m grid, picking up any abrupt changes of level or gradient between these intervals. An instrument man and two chainmen are needed to carry out the work. Ranging poles, two fibreglass tapes, and a number of pegs are required to set out the sight-lines at 20 m intervals at right angles from some appropriate baseline. Plotting work is easy, and contours may be reliably interpolated between the 20 m interval readings.

Tacheometric work can be faster in the field, but only if a special reading staff is used and the surveyor and chainman are both experienced in the procedure. If tacheometry is tried with a normal staff held vertical (or at right angles to the sight-line of the instrument) a good deal of instrument and calculation work is necessary and, unless the booking down is very clear, plotting work is difficult. Tacheometry is tempting because it offers less resetting of the theodolite: in practice it is not so simple or expeditious as spot levelling over a grid.

Aerial surveys may give ground levels up to 2 m error, because the camera tends to record the level of the top of the vegetation and not the actual ground level.

Site benchmark levels that will last throughout the job need to be established by the resident engineer. Before going to site he should ascertain what benchmarks were used on the surveys that form the basis of the design, and what levels were taken for them. Hopefully these benchmark levels should still exist: they are usually Ordnance Survey benchmarks on buildings, but the original surveyors may also have set up their own benchmarks nearer the site. These (if found) should be rechecked and levels should be brought to convenient benchmarks on the site itself, but in a position unlikely to be disturbed. At least three such site benchmarks should be established, precisely levelled in. The quickset level is the most convenient and practical to use. It requires only final adjustment of the collimation line for each sighting, which is quickly done. Occasionally the engineer may find he has to use a three-screw 'dumpy' level, which is cheap and robust. Any simpler types of level are not accurate enough for civil engineering work. The expense of the automatic level is seldom justified.

The contract drawings will normally include a plan of site levels, but this will probably not have been done in sufficient detail for the proper calculation of excavation and earthwork quantities. Contractually the contractor is most often responsible for taking all necessary levels, but as the calculation of quantities depends on the levels, the resident engineer's staff should check the levels that the contractor produces. However, to have two surveys of one area is a waste of one party's time. It is best in this case for the resident engineer's staff to undertake the survey, inviting the contractor's site engineer to apply such checks as he wishes.

Responsibility for setting out the works lies with the contractor, but he is entitled to call upon the resident engineer to check that his setting out is correct; although this does not absolve the contractor from holding responsibility for any errors that, even so, escape the notice of the resident engineer and his staff. This is the usual contractual position. But whatever the contract may say, the resident engineer acts churlishly – indeed unprofessionally – if he does not give such reasonable checks as the job demands and his staff can reasonably be expected to undertake, or if he does not immediately inform the contractor on finding some error. The contractor's staff are often hard pressed to set out all necessary levels and sight rails etc. when work is going at full speed, and the resident engineer should answer all calls for checking work. He should also assist in 'giving a level' to a foreman on occasion. Both the contractor and resident engineer have a duty to see that the work is properly constructed.

7.2 Setting out buildings

An accuracy of about 3 mm in 30 m is desirable; errors of over 5 mm in 30 m should be rectified. The setting out is done from a suitable baseline by use of a theodolite and steel tape. The appropriate time is when blinding concrete has been placed to column and wall foundations. The baseline, which is either the centre line of the building or a line parallel to it but clear of the building, should have been set out previously by end pegs sited well clear of the work. It is usual to work from coordinates along this baseline from some fixed zero point, and measuring right angle distances out from them. In this way lines of walls and column centres can be marked on the blinding concrete.

Distances have to be measured by steel or fibreglass tape pulled horizontally, so it is a great convenience if the site is level. If not, a plumb-bob has to be used to transfer distances. Distance coordinates along the baseline from the zero peg are set out, using the steel tape and marking a pencil line across the peg. The theodolite is set out over the pencil line, and its position is adjusted laterally so that it transits accurately on the two outermost baseline marks. The plumb-bob on the theodolite gives the mark for the coordinate point, a round-headed nail being inserted on this point. Distances at right angles to the baseline are then set out with theodolite and steel tape. The advantage of this method is that the theodolite can sight down into column bases, which are usually set deeper than the general formation level. For the assistance of bricklayers and formwork carpenters, sight boards can be provided, with the cross-arm fixed a given level above formation level and a saw-cut exactly on the line of sight. A builder's line can then be fixed through such saw-cuts. An alternative to the foregoing is to set out two baselines at right angles to each other and use theodolite right angle settings from these to give centres for such things as column bases.

7.3 Setting out larger sites

Triangulation from a measured baseline is the usual method adopted, the triangles being as well proportioned as possible. This method is usually better than a lengthy closed traverse when the weather is changeable, as a closed traverse represents more work to be done at one time and may be interrupted by bad weather. If a closed traverse has to be interrupted by bad weather and is left for a day, there is always a danger that one or other of the last two traverse pegs is disturbed by site plant. Even if the pegs have not been disturbed, a large closing error may cause the surveyor to think this has happened, and he will feel it necessary to do the whole job again.

It is worth going to some trouble to find a suitable baseline, which, for preference, should be level and horizontal. A level road is ideal – if untrafficked! If this is not available it is worth while cutting the grass or removing any humps from a piece of horizontal ground so that the tape may be laid flat and given the standard pull required by means of a spring balance. A new, tested steel tape should be used, the maker's corrections being known and allowed for. A thermometer is also necessary. The temperature should be fairly steady: for example, the work should not be done if there is intermittent hot sunshine between periods of cloud and cold. A quiet, still, cloudy day is best. Accurate measurement of angles with a theodolite is easier than accurate measurement of distances by tape, so it is worth finding a good baseline at the expense, possibly, of not having the best-angled triangles for setting out other points. Preliminary calculations before deciding on the baseline will indicate whether a satisfactory degree of accuracy can be obtained. A 1 s theodolite should give an accuracy of ±1.5 mm at 300 m.

Distances can also be measured by EDM (electromagnetic distance measurement) equipment, or by electro-optical instruments. The former are used for geodetic surveying over long distances and are not applicable to most site work. The latter can be medium- or short-range instruments, and may be useful for large sites. However, as the average construction site only needs the measurement of one baseline, and most of the rest of the work is set out by theodolite and tape work, the expense of this distance-measuring equipment is seldom justified. If a major survey has to be undertaken it is usually more economic to employ an experienced surveying firm. They provide the instruments and experienced surveyors and can get the work done quickly.

When using a theodolite it is best not to resort to more than the standard checks, such as face right, face left. It is often tempting, seeing another previously set-out point, to range in that observation 'just as a check'. This is likely to lead the engineer into a puzzling conundrum of calculations when he gets back into the office, trying to decide whether some discrepancy relates to his current survey or the previous one. The trouble is that 'check observations' tend to be done with less care than the main survey. Attention should always be paid to taking the main theodolite observations with maximum precautions for accuracy: for example, ensuring that the theodolite base is truly horizontal. Instrument errors due to wear can be a curse, such as when a theodolite gives slightly different readings on a mark for 'approach left' and 'approach right'. Additional precautions are then necessary, which must be consistently applied to each reading. Properly maintained instruments and regular recalibration are essential for reducing errors.

When measuring horizontal distances on a steep slope it is a good deal easier to use a light piece of straight timber just over 3 m long, on which a 3 m interval is accurately marked, a plumb-bob being suspended from one end mark. Work proceeds downhill, the timber being kept horizontal by means of a builder's level. Pegs are put in at the 3 m intervals, the exact 3 m distance – as shown by the plumb-bob – being marked on each peg.

The standard of setting out for tunnels must be high, using carefully calibrated equipment, precise application and double-checking everything. An accurate tunnel baseline is first set out on the surface using the methods described above. Transference of this below ground can be done by direct sighting down a shaft, if the shaft is sufficiently large to allow this without distortion of sight-lines on the theodolite. With smaller shafts plumbing down may be used. A frame is needed either side of the shaft to hold the top ends of the plumb-lines and to allow adjustment to bring them exactly on the baseline. The plumb-line used should be of stainless steel wire, straight and unkinked, and the bob of a special type is held in a bath of oil to damp out any motion. By this means the tunnel line is reproduced at the bottom of the shaft and can be rechecked as the tunnel proceeds.

Many tunnels are nowadays controlled by lasers, the laser gun being set up on a known line parallel to the centre line of the tunnel and aimed at a target. Where a tunnelling machine is used, the operator can adjust the direction of movement of the machine to keep it on target so that the tunnel is driven in the right direction. For other methods of tunnelling, a target may be set in the soffit of the last completed ring or at the tunnel face, the tunnel direction being kept on line by adjusting the excavation and packing out any tunnel rings to keep on the proper line.

Lasers are also used in many other situations, usually for controlling construction rather than for original setting out, as their accuracy for this may not be good enough. The laser beam gives a straight line at whatever slope or level is required and so can be used for aligning forms for road pavements or even laying large pipes to a given fall. For the latter, the laser is positioned at the start of a line of pipes and focused on the required baseline. As each new pipe is fitted into the pipeline a target is placed in the invert of the open end of the pipe, using a spirit-level to find the bottom point, and the pipe is adjusted in line and level until the target falls on the laser beam. Bedding and surround to the pipe are then placed to fix the pipe in position.

7.4 Setting out floor levels

A carpenter's spirit-level should not be used for setting out the level of anything more than incidental work. It is not sufficient, in conjunction with a straight edge for instance, for getting a floor screed uniformly level. It is difficult to get concrete floors uniformly level to an accuracy better than 5 mm, and a contractor should always be warned when greater accuracy than this must be obtained with concrete. Usually discrepancies of 5 mm can be taken up in the floor screed of granolithic or terrazzo ground down to the desired smooth finish. To get tiling accurately laid, small pieces of tile are mortared on to the floor base at intervals across it, their level being fixed precisely to the correct finished level by use of the instrument level (dumpy or quickset). A straight edge is then used to keep the finished tiling at the right level between tile pieces, which are cut off as the work proceeds. There are, however, some experienced tradesmen about who exhibit astonishing skill in tiling an area perfectly level given only one level point.

7.5 Site investigations

The principal site investigations should normally have been undertaken prior to the production of the drawings forming the basis of the contract for construction. The resident engineer should always procure a complete copy of such investigations before he goes to site, including complete data about all previous borings and tests.

Notwithstanding such early work, more detailed investigations may be advisable or required when construction commences, in order to amplify or confirm previous findings, or to investigate new areas. The ICE Site Investigation Steering Group's publications listed at the end of this chapter emphasize the importance of site investigations in reducing unexpected costs on a project. British Standard BS 5930: 1981 *Code of Practice for Site Investigations* acts as a general guide to the approach when conducting further site tests, but this needs to be supplemented by information contained in other publications as suggested at the end of this chapter. The resident engineer will be expected to have an understanding of the major principles and techniques of soil mechanics so that he can direct work intelligently. But for interpretation of site investigation results, or specifying and interpreting sample test results, a fully experienced geotechnical engineer is essential. If tests do not follow correct techniques or are not correctly interpreted, misleading assumptions can be made that later lead to serious trouble on a job.

Although the need for comprehensive site investigations before a project is started has rightly received much emphasis, some difficulties have to be recognized. At the planning stage for a major civil engineering project it is often necessary for several alternative locations of the project to be put forward. Negotiations to proceed on one of the sites may be a prolonged affair because of widespread opposition, often on planning or environmental grounds. During these negotiations some alternative sites may be suggested by opponents, and it may be difficult to investigate them all in the detail that is desirable. Yet, one of them may finally be sanctioned, and the promoter has no option but to go ahead with it, taking the view that any problems underground will have to be overcome as they are revealed.

Thus it often happens that the site not adopted is fully investigated, whereas the site that is adopted has a much reduced amount of investigation. If the promoter wants better assurance of the cost of the proposed project, he needs to be persuaded that further site investigations are necessary before design starts. This may still not convince him of the need, because he feels that he has no option but to go ahead despite any construction difficulties, and he does not want more delay. The engineer on the other hand has no knowledge of any serious difficulties ahead, so this weakens his stance, and the promoter's view prevails. Consequently the project is committed to a site that is not as fully investigated as the engineer would have wished.

There is an 'art' as well as a science in deciding what site investigations should take place at an early stage. Primarily they should find out whether it is possible to build the project on a given site at reasonable cost: this is a different matter from finding out everything needed for design. The latter is often impracticable of achievement, as in the case of pipelines and tunnels, where it is unrealistic to think that every trouble that lies ahead can be discovered beforehand. For instance, boreholes 10 m apart, rather than 20 m apart, double the chance of penetrating a 2 m wide disruption below ground; but they only reduce the chance of missing such a disruption from 90% to 80%. In fact money can be wasted by gridding a site with boreholes instead of placing them where conditions suggest they would be most informative.

Of course, a geotechnical engineer or engineering geologist should always be employed to examine a site, and his recommendations about sinking trial boreholes should be followed. But when choosing where to site extra boreholes in addition to those purposefully planned, 'hunch' and 'suspicion' can play a part. A hunch should not be dismissed as unscientific; it usually arises from familiarity with all the available evidence and circumstances applying, and often includes an awareness, or apprehension, that more needs to be known about some aspect of a situation than is currently known at the time. An experienced engineer always worries more about what he does not know about below-ground conditions, than what he does know.

7.6 Trial pits

Hand-dug trial pits are expensive, take time to excavate, and are not always as informative as expected. They do, however, expose a formation so that it can be examined in detail. This may be important if a thin layer of weak clay is suspected below ground. The starting size for a pit depends on the depth it is to be sunk. If required to a depth of 5 m for instance, it will have to be started between 3 and 3.5 m square, because the timber supports to it will have to be 'brought in' twice, and the reduced area at the bottom of the pit must be large enough for the men to work in, with a crane skip present and also possibly a pump.

Before starting a trial pit it is necessary to define:

- what information is required and what are the chances of getting it;
- what depth it is to be taken to, and what samples will be required;
- the estimated cost and whether this can be justified by the expected results;
- whether the time period required to excavate, take and test samples is acceptable.

The last point is sometimes highly relevant. It may be a month before the pit is dug and samples test results are received; if by that time the permanent excavation will have revealed the below-ground conditions anyway (or have made cheaper methods possible to get the same information), there is no point in undertaking the trial pit.

Defining the purpose of a trial pit is all-important. If the requirement is simply to find rock level, then a boring would be cheaper and quicker. If it is required to ascertain whether soft material lies below hard (such as a boulder), again a boring is cheaper and quicker than a trial pit. If one is looking for clay, silt, or soft material, a most important matter is whether the pit is to find the full depth of such material or just penetrate into it. The former can be much more difficult and expensive than the latter.

If undisturbed samples are to be taken it is necessary to know whether they are to be taken horizontally into the sides of the pit, or vertically from the bottom. Pushing a 100 mm diameter sampling tube horizontally into the side wall of a trial pit often involves the use of jacks, and digging the tube out is no easy matter. A further possibility to be borne in mind is that the presence of hard rock or boulders, very soft clays or silts, or loose sands below the water-table which may run or blow when excavated, may prevent a pit from being taken down to the intended level unless elaborate measures are taken, such as rock-breaking equipment, close supports, water pumping or groundwater lowering.

7.7 Test borings

Test borings can generally be classified into three kinds:

- cored holes in rock, rotary drilled by diamond drill;

- lined holes in soft ground, sunk by clay cutter or shell;
- uncored holes drilled by percussion in hard ground.

It is, of course, necessary to have an idea what sort of ground must be penetrated before the right type of boring equipment can be chosen; also, it is necessary to know the kind of information required. It is not always possible to know the nature of the ground beforehand; soft ground can contain large boulders, and hard ground bands of soft or loose material. Mixtures of this type will cause delay. The probable level at which water will be met is also useful information when deciding on the drilling method.

Cored holes in rock can be drilled by the rotary method using a diamond drill bit. The standard sizes in use are given in BS 5930. The most usual starting sizes adopted are NX and HX to give good-sized cores of 54 or 76 mm diameter respectively, which are less liable to fracture during the cutting process and which permit size reduction to deepen a borehole; sometimes larger sizes are called for. It is important that cores are inspected immediately upon withdrawal in order to note whether fractures are fresh and caused by drilling, or whether they are natural to the rock. The cores must be labelled 'top' and 'bottom', the depth must be marked on them, and they must be placed for safe keeping and later inspection, in sequence, in purpose-made core boxes. A label should be attached to the box stating the borehole reference, date of start of drilling etc. In soft ground the geotechnical engineer may request the use of double or triple core barrels. The former has an inner tube into which the core passes, so protecting it from the flow of drilling water. The triple barrel has a second inner tube, which is spring loaded and advances ahead of the bit into soft ground, thus further protecting it *in situ* from the drill water.

When drilling, the need to get complete and reliable information on the groundwater is important. In drill holes and boreholes the water level at the beginning and end of each day's work should be measured, and preferably before and after each midday break. The sinking of the hole disturbs the natural groundwater conditions, but the changes in level recorded give valuable information on the probable natural conditions and the rate of inflows and outflows at various levels. On completion of a hole it is valuable and often essential to install a piezometer by which the longer-term natural groundwater levels can be recorded, and the influence of climatic and seasonal variations can be observed.

If gravel, sand or soft material is encountered below rock, difficulties are immediately increased and a variety of methods may have to be tried to deepen the hole in the softer material. It may even be necessary to ream out a hole through rock in order to pass a casing down to the soft material below.

Particular attention should always be paid to any hole that the driller reports as difficult to sink: for example if the drill bit gets jammed or the drill goes off line. If a driller's report says 'hole abandoned and new hole drilled adjacent', this should ring alarm bells with the resident engineer. The most frequent cause of such problems is some dichotomy in the formation at the base of the abandoned hole or where the bit got jammed or started going off line. This dichotomy may be a geological fault, fractured strata, or a change of inclination of strata and so on.

Any of these changes may be of crucial importance to the job, and in every such case it is wise to try another hole or two in the same area.

Lined holes in soft ground are usually of larger diameter than other types of hole, being often 150 mm diameter, or perhaps larger at the start to permit reduction of diameter if much depth is to be penetrated. The hole is excavated by bumping a 'shell' or clay cutter on the base of the hole. The shell is used on non-cohesive soils, such as sands and gravels, and is simply a heavy cylindrical tube with a lower cutting edge and some form of non-return valve inside. Material entering the shell is retained and withdrawn with the shell, which is removed every 0.5 m or so of boring and emptied. The clay cutter is similar to a shell, but has a retaining ring at the base to hold the clay in, and has open slots either side for removal of the clay. The material inside the shell or clay cutter is partly disturbed, but its nature can be inspected and logged. To take an undisturbed sample, a 100 mm diameter sampling tube attached to the rods is pushed into the base of the boring, given a slight twist to break off the sample, and withdrawn. The sampling tube has a detachable cutting shoe with a small internal lip to retain the sample. If the ground is very weak it may be necessary to push lining down as the hole is deepened. After this it may be necessary to use a shell or cutter of slightly smaller diameter to continue drilling.

Percussion drilling may be used to penetrate rock or boulders if no cores are required. A percussion chisel, usually of cruciform shape with a string of tools to give it weight, all suspended on a wire rope, is raised and let fall repeatedly on the rock base of the hole. The chisel has to be let fall with a clean blow on the base, and it is caused to rotate a little with each blow by the suspension wire having a left-hand lay, and a friction grip attachment that lets the wire re-set from time to time. The drill chisel must be sharpened regularly. The rock chips are removed by water flush in small holes; in larger holes a bailer, very similar to a shell, has to be lowered at intervals to collect the chippings.

Through uniform sound or soft clay a 20 m depth of hole 150 mm diameter may be sunk in a day or two. But if soft ground with boulders in it, or bands of rock, gravel and clay have to be penetrated, progress can be very slow because of the need to change drilling techniques. If any of the soft or non-cohesive strata need support, a lining will have to be inserted, and the hole continued at a smaller diameter than before. It is also very difficult, with percussion drilling, to take a sample from a thin bed of clay between bands of hard material, so core drilling will then be necessary.

Sometimes it is necessary on site simply to investigate the depth below ground surface of hard material, and to ascertain whether soft material lies below it. Such information may be required for construction of bored piles, sheet piling, or a cut-off, or for grouting purposes. In this case the 'down the hole' hammer drill can be used at a relatively small diameter. The blows to the cruciform bit are applied by a compressed-air operated hammer adjacent to the bit. The rock fragments are either blown out to the surface, or washed out by drilling water supplied through waterways inside the drill rods. If blown out, the chippings collect in a small pile at the top of the hole and can be examined. If washed out, the washwater is led to a stilling tank for settlement of the fragments. Small percussion drills of this type, 50–75 mm in size, are fast and can penetrate something of the order of 6 m of rock or concrete per hour. Hence they are useful for ascertaining depth to hard material over a wide area. However, when air driven they are not effective under more than a certain depth of water.

7.8 Other means of ground investigation

The hydraulic digger (or backhoe) is useful as a means of revealing the nature and extent of shallow overburden material on site. It can excavate a trench 6–8 m deep in soft or moderately hard material, at a fast rate and cheaply. The substantial cross-section of material then revealed for inspection can be more informative than samples from a few borings. However, trenches of this depth must be securely timbered before access for inspection is allowable; also, the width of the trench may be too narrow to permit a sample tube to be jacked into the side wall of the trench to take a horizontal sample. A sampling tube can sometimes be pushed into the base of the trench using the digger bucket, and then dug out by the same machine.

The auger may be used for boring holes in soft materials. A lining may be required to keep a hole open during and after boring. Large augers, machine driven, are used for sinking shafts for the formation of *in situ* concreted piles. For site investigations, the hand auger is a simple little tool, usually of 75–150 mm diameter, for penetrating shallow depths of soft material. About 300 mm of material is penetrated at a time before the tool is withdrawn and the material taken out of it and examined. Two men are usually required to twist the auger, the hole being watered from time to time if necessary in order to reduce friction. Penetration is usually of the order of 1.5–2.5 m; to get a hole deeper than 3 m the ground has to be very soft. Gravel or cobbles cannot be penetrated. The tool is useful for locating the extent and depth of shallow, very soft overburden material.

7.9 Judging the safe bearing value of a foundation

The safe bearing value for a given foundation material ought not to be decided by the resident engineer but by the engineer or his specialist advisers. However, the engineer will not thank the resident engineer for referring to him questions about foundation materials that are obviously satisfactory, such as gravel and rock, where the load thereon is well within the traditionally accepted bearing strength. In clays or silts, or materials having clay bands or organic layers, and other mixtures containing weak layers, careful special investigations, sampling techniques, and sophisticated analyses may be necessary before a safe bearing value can be advised, dependent upon the type of structure the formation is to support. These matters need to be considered by an experienced geotechnical engineer. No site bearing tests may be relevant, except the 'standard penetration test', which, however, must be regarded as adjunct only to more sophisticated investigation techniques. Details of the standard penetration test are given in BS 1377 Part 9: 1990, para 3.3. Its widest use on site is to reveal any weak spots in an otherwise consistent foundation material.

7.10 Testing apparatus for a site soils laboratory

The usual apparatus suitable for a small soils laboratory on site, to be run by the resident engineer's staff after proper instruction from a geotechnical engineer, is set out below.

Moisture content determinations

1. Beam balance weighing by 0.01 g divisions;
2. drying oven, thermostatically controlled (not absolutely essential; for rough measurement of moisture content the sample can be dried on a flat tray over a stove);
3. six drying trays.

Grading analyses of soils

4. A set of BS sieves (woven wire) with lid and pan for each different diameter: 300 mm diameter – 38 mm, 25 mm, 19 mm, 13 mm, 10 mm (these can also be used for testing concrete aggregate gradings);
   200 mm diameter – 7 mm, 5 mm, 3 mm, and Nos 7, 14,25, 52, 72, 100 and 200;
5. balance weighing up to 25 kg;
6. balance capable of weighing up to 7 kg by 1 g divisions.

In situ *density test (sand replacement method)*

BS 1377 Part 9:1990 gives four tests, of which Test 2.2 is the most useful because it can be used on fine-, medium- and coarse-grained soils. A metal tray with a 200 mm diameter hole cut in it is placed on the formation and material is excavated via the hole. The volume of the excavation is measured by pouring uniformly graded sand into it whose bulk density has been measured.

Apparatus required (additional to 1, 2, 3 and 6 above):

7. small tools for excavating hole;
8. a rigid metal tray 500 mm square or larger with a 200 mm diameter hole cut in it;

9. dried clean sand all passing No. 25 sieve but retained on No. 52 or 100 sieve and suitable airtight containers for storing it (about 20 kg of this sand will be required initially);
10. a pouring cylinder (as BS 1377 Part 9 Fig. 4);
11. a calibrating container 200 mm diameter by 250 mm (as BS 1377 Part 9 Fig. 5);
12. airtight containers for the excavated soil.

The method can be applied to larger test holes in soils containing some gravel; the sand is poured in layers from a can with a top spout. A length of hose is attached to the spout with a conical tin shield wired to the lower end, so the sand has only a short standard free fall. Tests to fill measured containers can show the accuracy in ascertaining the bulk density of the sand as poured.

Compaction tests

BS 1377 Part 4: 1990 describes tests using 2.5 or 4.5 kg hammers on soils with or without coarse grains.

For the 2.5 kg test on fine- and medium-grained soils the apparatus required (additional to 1, 2, 3 and 6 above) is:

13. compaction mould (BS 1377 Part 4: Fig. 3);
14. 2.5 kg metal rammer and guide (BS 1377 Part 4: Fig. 4);
15. palette knife;
16. glass sheet or metal tray (for mixing in added moisture to sample);
17. 19 mm sieve (from 4 above);
18. a 1 litre glass graduated measuring cylinder (for measuring volume of surface-wet material over 19 mm sieved out).

The compaction test and *in situ* density test are important for earthworks construction. The former indicates the maximum density and optimum moisture content of fill material achieved under 'standard' compaction; the latter shows the density of fill achieved. Specifications often require fill as placed to achieve 90 or 95 per cent of the maximum density obtained under one of the compaction tests stipulated; the 4.5 kg hammer test is used for road construction, the 2.5 kg test for other earthworks.

A small unconfined compression testing apparatus for testing the shear strength of 38 mm diameter undisturbed clay samples is a useful addition to the site laboratory in certain circumstances. This machine is cheap, easy to operate, and gives a useful indication of variations of clay strength, as for road making etc. The results given by it are not, however, adequate for design purposes. The triaxial compression testing machine would be used for testing soils for design purposes; but this is a sophisticated piece of apparatus, not suitable for site control purposes unless a full-scale soils laboratory has been set up on site under the direction of a properly qualified geotechnical engineer. It is also useful to have some standard 100 mm diameter sampling tubes on site, to prevent a delay in getting such tubes when an excavation reveals material that needs to be tested.

Provided proper briefing has been given by an experienced geotechnical engineer concerning the techniques of testing to be followed, the foregoing apparatus should permit a useful range of quality control tests to be carried out on site. Most other tests that might be required – such as consolidation, permeability, and triaxial compression tests – must be regarded as advanced laboratory tests to be carried out by trained technical staff.

7.11 Site layout considerations

Some factors that have a bearing on site layout are mentioned below. Access to the site should be described in the contract for construction; but the haulage roads within the site will have to be planned and designed by the contractor.

Haulage roads

Haulage roads for taking excavated material off the site, or to a tip within the site or elsewhere on the employer's land, must be planned by the contractor for maximum economy and efficiency. The decision is related to the type of excavating machinery that the contractor proposes to use. Motorized scrapers and balloon-tyred wheel loaders can pass over hard to moderately soft ground, and will not seriously disrupt the surface. Flat-tracked machines, such as dozers, cannot pass frequently over metalled, waterbound, or sprayed and chipped roads without ultimately damaging the surface, though occasional traverse is possible. Machines with gripped tracks, such as large dozers, will quickly break up the surface of any road, and cannot traverse or cross a public road. Laden haulage trucks can apply heavy wheel loads; they cannot pass over soft ground unless equipped with balloon tyres, and they are frequently slow on steep gradients both uphill and downhill.

The consequence of the foregoing is that internal roads on site have to be designed according to the anticipated usage of them. For maximum output from motorized scrapers it is important that haulage roads should have easy gradients. Haulage roads for heavily laden trucks must be soundly built; that is, of adequate thickness, suitably topped (or constantly regraded) to prevent rutting and ponding, and well drained. Any attempt to save money by building an access road of inadequate thickness, without proper drainage ditches either side and a surface kept to a camber to shed rainwater, is a false economy. It will quickly break up and cause repeated delay to the job. Mud is a particular nuisance on public roads; frequent cleaning of the road and hosing of traffic leaving the site will be needed if public objection is to be avoided.

Planning bulk excavation

The order in which an excavation is to be undertaken has to be planned. The excavating machine must be able to work to its maximum capacity attended by a continuous flow of dump trucks in and out. As bulk excavation proceeds, formation trimming and minor excavation will follow, then the placing of fill or concrete. For speed of execution these follow-on operations will need to be started before the bulk excavation is completed. Hence the excavation must be planned in such a manner that the different operations carried on simultaneously do not interfere with each other, and so that the excavator can withdraw without difficulty after it has completed its work.

Concrete production plant

This needs to be positioned so as to give easy delivery to the parts of the work where the main concrete is required. Delivery lorries to the stockpiles of aggregates should preferably not follow the same routes as muck-shifting plant, or they will pick up mud and track it into the aggregate bays. The bays should have concrete floors laid to a fall so that the aggregate can drain.

Power generators and compressors

These may need to be housed, even if mobile, because their noise can create a nuisance to local residences. Their siting should be such that the noise they create is 'blanked off' from any such residences. Even though the noise from a construction site may be 'music to the ears' of a civil engineer who likes to hear the job 'humming along', the public at large take a diametrically opposite view. Authorization of night working may be difficult to obtain if attention is not paid to reducing noise as much as possible.

Extra land

Extra land outside the site or extra access to the site can be obtained by the contractor if he so desires, provided it is not disallowed under the contract, and the contractor gets the necessary permissions, wayleaves etc. and bears all costs involved.

Main offices

The contractor's main offices and stores need to be near the site entrance. Most vehicles carrying materials to site must stop at the checker's office, and it is convenient to have this near the agent's offices and the stores. The resident engineer's office should not be far away from the agent's offices, so that easy communication is maintained at all staff levels, and there is economy in providing telephone, heating, lighting and sewerage.

7.12 Temporary works

Temporary works are designed by the contractor, but the resident engineer will need to check the design because of the safety responsibility also held by the engineer (*see* Section 5.8). On a large project the temporary works may comprise major structures, such as caissons, cofferdams, river diversion works, sheet piling, and access bridges. Designs for such structures will normally have to be forwarded to the engineer for approval, though the resident engineer should apply his site checks first so that he can draw the engineer's attention to any matters of doubt seen on site.

7.13 Work in public roads

Under the New Roads and Street Works Act 1991 (applying to England, Wales and Scotland) a **street works licence** has to be obtained from the relevant highway authority before any work to install, maintain or alter apparatus in the highway is permitted, except emergency work. The ICE Conditions of Contract state that the employer will obtain this licence, but that the contractor must comply with all other requirements of the Act and any conditions attached to the licence (Clause 27). The contractor has to give notices as required by the Act and the Street Works (Registers, Notices, Directions and Designations) Order 1992. Notice to start work must be given at least 7 working days in advance, and the work must be started within 7 days of the notified starting date. The Street Works (Qualifications of Supervisors and Operative) Regulations 1992 require a qualified supervisor and at least one qualified operative to be full time on site. Road reinstatement requirements are set out in the Street Works (Reinstatement) Regulations 1992 and a Code of Practice issued by the Secretary of State.

A highway authority can direct the timing of works, require safety measures and stipulate avoidance of unnecessary delay or obstruction. A standard charge for inspections can be made and the authority can also charge for the occupation of a highway where works are unreasonably prolonged, and for the cost of temporary traffic regulation.

The highway authority is required to keep a register of street works; this can be of use to the contractor but, in the nature of things, it may not show every service that lies underground nor provide exact information as to its position. A highway (termed a 'street' in the 1991 Act) normally means all the land between the boundaries of private properties fronting on a public road: that is, including the road verges.

The diversion of existing services often requires joint action by the agent and resident engineer. If need be, the resident engineer should arrange for meetings with the district engineers of the authorities concerned, such as the county or district roads department, gas, water, sewerage, electricity, telephone and TV cable authorities. The resident engineer must see that the reasonable requirements of the various authorities are complied with by the contractor; but he should help to resist any unreasonable requests being put upon the contractor. Most authorities prefer to divert their own services; many will not permit a contractor to undertake diversion of their equipment. Similarly, with respect to final road reinstatement, the road authority has power to do this and may prefer to do so. A common requirement of a road authority is that a trench for a pipeline, sewer etc. laid along a road must be at least 1 m away from the road edge i.e. fully in the road or fully in the verge, except where it has to cross below a road edge.

7.14 Site drainage

Site drainage and flood protection is important. Difficulty often occurs in draining a site where large-scale earthmoving is taking place. The excavations disturb the natural drainage of the land, and large quantities of mud may be discharged to local watercourses during wet weather. Complaints then arise from riparian owners and water abstractors downstream. If this possibility should occur, the resident engineer should advise the contractor to approach the appropriate drainage authority (the National Rivers Authority in England and Wales) to seek advice on the best course of action to alleviate the problem, such as arranging some form of tank to pond the runoff and allow the heaviest suspended solids to settle out. It is the contractor's responsibility to dewater the site, and this includes the obligation to do so without causing harm or damage to others.

Dewatering can range from simple diversion or piping of ditches, to full-scale 24-hour pumping and groundwater table lowering. It is usual to cut perimeter drains on high ground around all extensive excavations. In dry weather this may seem a waste of time, but once wet weather ensues and the ground becomes saturated, further rain may bring a storm runoff of surprising magnitude. If no protection exists for these occasions extensive damage can be caused to both temporary and permanent works. The resident engineer should assist the contractor to appreciate the danger of flood damage by providing him with data showing possible flood magnitudes. A frequently used precaution is to assume that a flood of magnitude 1 year in 10 (i.e. 10 per cent probability) will occur during the course of construction.

The need to dewater an excavation in the British Isles is the rule rather than the exception. Once dewatered an excavation should be kept dewatered. It can be dangerous to repeatedly dewater an excavation during the day and let it fill up overnight; this can cause ground instability, and timbering to excavations may be rendered unsafe. The need for 24-hour pumping should be insisted upon by the resident engineer if he thinks damage or danger could occur from intermittent dewatering. The electric self-priming centrifugal pump is the most reliable for continuous dewatering, having the advantage that it is relatively silent for night operation as compared with petrol or diesel engine driven pumps.

For groundwater lowering, pointed and screened suction pipes are jetted into the ground at intervals around a proposed excavation and are connected to a common header suction pipe leading to a vacuum pump. It may take a week or more before the groundwater is lowered but, when the process works well (as in silt or running sand), the effect is quite remarkable. It permits excavation to proceed with ease in ground that, prior to dewatering, may be semi-liquid. However, it can be difficult to get the well points jetted down into ground containing cobbles and boulders; and in clays the well points need to be protected by carefully graded filters, or the withdrawal of water may eventually diminish because the well point screens become sealed by clay.

Special precautions must be taken to avoid damage to any adjacent structures when dewatering any excavation or groundwater lowering. In some soils groundwater lowering may cause building foundations to settle, causing considerable damage. The contractor may have to provide an impermeable barrier between the pumped area and nearby structures, monitor water levels, and perhaps provide for re-charge of groundwater under structures. A vital precaution is for the resident engineer to record in detail all signs of distress (cracks, tilts etc.) in adjacent structures and take photographs of them, dated and sized, before work starts, in order to provide evidence of the extent of any damage that may occur.

The drainage of clay or clay and silt can present difficulty. The problem is not so much that it cannot be done, but that it can take a long time, perhaps many weeks. Sand drains, such as bored holes filled with fine sand, can be satisfactory as part of the permanent design of the works, but they usually operate too slowly to be of use during construction. If ground is too soft, any attempt to start excavating it by machine may make matters considerably worse, and end with the machine having to be hauled out. The act of removing overburden may make a soft area even softer as springs and streams, otherwise restrained by the overburden material, break out and change the area to a semi-liquid state. If the resident engineer sees the contractor moving towards these difficulties he should advise him of the possible consequences, and endeavour to give assistance in devising a better approach. A paramount need may be to call in an experienced geotechnical engineer to investigate the problem and give advice as to the best policy to handle the situation.

Further reading

Bannister A, Raymond S, Baker R. *Surveying*. Harlow: Longman, 1993.
Construction Industry Research and Information Association (CIRIA). *A manual of setting out procedures*. 1973.
ICE *Conditions of Contract for Ground Investigation*, 1983
ICE *Site investigation in construction*, 1993. (Part 2 Planning, procurement and quality management; Part 3 Specification for ground investigations.)
Terzaghi K, Peck RB. *Soil mechanics in engineering practice*. New York: John Wiley, 1967. (An authentic text.)
Transport and Road Research Laboratory. Road Note No. 17, *Protection of subgrades and granular bases by surface dressing* (An early publication but useful for construction of site roads).
Weltman AJ, Head JM. *Site investigation manual*. CIRIA, Special publication 25, 1983.
BS 1377: 1990: *Methods of test for soil for civil engineering purposes*, Parts 1–9. (Part 1 General requirements and sample preparation; Part 4 Compaction tests; Part 9 *In situ tests*).
BS 5606: 1990: *Guide to accuracy in building*.
BS 5930: 1981: *Site investigations code of practice*.
BS 5964: 1980: *Methods for setting out and measurement of buildings*.
BS 8004: 1986: *Foundations code of practice*.

8

The resident engineer's office records

8.1 Importance of records

An important part of the resident engineer's work is to keep adequate records. His personal success in the job and the assistance that he can give the engineer depend to a considerable extent upon the efficiency of the record systems that he sets up. These records keep watch over the progress of the work, form the basis for fixing payments to contractors, and testify to the proper execution of the works. They make it possible for designers to be assured that the design assumptions are valid, assist the resolution of new design problems arising during construction, and can throw light on the subsequent performance of the works. Without adequate records the resident engineer fails in his obligations to the engineer and the employer.

8.2 Types of records

Records are of four classes:

- *historical:* showing progress of the work, stage by stage, as proposed and as achieved, including all relevant information having a bearing on the subject, such as records of weather, notes of discussions and decisions and other key matters influencing the job;
- *quantitative and financial:* measuring all that is done together with all relevant particulars, so as to form a basis of fair payment to the contractors and for the furnishing of figures that show the cumulative cost of the job, the cost of separate parts of it, and the estimated final total cost at any time;
- *qualitative:* being a record of all measurements and observations of the quality and behaviour under test of the component parts of the works, the raw and made-up materials used, and the foundation and other conditions whose characteristics have an influence on the behaviour of the works;

- *'as built' records:* being a pictorial record (the record drawings etc.) of all the works as completed, showing the whereabouts and dimensions of all parts as they exist at completion, together with factual descriptions of the origin of equipment and materials incorporated in the works, the proper operation of the works as described in instruction manuals, and the performance of the works under test.

8.3 Correspondence filing system

The first matter to be dealt with is the setting up of a correspondence filing system. A filing system of the type outlined below allows additional files to be added in their right place.

General files (Series 1–9)

1. Employer (including copies of letters sent by engineer to employer);
2. Monthly progress reports to employer – drafts sent to the engineer and copies as sent by the engineer to the employer;
3. Meetings file – second copy of minutes or notes taken of meetings on site, in date order (from files 1, 10 and 11);
4. Planning authorities etc.;
5. Road authorities and public utilities;
6. Miscellaneous (job) – e.g. re telephone, visitors to site;
7. Staffing – reappointment of inspectors, office staff ;
8. Miscellaneous (personal) – resident engineer's personal correspondence – e.g. invitations to speak at meetings.

Head office (Series 10–19)

10. Engineer;
11. Specialist advisers – correspondence with other advisers – e.g. geologist, landscape architect;
12. Informal memos to designers – copies of notes sent to colleagues in the engineer's office (though most correspondence should be through the engineer);
13. test certificates etc.;
14. other special subjects as required.

Separate supply contracts and subcontractors (Series 20–29)

20. Supply contractor A;
21. Supply contractor B;
22. Supply contractor C etc;
23. Nominated subcontractors/suppliers.

Main contractor (Series 30–39)

30. Contractor's head office – copy letters sent by the engineer (the resident engineer would not normally send any);
31. Contractor's agent – excludes Instructions (File 32);
32. Instructions to contractor;
33. Applications for interim payment from main contractor;
34. Engineer's interim certificates and correspondence thereon;

35/1. Variation orders – Passed (copy as signed by engineer);
35/2. Variation orders – Draft/pending (as sent to engineer);
36. CVIs from contractor (*see* Section 8.4 below);
37/1. Claims – Pending/Rejected;
37/2. Claims – Settled.

Under File 37/1 all claims should be numbered, usually in order of receipt. Each claim and correspondence thereon (copied from File 31) should be filed as a separate section with a tabbed index. All claims should be listed at the front of 37/1 and marked with the subject, and whether 'Pending', 'Rejected' or 'Settled' (in the last case transferred to File 37/2).

If there are other construction contracts forming the project, they would be numbered 40 series, 50 series etc. It is worth spending a little time planning a filing system. The above list is only an example for guidance. On a small job some files can be merged; on a large job a more extensive system may be required.

It is best to file correspondence under the name of the addressee. This way, letters do not get misfiled. Any file can be broken down into subfiles, e.g. 11/1, 11/2, ... etc. with one addressee for each subfile. Sometimes a special subject will crop up, such as a major design modification or site investigation, and it is useful to collect all the relevant data in one file in Series 14–19. Letters do get lost, especially the important ones! The reason can be that they are so important that they are kept out of the filing system, and then get lost in some temporary folder of working papers. Important letters that take time to deal with should be photocopied so that the original can go straight on file, and the copy can be used for working purposes.

Several files will be required for dayworks sheets. These pose a special problem, which is dealt with in Section 8.10.

8.4 CVIs from contractor and instructions to contractor

CVIs are **confirmation of verbal instructions** (sometimes otherwise called 'CVOs' – confirmation of verbal orders) sent by the contractor to the resident engineer when some verbal instruction has been given to the contractor by the resident engineer or any member of his staff. (Strictly speaking, the instruction is 'oral': i.e. by word of mouth.) These CVIs raise a number of problems, which are discussed in Section 12.6. They should be filed together with the resident engineer's reply and subsequent correspondence. Usually the contractor will have numbered the CVIs in order. If a dispute arises as to whether any payment is due under a CVI, this should be given a claim number and transferred to the Claims File 37/1.

As already mentioned, all instructions to the contractor have to be given in writing or, if given orally, confirmed in writing as soon as possible. Major instructions will be by letter, copies being put on File 31; but there are many other day-to-day instructions of a minor nature, such as supplying the general foreman with a sketch of some levels, or listing quality requirements for materials. To deal with these, the resident engineer should be supplied with forms that can be used for such instructions. The forms should be A4 size, drafted thus:

A-B-C PROJECT
Site Instruction No.......... Date...........

TO: The Agent, Messrs XYZ
FROM: Resident engineer

Subject ....
You are requested ...etc.
. . . .
. . . .

This instruction does/does not constitute a variation to the works.

If an instruction does not vary the works or does not entitle the contractor to varied or additional payment, this should be stated. If the instruction does vary the works, a statement should be added indicating how it is to valued: for example, at dayworks rates, or bill rates, or at varied rates to be proposed by the engineer. It is not necessary to state on the instruction the actual rates that will be used; if they are to be varied rates they will need discussing with the contractor before a decision is reached on them, so the instruction would state: 'at rates to be agreed'.

A copy of each instruction must be kept on file. They can be handwritten. There is no need to issue an instruction to the contractor if, for instance, an inspector or assistant engineer finds some formwork that is out of line and orally requests that it be corrected. Matters requiring compliance with the workmanship specified are only oral restatements of what the contract requires. If any such oral request results in a CVI from the contractor that implies that a claim will be submitted for extra payment, the CVI should be promptly countermanded by a formal letter, rejecting any basis of claim. But if dimensions are given orally, these should always be confirmed by a written memo as a record in case errors occur.

8.5 Register of drawings

Drawing registers are required. One should be for 'Drawings Received' and should log down title, reference, date received, and how many copies received. The other should be labelled 'Site Drawings', being a register of all drawings made on site and logging down:

- consecutive site reference number;
- subject/title;
- size and type of drawing;
- to whom copies sent and when.

The information under the third item is useful, as a register is not consulted by a person who knows where a drawing is, but by a person who needs to know what to look for: for example, a pencil drawing on a print of a contract drawing, or a pencil or ink tracing, and the size of it.

8.6 Daily and other progress records

The principal records that have to be kept in this category are:

- the inspectors' daily returns;
- the site diary and weather records;
- resident engineer's diary;
- weekly and monthly progress records;
- progress charts (these are dealt with in Chapter 9).

The inspectors' daily returns are a vital record. If no inspectors are employed, then each assistant engineer should complete a data form each for his own section. If the resident engineer is on his own he should endeavour to keep the necessary log going in his diary. A typical inspector's return is shown in Fig. 8.1. The sheet is purposely simple because it is intended to encourage the inspector to put down the following information:

- where and what type of work was being done that day;
- how many men and what machines were engaged on each separate occupation;
- what delays and bad work were experienced and why.

The inspector is given an *aide-mémoire* at the top of the form to remind him of the

Date 4/8/93
Shift: ~~Night~~/day

INSPECTOR'S REPORT

	WORK DONE BY CONTRACTOR (1) Valve Tower and Bellmouth, (2) Tunnel and Stilling Basin, (3) Dam, (4) Quarry and Road, (5) Road Diversions, (6) Miscellaneous	No. of Men
3	1 D8 dozing Rip-rap limestone up U/S slope east side. 2nd D8 and roller spreading sand in northwest corner. D6 and roller also spreading sand, south east of wall. Cat 953 dozing sand up south west hillside to make up gradient to original slope, before placing filter. Small JCB 406 assisting D8 in north west corner. Rollers compacting fill both sides of wall. Leyland truck and bowser watering bank. 2 Aveling RDs and 1 Cat D25 trucks and 2 Cat 621 scrapers delivering sand until 2.30 pm.	1 Foreman 1 Ganger 1 Chargehand 2 D8 drivers 1 D6 " 1 Cat 953 " 1 JCB " 2 Roller " 1 Leyland " 1 Bowser " 2 Aveling " 1 D25 2 Cat 621 " 10 Labourers
4	2 O & K RH30s and JCB 425 loading vehicles until 2.30 pm. Drillers drilling quarry face, Shotfirer and 1 labourer blasting.	1 Ganger 1 Chargehand 2 O+K 1 JCB 2 Drillers 1 Labourer
5	Poclain tidying up bermes at side of Green road. Hired lorry removing excess spoil to tip, D4 levelling bermes at side of road. 13 labourers working at Middle road tidying limestone bermes and 5 finished at 12.30 pm. 13 labourers working at Green road tidying up verges, helping curblayer to make curbs and channels up to Gully gratings.	3 Gangers 1 Poclain driver 1 D4 " 1 Lorry " 1 Joiner 1 Joiner 1 Curblayer 26 Labourers
6	Men felling and burning trees in Hawthorne wood 10 finished at 12.30 pm.	1 Ganger 16 Labourers
	REPORT ALL DELAYS AND BAD WORK 1 D25 broken down all-day 1 D8 " " " 1 Daf truck broken down from 9 am. 1 D6 tractor " all day vibrating roller and JCB 2X standing all day	Time lost and No. of men Involved 1 D8 driver 1 truck "

Hours worked by Inspector ....9½....

Fig. 8.1. A well-written inspector's report

separate sections of the job needing coverage. The last section permits the inspector to comment on what he sees, in addition to logging down delays etc. This gives the inspector an opportunity to put his comments on record, thus contributing to the resident engineer's successful control of the job.

Inspectors' records are invaluable for dealing with claims from a contractor for delay, disruption, lack of instructions, or 'uneconomic working'. These are all difficult to handle if only general progress charts are available. But, if it is possible to compare the productivity of a workforce before a disruption occurred with the productivity during the disruption, there is a possibility of estimating any loss. This can be done if the inspectors' records show the numbers of men on each type of operation and what is accomplished each day.

The site diary is a day-to-a-page diary that notes matters not on inspectors' daily returns, such as weather, visitors to site, and meetings held. Weather records are important, but need not be strictly meteorological. It can suffice to note weather that affects work, such as stoppages due to rain or snow; freezing conditions that can affect concrete, showers interrupting concreting, or excessive heat causing over-drying of concrete etc. A note such as 'Heavy showers interrupting concreting' can, for instance, be the explanation for leaks found later in the concrete walls of a tank, which appear to be due to poorly compacted concrete.

The resident engineer's diary is not easy to keep, because progress on the job is recorded elsewhere, and it is difficult to decide what else to record that will be of use later. The aim therefore is to record events not recorded elsewhere, such as decisions on problems, comments made by the employer or specialist advisers, and important telephone calls. When things get in a tangle and misunderstandings occur, it can be particularly important to be able to say, with certainty, when a discussion or telephone conversation took place. As an instance, an agent maintained that he was authorized to take a certain action by the resident engineer, but the resident engineer's diary showed that the telephone conversation took place after the contractor took his action. Noting phone calls or chance discussions may also remind the resident engineer of the need to put a record of a conversation in more detail on some other file.

The style of operation of the agent will decide how meetings with him are recorded. Formal meetings (usually over claims!) have to be minuted and agreed. But many informal discussions may take place between an agent and the resident engineer, and there may be no need to record such meetings and exchange notes about them. A good agent will often wish to 'sound out' the views of the resident engineer on some problem, and if this should lead to some oral agreement on a course of action the agent will not act otherwise. Many a job is run almost entirely by oral discussion and agreement between resident engineer and agent, without any need to record what was decided except, of course, when a variation has been agreed and a variation order must be issued, or perhaps when a complicated series of operations have been agreed, which the staffs of either side must follow. To issue 'written instructions' or notes of every discussion with a responsible agent would be inappropriate; it might seem to imply that his oral agreement to some course of action was not to be trusted. The resident engineer must endeavour to establish a good working relationship with the contractor's agent, and not treat him as if he was not to be relied upon.

The weekly report is sent to the engineer, and a typical example is shown in Fig. 8.2. It summarizes work done during the week and total progress to date. It might not be adopted where the site is remote, e.g. overseas. The monthly report is written in a fashion suitable for the employer; it will not be so technical as the weekly report because it endeavours primarily to inform the employer of overall

XYZ CONSTRUCTION SCHEME
Weekly Report No. 80
(For week ending 26th June 1993)

Contract 52: Extension to pumphouse

Continuous rain delayed waterproofing of roof until 25th. Plastering sub-contractors started work on 21st. They will finish next week. Installation of switchboard awaits arrival of manufacturer's fitters promised for 29th.

Labour: 2 plus 2 plasterers.

Contract 54: Electrical re-wiring

Cable laying completed but awaits connection to switchboard. Lighting wiring completed as far as possible. Contractor withdrew men from site on 24th and will return to complete after switchboard connection made.

Contract 57: Mainlaying

The extra sluice valve required at Ch. 3500 was delivered. This completes all deliveries under the valve contract (Contract 53).

Delivery of steel 600 mm diam. pipes continues. Total delivery to date 4600 m or 82 per cent order (Contract 55).

Supply of small cast-iron pipes and fittings continued. Only a few items now outstanding (Contract 56).

Approx. 260 m of pipe laid during week by two gangs working from point 'F' forward and point 'G' back; chainages 3260–3840 and 4480–4210 respectively. Suppliers are being pressed for delivery of special T-junction Ch. 3500 which is promised for next week.

The crossing under the two main-line tracks was completed successfully at Ch. 4400 and in 14 h continuous working.

Labour: 1 General foreman, 2 section foremen, 3 gangers, 3 jointers, 7 drivers, 11 labourers.

Plant: 2 JCB excavators. 1 Case loader, 3 dumpers, 2 D4 dozers, 4 lorries.

Testing. Testing to point F from H was satisfactory and the section left out at Point F for testing was re-inserted and the line made good. Main has now been passed from Ch. 500 to Ch. 3260.

Miscellaneous. A director of Messrs. Smith accompanied by the sports ground manager inspected the reinstated trench through the sports ground and was satisfied.

General

Weather:	Wet. 2.15 in. rain	
	Temp. 57° to 68°F.	
Lost time:	2 men × 6 h	Contract 52
	Nil	Contract 57

Visitors

Director Messrs. Smith & Co.	25th
District road inspector to Contract 57.	25th
Representative pipe suppliers.	21st

A.B.C.
Resident Engineer

Fig. 8.2. Typical weekly report

progress achieved. A draft of the monthly report is usually sent to the engineer, for him to amend as necessary and send under his own hand to the employer. On overseas sites the report may go direct to the employer from the resident engineer, with a copy to the engineer.

8.7 Quantity records

The measurement of quantities of work done will be one of the most important tasks undertaken by the resident engineer and his staff. Two essentials for any system are:

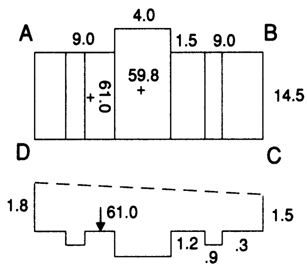
- It must be possible to ascertain from the records what has been measured and what has not been measured;
- the records must clearly show what has been paid for (under interim certificates) as distinct from what has been measured.

For example, brickwork to walls up to dpc may be incomplete at the time of measurement; but the measurement engineer would quantify the brickwork as if it were complete up to dpc, and then apply a percentage to that quantity representing approximately the amount done to date. He therefore needs to show these two matters separately in the quantities records.

For interim measurements the measurement engineer will work from notebooks containing dimensioned sketches of the amount of work done measured by himself, or by assistant engineers and inspectors who send him notes. All these he will file, and armed with the quantities he calculates as a result, he checks the contractor's monthly claim in detail, item by item. Where he thinks something has been mismeasured or overclaimed by the contractor he raises this with the contractor, or more usually with the contractor's quantity surveyor. Comparison of quantity measurements takes place to see where the difference might lie. If the difference is one of interpretation of how the quantity should be measured, the resident engineer will have to decide what is the correct interpretation. If the contractor wishes to argue the matter, it becomes 'a claim', and is put in the Claims Pending file with all details attached. The resident engineer may raise the problem with the engineer's contracts department when he sends in the contractor's application for checking. If the contracts department agree with the resident engineer's ruling, there is no further action to be taken; but if the department agrees with the contractor they may re-insert the contractor's claimed amount or whatever the resident engineer has advised would be the figure in that case.

The measurement sheets are best filed in lever-arch files, in order of the bill items, with all calculations relating to an item being filed under that item. A typical sheet is shown in Fig. 8.3. In the early stages of the job it may not be worth while attempting to make any exact calculation of the quantity of an item. In that case a rough sketch is drawn on the measurement sheet, showing how an estimate of the work done has been calculated.

			p. 12
Quantity calcs.			
Excavation		Measured	Paid
Item E325.1	b/fwd	Nil	



ABCD only to 61.0			
22.0 x 14.5 x 1.65 av	526.35		
Less topsoil x .15	47.85	478.5	500 Cert 2
ADD below 61.0 etc.			
2/14.5 x 0.9 x 0.3	7.83		
14.5 x 4.0 x 1.2	69.60		
End			
4.0 x 1.5 x (1.65+1.2)	17.10		
	94.53		
Less topsoil		93.6	
4.0 x 1.5 x .15	.90	572.1	572 Cert 3

Fig. 8.3. A page of a quantities calculation book

8.8 The contractor's interim payment applications

The contractor's monthly application for interim payment should normally be set out as shown in Fig. 8.4. Initially only the items under which work has been measured need be listed, divided into bills. Later, when all the work listed on a page of the bill of quantities has been completed, the page total need only be quoted in the bill summary. Where work is incomplete and only an estimate can be made of the work done, the resident engineer may accept the contractor's figures if they are reasonable. But where work is completed, the contractor's final measurement of a quantity should check reasonably with the resident engineer's estimate. In such matters as excavation the resident engineer should not require an unreasonable degree of accuracy; measurement to the nearest 1 m^3 is adequate. If there are minor differences between the contractor's figures and the resident engineer's, a compromise figure should be agreed. Major differences should be looked into.

For reasons discussed in Section 11.2 it is best if extra items are put on a sepa-

Bill Section 4: Inlet Works

Item no.	Item description	As bill		As measured			Bill rate	Amount
		Quant	Unit	Last cert	Since last cert	Total to date	£	£
	CONCRETE ANCILLARIES Formwork: Type B as specification Clause 411							
G213	Plane horizontal to suspended floor slab soffit. Width 0.2–0.4 m	3	m2	3	–	3	34.12	102.36
G214.1	Plane horizontal to suspended floor slab soffit. Width 0.4–1.22 m	136	m2	52	85	137	21.54	2950.98
G214.2	Plane horizontal to service ducts. Width 0.4–1.22 m	8	m2	–	–	–	34.12	–
G215	Plane horizontal to suspended floor slab soffit. Width exceeding 1.22 m	152	m2	100	52	152	21.54	3274.08
G223	Plane sloping to corbel at top of external wall. Width 0.2–0.4 m	43	m2	20	23	43	33.38	1435.34
G224	Plane sloping to grit sump. Width 0.4–1.22 m	3	m2	–	–	–	37.20	–
G242.1	Plane vertical to suspended floor slab. Width 0.1–0.2 m	198	m2	120	78	198	7.16	1417.68
G242.2	Plane vertical to drainage channels rebate. Width 0.1–0.2 m	125	m2	30	95	125	7.16	895.00
				Total page 4/7 to summary				10 075.44

Note: The letter and first three figures of the Item No. are the CESMM Class and 1st, 2nd, and 3rd Divisions respectively.

Fig. 8.4. Example of a contractor's form of application for payment

rate sheet or sheets, grouped for each separate bill of quantities, where possible. Extra items not authorized by a previously issued variation order (VO) must be checked by the resident engineer. If he agrees them, he must send a draft VO to cover them to the engineer. If he thinks an extra is invalid, or the rate or quantity is wrong, he should discuss this with the contractor, and may then decide to delete the item, accept it, or substitute a rate or quantity he considers fair. He draws the engineer's attention to his decision when forwarding the contractor's payment application. If the contractor continues to dispute the item after the engineer's decision on it, the matter becomes a claim, is given a number and put on the Claims Pending file for further consideration.

It is preferable for each VO to cover one instruction only. However, one VO can be made to cover a series of related instructions, provided the instructions covered are itemized. A typical style of variation order is shown in Fig. 8.5.

VARIATION ORDER

No..............

Job ....

Contract No. . ... Description ....

Contractor ....

In accordance with and subject to the Conditions of Contract you are hereby instructed to execute the following work:

The prices to be allowed for the above work shall be:

This work is additional to / substituted for work hitherto included in the Contract.

You are instructed to omit items of work as follows:

Drafted .... Signed ....
Resident Engineer Engineer

Date .... Date ....

ESTIMATED NET EFFECT ON THE COST OF WORKS

This Variation Order	....	increase/decrease
Add total effect of previous Variation Orders issued	....	increase/decrease
Total estimated effect	________	increase/decrease

Fig. 8.5. Layout of a Variation or change order

8.9 Authorization of dayworks

Some extra work ordered may be paid for at dayworks rates, instead of at some unit rate. This is adopted when no unit rates seem applicable, or when the amount of work required is indeterminate. A typical application of dayworks rates would be for offloading and stacking pipes delivered by the employer for use on the job, if no bill item for this has been allowed. In the UK the *Schedules of Dayworks Carried out Incidental to Contract Work* issued by the Federation of Civil Engineering Contractors is widely used as a basis for charging dayworks. The most recent Schedule provides for payment as follows:

- The cost of labour per hour is to be taken as the wages paid to a worker (inclusive of overtime, bonus, travelling time and lost time due to weather) plus 148 per cent; plus subsistence or lodging allowance and travelling allowances plus 12.5 per cent.
- The cost of labour subcontractors and hired drivers is at invoiced costs plus 88 per cent.
- The cost of materials is the invoiced cost to the contractor of those materials plus 12.5 per cent.
- The cost of plant used is to be taken at the rates listed in the Schedule, and hired plant at invoiced cost (excluding driver) plus 12.5 per cent.
- Cash discounts up to 2.5 per cent are not deducted.

The percentage additions may vary from time to time as new editions of the Schedule are published following agreement reached in the industry. The plant rates in the Schedule cover most types of plant inclusive of fuel but exclusive of driver. For most items hourly rates are quoted, for others daily or weekly rates.

As an alternative to the Federation's dayworks rates, tenderers may be required to quote their rates against a list of labour categories put in a schedule attached to the bill of quantities. This is necessary in any case for work done outside UK where no locally recognized schedule of dayworks rates may apply. The method is also useful since the labour categories listed can be grouped into four or five classes according to skill or range of pay, and prices entered may be specified as inclusive of all on-costs and overheads. This simplifies the work of costing daywork sheets, as individual rates of pay and on-costs do not have to be ascertained. Dayworks rates for plant are usually inserted by the contractor who may price them 'at invoiced hire and transport cost plus 15 per cent for fuel etc.' if all his plant is hired from an outside source. Alternatively he may list prices for items of plant most likely to be used, anticipating that if different plant is used an adjusted rate would be negotiated.

As soon as any dayworks have been authorized, the resident engineer must arrange for the labour, materials, and plant used on the dayworks operation to be observed and checked by his staff – usually by one of his inspectors. The contractor's foreman in charge of such dayworks will normally submit daily time and materials sheets to the inspector for him to check and sign that they are correct as to hours, materials, and plant used. From these sheets the contractor makes up the dayworks account – typically as Fig. 8.6 – in duplicate, and submits invoices to support the prices for materials. After checking and signing by the resident engineer, one copy of the account is returned to the contractor for inclusion in the next monthly application.

8.10 Filing system for dayworks sheets

On a large job there may be a thousand or more dayworks sheets. It is therefore essential to set up a filing system to handle them. The following files will be necessary:

- DW1 Dayworks sheets: New/To be dealt with;
- DW2 Dayworks sheets: Checked/Pending signature;
- DW3 Dayworks sheets: Signed and returned to contractor;
- DW4 Dayworks sheets: Rejected and returned to contractor;
- DW5 Resubmitted dayworks sheets: Pending.

Arrangements should be made with the contractor for all dayworks sheets to be numbered consecutively, and all sheets must be submitted in duplicate. An exact copy of every sheet returned to the contractor must be kept, showing corrections and comments made on the sheet. Such sheets must be signed and dated by the resident engineer. If care is taken to ensure that sheets are filed as soon as they

DAYWORK/RECORDED COSTS

Sheet No :- 57

Contract No. TF/04

Description :- Excavate for & cut hole in 250 mm T.C. wall for 400 mm £ pipe

W.E. :- 25/6/94

Eng Ord :-

Basement extension

Name	Trade	M	T	W	T	F	S	S	O/T	T/T	Total	Rate	Bonus	£	Subsistence	£
Hunt A	CL hand				8	5					13	7.38		95.94		
Jaggers J	Lab				8	5					13	5.81		75.53		
Smith A	Welder				2						2	7.30		14.60		
Johns KA	Carp				3						3	7.30		21.90		
Casey J	Driver				4						4	7.08		28.32		
														236.29		
													+ 148 %	349.71		
														586.00		586.00

Plant	M	T	W	T	F	S	s	Tot	Rate	£
Poclain				4				4	24.80	99.20
Compres.				4				4	15.04	60.16
										159.36
									+ 12½ %	19.92
										179.28

Materials			Rate	£	£
4m 50 x 75 sft wd	4	m	1.60	6.40	
2 x 1½m chipbrd	3	m^2	3.45	10.35	
Cement	25	kg	£85/t	2.13	
agg. 150 kg	.15	t	8.40	1.26	
				20.14	
			+ 12½ %	2.52	
				22.66	22.66

	22.66
	179.28
Total £	787.94

Certified Correct. Site Agent :- D.J.M Resident Engineer :-

Fig. 8.6. Dayworks sheet

come in, so that none is lost, the sheets themselves can form the record, and there is no need to provide an index of them. Comments can be written on a sheet returned, or on a signed note stapled to it, provided a copy is kept (one reason for a photocopying machine on site). It is too time-consuming to write letters to the contractor about dayworks sheets. If the contractor maintains a dispute over a dayworks sheet after the resident engineer has given his final decision on it, the contractor must be told to treat it as a claim and give it a claim number. If many hundreds of daywork sheets have to be dealt with, there will be a number of files under each of the above file names.

The file DW5 – for Resubmitted sheets: Pending – is for sheets returned by the contractor because he disputes a correction or rejection made by the resident engineer. These sheets eventually end up in Files DW3 or DW4 after being dealt with a second time by the resident engineer. Alternatively the resident engineer may, in such a case, send a letter to the contractor stating why his previous decision stands.

The problem of handling dayworks sheets submitted 'For record purposes only' – called **FRPO sheets** – is discussed in Section 12.7. The filing of these will depend on the policy adopted with respect to them by the resident engineer after consultation with the engineer. If the decision is not to return them to the contractor, only one file for them is needed, the resident engineer's factual findings and comments thereon being filed with each sheet. If some FRPO sheets are returned to the contractor after checking, two files will be necessary: FRPO/1 for incoming sheets; and FRPO/2 for copies of sheets returned.

8.11 Check of materials on site

Most contracts permit the engineer to certify payment on account of materials delivered to site but not yet incorporated in the works. Section 11.5 sets out the matters to be taken into consideration when assessing what payment can be allowed. The value of materials to be taken against which a percentage on account payment can be made, is represented by their purchase price to the contractor, and evidence of this may need to be provided by him. Usually a contractor will only ask for payment on account of relatively expensive items, such as steelwork, reinforcement, pipes and valves. Before agreeing to payment on account the resident engineer will need to inspect the materials to ensure that they conform to specification, and may need to get confirmation that the contractor has paid for them or otherwise has ownership of them (*see* Section 11.5).

8.12 Price increase records

As mentioned in Section 11.8, contracts extending over a lengthy period of time may incorporate a price variation clause under which the contractor is entitled to receive reimbursement of extra costs caused to him by inflation of prices for labour, materials and plant since the date of his tender. The amount due to him under this clause can be calculated according to a formula incorporated in the contract conditions, or by direct examination of the contractor's wages sheets and invoices received by him for materials or hire of plant.

If a formula is used, this will be recalculated each month: hence a file of the price indices used for such a formula is necessary. However, if – more rarely – the price increase has to be calculated by reference to the contractor's wages sheets and invoices, a separate filing system for the extensive calculations involved will be necessary. A file of basic costs at time of tender will be needed, another for wage increase calculations, and another for materials and hired plant. When invoices showing price increases are submitted, a check needs to be made to ensure that the invoiced quantity of materials shown on the invoice has been used on the job. For materials such as cement, aggregates, reinforcement, or fuel (for plant), a running total of quantities delivered as shown on the invoices must be kept, to ensure that the total does not exceed the possible use on the job. All invoices must be marked 'Seen' and initialled before return to the contractor, who must be instructed to file and keep them in case the employer's auditors wish to check the assessment of the price increases certified.

8.13 Supply contract records

On some projects separate contracts are let for the supply of pipes and valves, and other types of material to be incorporated in the works by the civil engineering contractor. Some of the materials, especially large pipes and valves, may be on relatively long delivery so that, to get a project completed as early as possible, contracts for their supply have to be let before the main civil engineering contract commences. When this occurs it is essential to set up a stockbook in which a record is kept of all items ordered, and those delivered. The items, when delivered, would be stored in stockyards, from whence they need to be issued and accounted for in various parts of the work. Even if pipes are strung along the route of the pipeline, their location needs to be logged. The factors that may need to be taken into account when setting up a system include the following:

- Items need to be inspected for damage as they are offloaded.
- Some items may be delivered before the civil contract starts, and some after.
- Some items may be supplied by the employer from his own stocks, but have to be collected by the contractor.
- There may be separate supply contracts for different types of pipes, and for valves.
- Some further items may have to be ordered and delivered.
- Jointing materials, bolts and other small items will need storage under cover.

The resident engineer will need to keep the stockbook, and he should supply the contractor with a list showing where all items delivered are stored, and keep the list updated as more materials come in. He must make arrangements with the agent as to how materials are to be taken from stock. Usually the resident engineer's pipeline inspector will take charge; he will tell the pipeline foreman where the appropriate pipes and specials are, and will see that the right ones are taken.

A typical stockbook page is shown in Fig. 8.7. It lists items ordered, where they are to be used, items delivered and where stored, and how finally used. The last three columns are useful to record a number of matters that, if not recorded, can cause confusion, such as pipes cut and the unused portion returned to stock, or a bend taken out but not used and returned to stock. If no proper stockbook is kept, there may be considerable wastage due to failure to make economic use of pipes and specials; or delay and extra cost can be caused by failure to use specials in the right place, so that more have to be ordered.

For the financial bookkeeping a pipe (or valve etc.) delivery schedule should be kept in the style shown in Fig. 8.8. Under the columns headed 'Deliveries' the delivery position at any time can be known, and the tonnage weights entered can be used to calculate payments to the contractor for haulage on a tonnage rate basis. Under 'Payments' the checked invoice prices are inserted, and the date when the invoice is included in a certificate for payment. A transmission letter should always accompany transfer of invoices to the engineer, listing them by their reference and invoiced price. This acts as a check if an invoice goes astray.

The question can be asked: need the resident engineer keep such a stock register if the contractor supplies the pipes and valves etc.? The answer depends on the method of payment to the contractor. If he is paid unit rates for 'supply, lay and joint...' pipes and valves, then it is not necessary for the resident engineer to keep a stock record, but the contractor will be wise to do so for the reasons given above. If, however, the contractor is to obtain the pipes and valves from nominated subcontractors whose charges are reimbursed to the contractor, then the resident engineer should set up the stockbook to check that mismanagement of items and unnecessary wastage do not occur. There can be considerable money in pipes and valves, and only their careful control will prevent unnecessary expenditure where they are supplied in this way. Any materials left over on completion of the contract remain the property of the employer if supplied by him. This is another reason why control via a stockbook should be exercised by the resident engineer, so that the employer does not get returned to him a miscellany of cut pipes of little use to him, but as many whole pipes and undamaged specials as possible.

8.14 Registers of test results

Test results on materials should normally be recorded on special forms to a format supplied by the engineer. A file for each type of test should be kept on site, copies of the tests being sent to the engineer. A general classification of tests for filing would be as under:

- Borehole logs, trial pit results etc.
- Foundation material tests: grading curves, sample tests, analyses etc.

PIPE STOCK BOOK

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)
Item no.	Description	No.	Where required	Deliveries		Where Placed	Used	Surplus	Disposal
				Date	No.				
1	*750 mm × 4 m S. & S.*	24	*Pipeline* 24	*On site*	8	*Verge by crossing* 8			
				12 Sept	8	*Verge near entrance* 8	*15 & 1 No. 2 m s.p.*	*2 m p.p.*	*Scrap*
				1 Oct	8	*Entrance* 8	*6*	*2 No. (1 cracked spigot)*	*3 m length in tank: 1 No. stock*
2	*750 mm × 3 m S. & S.*	1	*Tank*	*17 Sept*	1	*Site Dump* 1	*1 No.*		
3	*525 mm 45° S. & S.*	6	*Tank inlets* 2 *outlets* 2	*1 Oct*	6	*Site Dump* 4	*2 inlets* *2 outlets*	—	—
			Pipeline (crossing) 2			*Crossing* 2	*Not used*	*2 No.* — *(This column recorded in pencil and brought to date before stock check takes place)*	*2 No. stock*

Fig. 8.7. A page of a pipe stock book

PIPE DELIVERY SCHEDULE

Bill item	Description	No	Deliveries: Advice note	Deliveries: No.	Deliveries: Weight[a] (tonne)	Deliveries: Delivered	Payments: Invoice no.	Payments: Amount £	Payments: Passed for payment
D18	*400 × 150 fl. Tee*	3	*44/5838*	3	*0.30*	*15 Oct*	*5838*	*1 125.00*	*21 Oct*
							(Overcharge £46.0 deleted. See invoice.)		
D19	*300 × 150 -do-*	5	*14/7953*	2	*0.14*	*29 Oct*	*7953* }	*895.00*	*15 Nov*
			8/2572	3	*0.20*	*6 Nov*	*2572* }		*-do-*
D20	*150 × 5.5 m Sp/So.*	4	*14/7953*	4	*0.64*	*29 Oct*	*7953*	*250.00*	*-do-*
D21	*300 22½° bend*	2							
D22	*300 × 2.0 m fl/plain*	2	*14/7953*	2	*0.32*	*29 Oct*	*7953*	*454.00*	*15 Nov*
D23	*400–300 conc. taper*	1							

[a]The weight is only required if the contractor is paid by weight of pipes offloaded and hauled.

Fig. 8.8. A page of a pipe delivery book

- Earthwork tests: Proctor compaction tests, *in situ* density tests etc.
- Concrete tests: aggregate gradings and tests, cement tests, cube and beam tests etc.
- Pipeline tests.
- Miscellaneous tests.
- Other manufacturer's tests.

The nature of the project will decide what other tests may have to be filed. Where extensive tests of a particular kind have to be conducted, as for concrete, or for earthworks compaction, the appropriate file should be fronted by a register of all tests taken. The particulars on the register must show where the sample is taken from, the date taken, date tested, and nature of test. Reference numbers for all samples must be given, and indelibly written on the sample packaging. Simple errors in mislabelling concrete test cubes, for instance, can lead to time-consuming, expensive and unnecessary alarms.

The position of all foundation or earthwork investigations, inspections, probes, samples etc. should be marked on a plan. It is essential to keep a second updated copy of this plan, as loss of it can greatly reduce the value of such investigations.

On many civil engineering projects equipment installed of various kinds may need to undergo performance tests, some of which may be extensive, lasting several weeks. Also, logs of various observations of the performance of the works may be needed, such as movements of a dam during filling, or settlement of earth structures. The results of these tests and observations must be collated and preserved, as they will all need to be supplied to the employer when he takes over the project. They may include a wide variety of data, such as test results on mechanical and electrical plant, crane test certificates, logs of underdrain flows and pore water pressures, settlement readings, and many other matters. A number of observations may have to be started as soon as part of the works are completed and kept going for the rest of the job. All these matters are important because, at the end of the project, all such performance records may have to be summarized in a suitable form and presented to the employer in a **completion report**.

8.15 Photographs

Photographic records of the project can be invaluable, and their cost is small relative to their worth. The following list shows the type of photographs that can prove useful:

- Photographs before any work is undertaken of:
  the site generally (e.g. picture views);
  any buildings to be demolished;
  the condition of any adjacent buildings liable to be affected by the works (including a careful log by close-up photos of all existing cracks etc.);
  views of access tracks and public roads to be used by contractor, plus close-up

photos of surfaces of public roads before use.

- Monthly progress photographs of the work during construction.
- Photos of technical matters (such as the nature of foundation material etc. covered up) which need recording.
- Photos to illustrate any problem that has occurred on site and which needs to be reported to the engineer for comment or advice.
- Photos of the completed works; particularly after all rubbish has been cleared away.

The monthly progress photographs and those taken before and after the construction of the works will normally be undertaken by a professional photographer commissioned and paid for through the contract. For monthly progress photos they should be taken from fixed camera positions. Photos of particular features will generally have to be taken by site staff as and when appropriate. Not too much thought should be given to choosing that which is possibly significant, as the eye does not see on site what may later show up as important. Colour photos are in all cases preferable to black and white. It can be useful to use a Polaroid camera, as 'instant' photos can be produced to aid discussion with the agent over some feature, or to illustrate some problem that needs to be referred to the engineer.

It is essential that all prints are marked on the back indicating the job, the feature shown, date taken, and the negative reference. Filing of photos is not easy: the classification above is a starting point. Over-large albums should be avoided, as they often do not fit in standard shelving: ultimate box-file storage is usually most practicable.

8.16 Record drawings

The engineer's agreement with the employer will usually require him to provide the employer with 'as built' record drawings of the completed structure. It is the resident engineer's job to supply these drawings to the engineer for reproduction. The normal practice is for the resident engineer or his staff to mark all amendments or additions in red on a copy of the contract drawings, the original master copy of the contract drawings then being amended. This is not entirely satisfactory, because not all contract drawings are relevant or sufficient for record purposes. To make a good set of record drawings may involve discarding a number of contract drawings, and using 'cut-and-paste' methods to make up a single drawing from parts of contract drawings, or producing completely new drawings. Of the latter, the foundation drawing is most important. It should be started early in the contract, and may in any case be needed to show the contractor precise dimensions and levels for foundation excavations.

A drawing showing important details of construction can often be made up from copies of sketches supplied to the contractor. Such details can be invaluable in tracking down the possible cause of some after-trouble, such as damp penetration. In general, record drawings should give:

- a good detailed layout plan of the project;
- a detailed foundation plan;
- floor plans for inside of buildings;
- plans showing the location of everything underground and what depth it is;
- details of construction, where these are hidden from view.

It is not necessary to show all the minutiae of construction, which, as often as not, can be seen on site or in any case have to be measured on site (rather than from a drawing) if some alteration is required later. Copies of reinforcement drawings are usually supplied separately bound from the record drawings. Their main purpose is to show what size and spacing of reinforcement was used, in respect of which they must be correct. They cannot show the exact position of bars.

On clearing up the site supervision organization, one of the enduring nuisances resulting from the indiscriminate packing up and archiving of all drawings of a project is when drawings of things intended but never built are not destroyed. If superseded drawings are not destroyed it may be impossible to discern later how a structure was actually built. This can not only be highly frustrating to later engineers, but can also give rise to serious difficulties when, for instance, repairing a dam, tunnelling below structures, or needing to know where underground services lie. A considerable amount of time has to be reserved for going through all drawings on site, destroying those not applicable, and gathering in some order those to be kept and indexing them.

8.17 Other records

A **job completion** report may be of significant value later, both for publicity purposes and for logging down experiences that can be of value later. The salient facts about the project should be listed: client; description of works; purpose, sizes and outputs; designers and contractors involved; dates started and finished; budgeted cost, final cost and chief reasons for any difference; date of opening ceremony etc. A short report should be attached of any significant technical problems encountered and how they were overcome. The report should concentrate on matters that, from experience, can form useful guidance for future designers and those who draw up contracts. It might cover such matters as: aspects of design that needed modification; work inadequately specified; errors in the bill of quantities that have caused problems; and better techniques of design or construction that have become available.

The specification should state how many copies of drawings and instruction manuals suppliers of equipment are to provide: usually at least two copies, preferably three. The requirement is notable for the frequency with which it fails to get through to suppliers, who supply only one copy, which the fitter erecting the equipment borrows and soon reduces to a state unfit for sending to the employer. The resident engineer will save himself much later time and trouble if, as soon as any equipment arrives, he takes charge of the drawings and instruction manuals for it and asks the manufacturer for two more of them or gets them copied locally. They are often of importance to the employer, and so should be collated in some orderly fashion.

A file should be made listing the names and addresses of all equipment suppliers, and of the suppliers of key materials used in the works, such as ceramic tiles, facing bricks, aggregate and cement sources. The file should give details of what was supplied and the date it was ordered. A copy of this file should be given to the employer, for whom it will be valuable when it is necessary to repair or replace items, or if performance problems occur. Instruction manuals and plant test data, such as performance curves of pumps, turbines and motors, should all be collected, and two sets of each should be obtained to supply to the employer. Unless these matters are attended to during the currency of the contract, the resident engineer may find himself spending another month or more on site after the works are complete, solely to deal with them.

9

Programme and progress charts

9.1 Responsibilities for programming the construction

The contractor is responsible for producing a programme for construction for the job, though he must comply with any special requirements laid down in the contract documents. The ICE Conditions require the contractor to submit his proposed programme within 21 days of being awarded the contract (Clause 14(1)). As mentioned in Section 5.7 the engineer must accept or reject it, or call for more information on it within 21 days; if not, he is deemed to have accepted it (Clause 14(2)). If the engineer calls for more information, the same time limits are repeated.

The programme for construction should therefore have been agreed before the resident engineer goes to site. However, it may set out the programme only in general terms, and its details and implications need to be studied by the resident engineer. In particular, the resident engineer needs to check what the programme requires with respect to (1) the provision of further drawings and information to the contractor, and (2) the provision of any materials or services that are to be supplied by the employer under separate contracts he has entered into, or which are to be obtained by the contractor from specific named (i.e. nominated) suppliers.

In the case where there are separate contracts for supply of materials or services, their delivery times must not delay the contractor from achieving his intended programme. These delivery times should have been quoted in the main civil engineering contract, which should require the contractor to allow for them when drawing up his programme. The resident engineer must therefore ensure, as far as possible, that these separate suppliers deliver on or before their promised time.

Where materials or services are to be provided by nominated suppliers or subcontractors, the order for them cannot be placed by the civil contractor until after he is awarded the contract. Thus an early task for the resident engineer is to check the delivery time required by each nominated subcontractor and supplier after receipt of order. These findings need to be checked with the contractor's programme, and the contractor should be advised of the latest times by which he must place orders. If any nominated subcontractor's delivery time delays the contractor's programme, then the contractor would be able to claim for delay. Hence it is prudent to add 'margins of safety' to the delivery times quoted by nominated subcontractors and suppliers, before advising the contractor of the latest time by which he should place his order.

9.2 Alternative ways of handling delivery problems

The use of nominated subcontractors or nominated suppliers is disfavoured by many engineers because it can give rise to so many problems. The contractor may seek to impose liability for damages on the subcontractor for late delivery out of all proportion to the value of the subcontractor's work. As a consequence, the nominated subcontractor or supplier may refuse to accept the contractor's order. Other disputes can arise: the contractor may want a trade discount but the supplier refuses to give it; or the contractor makes excessive charges for supplying the subcontractor with site services such as lighting, power or access.

Although some of these problems can be overcome by careful detailing of all the necessary provisions in the specification, there is never any certainty about the matter. A nominated subcontractor can sometimes simply refuse to accept an order from a contractor for reasons he will not disclose, usually because of some past experience with the contractor. The purpose of nomination is then frustrated. To avoid nomination the specification can specify the work required and leave the choice of subcontractor to the contractor, with the proviso that the subcontractor must be approved by the engineer (*see* Section 10.8). Nominated suppliers are also avoided wherever possible by specifying items – 'As Messrs XYZ's product or similar' – leaving the onus on the contractor to choose his source of supplier.

Inevitably there are cases where it is impossible to avoid the use of a nominated supplier. Facing bricks are an example: the designer (or employer) may wish to use only one type of facing brick from one supplier. Their late delivery could, of course, seriously delay a contractor. In such cases, the resident engineer must take action in good time to check with the supplier that he will keep to time. An alternative is for the employer to place a separate order direct with the supplier. Some employers are willing to do this; others are either unwilling to get involved in transactions of this kind or find it difficult because of the standing rules under which they operate. If there is to be a separate supply contract, problems of offloading and storage will need to be attended to by the resident engineer.

Fortunately, many of the smaller proprietary items that are specified for incorporation in civil works are not required until the finishing stages of the contract. These usually do not give rise to many problems, and the contractor can be encouraged to order them in good time by the engineer's certifying part payment of their value under 'materials on site'.

9.3 Role of the resident engineer

The role of the resident engineer is therefore to check everything ordered under separate contracts or from nominated subcontractors and suppliers. He contacts them, advising that construction has started, and gets them to confirm their delivery times. He also makes sure that all technical queries are settled. Where suppliers have to manufacture much equipment before supplying it, he will check their progress, and may visit them to make personal contact. He will do everything possible to prevent any delays occurring, and if he sees that some delay is unavoidable, he will inform the engineer and make suggestions as to how any consequential delay to the contractor can be avoided. However, he should only make direct contact with nominated suppliers or subcontractors before the contractor places an order; not after. If there are further problems after the contractor has placed his order, the resident engineer's contact with nominated subcontractors and suppliers must be via the contractor, unless the contractor permits otherwise.

Once the foregoing matters have been resolved and delivery times are known, the resident engineer is in a position to check the contractor's programme in detail, noting down in consequence when certain materials must be ordered, so that he can remind the contractor of this.

There may be other matters with respect to the programme that the resident engineer should look into. In some cases the employer may require access to his works through the project area at all times for large delivery trucks. Or perhaps work by the contractor must necessarily interrupt services which the employer relies upon, such as electricity, drainage, or water lines. There may therefore be a strictly limited time during which the employer can tolerate such interruption; and he may prefer the interruption to occur at some particular time of year rather than another.

The influence of the weather may be an important factor to take into account when examining a contractor's programme, especially if the contract involves substantial earthwork construction. The resident engineer may need to discuss with the contractor where he thinks the programme should include optional strategies according to weather. He should be able to indicate what sort of wet weather would be likely to bring filling to a stop, or what sort of measures could be taken to minimize the effect of weather.

9.4 Programme considerations

When a contractor draws up his programme for construction he has to ensure that it fosters efficient, economic working. Among other things he has to meet two conditions as far as possible:

- Once he has brought men and machines onto the site, he must be able to use them continuously until their tasks are completed.

- The outputs required from men and machines must be near their sustainable maximums and be kept as steady as possible.

A contractor cannot have thirty carpenters on the site one month, half a dozen the next and twenty or more the next. He wants to arrange the work so that he keeps a steady force of carpenters fully employed for the whole three months. Similarly, he needs to use machines continuously on steady outputs at or near their maximum capacity. It is an expensive matter bringing a large machine on to site and taking it off, so not only must it have sufficient work to justify its transport costs, but its size (i.e. output capacity) is also a matter of careful judgement. It is not a question of a contractor 'wanting' these conditions fulfilled; he must have them in order to get work done at lowest possible cost, so that he can make a profit and continue in business. Hence the resident engineer must appreciate the pressures on the contractor and accept on occasion the reasons why a contractor sometimes has to do things in an apparently idiosyncratic way. The resident engineer can only interfere when he is certain that some method proposed by the contractor will result in unsatisfactory work or some unacceptable risk to safety. Often a contractor has to 'make do' with what plant he has on site to undertake some operation, because the expense of bringing in extra plant to do a one-off job is too great to be economic.

9.5 Time schedules

The programme of construction must be drawn up by the contractor, but it is useful for the resident engineer to draw up a list of dates by which different operations must be undertaken. If there are several contracts let for the construction of a project, the list will be essential for coordination of the work of different contractors. A typical example is shown in Fig. 9.1. It expresses the chief requirements for maintaining progress, and it may need several adjustments before it can be regarded as reasonably satisfactory. It comprises a list of work to be executed and associated things to be done by a given time. It is useful as an overall guide for checking if the contractor is keeping to time; and it forms the basis on which a more detailed bar chart, referred to below, is developed. As work progresses it may be necessary to produce a revised schedule showing in more detail the interleaving of finishing operations, especially when extensive plant has to be installed.

The detailed planning of the constructional work is, of course, the contractor's responsibility, but the resident engineer has an obligation to assist progress, keep check on it, and ensure that the contractor is not held up by any failure to supply information or materials for which the engineer or employer is responsible.

9.6 Bar charts

Once a schedule of important dates has been developed, more detailed investigation can translate the dates into a **bar chart** that, setting out the programme in

TIME CHART

CONTRACT TIMES				
		Tank	*Admin. Block*	*Pumping Station*
1st Year	Jan.			
				Order windows,
	Feb.		Order roof trusses	roof beams
	Mar.	Excav.	Prelim.-heating	Founds. in
	Apr.			
	May			Walls
	June	Walls		
	July			Floors
	Aug.		Order slates	
	Sept.		Order guttering	Pump founds.
	Oct.			
	Nov.			Piping
	Dec.			
		Cols	Roof on	Windows
2nd Year	Jan.			Roof beams
	Feb.	Floor		Roofing
	Mar.			
	Apr.	Main		Roof on
		laying	Plumber	
	May	Roof		Commence install.
	June		Heating	machinery
	July	Asphalting	Glazing	Doors. Glazing
	Aug.		Electrician	Electrician
	Sept.	Testing	Plastering	Plastering
	Oct.	Finish embanking	Seeding	
				End install.
	Nov.	Seeding	Decorating	machinery
	Dec.	Manholes		Testing
3rd Year	Jan.			Painting
	Feb.		Final decorating	Roads – final
	Mar.			
	Apr.			
	May	Completion		

Fig. 9.1. A list of target times from which a bar chart can be derived

visual form, permits the rate, sequence, and duration of working on each particular operation to be seen. Figure 9.2 shows a typical bar chart for a single structure. The length of the broad bands shows the time duration expected for each operation; these are coloured or hatched in as work proceeds to show how much of an item of work has been completed. The solid black lines indicate the actual time periods taken to achieve the quantity entered in the broad band. Figures can be written in as shown in Fig. 9.2 to show the quantity of work done by the end of each week, as compared with the quantity planned to be done. Usually the planned output is shown in black, and the actual performance is

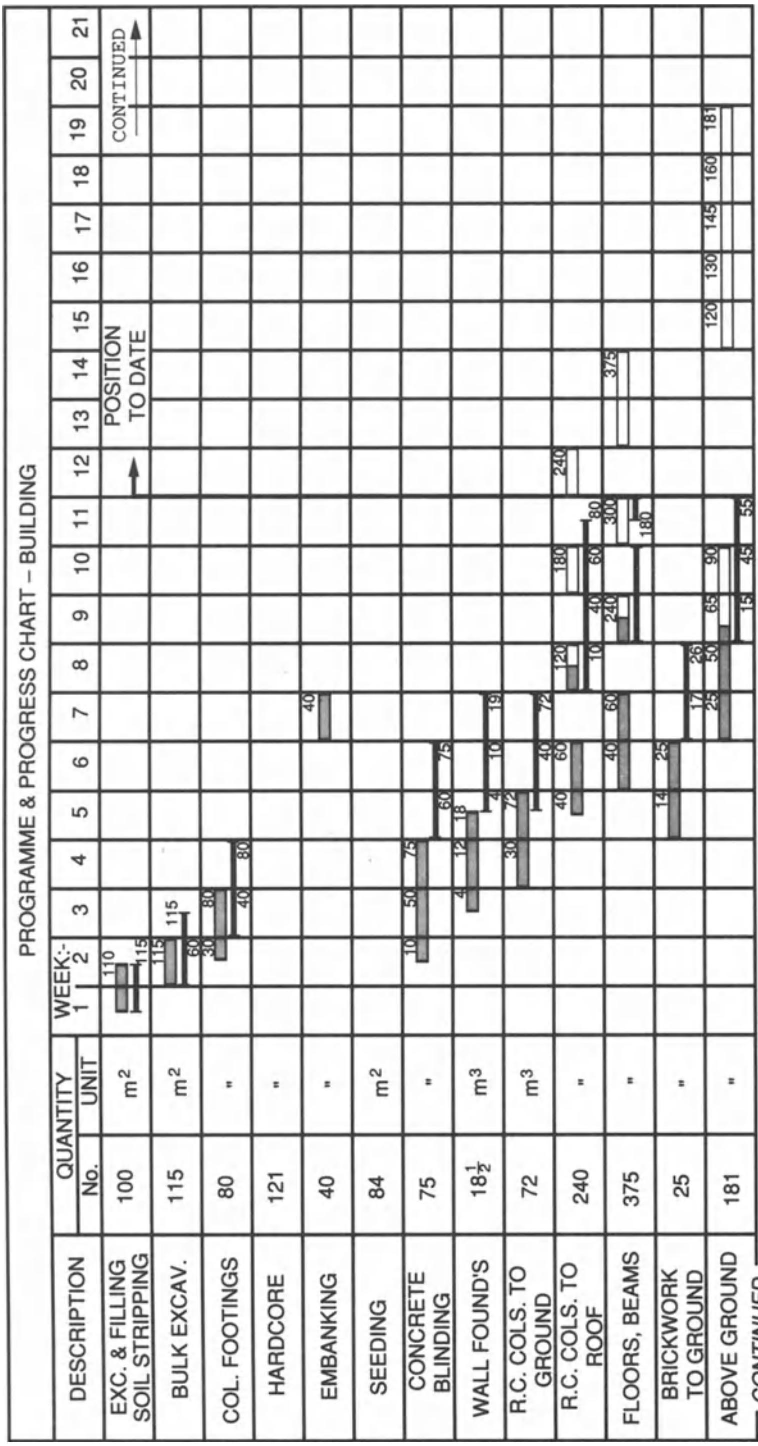


Fig. 9.2. Part of a bar chart for constructing a building
planned time and quantity
amount of work done
actual time done and quantity

entered in red. Figure 9.3 shows a simpler version, where pictorial representation is sufficient to show progress.

The advantages of a bar chart are that it is easy to interpret, produce, and keep updated. An agent will almost always have a bar chart pinned up in his office, which his site engineer updates each day. The resident engineer will have one of his own, made up from the monthly measurements. In the production of the bar chart, also, the contractor is forced to think of the order in which things can be done, so that he sees the earliest dates for which operations can start. The disadvantage of a bar chart is that it is difficult to apply to a complex project. The bar chart shown in Fig. 9.2 can only be meaningful in relation to one structure. If several structures are to be constructed under a project, it is not satisfactory to lump all their excavation, concreting, brickwork quantities etc. together. Either separate bar charts have to be produced for each structure, or progress on each structure has to be measured in a more simple way: for example, by estimated percentage completion of foundations, framework and floors, exterior walls and roof; internal structural work, finishes etc.

An alternative now available is to use a computer. Advances in computer software have made it possible to operate and display bar charts at several levels of detail. For resource planning and material ordering purposes the detailed operations required for each structure can be shown, and these can be summarized into one bar representing each structure so that an overall view of the whole project can be displayed at will. Critical linkages between operations can be fed into the program as for network diagrams (*see* Section 9.8), and the resulting critical paths and 'floats' can be derived. Adjustment to a detailed bar chart, whether due to a variation or a delay, is automatically reflected in the overall summary bar chart display. Of course, the operation of such software requires investment and the use of skilled operators, so this may be a function carried out only in the contractor's head office; but printouts of the bar charts can of course be sent to site.

9.7 Progress charts

The simplest form of overall progress chart marks the cumulative value of work done month by month for the duration of the contract. A simple chart of this type is shown in Fig. 9.4. The straight line from start to the finishing value of the contract shows how valuations would accumulate if the value of work done each month were uniform. Against this the plotted line shows the actual cumulative values of work done month by month. However, to ensure that such a chart does not give a false impression of progress, the following adjustments are advisable:

- Expenditure of the contingency money provided in the contract should be shown separately, so that any excess incurred can be added to the estimated final cost target.
- If there is a major item of expenditure incurred late in the contract (such as for

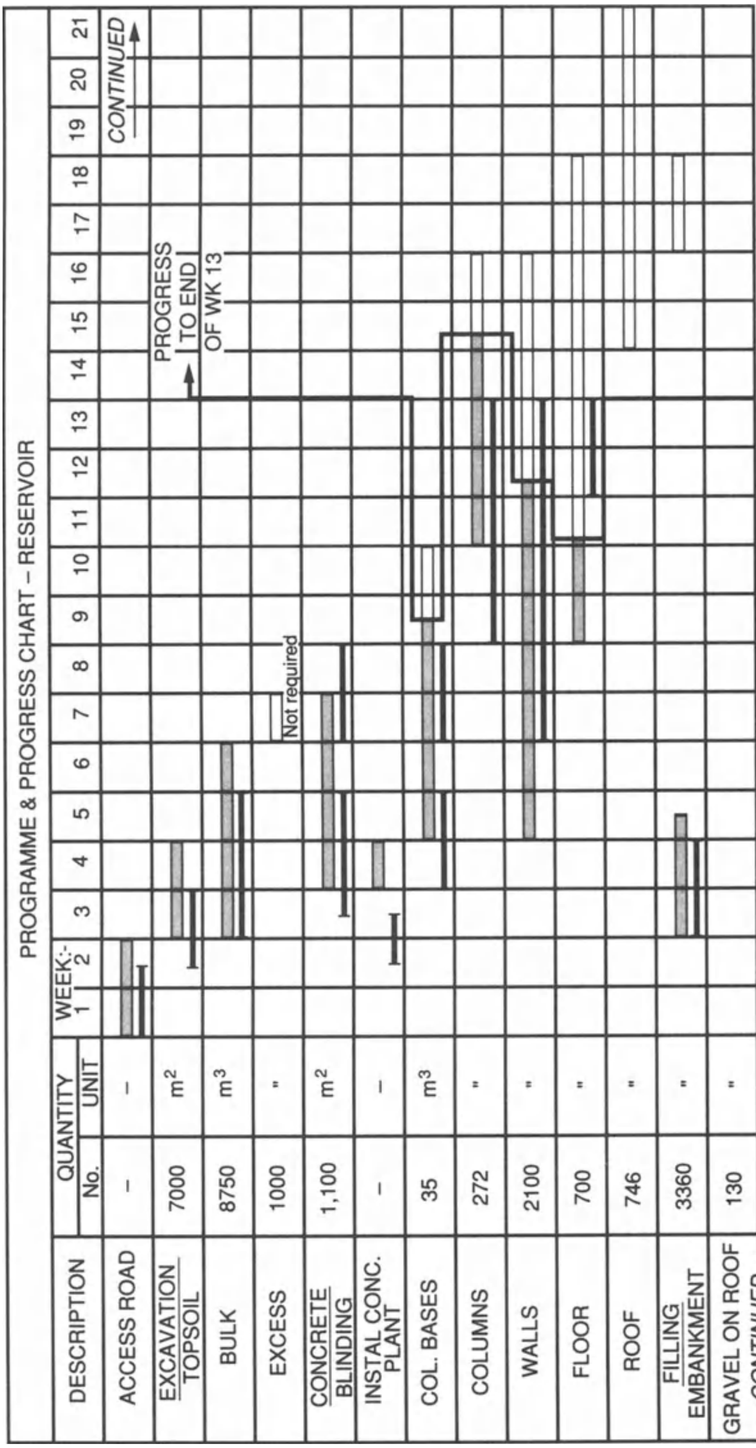


Fig. 9.3. Part of a programme and progress chart for a reservoir (simplified version) The quantity done would be coloured in. Progress lines would be different colours.

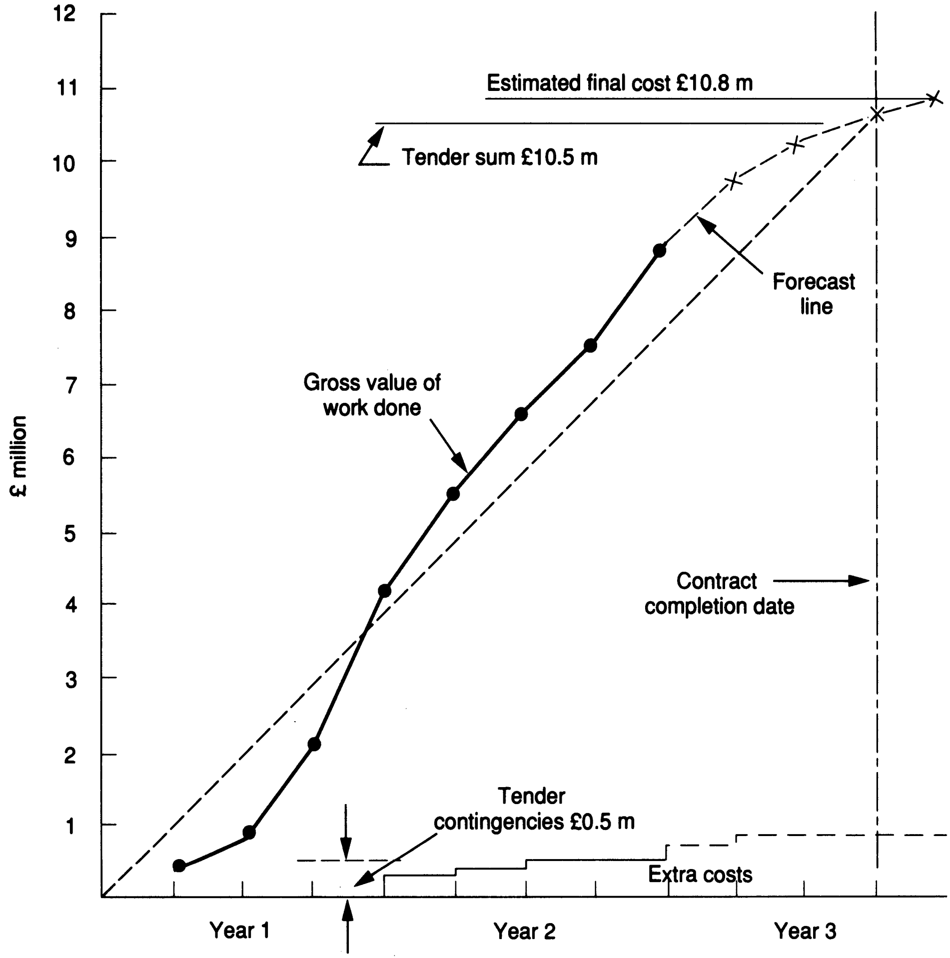


Fig. 9.4. Financial progress chart. The forecast line shows that the contract is likely to be completed about 3 months late at £0.3 million excess cost

supply and installation of plant), the value of this should also be excluded, or be plotted separately as an additional line.

- The cumulative valuations plotted monthly should not have retention money deducted, but should exclude payment for materials on site and any reimbursement of increased costs of wages and prices.

The aim is to plot 'like with like'; for example, plotting valuations either inclusive of extras to compare with the contract value including general contingency money, or to exclude extras and general contingency money. The former is best, as it indicates the trend towards the final total cost. Although such a progress chart is not exact, it is a good indicator of progress. Usually the plot of valuations forms an S-curve, having its steepest inclination during the central part of the contract period, when productivity should be at its greatest. As a consequence, if the plotted line of valuations does not rise above the straight line some time during the middle period of the contract, then almost certainly the contract will finish late.

One advantage of a progress chart of this kind is that, when an employer needs an estimate of future rates of expenditure, this can be estimated by sketching in an S-curve of the type shown and reading off the monthly rates of expenditure that it implies. Some standard conditions of contract, such as those of FIDIC (*see* Section 2.2) require the contractor to produce a cash flow forecast along with his programme for construction. It must be remembered, however, that the cash flow from interim payments does not directly represent progress in construction, as it is affected by retention, advance payments (if any), and materials delivered to site but not yet fixed.

Similar types of cumulative output chart can be applied to specific types of work. One for concrete work to different structures is shown in Fig. 9.5. The chart comprises horizontal bands showing to scale the amount of concrete to be placed in each structure. The cumulative amount of concrete placed month by month can be plotted for each structure, and their total shown separately. When all the concrete work is completed, each separate plot should reach its upper boundary, and the plot of total placing must reach the top line of the chart. Such a chart is useful for indicating where slow progress is occurring.

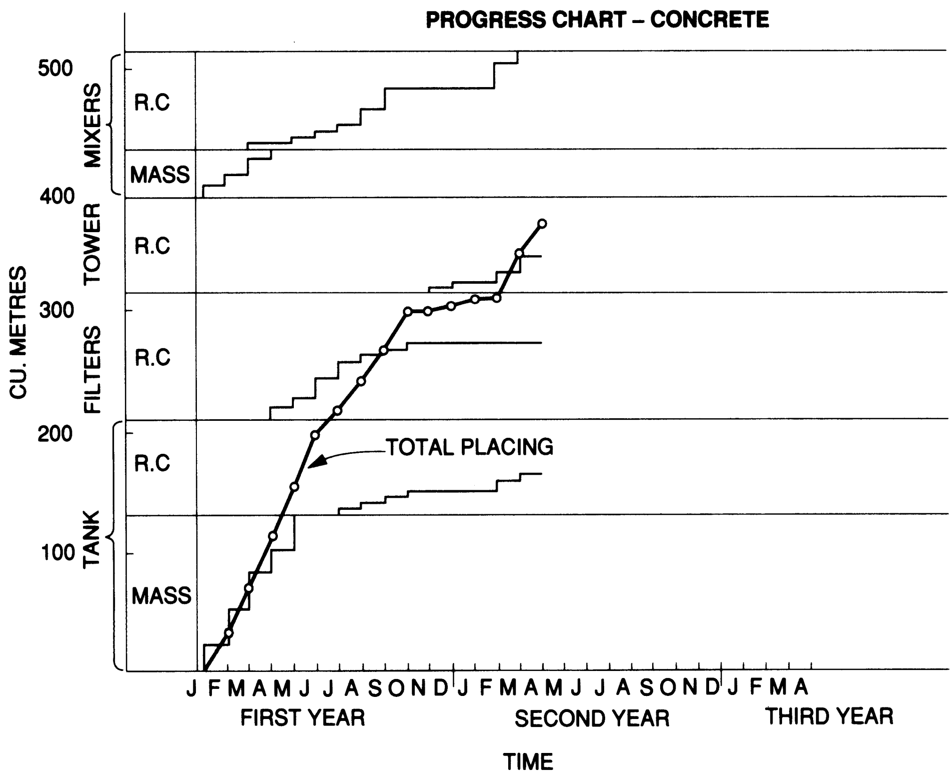


Fig. 9.5. A progress chart for concrete work

For a main-laying contract the type of progress chart shown in Fig. 9.6 can be used. It is self-explanatory and instantly informative. The profile of the main may have to be shown in a condensed form; it also shows where specials are required.

9.8 Network diagrams and critical path planning

The use of network diagrams and critical path planning for civil engineering projects was at one time much in vogue, but declined in the 1980s and is now only used for special purposes. In practice the 'diagram' is put on a computer, each constructional activity being given a reference and its estimated duration, usually in weeks. **Connections** are made between activities, stipulating the earliest and latest times each can start relative to some prior activity. The 'diagram' thus comprises many parallel strands of activities interconnected at many points where an activity cannot be started before certain other activities are wholly or partly complete. The computer traces through this network to find the longest total time taken by some unavoidable sequence of activities. This is the **critical path**, which determines the minimum time to complete the whole project. However, if the duration of some activity along the critical path can be halved (say by doubling the labour on it), or if some different order of construction of structures can be adopted, the next computer run will reveal some other critical path running through a different sequence of activities.

As an actual network comprises a complex 'spider' of interconnected activities it is difficult to interpret visually and relate to real time. Hence modern computer network programs reproduce the analysis findings as bar charts on the screen, with differing colours for critical and non-critical activities, and showing **float** times also – the latter being the spare time available for completion of a given activity before it becomes 'critical'. This presentation makes the results of the analysis much easier to understand.

However, setting up a network for a project involves assuming some order of construction for the various structures to be built, and estimating the duration of each building operation to the end of the job. Inevitably, soon after construction starts, things may not go as planned, owing to adverse weather, labour, plant or constructional problems. The planned sequence of construction may comprise activities numbered 1, 2, 3, ..., n, $n + 1$ in that order; but site may report that actual activities have been 1, 2, 4, 9, 10, ... etc., so that the network sequence assumed no longer applies, and has to be reprogrammed. This revision has to be practically continuous, and for a complex network is time-consuming and expensive. It involves the use of an engineer familiar with the computer program to make the necessary adjustments. Also, when the method forecasts some critical sequence of activities lying ahead, this may not be particularly significant because of the ever-present possibility that circumstances will change before such activities become necessary.

Critical path planning is only of value if adequate resources are available to keep the analysis updated promptly after every change on site. Bar charts are

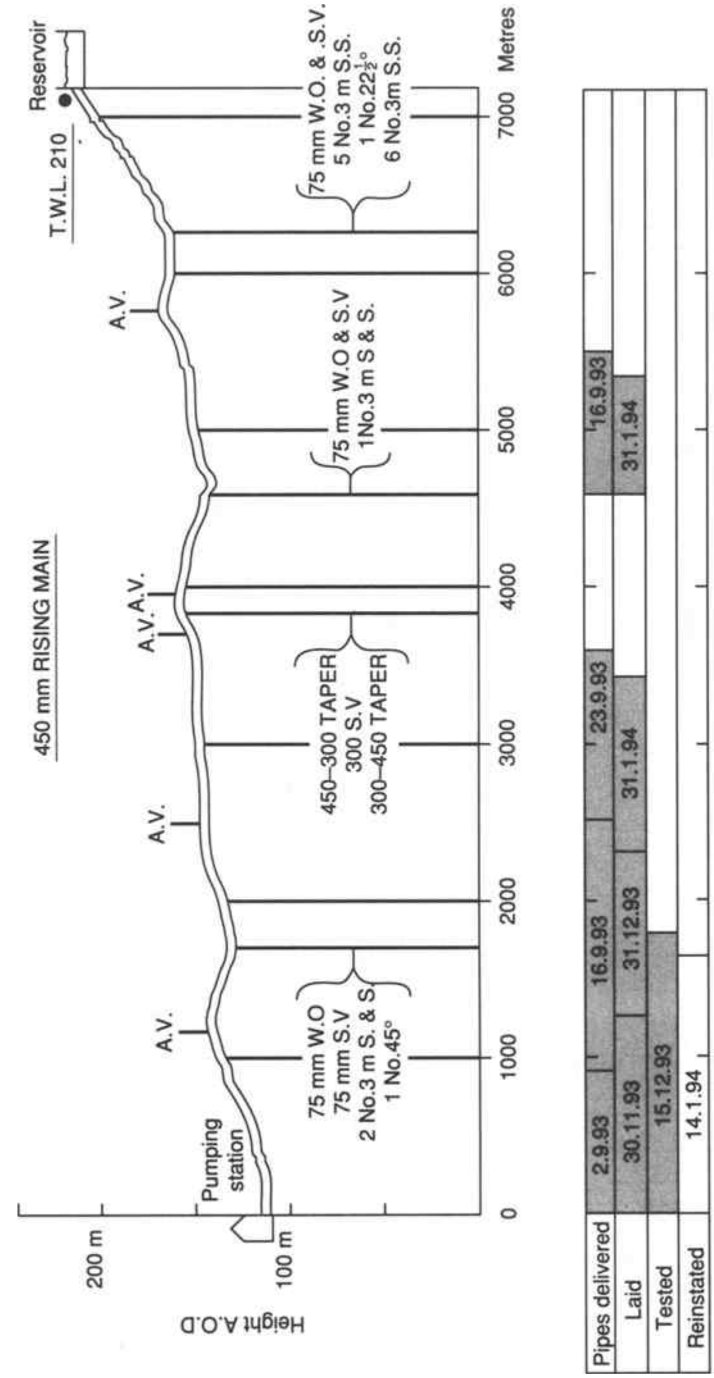


Fig. 9.6. Pipeline progress chart

preferred for most jobs, as they involve less work and are easy to draw and keep updated. Contractors sometimes use the critical path method to support a claim for delay; but it needs to be borne in mind that any particular network analysis is based on only one set of assumptions about the order in which structures are built, and other possibilities may exist.

9.9 Part played by the agent in achieving progress

It is the contractor's agent who has on-the-spot responsibility for programming the work and keeping progress in line. The resident engineer's job is to assist the agent, if asked, and provide any information that the agent needs or that will be helpful to him. As the work proceeds the resident engineer will keep a check on progress, and he must advise the engineer when unacceptably slow progress is occurring. Before acting formally in this matter the resident engineer will have to put his comments to the agent, seeking to find out why work is going slow, and endeavouring to persuade him to take steps to speed up construction.

Slow progress can be caused by many factors: lack of labour, lack of skilled key men, a weak general foreman, or an agent not sufficiently decisive or good at organization, or tending to underestimate the difficulty of a job and failing to foresee problems arising. Sometimes the cause may lie with the contractor's head office: such as slowness in getting materials or equipment to site. This may be indicative of the contractor being overstretched, either organizationally or financially. It is important that the resident engineer gets sufficient information to give the engineer reliable advice as to where the cause of slow progress lies, because, if the lack of progress continues, the engineer will have to take up the matter formally with the contractor.

A good agent is an inestimable benefit to a project. He automatically thinks in terms of the 'critical path' that lies ahead, and has clearly in his mind where the job 'ought to be' in a month's or two months' time. But to get there he has to make many decisions in the present. He has to seize opportunities, overcome delays, take extra work into account, suffer inefficiencies of labour and breakdowns of plant, find solutions to unexpected problems, face the vagaries of the weather and, despite all these, keep the work going at the required pace to gain his targets. The immediate targets are short term: this week's in detail, next week's in outline. If he can achieve them, he knows that they are within the longer-term strategy he has already worked out. If he does not make those targets, he has to think up ways of gaining lost time.

He has also to be aware of the need to have safety margins of time in hand for overcoming all sorts of difficulties that his experience tells him will inevitably crop up, even though he cannot forecast the precise form they will take. Many factors influence his judgement. He will be quick to detect when things are in his favour – when weather seems to promise fine, when the spirit on the job is good and the men are working efficiently as a team – and, grasping such opportunities, he will use them to drive the job onwards, knowing that one success leads to another. By experience and force of his personality he may pull the job ahead of schedule and complete before the promised time.

9.10 Estimating the probable final cost of works

The resident engineer will often be asked to report on the probable final cost outcome of the contracts under his charge. The employer may need quarterly or half-yearly estimates of his future expenditure so that he can plan to raise the necessary money at least cost. It is a help in estimating the final cost of a project if the bill of quantities comprises separate bills for separate structures. This makes it easier to identify where extras have arisen and where further extras can be expected. The following type of analysis may then be adopted:

- An analysis of amounts incurred under variation orders is made, dividing them out over the separate bills. The analysis should include VOs pending. If a VO covers many extra items spread over several bills, it can be allocated to general contingency money, to save time spent on too much detailed analysis.
- The page totals in the priced bill of quantities should be compared with the latest page totals for interim payments certified to date. Additions should be made where, by examination, it is estimated that payment for items on that page will add £500 or more to the original page total; deductions will be made where it is expected that a page total will reduce by £500 or more because of omission of items etc. Smaller differences are ignored. The net change to each bill total is derived. (A page total for a string of minor items that adds to less than £2000 can usually be ignored, as it is unlikely to be altered by any significant amount.)
- The probable final cost outcome of the main construction contract can then be assessed as shown in Table 9.1.

Using the estimated final cost derived as in Table 9.1 and graphing out certifications to date will permit an S-curve to be drawn to show how payments are likely to occur to completion (*see* Section 9.7). From this curve can be derived quarterly or half-yearly estimates of future expenditure, making allowance for retention money and its ultimate release. On some projects there may also be separate supply contracts for plant and machinery etc. whose final cost has to be estimated and added in. Additions and deletions to these are often as lump sums, and schedules of these will keep the total cost commitment for them updated.

Table 9.1

Estimated Final Cost of Contract XYZ

	Bill 1	Bill 2	.... etc	General contingency	Total all bills
	£	£	£	£	£
(a) Total of original bill items	....	....	....	Excluded	....
(b) Estimated change to bill items	....	....	....	....	....
Revised bill items	....	....	....	....	....
(c) Payable under VOs issued and pending	....	....	....	....	....
(d) Allow for further VOs	....	....	....	....	....
Total measured items	....	....	....	....	....
(e) Dayworks:					
paid to date				....	
allow for sheets in hand not yet paid				....	
allow for further Dayworks to come				....	
					....
(f) Claims paid and claims agreed but not yet paid					....
(g) Allow for – claims pending not yet agreed					....
– possible other matters					....
Estimated total final cost					£ ....

Notes: (b) includes estimated extra costs due to increased quantities, less deductions for items superseded by new items covered by VOs.
(c) is the total payment under VOs, divided over the bills as far as ascertainable, the balance being put under general contingencies.

10

Measurement and bills of quantities

10.1 Principles of pricing and payment

A construction contract is concerned with the provision of goods and construction of structures by a contractor and payment for these by the employer. The question of payment inevitably involves an assessment of how much is due and when it is to be paid. Discussion of the various payment arrangements that can be made was given in Section 1.7.

In the simplest contracts the amount due may have been pre-agreed as a lump sum, or a series of lump sums relating to different items to be provided, and payment will depend on these being completed. In principle many turnkey types of contract and some design and construct contracts follow similar arrangements, although in practice things seldom turn out so simple. For many construction contracts the works required cannot be precisely defined at the time when the contract for their construction is entered into. The exact nature of the ground that they are to be built on may not be known in advance; some of the design may not be completed; or the employer may not have finally decided everything he needs. In such circumstances a remeasurement type of contract may be the most suitable. Such a contract must set out exactly what is to be measured for payment purposes, and when the payments are to be made. Hence it also needs to show, either specifically or by implication, what work is included in the prices paid.

Under most standard forms of contract the contractor undertakes to carry out the works described in a specification and on a set of drawings, and to do so according to the terms of the contract. This obligation of the contractor is one that he takes on independently of the terms set out in the contract as to how and what he will be paid for his work. The employer's obligations to pay and the manner in which he pays are also a separate matter set out in the contract. When a bill of quantities is used for the basis of payment, the specification and drawings will describe what is required in detail, and the tenderer has to consult these when he prices a bill item. He cannot just look at the item entries in the bill of quantities, but has to see from the rest of the contract what are the obligations that he must cover when he enters a price against a bill item.

The bill of quantities is, of course, of importance in the tendering process because it allows a reasonably fair financial comparison of tenders, but it in no way limits what is to be built, nor limits the contractor's obligations. Under the ICE and similar conditions, once a contract has been awarded, the bill of quantities is merely used for the ultimate task of pricing the works actually constructed. What is to be built will depend on the drawings, specification, and instructions issued by the engineer, which the contractor is bound to follow; what is to be measured as a basis of payment is fixed by the method of measurement set out in the contract.

10.2 Methods of measurement for bills of quantities

The choice of items to be measured for payment under a bill of quantities contract can vary greatly. The itemization adopted depends on the type of work involved and the complexity or degree of detail in which it is decided to break down the work for billing purposes. For even a simple job it might be decided that a detailed listing of all the individual items of work is needed to allow for any variations and adjustments to the work shown on the tender drawings. However, for another job, it might be considered sufficient to list only the main constructional operations of the work, leaving the tenderer to include in his prices for these all the other minor requirements shown on the drawings and described in the specification. For a large project a considerable amount of detailing is almost inevitable, as many different types of work will be involved in different circumstances in different parts of the project.

When the itemization in the bill of quantities is reduced, then individual items will tend to be inclusive of a number of matters that the contractor must provide. The tenderer has to ensure that he has allowed for all these ancillary matters in his price for the item; he takes a bigger risk with that price and has to allow for the effect of any change of quantity finally measured under that item. Obviously, his rates will have to be high for such an item, both to cover the work included that is not separately measured and the risks that he runs in the admeasurement process. The latter problem of course, affects the employer also, as increased quantities may result in a disproportionate increased amount of payment due to the high rates set against each item.

Clearly, there is a wide selection of possible methods of measurement and the detail adopted. The choice of method for civil engineering work in the UK lies between using the Civil Engineering Standard Method of Measurement (CESMM, *see* Section 10.3); using the standard method for billing some types of work plus a different method for the rest of the work; or using a different method throughout. Where the standard method is used it must be strictly followed, and any departures from it must be clearly stated in the preamble to the bill or in item descriptions. If the standard method is not used at all, Clause 57 of the ICE Conditions must be amended, and the method adopted must be clearly defined.

In making the choice of method a balance may have to be struck between opposing requirements. The standard method itemizes work in considerable detail, and therefore reduces the risks to both parties when admeasurement of the work takes place. There are also computer programs devised to assist billing and pricing by the standard method, and this may be of use to tenderers' estimators who are familiar with the method. But it is complex, producing much detailed itemization of the works and consequently involving considerable work and increasing the risk that something will be left out or incorrectly itemized when compiling the bill. Much depends on the nature of the project to be billed, but it is quite common practice to adopt the standard method for the majority of the work, and a different method elsewhere when this seems sensible and reduces the number of items required.

It should be noted that the different methods referred to above are not completely different from the standard method; they are usually items of a more inclusive or simplified nature, which do not break down the work in such detail. Often they are similar to the earlier ICE measurement recommendations of 1953, or the 1976 edition of the standard method, neither of which is so complex as the later 1985 and 1991 editions of the standard method.

For overseas contracts the 1991 standard method is seldom followed. For local contracts that are to be undertaken by overseas local contractors, the method used will be that normally followed in the area, as instanced by the type of contracts used by the local state or public authority. It is essential that these are followed, otherwise tenderers might not understand how to price items.

10.3 The ICE standard method of measurement (CESMM)

The ICE standard method of measurement is not mandatory, but the ICE Conditions of Contract require the method to be used 'unless general or detailed description of the work in the bill of quantities or any other statement clearly shows to the contrary'. The most recent (third) edition of the standard method was published in 1991 with corrections in 1992, and is commonly referred to as **CESMM3**. The standard method is not a contract document, and is thus not to be used in interpreting the contract, except in so far as its provisions are repeated in the contract documents (see below). Its use is solely as a recommended method of measurement in conjunction with the ICE Conditions, and is therefore on the basis that all the works will be designed by the employer or his engineer.

Use of the standard method over a number of years has indicated several potential problems in the compilation of bills of quantities and measurement. There are seven introductory sections printed in the method, and although these are largely guidance notes for people preparing a bill, some parts are needed in a contract, such as those dealing with adjustment items or method-related items, whereas other parts may need exclusion to prevent the parties trying to alter the method after award of contract. Also, the measurement rules may not apply or may not be suitable if the contractor is required to undertake some element of design, such as providing bearing piles. However, it is not usual to depart from the units of measurement given, or the measurement rules and coverage rules set out in the work classification sections of the standard method. The measurement rules say, for instance, that when measuring concrete volume there is to be no deduction for the volume occupied by reinforcement, rebates, grooves, and holes up to a certain size etc. The coverage rules denote, for instance, that an item for supply of timber components includes their fixing, boring, cutting and jointing. Such rules are useful in making clear what the bill items are intended to include.

The standard method results in lengthy bills, and for some types of work may be seen to give an unnecessary number of items, or to divide work down into such detail that considerable thought has to be given to billing and pricing. Modifications to the method must, however, be very clearly put as to their extent in order to avoid the possibility of the parties' trying to argue for remeasurement or additional measurement where this was not intended. For instance, instead of itemizing painting of step irons, ladders etc. separately, a subheading can be put at an appropriate position in the bill stating 'The following items to include painting after fixing'. The standard method mentions that a line must be drawn across the description column in the bill below the last item to which the subheading is to refer. If, however, there is so much painting that a contractor would probably sublet the work, a non-CESMM item might be given as 'Painting items N1 to N13 after erection . . . Lump Sum'; or a provisional sum for painting can be entered. By such procedures the number of items in a bill can be reduced.

The standard method states that item descriptions are to avoid unnecessary length, their intention being to 'identify the component of the works and not the tasks to be carried out by the contractor'. Nevertheless, descriptions according to the CESMM method tend to be lengthy in some cases. Each item has a letter and three-figure code number, which identifies the work required according to the CESMM classification; but the code descriptions are not taken as definitive and, to avoid ambiguity, the actual descriptions have to be written out in words. The bill items have also to be read in conjunction with the specification and the drawings; and it is an essential matter for the drafter of the bills to ensure that these all relate. The location of items may need to be specifically stated also, and any additional description rules specified by the CESMM must be followed, in order to ensure that all detail necessary to identify the work is shown as required by the standard method.

10.4 Classification and number of items

For most works of any size there should be separate bills for obviously separate parts of the project. This clarifies the location of work under bill items, makes it possible to cost structures separately, and may be needed if completion of certain parts of the work is required by a given earlier time. Within each bill the items will be classified into different types of work, always taken in the same order in all bills.

The standard method lists twenty-six classes of work labelled A to Z, class A being for general items (more commonly known as 'Preliminaries'). Class B is for site investigation including sampling and laboratory testing; Class C for geotechnical processes such as grouting and construction of diaphragm walls; Class D for demolition and site clearance. Thereafter there follow classes for the common constructional operations – earthworks, concrete, pipework etc. – through to Class Y, which is for sewer and water main renovations. The final Class Z is for 'Simple building works incidental to civil engineering works', and covers carpentry and joinery, doors and windows, surface finishes, and services etc.

Not all the twenty-four classes of construction work, B to Y, will normally be used on most projects, and a problem is that if the project includes a large building, the items under Class Z may be numerous and so need subclassification. There may also be some difficulty in deciding where to bill certain types of work to achieve a logical order, as some work that would normally be considered part of the finishing building trades (such as painting) is in the civil engineering classes of work. However, the standard method of classification is normally used, because there are computer programs available to aid billing which are based on the A–Z classification. If a non-CESMM method is followed throughout, such as for overseas work, then the classes of work can follow the traditional building order.

Some civil engineering bills of quantities contain upwards of a thousand items, because many different types of operations over many different structures are involved. Where possible, an effort should be made to keep the number of items to no more than they need be. This helps to reduce the work involved in measurement throughout the contract; but departures from the standard method may make the estimator's task more difficult and so should be kept to the minimum necessary.

The question of how detailed the billing should be depends on the nature and size of the works. What is to be measured for payment can vary widely. For instance, in a contract for the construction of a dam, some minor gauge house might be billed as a single item, the drawings and specification providing all details of what is required. Often where there are repetitive structures, such as access chambers to valves on a pipeline, these too can be billed complete by number. In civil engineering it is quite common to bill items such as standard doors simply by number, the specification describing what is required, including the frame, priming and painting, and the type of door furniture required. If a special door is required, such as for the front entrance, again this is shown on the drawings and specified in detail; so the item in the bill appears as 'Front entrance door ... 1 No. ...'.

Where methods of measurement depart from the ICE standard method, this must be made clear in the bill. Although the standard method permits the detailed description of an individual item, to make clear that it is not measured according to the standard method, it is preferable to group such items together. Either they can be grouped under some appropriate subheading, or it may be decided that certain types of work throughout the bills are not to be measured according to the standard method. When this policy is adopted, a statement should appear in the preamble to the bills of quantities (see below), such as 'Painting of metalwork is not measured separately and is to be included in the rate for supply and fixing of metalwork'. To prevent errors, a subheading before metalwork items would repeat this briefly.

10.5 Accuracy of quantities: provisional quantities

In preparing the bills, the quantities should be accurately taken off drawings in accordance with the standard method of measurement. The quantities billed should not contain hidden reserves by 'overmeasuring' them when preparing a bill. There may be a temptation to do this when, for instance, billing the trench excavation for a pipeline. If the engineer increases the length at greater depth and decreases that at shallow depth to compensate he may, if he overdoes this, give a false impression of the nature of the work. It needs to be borne in mind that sometimes it is the practice to 'agree bill quantity' for an item if there is no obvious large variation from the drawings. Hence quantities should represent a best estimate of what will occur, in order to be fair to both contractor and employer.

A problem occurs when billing rock, which may be suspected but whose incidence is not known: as in the case of a long pipeline, where it is impracticable to sink enough borings in advance to discover the depth and extent of rock everywhere. Sometimes a provisional quantity is put in for rock, but if the quantity is not known, what provisional quantity is to be put in and how can the tenderer price it? Instead, it is suggested, a provisional sum should be included in the bill for rock excavation, and a price for excavating rock should be agreed with the contractor if rock is encountered. This raises the problem that, if rock is encountered, it will almost certainly delay the work, so the contractor will put in a delay claim. However, there is much to be said for then negotiating a rate, as this can relate to the method used for excavating it, which can vary according to the nature and location of rock encountered.

Any provisional quantities therefore need to be used with care. They should relate to something known to be required, the quantity being a reasonable judgement as to what might be required. This would also apply to such matters as bedding pipes on soft material, or bedding and haunching pipes in concrete, or fully surrounding pipes in concrete where the extent of such work depends on the site conditions encountered.

10.6 Billing of quantities for building work

Quite complicated buildings often form part of a civil engineering project: for example, power station buildings, pumping stations, stores, administrative offices, or laboratories. The civil engineering standard method gives units of measurement for some common building operations, but the nature of building work is so diverse that in practice many more items will be found necessary. In certain cases it might be expected that the civil contractor would sublet the work to specialist building subcontractors, who would expect the building items to be billed according to the standard method of measurement for building work. Hence, if possible, it is preferable to bill extensive building work separately. Also, if the building work comprises a whole structure, it might be decided to use quantity surveyors to bill it separately according to the building method of measurement, but this is not essential. A civil engineering contractor is quite capable of undertaking building work so long as the drawings and specification show all details required, and the items in the bills of quantities are written in such a manner that they are clear.

The civil engineering standard method of measurement will usually be found suitable for billing all work required to complete the framework, walling, cladding, and roofing to buildings, and such matters as pipework, roads, sewerage, landscaping and fencing. Thus the building trade items primarily cover the interior finishes, carpentry and joinery, and other miscellaneous matters. Once a policy decision has been made on these matters, the preamble to the bills of quantities should clearly state which classes of work are not measured in accordance with the civil engineering standard method, and this distinction must be maintained through all bills.

A strict adherence to the details of the standard method of measuring building work is not essential: for example, the many 'extra overs' listed in that method need not be adopted. However, it needs to be made clear in the specification and bills what the various items are to include. For matters that it is likely the contractor will let to specialist subcontractors, such as terrazzo floorings, balustrading, or ceramic tiling, either lump sums can be called for if the drawings and specification define everything required, or provisional sums can be inserted.

10.7 Some problems of billing

Excavation

Apart from excavation by dredging or for 'cuttings', the standard method distinguishes only between 'excavation for foundations' and 'general excavation' (list numbered in that order). However, the more logical order should be adopted of billing general excavation to a stated level (the 'final surface' for that item) followed by excavation for foundations below the final surface reached by the general excavation. This can result in items referenced 'E400' preceding those referenced 'E300'; but these references should not be changed.

If the general excavation has to be taken down to two different levels, that is to a 'stepped' formation, then under the CESMM method it is billed as one item to the lower of the two 'final surface' levels. If an attempt is made to bill it as two excavation items 'banded horizontally', one below the other, sundry complications occur, which are best avoided. Nor should it be taken as two separate items, the depth of each being measured from ground surface, because it is not excavated in this manner when the areas are adjacent.

Rock excavation has to be itemized separately from other materials, the volume of rock being measured independently. Usually neither the quantity nor the depths at which rock will be encountered may be accurately known; but the quantity should be estimated on the basis of the geophysical data available. These data must be supplied to the contractor, and permit him to make his own judgement as to the depth and extent of rock likely to be encountered.

The definition of 'rock' presents difficulties, but it must be stated in the preamble to the bills of quantities. Geophysical data may occasionally permit a given rock to be defined, but in most cases rock is probably best defined according to the method of excavation. Unfortunately, methods for removal can vary greatly, but for specification purposes three methods can be distinguished:

- use of explosives;
- use of hydraulic hammers or compressed air operated tools;
- use of mechanical rippers (in open excavations only).

It is usual to combine the use of either of the first two methods as defining rock; that is, 'Rock is material requiring to be loosened or broken up *in situ* by use of explosives or hydraulically or compressed air operated rock-breaking equipment before being removed'. From the contractor's point of view this is not entirely satisfactory, as some kinds of rock can be excavated by a suitably powerful digger, albeit with difficulty and at a slow rate, involving substantial extra cost. Mechanical ripping is sometimes useful in breaking up hard bands of material that could not otherwise be excavated by scrapers. If such hard bands are expected in open or general excavation, an item for ripping might be included; otherwise the contractor might elect to use hydraulically operated rock-breaking equipment solely in order to be paid the higher rate for rock. Measurement of excavation in rock for valuation is not easy; it is best done by a member of the resident engineer's staff and the contractor's staff viewing the excavation together in order to agree on the rock volume.

Working space

Contractors often claim payment for additional excavation to provide working space, despite the fact that most contracts and the standard method of measurement clearly state that only the volume vertically above the limits of foundations will be measured for payment. If therefore some exterior tanking or rendering to a basement is required, it is advisable to repeat in the item for this that the contractor must allow in his rates for any working space he requires.

Pipelines

Trench excavation for pipelines is covered piecemeal in Classes I, K and L of the standard method (Class J covers provision of fittings and valves). Trench excavation to pipe invert level is included in the supply, laying and jointing of pipes per linear metre in Class I. Excavation below that for bedding is included in the supply and placing of bedding material, also per linear metre, in Class L. Extra excavation for manholes is included in the rates for manhole construction in Class K. Rock is an extra item payable per cubic metre in Class L. Excavation of joint holes is not specifically mentioned, so needs to be specified and included in the rates. All pipework excavation items include backfilling.

If the standard method of measurement is not used, it can prove simpler to take excavation (including backfilling) separately from pipe supply and laying etc. The maximum and average depth of trench, including any depth required for bedding, is stated for any given length of pipeline and is taken for payment per linear metre. Excavation for joint holes should be stated as not measured but included in the rate for trench excavation. The drawings should show the standard trench widths taken for payment, and the depth of any bedding. Rock is paid for as an extra over per cubic metre within the payment limits, the rate to include for overbreak and backfilling thereof. Bedding, haunching and surrounding are measured per linear metre for supply and placing.

Thrust blocks for pipelines have to be constructed against vertically cut undisturbed ground. It avoids argument if items for thrust blocks to dimensions shown on the drawings are followed by an extra-over item for trimming sides of excavation adjacent to thrust blocks to the vertical, including any backfilling between a thrust block and the vertical excavated face with concrete. Under the standard method thrust blocks are measured per cubic metre inclusive of concrete, formwork, reinforcement etc. For large pipes requiring major blocks it may be better to deviate from the standard method by treating these blocks as structures in their own right.

Earthworks

Earthwork construction is measured as the net volume as placed. The source of the filling should be stated. All information available about the nature of the proposed fill material should be supplied to tenderers so that they can make their own estimate of the bulking factor of loose filling, its weight per unit volume loose and when compacted etc. When the filling is to be obtained from a borrowpit, information concerning the extent and characteristics of the borrowpit material should be provided to tenderers.

If material for filling is to be obtained as selected material from a borrowpit, the removal or set-aside of unsuitable material from the borrowpit has to be included in the rate for filling. It may also be necessary to include re-handling of the unsuitable material in order to replace it within the borrowpit. It is impracticable to measure the unsuitable material, as some may be worked around and not actually excavated. Hence it is of much importance to define what the rates for placing filling obtained from a borrowpit are to cover. Failure to include any necessary double handling of unsuitable material can result in a large claim for extra payment from the contractor. Sometimes an item for stripping overburden from the borrowpit is allowed, and an item for reinstatement of the borrowpit. If so, the specification should set out all the requirements needed for reinstatement, which it should then be possible to bill as a lump sum item for pricing. One point to note is that when 'suitable material' has to be taken from a borrowpit, it may be helpful to specify instances of 'unsuitable material' also.

Concrete

Concrete *in situ* is measured in the standard method as two operations: supply according to various quality grades; and the placing of concrete according to its location in beams, columns slabs etc. This suits the modern practice in the UK and similar developed countries, where widespread use is made of ready-mix concrete delivered to site. The totals of concrete in the various grades must therefore sum the same as the relevant placing items per grade. If the standard method is not used, the supply and placing of concrete can be itemized together, the grade of concrete being stated. This reduces the number of items in the bill and simplifies measurement for valuation.

If holes in slabs have to be left open for some other contractor, such as a separate plant contractor, then the bill should include items for the supply and fixing of temporary covers to them to prevent accidents.

Brickwork

The standard method measures brickwork per square metre, the thickness being stated. It does not classify brickwork according to height above ground, but it can be useful and assist measurement to measure external brick walling from footings to dpc level, and thereafter in one- or two-storey heights. The specification should state what is required in respect of bricks and blocks to be used, wall ties, surface finish and type of joint etc. But in order to make clear what the items cover, some of these matters will also have to be indicated in the item descriptions, such as brick type, whether solid or leaf to a cavity wall. Wall ties (measured per square metre) and fair facing of brickwork have to be itemized separately. The standard method does not mention ventilators to walls and fixing items required for brick or masonry cladding, such as angle supports, cramps or dowels (often of stainless steel), which may need to be added.

10.8 Use of nominated subcontractors

The problems associated with the contractor's use of subcontractors have been described in Sections 4.10 and 9.2. It is now necessary to consider further the problems that can arise when the employer requires the contractor to use a particular subcontractor.

Sometimes the employer may wish to retain to himself the choice of a particular specialist to carry out work or supply materials under the contract, and the firms consequently specified are referred to as **nominated subcontractors**. By this means the employer will hope to get a standard or style of workmanship, which he desires but might not get if the choice of specialist were left to the main contractor who could accept the cheapest available offer. The employer may thus obtain quotations direct from suitable firms and then instruct the contractor to accept the chosen tender. When such a procedure is followed it is important that the specification sets out exactly what ancillary services the contractor is to supply to the nominated subcontractor. These may include such matters as providing access, offloading materials, providing electrical power, scaffolding and cranes, and permitting use by the subcontractor's men of the contractor's canteen and welfare facilities. It will also be necessary to define what notice the subcontractor must be given before he is able to deliver or start work, when he can undertake his work and how long it will take.

However, the actual terms of the subcontract have to be decided between the contractor and subcontractor, and there can be instances where they cannot agree. The subcontractor may refuse to accept the extensive liabilities set out in Clause 3 of the ICE Form of Subcontract (described in Section 4.10 above), because the value of his work may be so small that he is not prepared to indemnify the contractor against liquidated damages for any delay he might cause. A nominated subcontractor supplying a few road gullies might not, for instance, be prepared to indemnify the contractor against very high liquidated damages for late completion of a road due to some delivery mishap with the gullies. There can also be refusal of either party to accept the other's terms for payment.

Although Clause 59(7) of the ICE Conditions of Contract endeavours to protect a nominated subcontractor by providing for direct payment to him if the main contractor fails to pay him, the contract also entitles the contractor to refuse to enter a nominated subcontract if the subcontractor will not indemnify the contractor against all damages, costs etc. arising from the failure of the nominated subcontractor to fulfil any of his obligations. It is true that, under Clause 59(1), the contractor has to have a 'reasonable objection' for refusing to employ a nominated subcontractor, but this constraint is of little value in practice. The practical result is that if the contractor or nominated subcontractor will not enter a contract between them for any reason, the nomination fails. The engineer then has to nominate another subcontractor, or ask the contractor to do the work himself or find his own subcontractor.

This mixing of responsibilities between the employer and main contractor for the performance of a nominated subcontractor leads to frequent disputes. If the nominee fails to do the work or goes into liquidation, the employer must take action without delay, as the main contractor has no duty to carry out the work himself and will claim for any delay in getting it done. Further, if the work when done proves unsuitable or not fit for its purpose, the main contractor will deny responsibility, unless he was expressly charged in the terms of the subcontract to take such responsibility, as he had no choice in the selection of the subcontractor. The extensive disputes that have arisen over the years on these matters, more particularly in building work with its wider use of nominated subcontractors, has led many engineers to take the view that use of nominated subcontractors in civil engineering should be avoided wherever possible.

Problems with nominated subcontractors mostly arise when the work of a subcontractor comprises some operation on site whose late completion or defective performance would affect the contractor or his other subcontractors. Wherever possible, a better alternative is to specify the work in detail, providing for its payment by measure under appropriate bill items. If specially skilled or experienced workers are required on the work, there is no reason why this cannot be specified by calling for particular craft skills and requiring evidence of same. Alternatively, if only one firm can provide the special techniques required, the letting of a separate contract for such work can be considered. Although the organization of separate contracts has to be carefully managed (as described in Section 2.9 above), the engineer has the advantage that he retains direct control over the specialist's work and can act to avoid or solve problems arising. Where a subcontractor is to supply only certain items, various options to avoid trouble are possible. The employer may be persuaded to order the materials direct and store them in advance of being needed; or the contractor may be instructed to order them early and be paid for offloading and storing them on site under items provided in the bill of quantities.

10.9 Prime cost items

When a nominated subcontract is intended, a prime cost item is inserted in the bill of quantities by the engineer to cover the work and/or materials to be supplied by the nominated subcontractor. The sum entered by the engineer is that which he estimates will cover the subcontractor's charges. The actual charges made by the subcontractor will be refunded to the main contractor. To the prime cost item are appended two other items to be priced by tenderers. One consists of a lump sum to cover any welfare facilities, use of scaffolding etc. the contractor is to provide for the subcontractor; and the other, expressed as a percentage of the prime cost, is to cover all the contractor's other charges and his profit. The ICE standard method of measurement states that, unless expressly stated to the contrary, the lump sum item added by the contractor to a prime cost is deemed to cover only general facilities provided by the contractor, such as: access; use of scaffolding, hoists, contractor's messrooms and sanitation; space for office and storage; light and water. It thus excludes any labouring assistance required by the nominated subcontractor. If, however, the subcontractor supplies materials only, the lump sum is deemed to include the contractor's unloading, storing and hoisting of materials delivered.

Neither prime cost items nor nominated subcontractors can be wholly avoided on every contract. Each case has to be decided with reference to the nature of the work or item required, whether nomination could raise serious problems, and whether any satisfactory alternative exists. A prime cost is best used for the supply, or supply and fixing, of minor items, preferably those used in the finishing stages of a project such as door furniture, entrance gates, signs, and lighting equipment. A prime cost can be used for larger matters, such as for plumber's work, but it is better to include a provisional sum for such work so that, when the full details are available, the contractor may be given the option of doing the work himself or finding his own subcontractor to undertake it.

It is inadvisable to specify that a contractor must subcontract certain work to a specialist subcontractor of his own choosing, the contractor being reimbursed the subcontractor's charge as a prime cost. In that case the subcontractor's quotation is submitted only to the contractor before being passed to the engineer. This procedure could conceal a situation where the subcontractor's price includes work paid for separately under other bill items. The contractor would then be paid twice for the same work, once under the prime cost and again under bill items. A preferable alternative is to specify that the work must be undertaken by appropriately skilled persons (as mentioned towards the end of the previous section), paying by measure of work done, leaving the contractor to decide if he will subcontract to specialists.

10.10 Preliminaries bill and method-related items

A preliminaries bill lists items that apply to the contract as a whole, such as insurance of works, offices for the resident engineer, provision of laboratory, surveying equipment, transport, telephone, and tests on materials or the works. The units of measurement will be appropriate to the type of item, lump sum, or per week or month, or per number of tests etc. Sometimes an item needs to be split into two parts, such as a lump sum for provision of the engineer's site office, with a second item for its maintenance per week or month. Such items listed by the engineer in the bill must be supported by descriptions in the specification stating exactly what the contractor is to provide. *See* Fig. 10.1, which shows part of the first page of a preliminaries bill drawn up according to CESMM.

The engineer may also list temporary works that the contractor has to provide, such as access roads, a temporary sewage treatment plant and similar. The listing of such temporary works permits the contractor to put a price to them, which may be to his advantage. Insurance is costly, so that if a tenderer prices this item, he can be reimbursed his expenditure on it as soon as he shows evidence of obtaining it. He does not have to wait for its reimbursement as he would have to if he spread the cost over the constructional items. Also, a priced item for such as

CLASS A: GENERAL ITEMS

Item no.	Item description	Unit	Quantity	Rate £	Amount £
	CONTRACTUAL REQUIREMENTS				
A110	Performance bond	Sum		—	16 000.00
A120	Insurance of works	Sum	)		
A130	Insurance of constructional plant	Sum	)	—	33 500.00
A140	Insurance against damage to persons and property	Sum	))		
	SPECIFIED REQUIREMENTS				
	Accommodation for engineer's staff as specification Cl.112				
A211.1	Provide and erect	Sum		—	9 500.00
A211.2	Maintain	Wk	104	200.00	20 840.00
A211.3	Remove	Sum		—	1 000.00
	Services for engineer's staff as specification Cl.113-116				
A221.1	Provide transport vehicles	Sum		—	17 500.00
A221.2	Maintain and service transport vehicles	Wk	104	70.00	7 280.00
A222	Install telephone and fax	Sum		—	1 000.00
	Equipment for use by engineer's staff as specification Cl.117-118				
A231.1	Provide office equipment	Sum		—	10 000.00
A231.2	Maintain office equipment	Wk	104	30.00	3 120.00
A233.1	Provide survey equipment	Sum		—	12 000.00
A233.2	Maintain survey equipment	Wk	104	10.00	1 040.00
A239	Insure telephone, fax, office and survey equipment	Sum		—	Included
	Attendance upon engineer's staff … … etc				

Notes: The above assumes water supply, sanitation and electrical supply are specified under accommodation; they could have been separately itemized. Fuel for vehicles, and telephone charges would be paid by engineer. Removal of telephone, office and survey equipment could have been itemized but is ignored.

Fig. 10.1 Typical example of the first page of a preliminaries bill, drawn up according to CESMM Class A requirements, and priced by tenderer

the sewage treatment works is of advantage to the employer, as payment for such works can be withheld if the plant is not as specified or does not work properly. However, the pricing is in the tenderer's hands, and he does not have to put a price to any of the items listed by the engineer in the preliminaries bill. He can mark them 'included', meaning that the cost of meeting the item requirements is included in his bill rates for the construction items, or he may enter a low figure.

A tenderer may sometimes add an item that is not in the list set out in the preliminaries bill. For instance, he might wish to price separately some specially expensive temporary works equipment such as steel shuttering. However, the employer may have laid down in the Instructions to Tenderers that 'no items shall be added to the bill of quantities'. The employer can refuse to consider such a tender; but if it is the lowest tender received the employer may decide nevertheless to consider it. This depends on the rules under which the employer himself operates, such as the standing rules of a public authority, or government regulations. Normally, however, an extra item or two added by a tenderer in the preliminaries bill would not be taken as invalidating a tender. Some contracts specifically allow this by writing in the preliminaries bill 'Other items added by contractor ...'. If a tenderer does add such items they would be discussed at tender negotiation stage to agree how they should be paid, as payment of a lump sum for such as the steel shuttering mentioned above might need to be agreed as a certain percentage on delivery, the balance on completion of its use.

The ICE standard method of measurement of 1985 first gave formal recognition that items of the above kind could be added by tenderers. It called them **method-related** items, though they are not confined to construction methods but include organizational measures as well. The ICE standard method of 1991 (CESMM3) lists over forty such matters that a tenderer can add, covering such things as accommodation (offices, stores, canteen, etc.), services (water, power, site transport, welfare, etc.), plant and temporary works of many kinds, and 'supervision and labour', and also permitting a tenderer to add other method-related items not in those listed. All such method-related items are to be priced as lump sums, but they have to be defined as either **fixed** or **time related**. If fixed, the lump sum is only payable when the work itemized is completed. If time related, the payments are spread out over the time taken to achieve completion of the work covered by the item (see clarification in Section 11.4). Clearly, some items – such as supervision, site transport, and welfare – should not be designated as 'fixed', as there is no definable time when they could be said to be completed, other than the end of the contract. A tenderer has to define exactly what any item added by him covers, and whether it is fixed or time related. Figure 10.2 shows some typical method-related items entered by a tenderer.

The standard method has five main divisions or categories of items that can be put in the Class A preliminaries bill:

1. 'Contractual requirements' (bond and insurances);
2. 'Specified requirements';
3. the 'Method-related charges' referred to above, which the tenderer is to insert;
4. provisional sums;
5. and 6. 'Nominated subcontracts', which include or exclude work on site respectively.

CLASS A: GENERAL ITEMS

Item-related	Item description	Fixed charges £	Time-related charges £
	METHOD-RELATED CHARGES		
A311.1	Offices	39 000.00	—
A311.2	Maintain offices	—	3 900.00
A314	Stores	9 000.00	—
A315.1	Canteen	11 000.00	—
A315.2	Maintain canteen	—	5 200.00
A320.1	Services, install	15 000.00	—
A320.2	Services, maintain	—	10 400.00
A320.3	Services, remove	1 500.00	—
A330.1	Plant, provide	20 000.00	—
A330.2	Plant – maintain 60 weeks	—	30 000.00
A330.3	Plant, remove	2 000.00	—
A333.1	Piling plant, provide	14 000.00	—
A333.2	Piling plant, remove	1 000.00	—
A341.1	Drilling plant, provide	3 500.00	—
A341.2	Drilling plant, remove	1 000.00	—
A356.1	Provide pumping plant	2 000.00	—
A356.2	Remove pumping plant	500.00	—
A357	De-watering	—	10 000.00
A363.1	Provide piling	25 000.00	—
A363.2	Remove piling	8 000.00	—
A370	Supervision and administration	—	104 000.00
	Total fixed charges	152 500.00	
	Total time-related charges		163 500.00
	Total to summary		316 000.00

Note: Some of the fixed charge items need more precise definition so that it can be known when they are completed e.g. services, plant etc. The time-related item A330.2 cannnot be paid over 60 weeks at £500 per week, it must be paid over the contract period.

Fig. 10.2 Typical method-related items entered by a tenderer – one item wrong

The Specified requirements (2) cover accommodation and services for the engineer's site staff, tests on materials etc., and a range of temporary works that the engineer might wish to itemize.

The difference between temporary works that the engineer itemizes as 'Specified requirements' under Division 2 of the Class A bill, and the temporary works that a tenderer adds as method-related items under Division 3, should be noted. The former have to be fully specified by the engineer in the contract; the latter do not, being left to the tenderer to describe. Thus if the contractor is required in the specification general clauses to construct some temporary access road, then if the engineer itemizes it as a 'Specified requirement' in Division 2 the details of it must be fully described in the specification or contract drawings. If the engineer does not know how the access road should be constructed because he does not know what traffic the contractor will put on it, then he should not itemize it in Division 2 but leave it to the contractor to add in Division 3 as a method-related item, if he so wishes. It is important to follow the standard method requirements exactly, or problems of interpretation leading to claims from the contractor may arise. Of course, the contract can expressly state that items in the Class A Preliminaries Bill are not drawn up in accordance with the standard method; but then care has to be taken to define what each item entered covers, so that there is no ambiguity.

Problems with CESMM

The whole concept of payment for temporary works as set out in CESMM can be called into question, as it creates potential ambiguities. The engineer may choose not to itemize any temporary works under 'Specified requirements' because he leaves such works for the contractor to decide. But the contractor may maintain that the list of temporary works printed in CESMM A2.7 (such as traffic diversion, access roads, or dewatering) entitles him to payment for those works on the same principle as an item that CESMM lists for measurement has to be added if found missing from a bill (*see* end of Section 12.2). To avoid this ambiguity the preamble to the bill should state that Class A items shall be measured only to the extent that they are included in the contract at the time of the award, thus fixing the temporary work items measured.

Another difficulty arises with method-related items. CESMM clauses state that a method-related charge does not bind the contractor to use the method defined (7.5); is not subject to admeasurement (7.6); and is not to be increased or decreased for any change of method adopted by the contractor (7.8). But when the engineer orders a variation of some permanent work, the contractor may claim that bill rates for similar work do not apply because the temporary works associated with that type of work have been priced separately under a method-related item. This can raise debatable issues, because method-related charges are not subject to admeasurement; also, they need not bear any relationship to actual methods that the contractor uses.

Under the ICE Conditions (Clause 14(7)) the engineer is only required to state why a proposed method by the contractor fails to meet the contract requirements or would be detrimental to the permanent works. It is left to the contractor to decide what method he will adopt to gain the engineer's consent. Hence, if the engineer has no reason to specify a particular method, he should avoid mentioning any, lest this be interpreted as a 'specified requirement' as discussed above. Also, acceptance of a method-related item in a contract does not imply that the engineer has given his consent to the method stated. The preamble to the bill may need to make this clear.

10.11 Adjustment item to the total price

An **adjustment item** is an addition or deduction that a tenderer makes to the final total of his prices entered in the bills of quantities. The standard method permits an adjustment item as a lump sum addition or deduction, paid by instalments in the same proportion as the total payment to date, less retention, bears to the total of billed prices (*see* Section 11.4). The addition or deduction is not to be exceeded, and the full amount is to be allowed when a certificate of substantial completion for the whole works is issued.

In contracts that do not follow the standard method of measurement or the ICE Conditions, a tenderer is always free to add an adjustment item to his tender, or in fact, add any additional item for which he submits a separate price. His tender is only an 'offer', so he is free to offer his price in any way he likes. The employer can, of course, lay down rules that he will not entertain any offer that is not priced as he instructs, but this is a rule for himself. The tenderer has to run the risk that his non-conforming tender will not be considered; but this is rather unlikely to happen if his bid is the lowest! Thus, instead of inserting a lump sum addition or deduction as required by the standard method, he can insert an adjustment item, which comprises a percentage reduction (or, more rarely, addition) to be applied to all his billed prices. Sometimes this practice is actually invited by the employer who invites tenders for two contracts simultaneously, and provides a special item in one contract for the contractor to quote his reduction of price (if any) if he were awarded both contracts.

An adjustment item as such is added by a tenderer when, after having had all the items in the bill priced and totalled, he looks at the final total so derived and decides to increase or decrease it. This is his commercial decision. He will have made a check estimate of the cost of the whole contract in an entirely different manner from that obtained by totalling the priced quantities in the bills. This can be done, for instance, by costing the total materials and estimated labour and plant to be used on the job, and adding a percentage for overheads and profit. In the light of his findings and taking into account other factors such as risk, need for more work and late quotations, the contractor may decide to add an adjustment figure to the total of billed prices. He could, of course, select certain bill items whose rate or price he could alter to make the adjustment, but this could be risky if more or less work under such items should prove necessary.

10.12 Preamble to bill of quantities

There must be a preamble to the bill of quantities in which is stated, among other things, the following:

- the method of measurement used in preparing the bills of quantities;
- if the ICE standard method of measurement is used, the edition that applies

and which parts of Sections 1–7 of CESMM3 (which cover general instructions etc.) are to apply;
- the classes or types of work that are not measured in accordance with the ICE standard method;
- provisions with respect to method-related items;
- provisions with respect to any adjustment item to the total of billed prices;
- payments to be made in respect of prime cost items;
- the definition of 'rock';
- if no price is entered against an item, that it will be assumed that no payment is to be made under that item.

The provisions with respect to the method-related items inserted by the tenderer may need further amplification added before the contract is awarded, to clarify such matters as the method of payment of such items.

10.13 List of principal quantities

The standard method requires that 'the principal components of the works with their approximate estimated quantities shall be given solely to assist tenderers in making a rapid assessment of the general scale and character of the proposed works prior to the examination of the remainder of the bill of quantities'. This list is to precede the preamble to the bill of quantities. It is difficult to understand how this requirement could be of any real value to a serious tenderer. It would in any case be a subjective selection by the engineer of 'the principal components'. It is the tenderer's responsibility to select those components that are most significant to him in terms of cost or quantity or difficulty. The early part of the specification should describe the nature, magnitude, output or size etc. of the principal components of the works so that the extent of the works required is defined and readily appreciated. This is also useful if the cost of the contract is to be of value for cost analysis purposes in the future.

11

Interim monthly payments

11.1 Handling interim payments

Under the ICE Conditions of Contract interim payments, based on the quantity of work done during the previous month, must be made by the employer to the contractor at monthly intervals. The amount of work done is measured by the engineer under the contract, and valued in accordance with the terms of the contract. The engineer then issues a **certificate of payment** showing the amount that the employer must pay to the contractor. Occasionally other intervals for payment may be agreed to suit accounting periods: for example, payments at four-weekly intervals. Sometimes it is agreed that two out of every three monthly payments are approximate valuations of work done; thus only the quarterly payments are based on a detailed measurement of work done.

The ICE Conditions require payment to the contractor to be made by the employer within 28 days of the contractor's submitting his account. If payment is late, the contractor can charge interest on the overdue payment at 2 per cent per annum above bank rate for each day late. This is an onerous requirement for large projects, as during the period of 28 days the resident engineer has to check the contractor's account, amend it as necessary, and forward it to the engineer, whose own contract's department may need to check it; then the engineer issues his certificate and sends it to the employer. If the employer is a government department or a local government or other statutory authority it may need more than one person to authorize payment, and the account then has to be passed to the paying department of the authority. The stipulation of 28 days represents 20 working days, which may seem unreasonably short. A longer period may sometimes be appropriate. Few, if any, contractors pay their suppliers' accounts in 28 days. Under FIDIC conditions for international work the engineer has 28 days within which to issue a certificate for interim payment, and the employer a further 28 days within which to make payment.

As a consequence of the short time period for payment the resident engineer must try to agree quantities with the contractor before the contractor draws up

Plate 9a. The ubiquitous backhoe loader used on many sites. That shown is the JCB 3CX 56.5 kW, with shovel up to 2.3 m wide and hoe bucket 0.3–0.9 m wide. JCB Ltd, Rocester, UK

Plate 9b. A Mastenbroek 17/17 trenching machine with variable-offset heavy-duty cutting chain for trenches up to 0.6 m wide by 1.8 m depth. Larger machines are made. J. Mastenbroek & Co. Ltd, Boston, UK

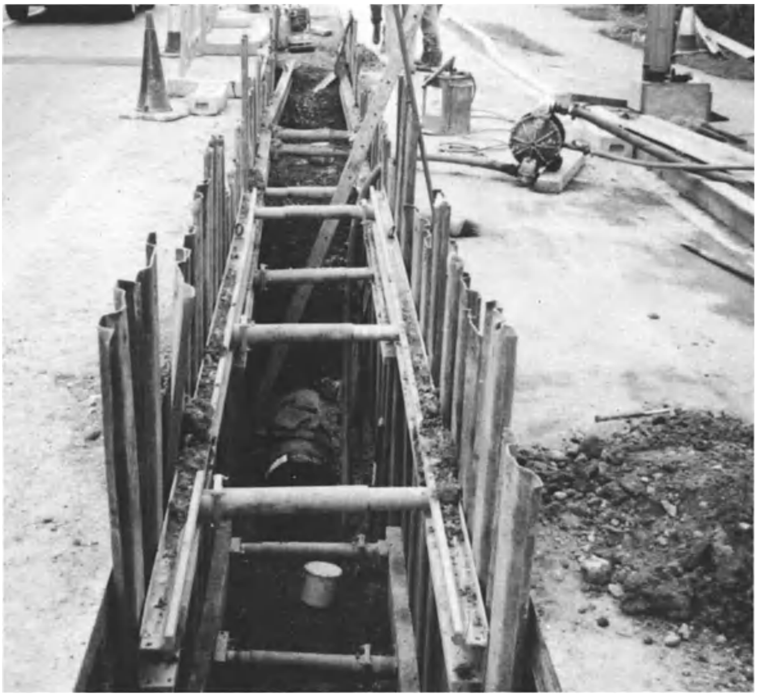


Plate 10a. A properly supported trench

Plate 10b. It is almost universal to use the hydraulic excavator also as a crane

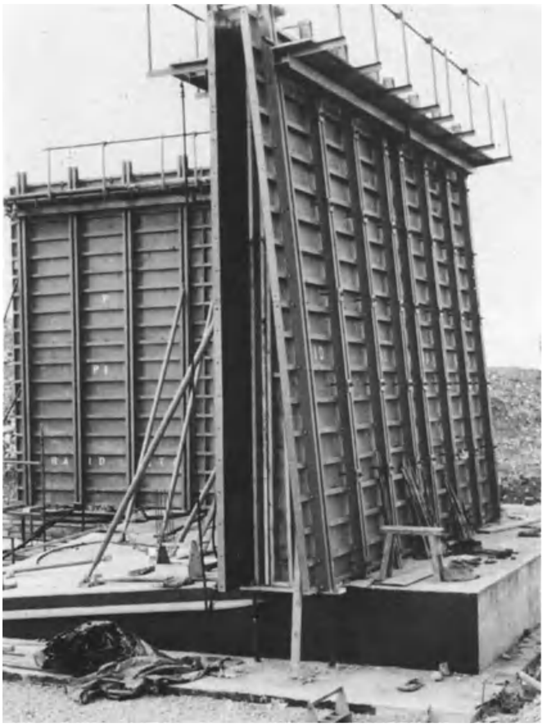


Plate 11a. Well-designed steel shuttering for a single-lift wall pour of concrete. Safety regulations require full boarding and a toeboard to the access walkway

Plate 11b. Excavating grab for diaphragm walling construction

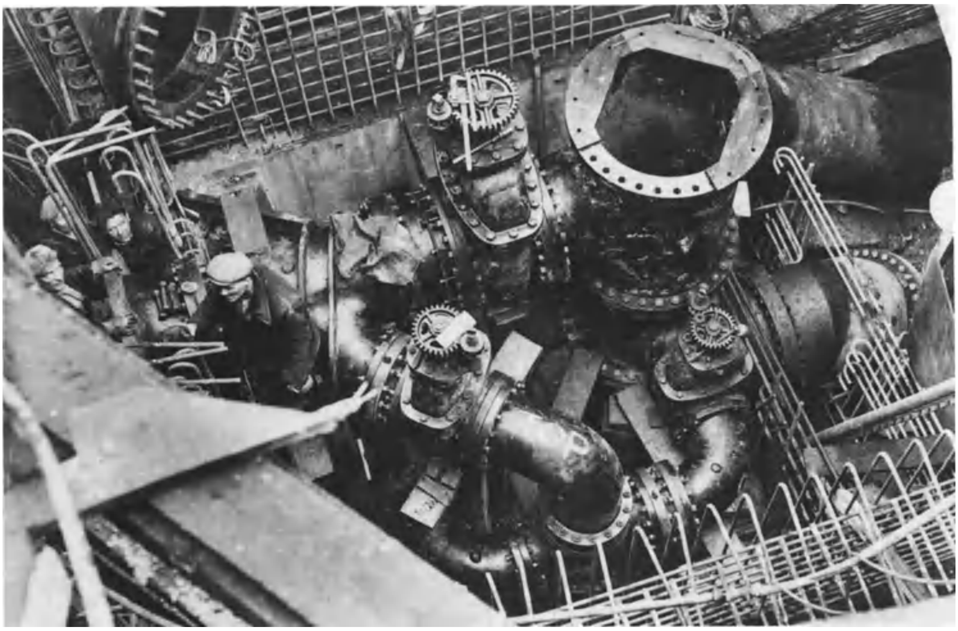


Plate 12a. The skill and teamwork required to erect an assembly of pipes like this is seldom appreciated by the layman

Plate 12b. On any job not properly supervised the strangest things can happen. It looks as if someone forgot the reinforcement until after the first placement of concrete. A resident engineer would stop the work and require it to be redone properly

his account. The contractor will need to be warned that if he submits quantities or items for payment that have not been previously agreed, there will be no time for the resident engineer to hold discussions on them; he will substitute his own measurement or amount payable in lieu.

The contractor should be required to submit his interim account in a standard form, which is set out in the specification to the contract (*see* Section 8.8). The account can comprise a computer printout in a form that should be agreed beforehand. It is useful if three quantities columns are included in the standard form of account, showing 'Paid last certificate', 'Addition this certificate' and 'Total to date'. The contractor should supply three copies of his account. The resident engineer will need to mark his amendments on them (the standard form should allow room for this) in a distinguishing coloured ink. He must put his amendments identically on all three copies, sending one to the engineer. Subsequently the engineer's contracts department may notify the resident engineer of any further amendments made by them or the engineer; and the engineer will send the top copy of his certificate to the employer with copies to the contractor and resident engineer. The latter will then need to send a written note to the contractor setting out the alterations made to his account. An important point that the resident engineer should remember is to mark on the contractor's account the date when it is received.

11.2 Agreeing quantities for payment

The way in which the resident engineer should measure quantities has already been described in Section 8.7. In that section the importance was emphasized of making clear in the calculations precisely what has been measured, and what has been agreed for payment – with sketches as necessary.

It is strongly advisable that the resident engineer should take the lead in assessing final quantities; that is, he or a member of his staff should supply quantity calculations to the contractor or his quantity surveyors and request agreement. When agreement is reached, the agreed figure should be initialled by both sides. If the opposite method is adopted – that is, the contractor supplies his quantity calculations to the resident engineer for checking – the resident engineer's task may be made much more difficult, because he has to examine the contractor's calculations to find out why they differ from his own when there is a discrepancy. If the contractor's calculations are done according to some computer package that is unfamiliar to the resident engineer, it may be impossible for him to understand how the contractor has arrived at his figure, especially if no sketches are provided. An impasse is liable to follow.

Some items will need measurement in the field, such as trench depths for pipelines, excavation, and mass concrete to foundations. This is often done by the resident engineer's inspector, who agrees the measurement with the appropriate foreman, a written advice note being sent immediately to the contractor giving the agreed figures; alternatively a joint survey is arranged. Other quantities will be taken from drawings when no variation has occurred. These need checking against the relevant billed quantities. Where an item of work is only partly done, a rough estimate of the proportion done should be agreed with the contractor. Sometimes all but a minor aspect of an item is completed: for example, final painting of valves in a valve chamber. It is better to certify the item in full rather than make some trivial reduction, making a note to remind the contractor if he fails to complete the painting.

If work has been done so badly that it cannot be accepted, no payment should be certified for it. If the contractor has agreed to do some remedial work that will make it satisfactory, some partial payment can be made. All depends on the circumstances. With a reputable contractor and a responsible agent there is no reason to assume that verbal promises will not be carried out. With good contractors most agreements are verbal anyway, and the paperwork is only for the purposes of record.

Some agents leave the contractor's quantity surveyors to prepare the contractor's accounts. When the quantity surveyors are approached and asked not to repeat in every account items of claim previously struck out as being invalid, they may reply that they have no authority to remove an item once it has been put into an account. Continued practice of this kind means that, as the measurement gets larger, the resident engineer may have to make an increasing number of corrections to items, page totals, bill summaries and grand summaries. If the engineer is unable to get the practice altered, if necessary by direct approach to the contractor's senior personnel, it at least eases the problem to insist, from the beginning, that all extras, added items and claims are billed on a separate sheet, grouped under each separate bill, so far as this is possible.

11.3 Payment for extra work, dayworks, and claims

When extra work has been ordered then, if any of such extra work has been done by the contractor, there should be some payment for it in the next interim payment certificate even if the rates for such extra work have not been agreed. The reason for this is that the ICE Conditions of Contract provide that work done shall be measured monthly and paid for within 28 days of the contractor submitting his account for same. Any dispute about the exact rate or amount for some extra should not therefore delay payment for it to the extent that the engineer considers reasonable; otherwise the contractor could claim he was not paid the undisputed portion of his application within 28 days of submitting his account, and so might be entitled to claim interest on it for late payment (*see* Section 12.13).

Dayworks charges (*see* Section 8.9) that have been checked and agreed by the resident engineer will also need to be included in the next interim certificate for payment, in so far as the contractor lists them in his account. The contractor's account may, of course, list other dayworks charge sheets that have not been previously submitted to the resident engineer for checking. If there is time to check them, the resident engineer should do so and include them for payment. Alternatively, he might include a round sum 'On account of unchecked daywork sheets submitted', the sum being what he considers will at least be payable under them. However, he does not have to include any payment against a daywork account that provides insufficient information for him to check it.

Similar problems of the need to make partial or 'on account' payments can arise in respect of claims submitted by the contractor that may be valid in principle but not supported by details as to the amount due. Again, however, nothing need be certified in respect of a claim insufficiently detailed for it to receive consideration (ICE Conditions Clause 52(4)). All such partial or 'on account' payments proposed by the resident engineer should be drawn to the attention of the engineer when the contractor's account is forwarded to him. Preferably the engineer and his contracts department should set out an agreed policy for the resident engineer to follow in respect of such payments.

Where the resident engineer has agreed rates for extras with the contractor he should draft an appropriate variation order, which he sends to the engineer for checking and issue.

11.4 Payment of lump sums, method-related items, and any adjustment item

Unless there is some stipulation that a lump sum is to be paid in stages, it only becomes payable when the whole of the work itemized under the lump sum is completed. However, a certain degree of common sense and fairness has to be applied when an item combines two operations, and nothing is stipulated about staged payment. Occasionally a lump sum item reads: 'Provide and set up engineer's offices as specified and remove on completion', so in theory the item is not payable until the end of the contract. At the tender negotiation stage, agreement should be reached as to how the sum is to be paid; but if the matter has been missed then it is up to the resident engineer to suggest how the item should be paid: perhaps 80 per cent on set up and 20 per cent on removal, or some other proportion. Lump sums for such things as insurance can be certified for payment as soon as the contractor produces evidence of insurance.

Payment of method-related items will depend on whether any special conditions have been laid down about them for staged payment; if not, it will be dependent on whether they are fixed or time-related. Fixed sums would be paid as mentioned above for ordinary lump sums, but problems can arise if the item description is imprecise. Thus if the contractor adds some method-related item for 'scaffolding' or 'site transport' as a fixed sum, it has to be further defined to relate to some specific scaffolding or specific transport; otherwise it is too vague to identify and cannot be paid until substantial completion.

When method-related sums are time-related they are paid in monthly instalments, but the proportion paid will depend on when completion of the relevant task will be reached. Thus if an item is completed when substantial completion is achieved, and the programmed time for this is 18 months, then 1/18th is paid at the end of month 1, so that at month 6 one third would be paid. But if it then appears that substantial completion will not be reached until month 20, the total payment due at month 7 is 7/20ths. This is irrespective of whether the delay in completion is due to the contractor's tardiness or to an authorized extension of the contract period. The reason for this approach is that method-related items are defined as covering 'costs not to be considered as proportional to the quantities of the other items'. If an extension of the contract period has been granted, then any claim for extra payment on that account is a separate matter to be decided by the terms of the contract. The lump sum payable under a method-related item remains unaltered.

An adjustment item in the form of a lump sum (*see* Section 10.11) is paid in the same proportion as the total payment due under other items, less retention, bears to the total contract sum less the adjustment item. If a percentage adjustment has been quoted, this is applied to the total amount payable under bill items and variations. In both cases the retention money is deducted after adding in the adjustment item.

11.5 Payment for materials on site

The ICE and other conditions of contract permit payment to be made to cover part of the cost to the contractor of materials delivered to site but not yet built into the works. This can ease the contractor's cash flow situation and is of advantage to the employer in encouraging early supply of materials so that unexpected shortages or late deliveries are less likely to hold up progress. In contracts that contain such a provision, tenderers can be expected to reduce their prices in anticipation of the expected financial benefit.

Certifying payment for materials on site is left to the discretion of the engineer. Under ICE Conditions Clause 60(2)(b) he has to certify such amounts (if any) as he may consider proper, not exceeding a percentage of the value stated in an appendix to the contract. In this he may need to act carefully because, even though material has been delivered to site, it might still remain the property of the supplier until he has been paid for it by the contractor. If the supplier falls into dispute with the contractor, or goes into liquidation, the materials he supplied might be reclaimed by him or his receiver. Before certifying any payment for materials the engineer will need to be reasonably certain that the contractor does own them.

In deciding what should be certified for materials on site, the resident engineer needs to check that they comply with the specification, are properly stored or protected, and will not deteriorate before use. The amount certified will depend on the nature of the material and also the circumstances of the contractor. If the contractor appears to be running into financial difficulties or shows signs of being unable to complete the contract, what should be certified for materials on site needs careful consideration by the engineer. The prospective value to the employer of the materials paid for then needs to be assessed in the light of the situation, allowance being made for any deterioration that might occur if there is a delay in their incorporation into the works. Reinforcement or structural steel left out too long in the open may rust to the point of scaling; improperly secured items may get stolen; pipes left too long on verges to roads may sustain damage to their protective coatings; valves can be damaged by frost and so on.

11.6 Payment for materials manufactured off site

The ICE Conditions also permit payment on account to be made for items manufactured off site (Clauses 54 and 60(1)(c)). This provision is intended primarily to cover mechanical or electrical equipment or prefabricated steelwork that the contractor has to supply for incorporation in the works. He will usually use a specialist manufacturer to supply such items. It is advantageous to the progress of the job for all such items to be manufactured and made ready for delivery in advance of the date planned for their incorporation in the works: hence payment for items manufactured off site encourages this.

However, only items listed in an appendix to the tender documents are to rank for on account payment: that is, the contract predetermines the equipment or plant to which the provision relates. Also two further conditions have to be complied with: (a) the equipment or plant must be ready for dispatch, and (b) the ownership of it must be transferred from manufacturer to contractor, and thence from contractor to employer. Clause 54 of the ICE Conditions sets out the details of the procedure required.

Clearly, before any payment on account can be made, the engineer or resident engineer will need to arrange for the manufacturer to be visited so that the plant to be supplied can be inspected to ensure that it conforms to specification and all necessary tests before delivery have proved satisfactory. Evidence of the proper transfer of ownership, and sundry arrangements for storage, insurance etc. will also be required.

11.7 Payment for manufactured items shipped overseas

When manufactured items have to be delivered to projects overseas, arrangements for staged payments will normally be provided for in the contract. Items will need to be inspected and tested at the place of manufacture, their loading to ships inspected, and inspected again when offloaded at the place of destination. If the civil engineering contractor is responsible for the supply of the items, he must arrange for the loading and offloading inspections; if items are supplied under a separate contract, the engineer will have to arrange the inspections. In either case, however, the engineer will need to ensure that such inspections are efficient, not only for the purposes of payment, but to ensure safe delivery, because it may take weeks or months to replace an item lost or damaged. Manufacturers normally only quote supply of equipment 'to dockside' or 'f.o.b.' (free on board), after which the carrier takes responsibility until he offloads. If equipment is not inspected at every stage, it may be impossible to know who is responsible for any damage or loss, leaving the employer to bear the cost of any replacement. The whole operation needs to be well organized if trouble is to be avoided.

11.8 Price adjustment

Some contracts contain a price variation clause in order to protect the contractor against the risk of rising prices due to inflation. Nowadays it is not usual for contracts in the UK lasting less than 2 years to contain such a clause. To calculate the amount due, either the contractor has to produce evidence of how prices have altered since he submitted his tender, or a formula that uses published indices of price changes is applied to the payments due to him under billed rates.

For contracts in the UK the price indices published by the Department of the Environment, often referred to as the **Baxter indices** and which are relevant to the civil engineering industry, are used according to a formula. The formula applies the indices via weightings given to labour, plant and specific materials in rough proportion to their use in the works being built. Standard types of formulae are included in the ICE and other forms of contract. At each interim payment the formula is recalculated using the relevant latest published indices to give a multiplier representing the change in construction prices since the date of tender. When applied to the value of work done in the month, as measured at bill rates, an approximately fair adjustment is produced.

Each month the resident engineer will need to check the calculation using the latest available indices, amending these in later months as final values for indices are published. Most price variation clauses provide that the price adjustment ceases for those parts of the works for which a substantial completion certificate is issued, or for which contractual dates for completion are reached (including any extension given), whichever is earlier. This provides an incentive for the contractor to achieve target dates.

If no authentic indices are available for calculating price variation, as may occur on overseas projects, then price increases have to be directly calculated. Tenderers are required to list the basic rates of wages and prices of materials on which their tender is based. Checking the authenticity of these is usually done before signing the contract. Prices of materials may have to be checked by contacting suppliers direct, asking them to confirm their price at the date of tender. Any wage increases charged should have some authenticity: for example, be in line with inflation of cost of living or relate to some government or state policy for equivalent labour. Wage sheets and invoices for materials have to be supplied by the contractor as work is done: these are analysed to calculate the extra costs paid by the contractor. Sundry checks have to be applied of an auditing nature: for example, that the wages shown on the paysheets were actually paid; that suppliers were paid what their invoices said; that the quantity of materials invoiced were used on the job and not on some other job; or that invoices are not submitted twice over.

In the hands of a competent and reputable contractor the checking work may be straightforward, though very time-consuming. Usually the contract will stipulate that 'only those materials named and priced by the tenderer will rank for price variation', so as to limit the number of items that have to be checked. The resident engineer will need to graph out the total price increases certified against total payments for work constructed, to ensure that the increases follow a consistent pattern and are believably in line with known current price trends. The work is so time-consuming, and open to mistake or even falsification, that every effort is usually made to adopt some simpler and more reliable measure.

11.9 Retention and other matters

The retention money, as stated in the contract (usually 5 per cent but subject to some maximum value), must be deducted from the total amount calculated as due to the contractor in interim certificates for work done. When a substantial completion certificate is issued the retention rate is halved for that portion or whole of the works to which the certificate applies, the amount so released being paid to the contractor. During the **defects correction period** (often termed the maintenance period), which is stipulated in the contract, the contractor undertakes to correct all matters listed by the engineer as needing remedial action. The resident engineer must forewarn the engineer when substantial completion of part or all of the works is likely. If this is later than the contract period, liquidated damages may apply, as set out in the contract. If any are applicable the employer must deduct them from any payment due to the contractor, otherwise they may not be recoverable. This matter must be handled by the engineer who will report the circumstances to the employer.

12

Variations and claims

12.1 Who deals with variations and claims?

The two parties immediately concerned with the issue of variation orders and the handling of contractor's claims are the engineer under the contract, and the resident engineer. While on overseas sites the resident engineer may have powers delegated to him to agree payments and to value variations (*see* Section 5.5); this would rarely be the case in the UK, and under ICE conditions he cannot be delegated powers to settle the contractor's claims for delay or the cost of meeting unforeseen conditions in accordance with Clause 12(6). Also, only the engineer has authority to issue the final certificate for payment, which of course can include revision of any payments previously certified in the interim payment certificates.

In practice the resident engineer conducts the 'first stage' negotiation work on payment matters, digging out and recording all the relevant information, examining and checking the contractor's claims or justification of new rates he wants for varied work, and endeavouring to reach agreement with the contractor on what a fair rate should be under the terms of the contract. He reports all this in detail as succinctly as possible to the engineer. Obviously, if the resident engineer can get the contractor's agreement to a payment that the engineer approves, this has the advantage that the contractor can have confidence that agreements he reaches with the resident engineer will not later be overturned.

The employer should normally be kept regularly informed of the progress and state of the contract. This information will include: major variations that the engineer has had to make; whether many claims have been put in by the contractor and what substance there is to them; and what the likely effect on the total cost of the contract will be. The employer may require to be consulted on any claim so that he can give his views on it before the engineer comes to a decision. Some contracts, such as the FIDIC 4th Edition, specifically require the engineer to consult with the employer as well as the contractor before reaching a decision on a claim. But irrespective of whether such requirements exist, the engineer should always report major claims to the employer so that the employer gets a chance to put his views on them.

On very large constructions, where an ordered variation may incur heavy extra expenditure, it is advisable that the employer is involved in the issue of any order that incurs significant extra cost. On the Mangla project mentioned in Section 2.9, the engineer reported any proposed major variation to the employer for his agreement, with a technical report in justification. Variation orders were issued in two parts: Part I issued the necessary instructions to the contractor; Part II set out the terms of payment. Thus urgent variations could be sanctioned by the employer agreeing to issue a Part I variation, the terms of payment being agreed after negotiation with the contractor and set by issue of Part II. The employer had a large technical staff available to appraise the technical issues involved without delay. The advantage to the engineer was that the technical issues were thoroughly examined and solutions accepted before commitment to the very large sums that sometimes had to be sanctioned, and the advantage to the employer was that he was fully aware of the changes needed and their effect on the final cost.

Although the rest of this chapter mostly refers to the powers of the engineer under the contract, this must be taken as implying that the resident engineer must act similarly. The ICE Conditions referred to are the 6th Edition 1991 for use with bills of quantities.

12.2 Payment for increased quantities

Remeasurement types of contract, such as those covered by the ICE Conditions, are let on the basis that the actual amount of work done is not expected to be exactly the same as that estimated from the contract drawings. There are several reasons for a measured quantity differing from the amount billed: it may not be possible to estimate the quantity accurately from the drawings; there can be an error in estimating; or there may be changed circumstances from those envisaged on the drawings.

The intention of the contract is that where a change of quantity requires no different method of working by the contractor and does not thereby delay or disrupt his work then the billed rates still apply. However, Clause 56(2) of the ICE Conditions recognizes that, if there is a considerable difference between the measured and billed quantity, the contract allows a review of the rate to ensure that a proper price is paid. If the engineer is of the opinion that a quantity has changed so much that 'any rates or prices [are] rendered unreasonable or inapplicable in consequence', then the engineer, after consultation with the contractor, can increase or decrease such rates or prices. The change in quantity has to be significant to justify an altered rate: in some international contracts any review of rates or prices is restricted to changes in individual quantities exceeding a given percentage. If it were intended that all changes in quantity justified a different rate, then the rates would largely become irrelevant. In practice therefore rates are seldom altered for what might be termed 'natural' variation of quantities. Most changes that are large enough to require reconsideration of rates stem from an instruction issued by the engineer or resident engineer, and this is a different matter, dealt with in Section 12.4 below. Occasionally an item gets missed from a bill that the contract provides should have been measured. Rates for these must also be set by the engineer in the same manner, but without there being any instructed change.

12.3 Ordered variations

Many types of contract allow the engineer to order variations but, as mentioned in Section 5.2, his powers to do so are usually restricted to changes that are necessary or desirable for completion of the works, including any changes requested by the employer. By this means the employer, through the engineer, can obtain the result he wishes if his ideas and desires have altered since he awarded the contract. Changes to the contract cannot be instructed by the engineer; and if the employer wishes to introduce an entirely new piece of works or otherwise alter the basis of the contract, he can do this only by agreement with the contractor. The intention is that the works as contracted will still be built; that is, the same concept or result will be achieved but the detail may alter. This is essential, as the contractor has the duty and right to carry out the contract works, and the contract will maintain his position even if the works are varied.

However, the resident engineer will need to be a little careful about the wishes of the employer to vary the works. He may sometimes receive a request from an employee of the employer to make some addition. He should refer the request to the engineer, who will need to consider whether the employer would agree to his employee's request, and whether it is within the engineer's power to instruct. Obviously in matters of choice or no great cost the resident engineer will assent to reasonable requests, such as colour schemes for finishes. But sometimes during the finishing stages of a construction, the request may be for something expensive or which could delay completion, and it is then necessary to be sure that the employer agrees with the request of his employee.

When ordering variations the ICE Conditions set out the procedure to be followed. All such variations have to be ordered in writing, or if given verbally, must be confirmed in writing. The types of variation ordered can range over a wide variety of matters. The ICE Conditions require the contractor to undertake such variations, and in general they are to be paid for at bill rates or rates based on them. In some instances this may seem harsh on the contractor, as he may be doing work somewhat different from what he expected, and from time to time the rates so applied may seem to him too low. But the reverse can also happen, and some of the varied work may leave the contractor with a welcome extra profit, if the relevant rates happen to be set high at tender.

Extensive variations can make the contractor's task of constructing the works to his original programme impossible, and can seriously affect his costs. They should be avoided if at all possible, but if they occur the added costs can be taken into account by allowing for them in the rates set under the variation order. But ordered variations must not be so large as to alter the nature of a contract. This problem more usually arises when the employer decides to delete some substantial part of the contract works, such as a complete structure or a length of pipeline. A large deletion may so change the content of the contract that it may have to be renegotiated, or perhaps some agreement has to be reached to reimburse the contractor part or all of his intended profit on the deleted work. Clearly this is a matter for agreement between the employer and the contractor, and could not be ordered as a variation.

Under lump sum contracts the ability to order variations may be much restricted, and may sometimes only be possible by prior agreement. Normally there will be some contingency money in the contract, which the engineer is authorized to expend on necessary variations. As there are seldom any unit rates in a lump sum contract that can be used, the engineer may have to request a quotation from the contractor for a proposed extra before he orders it. It depends on the contract provisions how he deals with a quotation that he thinks is too high. Sometimes he will have no power other than to negotiate a lower price from the contractor. If that fails he either orders the extra at the contractor's price or does not order it. If it is a matter of some importance he may decide to consult the employer on the matter. On lump sum or turnkey projects, care has to be taken to ensure that any extra required is a true addition, not included in or implied by the overall requirements of the contract. As may be imagined, this is a fruitful cause of dispute.

On some lump sum contracts, while all above-ground work is paid for by means of lump sums, a small bill of quantities may be included for below-ground i.e. foundation work, so that it can be paid for according to the prices entered by the contractor and the measure of below-ground work required. This covers the case where the extent of such work may not be exactly foreseeable. Other lump sum contracts may include a schedule of rates to be used for pricing ordered variations, typically adopted in the case of electrical or plumbing contracts, where additions of a standard nature are often found necessary.

12.4 Rates for ordered variations

Under the ICE Conditions Clause 52 an ordered variation can be valued in one of three ways:

- 'where the work is of similar character and executed under similar conditions to work priced in the bill of quantities it shall be valued at such rates contained therein as may be applicable'; or
- if not, 'the rates and prices in the bill... shall be used as the basis for valuation so far as may be reasonable failing which a fair valuation shall be made'; or
- the engineer can order the work to be carried out with payment to be made by dayworks if he thinks this necessary or desirable (*see* Section 8.9).

In addition, if the nature or amount of any variation is such that any rate in the contract 'is rendered unreasonable or inapplicable' the engineer can fix such rate as he thinks 'reasonable and proper'. This allows the engineer to look at the effect of any variation on the contract as a whole and to allow modification of other rates if necessary. Hence if a variation has the effect of extending the time to complete the works, any time-related or similar preliminary rates can be adjusted to allow for the consequence of instructing the change.

Where bill rates do not directly apply, an appropriate bill rate can sometimes be deduced by interpolation between existing rates. For example, if rates exist for trench excavation 1.0–1.5 m depth and 2.0–3.0 m depth, a rate can be interpolated for a depth of 1.5–2.0 m depth; and it might be possible to extrapolate a rate for 3.0–4.0 m depth. However, this simple approach is not always possible, because rates often exhibit discontinuities. Thus if there are rates for 100 mm and 300 mm diameter pipelines, the rate for a 200 mm pipeline may not lie halfway between them. To fix a new rate it may be necessary to break it down into its component parts. The price of the pipe and its weight for handling and laying may not be pro rata to diameter because of increased wall thickness; and the trench excavation may be virtually the same for a 200 mm pipe as for a 100 mm pipe. A rate derived from build-up of prices should be compared with one derived by deduction or addition from bill rates. The latter may prove fairer to both parties, because bill rates will include the addition chosen by the contractor for overheads, risks and profit.

A problem arises when a bill rate or price which could be used for extra work appears unjustifiably high or low, either by error or, in the case of a high rate, perhaps by intention. One party or the other may feel it is unjust to use such rates or base new rates on them for varied work. However, it can be pointed out that the use of existing rates is what the contract requires, and other rates in the contract must have been correspondingly low (or high) to arrive at the tender total. Even when existing rates cannot be used directly, using them as a basis for new rates, or adopting similar levels of overhead and profit, can be seen to give a fair result under the contract.

The problem of setting new rates for varied work or for omitted items, or where a quantity change of itself justifies a new rate, can sometimes prove difficult. The principle in these cases is, however, the same: the billed rates act as the predominant guide when developing varied rates, because they are the basis of contract. If this principle is departed from, it can be seen that many complications could arise in setting new rates since, if one bill rate is not adopted because it appears too high (or low), then either party could maintain that the same applied to other bill rates, and there would be no clear basis for setting new rates.

It should be noted that the phrase 'variation order' is not used in most conditions of contract. Variations in the works are **instructed** (ICE Conditions Clause 51) and **valued** (Clause 52). A form called a Variation Order is then often used as a matter of general practice, largely to confirm the agreed rates and formalize the change, but it is not essential.

In the USA the term 'change order' is used instead of variation order.

12.5 Variations proposed by the contractor

The contractor has no right to vary the works, and the terms of the contract will specifically preclude this. But he can make suggestions as to how the work might be varied, for his own benefit or the benefit of the employer or both. He has no power to adopt his suggestion; but if, say, he is unable to purchase an item required but finds an adequate substitute the engineer would no doubt agree. On occasion a good contractor will point out a minor change of design that has advantages, and the engineer should consider this because the knowledge of the contractor can assist in promoting a sound construction or reduced cost. A new rate will have to be agreed for the contractor's proposal, and this has to be settled by negotiation. If there is a cost reduction the benefit would no doubt be shared between him and the employer.

Situations can arise where the contractor's work does not accord with the stated requirements. This may be by default when materials or equipment have been ordered and delivered, only for it to be discovered that they are not in compliance with the specification. Or it may be that workmanship is found unsatisfactory only after some work has been built, such as concrete of too low a strength having been used in part of the structure. Under the contract the engineer has no option but to reject the work; but it may be to the advantage of progressing the works and preventing delay if the engineer discusses with the employer and contractor the possibility of accepting what has been provided, but at an adjusted price. Clearly this is not possible if the difference means that the works will be unsafe or not usable for their intended purpose, but the employer may be able to accept a lower-quality finish or the possibility of increased future maintenance if the cost of the works is reduced.

Any substitutions offered by the contractor should be referred by the resident engineer to the engineer, who will decide if the employer's views should be sought. The employer is entitled to receive what was shown on the drawings and specified, and not something else.

12.6 Claims from the contractor

The term 'claims' is loosely used and has several meanings, which can cause confusion unless the context within which the word is used makes the meaning clear. In ordinary parlance the word is used to mean 'claims for more money by a contractor, which may or may not be payable'; that is, matters other than those obviously payable under the contract, such as the contractor's monthly application for payment, or an account that he submits for daywork. A contractor who is described as 'tending to make many claims' or 'rather claims-conscious' means one who uses as many opportunities as possible to argue that he should be paid extra for this or that additional work or trouble that he alleges he has been put to.

However, most construction contracts formally recognize and define the types of 'claim' that a contractor can submit under the contract.

Clause 52(4) of the ICE Conditions sets out the procedure to be followed by the contractor if he wants to claim (a) a higher rate or price than the engineer has set under a variation order or in relation to some altered quantity under a bill item, or (b) additional payment that he considers he is entitled to under any other provision of the contract. Under (a) the contractor must give notice of his intention to make a claim within 28 days of being notified of the engineer's fixing of a price. Under (b) the contractor must give notice 'as soon as may be reasonable and in any event within 28 days after the happening giving rise to the claim'. The provisions with respect to (b) primarily relate to claims for encountering 'unforeseen conditions' or claims for delay. Both these are complex matters, which are dealt with separately in Sections 12.8–12.10.

Claims that arise concerning a rate or price set by the engineer for some varied work or excess quantity measured are often uncomplicated. Sometimes the facts need unravelling, such as: what activities is the rate to include; why do records of time or quantity spent on the operation differ between contractor and resident engineer? These matters have to be gone into in detail. The contractor may contend that the rate should allow for standing time, 'disruption' and 'uneconomic working', the latter being a favourite phrase of contractors. There is truth in a contractor's claim that any rate set should allow for these matters. 'Uneconomic working' depends on the nature and quantity of extra work ordered. To order something additional to a contractor's current work can put him to considerable reorganization. For instance, to order tie-backs to sheet steel piles after they have been driven involves obtaining extra steel, making extra excavation, and probably hiring welders. To get this organized may take some days, during which the contractor may not be able to start the next major operation scheduled on his programme.

Fairly frequent claims consist of the contractor claiming that he should be paid for something for which there is no obvious measurement in the contract. This type of claim depends on whether the terms of the contract allow payment or not. This is when the specification and bills of quantities come under close scrutiny, because any inconsistency between them is liable to give the contractor at least some kind of case for payment. When specifications and bills of quantities are very large, the odd error will invariably occur. The resident engineer will have to take care not to agree an extra, only to find later that it is not payable because of some provision he discovers in the specification.

Some contractors use CVIs (confirmation of verbal instructions) as 'claims' (*see* Section 8.4). The resident engineer or one of his staff tells the contractor that the blinding concrete looks too thin in places and must be, as specified, a minimum of 100 mm thick, and within an hour or so the resident engineer receives a signed CVI stating 'We are to thicken up blinding concrete at so-and-so'. At the bottom of the CVI form is printed 'and any extra work arising from the above instruction will be charged'. This sort of spurious claim has, of course, to be rejected immediately in writing by the resident engineer. Otherwise, if not contradicted and left on file, it may later be resubmitted by the contractor as a justifiable 'claim' long after the nature of the incident has been forgotten. If the resident engineer has, however, given a verbal instruction that justifies a claim for extra payment, he should confirm it in writing with precise details, and require the contractor to submit a detailed account of his costs promptly. He should also keep his own records of the work done by the contractor in response to the instruction.

12.7 Sheets submitted 'for record purposes only'

When a contractor considers that some work entitles him to extra payment but the engineer does not immediately agree, the contractor may suggest that he should submit daywork sheets for it 'for record purposes only' (FRPO sheets), so that the quantity of alleged extra work can be agreed. This suggestion may seem reasonable, but it can result in the contractor's submitting scores (or hundreds) of FRPO sheets for everything that he thinks he could claim as an extra. He can work on the basis that the more sheets he puts in, the greater is his chance of getting some extra payment, so he is not over-concerned as to their accuracy or validity. The resident engineer, however, may not have the staff to check so many sheets and may consider it a waste of time to check them if many appear obviously invalid claims.

Therefore, on the first occasion when the contractor suggests submitting FRPO sheets, the resident engineer should refer the proposal to the engineer since, once the principle is accepted for one matter, it may be difficult to prevent submission of FRPO sheets for other matters. Under Clause 52(4) of the ICE Conditions the contractor is required to give notice of a claim, and after that is required to submit full details of it. FRPO sheets are not recognized under the ICE Conditions, nor does the engineer have to evaluate a claim (if payable at all) on a dayworks basis (*see* Section 12.4). Hence the engineer may decide not to agree to submission of FRPO sheets, and if the contractor persists in sending them, he may advise the resident engineer not to reply to them, only to file them, putting notes thereon concerning their accuracy in case they later form the basis of a properly submitted claim. This avoids time-consuming correspondence and dispute on the sheets, which might inadvertently give the impression that the contractor has a claim that is valid in principle. If, however, dayworks sheets (whether labelled 'FRPO' or not) are submitted in support of some properly notified claim, the resident engineer must reply if he considers that the sheets are invalid or incorrect, or may need to reject dayworks rates as a means of payment unless work has been instructed on that basis.

12.8 Clause 12 claims for unforeseen conditions

Among the more difficult and therefore more challenging types of claim are those relating to 'unforeseen conditions' – usually ground conditions. Clause 12 of the

ICE Conditions permits a contractor to claim extra payment:

> if the contractor shall encounter physical conditions (other than weather conditions or conditions due to weather conditions) or artificial obstructions which conditions or obstructions could not in his opinion reasonably have been foreseen by an experienced contractor.

There has frequently been criticism of this Clause 12 definition, but it has stood the test of many contracts over the years, and no alternative phrase has ever been put forward that works distinctly better. Some employers have tried deleting the provisions of Clause 12 entirely; but the contractor then adds a premium to his prices for the added risk he takes, so the employer pays this whether or not any unforeseen conditions arise. A point to be borne in mind if Clause 12 is deleted is that it is usually impracticable to allow each tenderer to conduct his own site investigations, so he has no way of limiting his risk other than by raising his price. On a pipeline, for instance, the road authorities and private landowners would not permit each tenderer to sink his own test borings; nor could the employer allow each tenderer to sink test borings on the site of some proposed works.

A different attempt to avoid the problem of unforeseeable ground conditions is to specify the nature of the ground to be excavated as inclusive of practically everything: for example, 'in soft or hard material including gravel, cobbles, boulders, rock or concrete, running sand' etc. But if Clause 12 is left in the contract it overrides such a specification because the extent to which any of these materials occurs remains undefined, so 'unforeseeable conditions' could still occur.

Although there is plenty of scope for the contractor to claim that things have not turned out as he expected, the criterion is whether 'an experienced contractor' could have foreseen the 'event' or not. To decide this with respect to ground conditions depends on the geotechnical information made available to tenderers, together with any information readily available, such as that relating to the geology and soils of the area, and common experience locally. It needs to be remembered that when the contractor undertakes the obligation to construct the works he should have looked into these matters. Often it is not so much the event as such that is unforeseen, but its magnitude.

For example, test borings may show that hard bands of siltstone are likely to be encountered in tunnelling. But if, instead of occasionally appearing in the tunnel face and disappearing, a band manages to stay exactly in the soffit of the tunnel for a considerable length, this could greatly add to driving costs. The problem is that borings often reveal a range of ground conditions, but unless numerous borings are taken, they seldom disclose the degree of persistence and exact location of one particularly difficult condition. In fact, if an experienced resident engineer and the experienced engineer find themselves surprised by the 'unforeseen event', it is difficult to maintain that the contractor should have foreseen it. The problem has to be solved on the basis of reasonableness. A contractor could not reasonably be expected to foresee ground as uniformly bad when trial borings only show it to be of variable quality, good and bad. To 'foresee' something it is necessary to have a concept of what it is, at least roughly in nature and extent; and it has to be a reasonable possibility that an experienced contractor would have allowed for it from the information available.

The advantage of Clause 12 is that it permits many unforeseen conditions to be dealt with efficiently by a contractor with no dispute or problems of payment arising. It offers fair payment to a contractor, so he will cooperate with the engineer in dealing with the conditions as effectively and economically as possible. Thus the employer pays only that which is necessary for dealing with the unexpected problem. Quite often the employer has to pay no more than he would have done had the condition been known beforehand and written into the contract. Thus both employer and contractor are fairly dealt with if Clause 12 is properly interpreted.

12.9 Payment for unforeseen conditions

A problem arising with Clause 12 claims is assessing the cost of overcoming the unforeseen conditions. When the contractor has notified a claim under Clause 12(2) he has to give details 'as soon as practicable' of how he is overcoming or intends to overcome the unforeseen conditions, with an estimate of the cost and delay they will involve (12(3)). The engineer can step in and instruct the contractor what to do (12(4)). As the contractor has notified he is making a claim, the provisions of Clause 52 also apply. The engineer can require the contractor under Clause 52(4) to keep records of his work in connection with his claim, and send 'a first interim account' giving particulars of the amount claimed to date, followed by further accounts at intervals required by the engineer.

The contractor may have some difficulty in meeting these accounting requirements. At first he is busy dealing with the unforeseen event, which may not be a precise happening but a build-up of problems. He tries changing his methods but, as things get worse, he notifies a 'Clause 12 claim' and, after discussion with the resident engineer, may be instructed to tackle the problem in a different way. When he supplies the estimate required, he may not have good records of this 'build-up' period: hence his estimate will not unexpectedly be a round sum, and his 'first interim account' may be not much more detailed. His 'records' may comprise only the usual uninformative workmen's timesheets, lacking in detail. So his 'account' may have to be based on the number of men and machines he had on abortive work from the time when the troubles first appeared, to date. He adds the cost of materials and a sum for things he has probably forgotten, then applies multiplying factors for site overheads, office overheads, risks and profit, and provides a single sheet of sparse details summing to a figure that shocks the resident engineer. However, if the contractor employs quantity surveyors (and most do), their skill in finding costs will probably eventually produce an over-abundance of details, apparently justifying an even larger sum. Quantity surveyors employed by a contractor can, however, be useful to both contractor and engineer.

Nothing is more difficult to deal with than a claim from a contractor that he repeatedly submits as a few lump sums without any detailed breakdown. This defies logical discussion that could lead to settlement; and if the resident engineer substitutes his own, perhaps much lower, estimate, this leaves the contractor disgruntled and under the erroneous impression that he is unfairly treated. There is a need for face-to-face meetings with such a contractor to advise him how to put his case better. But when a fully detailed claim is submitted, the resident engineer's records, if properly kept, should enable him to query the more imaginative aspects of the account and bring the figures down to reality.

The contractor is entitled to receive his costs 'reasonably incurred' in overcoming unforeseen conditions 'together with a reasonable percentage thereto in respect of profit'. While only the engineer can finally decide what should be paid, the hard work of finding out all justifiable costs will fall upon the resident engineer. In doing this, the resident engineer assesses first the direct costs. For labour costs his records should show what men were involved on the problem from its start to the present, or to some date when the problem was overcome and payment could revert to bill rates or some new rates set. He costs these. He treats plant used similarly and adds also the cost of materials used. In getting these direct costs he will need considerable information from the contractor. The wages of men and wages on-costs will usually be ascertainable from the contractor's weekly paysheets. He may need to consider different rates for plant, one for having the plant on standby ready for use, the other a higher rate for plant when working. He may have to make a reasonable estimate as to the proportion of time for which plant was actually working.

The site on-costs cover so many matters, such as salaries and allowances for site staff, transport, office costs, plant maintenance, services, and 'consumables' of all kinds, that it may be impracticable to consider them all in detail. The contractor may have to show what ratio they bear to gross labour costs; if they can only be shown in total to date, the current ratio has to be estimated, as the ratio will be higher in the early stages of the contract, when site offices and services etc. have to be set up, than later when more productive work is being undertaken. Some data to support head office management on-costs, including profit where allowable, have to be provided. It is up to the contractor to supply adequate proof of all these matters. Evidence in support of major items should be possible; minor matters have to be reasonable. Where some costs are difficult to elucidate owing to lack of records, there are various price estimating books published annually, which can provide guidance or be used as a check on the contractor's submissions.

When the unforeseen conditions occur and the contractor notifies his intention to make a claim in consequence, the engineer should report the matter to the employer. He should take into account the employer's views as well as the contractor's when considering whether the conditions could 'not reasonably have been foreseen by an experienced contractor'. The employer may also require to be consulted on the contractor's claims and take part in meetings with the contractor about them. Under the ICE Conditions the decisions finally rest with the engineer, but he should endeavour to get agreement beforehand to his proposed decision from both contractor and employer, or at least their understanding of the reasons for his decision.

12.10 Delay claims

The handling of delay claims often poses difficulties. Under the ICE Conditions Clause 44, the engineer can give an extension of time for the contract completion period if the contractor is caused unavoidable delay. The causes of delay can be numerous, including failure of the employer to give access to the site, or failure of the engineer to supply drawings as requested, or to approve the contractor's proposed methods of construction in reasonable time. But the principal causes of delay are often variation orders for extra work, and the incidence of unforeseen conditions (i.e. Clause 12 claims). In addition, Clause 44 permits an extension of the contract period on account of 'exceptional adverse weather conditions'. Clause 44 sets out the procedure to be followed, which requires the contractor to give notice of the delay within 28 days of first experiencing the cause of delay or 'as soon thereafter as is reasonable'. The contractor has to give 'full and detailed particulars in justification of the period of extension claimed'. Although claims for delay are usually based on extra work ordered or caused by unforeseen conditions, there can be other delays not associated with extra work, such as when the engineer instructs the contractor to delay starting some foundation construction because of the need to conduct foundation tests.

Although a delay of some kind can be caused to a contractor's work, the delay of itself does not necessarily entitle the contractor to an extension of the contract period. The latter is a separate issue, which poses two particular difficulties:

- how to estimate the delay to the job as a whole caused by delay on just one operation (or a group of operations) when several hundred other operations are required to complete the job; and
- how to estimate what extra cost, if any, is caused by the delay, over and above that which the contractor is paid for the extra work (if any) causing the delay.

The answer to the first question is illuminated by considering how critical path programming (mentioned in Section 9.8) would deal with a delay. Under that programming, if an activity lying on the critical path has its duration extended, then the delay to the whole job is likely to be equal to the activity delay. But if the activity does not lie on the critical path, its increased duration can either have no effect on the time to complete the whole job, or it may create a new critical path that is longer by some amount than the previous critical path. However, if it is possible to alter the sequence in which activities are undertaken, a new critical path may emerge, which may be no longer than the original one.

The engineer has to consider whether the contractor could reasonably avoid delay to the whole project by undertaking other work available. Thus if the contract comprises the construction of a single building for which the ground conditions turn out so unexpectedly bad that piling of the foundations has to be added, this would justify an extension to the contract period. The view cannot be taken that construction of the building could be speeded up to compensate, because this could involve the contractor in adopting different methods for construction than he planned in his programme and involve him in more cost. However, if there are several buildings that the contractor has programmed to construct in sequence, and one of them is delayed by foundation problems, the contractor can divert his workforce to those not delayed, so there may be no need for an extension of the contract period. The resident engineer's records are vitally important when considering delay claims. It is reasonable to allow a contractor some costs of disruption when he has to change unexpectedly from one operation to another, but it is unreasonable for him to leave his men doing nothing when there is work to get on with. Also, a contractor cannot allege that he is delayed by 'late receipt of engineer's drawings or instructions' when he is in no position to do the work because he is behind his programme, or his plant is broken down.

With respect to 'exceptional adverse weather' as a cause of unavoidable delay, in the UK this usually means wet weather, including flooding, holding up crucial earthwork constructions, such as embanking and road construction. A contractor normally allows about 10 per cent time for 'lost time' due to weather in the UK, but this depends on the nature of the works to be constructed. It should be noted that an extension of the contract period on account of exceptional adverse weather does not entitle a contractor to extra payment on account of the delay; though if there are items in the bill of quantities payable per week or month, such as for the maintenance of the resident engineer's offices, these would continue to be payable for the extended contract period.

12.11 Estimating delay costs

The cost that has to be evaluated due to delay to a contractor varies according to whether or not the delay justifies an extension of the contract completion period. If the delay does not justify an extension of the completion period, then the basic delay costs comprise such matters as standing time, lost time, and 'uneconomic working' for labour and plant. These can occur when the contractor has to stop work, waiting for instructions, reorganize his work to cope with unforeseen conditions, or move labour and plant onto some other work available or as directed by the engineer. The 'lost time' by men and machines can be identified and costed, on the basis of the gross cost of men's wages etc. to the contractor and the cost of plant. The rates used for plant depend upon whether it is hired from an outside source, or owned by the contractor. In the latter case it is a reasonable figure for depreciation if standing unused, and a higher rate including wear and tear, fuel and maintenance when working.

Some site resources may have to be costed in also, as some may reasonably be needed during the delay: for example, continuing to keep an excavation dewatered, or time spent by the agent, office manager or site engineer ordering additional equipment or specialist contractors to cope with the additional work ordered or unforeseen conditions. Some materials may be involved, such as timbering to keep an excavation open. These delay costs are separate from and additional to the rates set to cover the work actually undertaken. The latter rates should allow for the further difficulties and costs encountered as the work proceeds: continued dewatering, for example.

If a delay justifies extension of the contract completion period, or if it extends a major activity, then clearly some of the site resources have to continue for that much longer. Hence site on-costs must be added (*see* Section 12.9). On large jobs with several sub-agents or teams of staff, each may have to be considered separately to identify the effect (if any) that a delay has had in keeping them on site. Head office on-costs may also need to be added, but these are often a source of much confusion in relation to extension of the contract period. A contractor is not entitled to maintenance of a steady income from a site irrespective of what is actually happening at the time. An attempt should be made to identify any head office costs associated with an extension of the contract period; but if this proves impossible a general percentage addition that represents reasonable costs likely to have been incurred can be added.

It must be emphasized that it is the conditions of contract that set out the delays for which payment of costs may be recovered by the contractor, and to what extent, and reference must always be made to them.

12.12 Quotations from a contractor for undertaking variations

On being instructed to vary the work or experiencing unforeseen conditions, it is sometimes the practice of a contractor to submit a quotation for dealing with the extra work involved, including some unspecified sum for overcoming any consequent delay alleged to have been caused. The resident engineer should not accept such a quotation, but must refer it to the engineer who, in turn, might think it necessary to refer the matter to the employer. The ICE Conditions for a bill of quantities contract give no power for the engineer to accept a quotation from the contractor for dealing with some extra work. Work has to be paid for either by measure under bill rates or revised rates, or by dayworks, or by the various procedures laid down for paying on the basis of the contractor's costs with a suitable amount added for his profit where allowable. The position is different under design and construct contracts and the New Engineering Contract, whose provisions are discussed at the end of this section.

It may seem that acceptance of a contractor's quotation has the advantage that it avoids complicated problems of checking costs and assessing any delay. But it can prove highly advantageous to the contractor and disadvantageous to the employer. The contractor need not justify the amount of his quotation, and as he makes the quotation before he undertakes the necessary work, the engineer can only make an estimate of what the contractor's costs might be to check the quotation. Similarly, with no work done, there is no factual evidence as to what delay, if any, the extra work would cause. Furthermore, as the quotation will be tied to the contractor's proposals for dealing with the variation, if his proposals run into trouble and have to be changed, the contractor may then seek to add a second quotation. This can create difficult problems if the second quotation is too high to be acceptable. Sometimes work on two or more variations can take place at the same time, or otherwise be so closely connected (using the same equipment, for example) that it becomes difficult or even impossible for the engineer to judge whether the contractor's quotations contain elements of double charging of costs or double claiming for delay.

It should be noted that both the ICE Design and Construct conditions of contract and the ICE's New Engineering Contract (*see* Sections 2.1 and 2.2) require the 'quotation approach' when variations are ordered. But those contracts are not necessarily based on a priced bill of quantities but often on lump sums, in which case the quotation method is appropriate when variations are required (*see* Section 12.3). The New Engineering Contract, however, also applies the quotation method to contracts based on priced bills of quantities, so some of the problems mentioned above could occur under it. However, both the Design and Construct and New Engineering Contract are administered by the employer's representative or his project manager and not by an independent engineer: hence the contractor's power to quote in advance for extra work can be seen as strengthening his position. It is true that under those contracts the employer's representative or his project manager can reject the contractor's quotation, substituting his own, but this must inevitably raise a conflict. Also, the potential risks to the employer remain.

12.13 Time limits and interest payable on late payments

The ICE Conditions require the contractor to notify his intention to make a claim 'as soon as may be reasonable' but in any case within 28 days of meeting the unforeseeable conditions or cause of delay, or receiving notice of a rate set under a variation order. If the contractor is late in his notification of a claim, he may lose a right to that part of it that the engineer cannot in consequence investigate properly (Clause 52(4)(e)). When costs are ongoing, the engineer can require the contractor to submit further accounts of his claim at reasonable intervals. There is no specific time stated when the engineer must come to a decision concerning a contractor's claim, nor does he have to make a decision on a claim that does not give 'full and detailed particulars of the amount claimed' (Clause 52(4)(d) and (f)). However, once the engineer finds some payment due in respect of a claim he must certify this payment in the next interim payment to the contractor (Clause 52(4)(f)).

If the engineer decides that some payment is due to a contractor but fails to certify it in the next certificate, or if the employer fails to pay part or all of an amount certified for payment by the engineer, the employer has to pay 'interest compounded monthly for each day on which the payment is overdue or which should have been certified' (Clause 60(7)). The same clause provides that should a matter in dispute go to arbitration, and 'the arbitrator holds that any sum or additional sum should have been certified by a particular date', then interest will be payable on it, starting from 28 days after the engineer should have certified the sum. The rate stipulated is 2 per cent above the base lending rate of the bank specified in the Appendix to tender.

12.14 Arbitration

All standard conditions of contract contain provisions for resolving any disputes that may remain under a contract despite the efforts of the parties and the engineer to settle them. Under the ICE Conditions of contract, Clause 66, either the employer or contractor can serve a Notice of Dispute on the engineer, stating the nature of the dispute. The engineer has to give his decision on the dispute within one month (or within three months if the Notice of Dispute is submitted after substantial completion of the whole of the works) and, if either party is dissatisfied with it, they can issue a Notice to Refer the dispute to arbitration. Once the engineer has made his 'Clause 66' decision his duties in respect of that matter are finished. He has no power to do anything further. Most disputes that go to arbitration are on claims by the contractor that he should be paid more under the contract than the engineer has certified. The employer can also dispute the engineer's decision: for example, he might claim that the engineer has certified more payment to the contractor than is due under the contract. In effect, most disputes between the employer and contractor are as to whether the engineer's decision was right or wrong within the terms of the contract.

Although arbitration may seem a reasonable way of finally settling a dispute, it has disadvantages. It may take months to find an arbitrator that both parties can agree to and who is willing and able to act. Both parties may decide to employ a lawyer to present their case because the dispute involves interpretation of the terms of the contract. Also, one party may need to employ the engineer to act as witness, because the dispute also relates to the facts of the case, which lie in records kept by the engineer. If the employer is disputing the engineer's decision, this puts him and the engineer in a difficult position: the contractor may wish to employ the engineer as witness, but the engineer may still be acting as engineer under the contract for ongoing work, and in the employ of the employer. The lawyers who present the case for each disputant will be chosen for their experience of building contract disputes, but they may still fail to understand or make use of significant technical data having a bearing on the dispute. They may try to raise issues not previously in dispute, and use legal arguments concerning the contract that the disputants are unaware of but which the arbitrator must note lest his decision be taken to court and overturned. Hence the outcome of an arbitration is uncertain and can be different from what either of the parties expected.

An arbitration is possible while work under the contract is continuing, but its outcome can then pose problems. When the arbitrator makes an award he may not have to give details as to how he arrives at his award figure. If he does not, this can leave the engineer in ignorance as to which of his previous Clause 66 decisions the arbitrator considered as wrong and why; so he has no guidance as to what policy to adopt in respect of any further claims of a similar nature that the contractor might make. Such problems can be reduced by requiring that reasons be given; but even so an arbitration during the course of the contract is best avoided if possible.

In practice, when the engineer has given his Clause 66 decision, there is a strong possibility that a civil engineering dispute will not go to arbitration. Both parties will need to decide whether they are so sure of their view as to be able to challenge successfully the independent professional opinion of the engineer. Where, as in so many cases, it is the contractor claiming that he should be paid more, the employer may think it worth while 'making an offer' to the contractor, conditional on the contractor's not pursuing the dispute to arbitration. Both parties will bear in mind that arbitration is a costly and legally binding process, the arbitrator's decision being enforceable in court and not challengeable except on limited legal points. If, nevertheless, arbitration is decided upon, procedures can be adopted to limit its coverage, reducing its complexity and restricting costs: for example, by making it a documents-only arbitration, or by referring only matters of principle for a decision in the first instance. The arbitration procedure set out by the ICE can assist in this.

12.15 Alternative dispute resolution (ADR)

The hindrances to a quick and cheap resolution of disputes by arbitration mentioned above have led to adoption of processes known as **alternative dispute resolution** (ADR). These include: direct discussion between executives of the parties; obtaining the advice of independent experts; using a conciliator trying to find common ground, or a mediator looking for an agreed solution. The ICE Conditions permit either party to refer a dispute to a conciliation procedure, provided the other has not already elected to go to arbitration. The difference between arbitration and conciliation needs to be appreciated. With arbitration each party states its case and is subject to cross-examination by the other party. The arbitrator's decision is based only on evidence submitted to him, although of course he can put queries to either party. But in conciliation procedure the conciliator, often a professional engineer, can investigate and call for information on all matters that he considers relevant to the dispute, and may interview the parties separately. This gives him a good chance of discovering the root cause of a dispute, enabling him to find a solution that both parties can accept. Of course, for any method of conciliation or mediation to be successful, there must be a willingness in both parties to try to find a solution; if so, it can be argued that such methods should largely be unnecessary. But it seems that sometimes an outside stimulus can provoke the parties into agreement, especially as they bear in mind the potential extra losses in legal costs, expert witnesses, staff costs and tying up senior management if they pursue arbitration or court action.

Provisions for ADR vary. Unlike the ICE Conditions, which allow conciliation as an option, the ICE Design and Construct conditions make conciliation a necessary precursor of arbitration. The ICE's New Engineering Contract requires an adjudicator to be named by the employer in the contract documents, a choice that the contractor can challenge prior to award of the contract; that is, every contract includes a pre-appointed adjudicator. The present wording of the NEC, however, allows only disputes as to whether the project manager has acted in accordance with the contract to go to adjudication, and does not specifically mention that disputes about the project manager's valuation of some extra can go to adjudication. Also, referral of a dispute to the adjudicator must precede arbitration. The GC/Works/1 conditions may allow for the appointment of a government officer as an adjudicator. FIDIC conditions do not provide for conciliation but require the parties to attempt to resolve their dispute amicably in a period of 8 weeks before arbitration can be started.

There is considerable debate concerning the relative merits of conciliation and adjudication. Conciliation proceedings are confidential, and the conciliator's recommendations cannot be quoted by either party in any subsequent arbitration. This aids reaching agreement, as the disputants can state their views to the conciliator without prejudice. Adjudication is more formal. It is not a method of reaching agreement between the parties but a decision as to what the contract provides with respect to the matter in dispute. Any submissions to the adjudicator can be referred to in a subsequent arbitration; and the adjudicator may decide that he needs to employ specialist advice on technical or legal matters. Under adjudication the parties may feel it necessary to employ legal advice in presenting submissions.

12.16 Minimizing claims and disputes

A key factor in avoiding claims and disputes is to ensure completion of the design in all essentials before construction commences. This permits the promoter to be shown the exact works that he will receive, and to check whether they are precisely what he wants. If the promoter is uncertain about some requirement, the designer can incorporate a degree of flexibility in the design to cater for possible options. Often the necessary provision comprises leaving space for possible extra equipment or runs of additional services. Incorporation of such provisions makes little change to costs, and avoids the need for design alterations during construction, which so often give rise to claims and disputes.

To ensure that designs are sufficiently complete, the designers will need to ascertain the requirements of all specialist suppliers and contractors involved, such as the supplier of a wide variety of mechanical and electrical plant, cladding, windows, cranes, lifts, heating and ventilating equipment. Consequently, the best arrangement is for the major specialists' work to be provided under separate contracts let by the promoter, so that they come under the direct control of the designer (see Sections 1.5(c) and 2.9). The details of all these contracts and their requirements must be incorporated in the main civil engineering construction contract. This permits the designers to sort out any difficulties that arise, and to ensure that the promoter gets exactly what he needs.

Any extra time that the designers need to complete their work can bring advantages. The extra design time can often be recouped by faster construction, because the contractor and the specialists have full details of what is required at the outset. Pursuing designs right through fosters the chance of achieving savings, as these are most often revealed when details of design are being considered. Fast unimpeded construction reduces a contractor's costs, so he is able to submit his lowest tender price.

There are, of course, other factors that help to avoid unnecessary claims and disputes. In civil engineering work, adequate site investigations are essential. The promoter needs to appreciate that curtailing time or money on site investigations can be a false economy, resulting in disastrous extra costs and delay. If unforeseen ground conditions are revealed during construction, claims and disputes can be avoided if the promoter is prepared to meet the unavoidable extra cost involved. In fairness, the contractor is not responsible for such conditions, and if the conditions had been known beforehand, the promoter would in any case have been involved in extra cost. There are contracts, of course, that put all risks upon the contractor; but the problem with this approach is that the outcome of any risk is capricious, varying from 'run of the mill' to 'beyond all reasonable expectation'. Consequently, putting all risks on the contractor is not necessarily a guarantee that disputes and claims will be avoided.

The third important factor in reducing disputes is to ensure that construction is supervised by a competent, experienced resident engineer and staff acting full time on site for the engineer. Troubles encountered during construction can be dealt with as soon as they arise, and, where necessary, instructions can be given that minimize delay and extra cost. Qualities of workmanship come under early scrutiny, thus helping to avoid after-troubles giving rise to disputes. Proper records kept by the resident engineer, together with his experience of problems faced by the contractor, can assist the engineer to make decisions that are as fair as possible to the promoter and the contractor and therefore less likely to be disputed.

The designers should estimate the cost of construction when designs are complete and before tenders are received. An experienced engineer should be able to do this with a satisfactory degree of accuracy. Any tender that appears to be unusually low should be checked for error or the tenderer's misunderstanding of the contract; and the contractor for construction should be chosen first for his competence and only second for his price. No type of contract and no level of supervision can force an incompetent or loss-making contractor to produce a good job in all respects.

13

Earthworks and pipelines

13.1 Excavating and earth-placing machinery

Bulldozers ('dozers') are used for cutting and grading work, for pushing scrapers to assist in their loading, stripping borrowpits, and for spreading and compacting fill. The larger sizes are powerful but are costly to run and maintain, so it is not economic for the contractor to keep one on site for the occasional job. Its principal full-time use is for cutting, or for spreading fill for earthworks in the specified layer thickness and compacting and bonding it to the previously compacted layer. It is the weight and vibration of the dozer that achieves compaction, so that a Caterpillar D8 115 h.p. weighing about 15 t, or its equivalent, is the machine required; not a D6 weighing 7.5 t, which is not half as effective in compaction. The dozer cannot shift material very far; it can only spread it locally.

A dozer with gripped tracks can climb a 1 in 2 slope, and may also climb a slope as steep as 1 in 1.5 provided the material of the slope gives adequate grip and is not composed of loose rounded cobbles. On such slopes of 1 in 1.5 or 1 in 2 the dozer must not turn, but must go straight up or down the slope, turning on flatter ground at the top and bottom. It is dangerous to work a dozer (and any kind of tractor) on sidelong ground, particularly if the ground is soft. Dozers cannot traverse metalled roads because of the damage this would cause, and they should not be permitted on finished formation surfaces. Sometimes a flat-tracked dozer (that is, with no grips to the tracks) can be used on a formation if the ground is suitable.

Motorized scrapers are the principal bulk excavation and earth-placing machines, used extensively on road construction or earth dam construction. Their movement needs to be planned so that they pick up material on a downgrade, their weight assisting in loading; if this cannot be managed or the ground is tough, they may need a dozer acting as a pusher when loading. This not only avoids the need for a more expensive higher-powered scraper, but reduces the wear on its large balloon tyres, which are expensive. The motorized scraper gives the lowest cost of excavation per cubic metre of any machine, but it needs a wide area to excavate or fill and only gentle gradients on its haul road. It cannot excavate hard bands or rock, or cut near-vertical sided excavations.

The **face shovel** or 'digger' can give high outputs in most types of materials, including broken rock. It comes in all sizes, from small to 'giant'; but for typical major excavation jobs (such as quarrying for fill) it would have a relatively large bucket of 2–5 m^3 capacity. The size adopted depends on what rate of excavation must be achieved, the capacity of dump trucks it feeds to cart away material, and the haul distance to tip or earthworks to be constructed. The face shovel would normally be sized to fill a dump truck in only a few cycles. The machine can only excavate material down to its standing level, and work a limited height of excavation face. Hence, if a deep excavation is required, the face shovel must 'bench in' and must leave an access slope for getting out when it has finished excavating. It must stand on firm level ground when working, and is not very mobile. It works in one location for as long as required, moving its position only as excavation proceeds. If it is to move to another location the move has to be undertaken slowly, care being taken to ensure that it does not 'come off its tracks'. Its major advantage is its high output and ability to excavate in most materials.

The **hydraulic excavator** used as a backhoe or backacter, cuts towards the machine. It is highly versatile. The larger size can cut to a depth of 6 or 7 m and excavate a face of the same height, slewing to load to trucks alongside. It can be used for lifting pipes into trenches, and 'bumping down' loose material in the base of a trench with the underside of its bucket. It can usually excavate trenches in all materials except rock; but sometimes has trouble in getting out hard bands of material that are horizontally bedded or which dip away from the machine. It can have a toothed bucket capable of breaking up a stony formation, be fitted with a ripper tooth for soft rock or a hydraulic breaker for hard materials, or have a smooth-edged bucket for trimming the base of a trench. A wide range of such machines are available, the smallest size often being used on small building sites; the larger sizes being used for large trench excavation and general excavation of all kinds.

The **dragline**'s principal use is on river dredging work from the bankside, and for other below-water excavation. Although the machine is slow in operation and has a smaller rate of output than an equivalent hydraulic backhoe, it can have a long reach when equipped with a long jib and can excavate below its standing level. With a 15 m jib, it can throw its bucket 20–25 m out from the machine: hence its use for riverbed excavation and bankside trimming. The dragline can also be operated to cut and grade an embankment slope below its standing level, or for dumping soil or rock on such a slope. A trained operator can be skilled at placing the bucket accurately to a desired position. The dragline offloads its material to dump trucks, but this tends to be a messy operation, because the swing of the bucket on its suspension cable tends to scatter material.

The **wheeled loader** is widely used for face excavation in soft material, but its predominant use is for shifting heaps of loose spoil and loading them to lorries. It may have a bucket size of up to 5 m^3; it is very mobile and, being soft tyred, can traverse public roads.

The **grab** has a low output rate, but is used when sinking shafts in soft material, especially when sinking caissons kentledge fashion. It is also used occasionally for the job of keeping aggregate hoppers filled with concrete aggregates from stocks dumped by delivery lorries at ground level.

The **clamshell bucket** has a pincer movement, hydraulically operated, and is principally used for the construction of diaphragm walls. The bucket is fixed to a long rod, which is lowered and raised down a frame held vertically (or at an angle) so that it can cut trenches up to 30 m deep in soft material, usually up to 0.6 m wide. The machine rotates so that the clamshell can be emptied to a waiting dump truck.

Trenching machines can be used either for excavation of pipe trenches or for construction of shallow diaphragm walls. They have a bucket chain cutter delivering material to the side of the trench or, by additional conveyor belt, can deliver to dump trucks. For hard ground the machine has special cutters cutting a groove at either side of the trench, with a third bucket cutter chain to remove the dumpling of material between.

13.2 Controlling excavation

The base of an excavation has usually to be trimmed level and cleared of disturbed or loose material so that it forms a solid base for concrete foundations, pipes or earthworks etc. Specifications often call for the last 100 mm of excavation to be 'carried out by hand': a costly procedure for the contractor, which he usually seeks to avoid. The resident engineer is then faced with the problem of what alternative he will allow in lieu of hand excavation. In some types of ground, such as sandy or gravelly clay, it should be possible for the contractor to machine excavate to formation level if he uses a plain-edged bucket to his machine, operates it with care, and uses the back of the bucket to recompact any small amounts of loose material. Large open areas excavated by scraper or dozer have to be graded, and recompacted using appropriate compaction machinery.

A formation in soft clay can be severely disrupted by tracked or wheeled excavating machinery. No amount of recompaction of disturbed, over-wet clay will prove satisfactory; it has to dry out to a suitable moisture content before it can be rolled and compacted back. If a contractor uses a D8 to excavate down to formation level in such material, the formation surface will be so churned up by the grips of the D8 tracks that it will be rendered useless as a formation. If the contractor does not use the right method on soft clays, the resident engineer must warn him that all disturbed material will have to be removed and the excavation refilled with suitable other material or concrete at the contractor's expense. The excavation should be undertaken by using an hydraulic hoe working backwards so that it does not have to stand on the formation. As it works backwards, suitable hardcore or other blinding material can be dozed progressively forward onto the exposed formation and compacted. Alternatively, it may be possible to use a flat-tracked loader shovel to skim off the last 150–225 mm of excavation, any loose material being either removed by hand labour or rolled back with a light roller before placing of the base course for a road or blinding concrete.

The presence of springs in a soft formation material exacerbates formation-finishing problems. Usually the specification will require spring water to be led away by grips or drains to a pump sump, which is continuously dewatered to prevent softening of the formation. If springs are encountered and have not been anticipated, or the method of dealing with them is not specified or shown on the drawings, the resident engineer should report the situation to the engineer. Special measures are often required to deal with springs to ensure safety of the structure to be built on a formation containing them.

13.3 Haulage of excavated material

For large open excavations, such as when road cuttings have to be made and the material tipped to form embankments, or for building an earth dam from open borrowpit areas, the motorscraper is the most economical machine for excavating, transporting and placing clays and clay–sand mixes. But the gradients traversed need to be gentle, and the motorscraper cannot pick up hard bands of material or rock, unless ripping beforehand can break up the material sufficiently. If hard or rocky material has to be excavated, the face shovel loading to dump trucks has to be used, the trucks commonly having a capacity of 50–60 t, sometimes larger. However, neither scrapers nor dump trucks can traverse public roads.

If the excavated material has to be routed off-site via public roads to some dumping area, the excavated material has to be carted away by tipping lorries licensed for use on the public highway. Tipping lorries have a lesser capacity than dump trucks, usually in the range 10–20 t. A factor often having considerable influence when needing to transport material along public roads is the reaction of the local road and public authorities, who may object to the extra construction traffic. If the local authority has also to give planning permission for dumping spoil on some given land, such permission may only be granted subject to restriction on the size of lorries used and their frequency of passage. This situation cannot be left for tenderers to find out; the employer has to obtain the necessary permissions, and the contract must reproduce exactly the conditions laid down by the planning or other authority concerned, and require the contractor to conform to them. If the restrictions limit the size and frequency of tipping lorries, the contractor may be forced to temporarily stockpile excavated material on site and double handle it in order to conform to his intended programme for construction and the haulage conditions laid down. This will raise his costs for excavation.

Assuming there are no planning restrictions, the contractor needs to choose that combination of excavating plant and haulage vehicles which achieves the required excavation rate at lowest cost. The face shovel or backhoe output must match the timing of empty vehicles back from the dumping ground and their loading capacity. This means that the excavator bucket size and loading cycle time must be such that one haulage truck is loaded and moving away by the time the next vehicle arrives. Hence the cycle loading time for the excavator must be known. Thus if 10 m^3 haulage vehicles return at 5 min intervals, and the cycle loading time is 1.5 min, only three cycles of loading are possible, so an excavator bucket size of 3.3 m^3 is required. Alternatively, if the cycle loading time could be 1.25 min a 2.5 m^3 bucket would suffice. Allowance has to be made for the bulking factor and unit weight of the material to be excavated. The bulking of granular of soft material may range from 1.1–1.3, through 1.4 for hard clays, to 1.6–1.7 for broken rock. Clays, clay–sand mixtures, gravels and sands may weigh 1.6–1.9 t/m^3 *in situ*, while rock and hard materials may vary from 1.9 to 2.6 t/m^3 *in situ*. The excavator bucket size has to allow for the bulking factor: for example, a 2 m^3 bucket may only lift and load 1.4 m^3 loose material at 1.4 bulking factor, so it will need seven loading cycles to excavate 10 m^3 *in situ*. If this is too long a loading time for the required rate of output, an excavator with a larger capacity bucket is required.

Correct assessment of the bulking factor is financially important to the contractor, particularly in relation to the use of tipping lorries for off-site deposition of material. Whereas dump trucks used on site can be heaped, tipping lorries have a limited cubic capacity and payload, neither of which can be exceeded. Thus if a bulking factor of 1.2 applies, a 10 m^3 lorry will take away the equivalent of 8.3 m^3 net excavation; but if the bulking factor is 1.35 the 10 m^3 lorry will take away only 7.4 m^3 net excavation. If the contractor has based his price on the former but experiences the latter, he would find his price for disposal of material offsite 12 per cent too low. This could mean no profit on the operation or a large financial loss, as there may be many thousands of cubic metres of material involved. In practice, a contractor's past experience will guide him as to what plant to use, taking into account many other practical matters that apply, such as reliability of different types of plant, need for standby, margins for hold-ups, length and nature of haulage road, cost of transporting plant to and from the job, and hire rates for different sizes of excavator and haulage vehicles.

13.4 Placing and compacting fill

When the contractor assesses the amount of filling he will need to transport to achieve a given earthwork construction, he has to allow for:

- fill after compaction occupying more, or less volume than it does in the borrowpit;
- settlement of the formation under the weight of new fill as placed;
- further compression of the fill after placement under the weight of the fill above.

Standards will be set in the specification for the permitted moisture content of the fill before it is compacted, and its density after compaction. For example, the specification may stipulate that fill type A must be compacted at a moisture content between 'optimum – 1 per cent' and 'optimum + 2 per cent'; while fill type B must be compacted at a moisture content between 'optimum + 1 per cent' and optimum + 3 per cent'. The optimum value is that determined by the standard compaction test, whether it is the 2.5 kg hammer method (the original Proctor test) for embankments, or the 4.5 kg hammer method as used for roads. The density to be achieved will be specified as some percentage (e.g. 90 or 95 per cent) of the optimum under standard testing. Samples will have to be taken from the fill to find the optimum moisture content and density under the standard compaction test specified, and *in situ* density tests must then be undertaken by the resident engineer to ensure that the right density is achieved. Normally, tests on fill materials will have taken place prior to the design of the earthwork, and the results of these tests and the method of testing etc. must form part of the data accompanying the specification. Care has to be taken to ensure that the method of specifying the required end result covers the range of materials likely to be encountered. It is then up to the contractor, from his experience, to know what type of plant he must use to compact the fill to the required standard.

Achieving the required moisture content may present difficulty. In wet weather the borrowpit material may be too wet to use, and the formation may be too wet to work on. The resident engineer may have to instruct the contractor to cease working when such conditions occur. There is little that can be done to protect borrowpit material against excess rainfall. The formation can be partly protected against rainfall by rolling it to a fall with a smooth-wheeled roller at the end of each day's placing. Sometimes an attempt to protect the formation by laying sheeting over it is adopted, but this is seldom practicable if the site is windy. If the material is too dry for placing it must be watered. Although watering at the borrowpit can be helpful it is usual to water-spray the spread material from water bowsers. Some mixing of the material by dozer may be necessary after watering to avoid only the surface material being wetted. In hot dry climates more than the theoretical amount of water may need to be added because of the high evaporation rate applying. A considerable amount of water may be needed, involving the use of more than one water bowser.

13.5 Watching fill quality

When fill from a borrowpit is of variable quality the resident engineer needs an inspector to watch the fill quality as placed, with power to reject unsuitable material or call in the resident engineer in cases of doubt. Although the borrowpit must be examined to point out to the contractor where suitable and unsuitable materials appear to exist, the actual watch on material quality must take place as it is dumped, spread and compacted. The characteristics of a material are then more clearly revealed. There is not time to conduct *in situ* density tests: the contractor has to know immediately whether he can continue placing the material. Familiarity with the behaviour of suitable material as it is compacted and trafficked will soon indicate its characteristic behaviour. Excess of granular material such as sand or gravel in clays is easily observed, while too much clay or silt in a

(a) A satisfactory mix

(b) An over-sanded mix

(c) A mix that is too harsh

Plate 13a–c. Judging the quality of a concrete mix. Photos from *Concrete Materials and Practice* by L J Murdock, K M Brook and J D Dewar, 6th edn, Edward Arnold, 1991

Plate 14a. The typical fluidity of pumped concrete; but it still needs vibrating in place

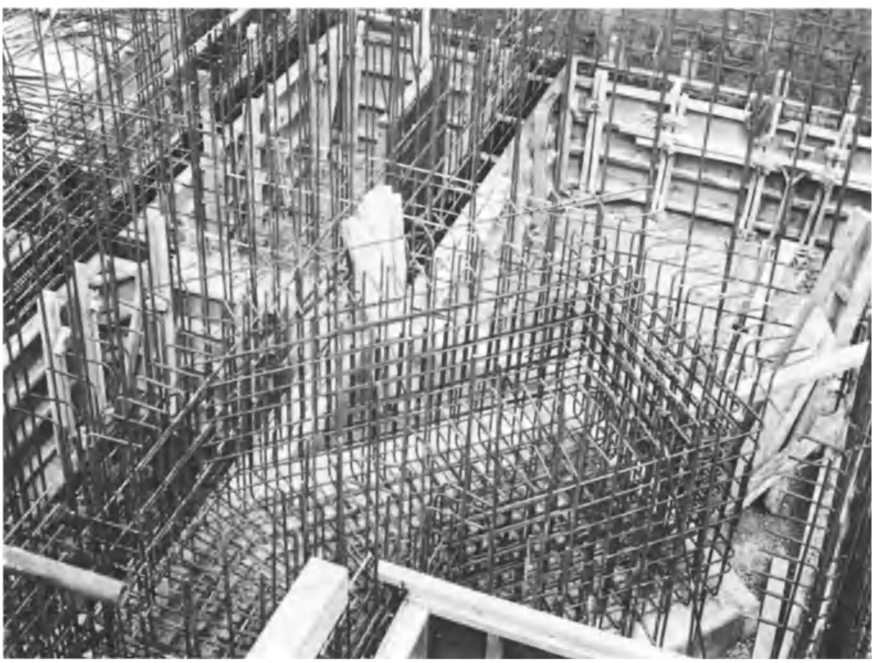


Plate 14b. Reinforcement must be accurately dimensioned and bent, and laps must be provided that permit the steelfixer to make adjustments for unavoidable discrepancies in the concrete work

Plate 15a. Column base excavations are always liable to fill with rainwater. A sump should have been excavated beside each to permit dewatering before concreting

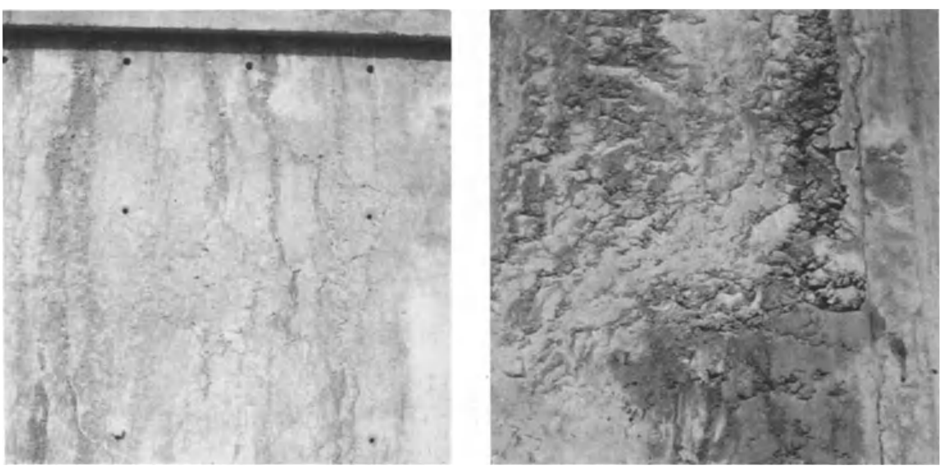


Plate 15b. Sand runs on a concrete surface. Photo on the right also shows lack of compaction probably due to a slight movement of formwork adjacent to the vertical joint

Plate 16a. If reinforcement is not designed to provide for easy access this is what happens to it

Plate 16b. Accurately placed reinforcement, strong enough to walk on

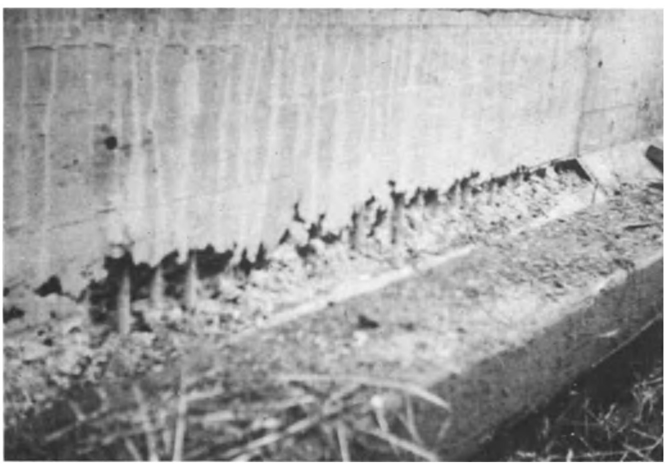


Plate 16c. The concrete was not fluid or vibrated enough to reach the base of the formwork. Even so, fillets of the type shown at the base of a wall are always difficult to shutter and concrete satisfactorily, and the designer should consider possible alternatives that make the contractor's work easier

clay–sand mix is evidenced by the behaviour of the material under traffic. 'Cushioning' or 'bounce' under the wheels of lorries passing across the formation are signs of inadequate compaction, which may be due to the material being too wet or containing too much clay or silt. Severe rutting by lorries can indicate material too wet or too clayey. Change of colour of a clay, on the other hand, may not indicate any change of suitability. The contractor must be warned immediately when material being placed appears unsuitable. If the placing is stopped after a few loads of unsuitable material have been delivered, these can usually be 'lost' by dozing the material out to mix it with previously placed suitable material.

Purpose mixing of two different kinds of fill is seldom practicable. It may be difficult to ensure that loads of the two materials are delivered in the right ratio, and if they are not clearly distinguishable by appearance, the mixing may be haphazard and incomplete. If two dissimilar materials must be used, the designer should preferably devise some means of zoning each separately. When zoning is adopted, the resident engineer should check from time to time that a supposed difference between materials is occurring, because material from a borrowpit can change its composition gradually.

In situ density tests need to be taken to prove compliance with the specification; but the sand replacement method as described in Section 7.10 takes some hours to complete, this is a record of past achievement and cannot be used as an instant control measure. The moisture content can possibly be quickly measured by using an appropriate moisture meter, but judging by eye can be equally effective and has the advantage that the whole area of placing can be kept under survey. The compaction equipment used by the contractor will vary according to the nature of the fill. Apart from the use of a large dozer to spread, compact and vibrate fill in place, the passage of laden dump trucks across a formation achieves a substantial degree of compaction. Hence the contractor will usually arrange a method of placing material that makes effective use of the compactive effort of the delivery vehicles.

13.6 Site roads

A contractor who pays insufficient attention to the right construction of site haulage roads runs the risk that the road will begin to break up and cause delay just at some crucial time of construction, such as when autumn rains begin and the contractor is hoping to get filling finished before the heavier rainfall of winter occurs and delays construction. Pushing hardcore into the worst patches is no real solution, and more troubles come when haulage lorries get bogged down in the road or break a half shaft. For heavy construction traffic, a road must be thick enough; have deep drainage ditches either side; be made from good interlocking angular large material at the base and similar smaller material above; and be formed to a camber or crossfall that sheds rainwater. Poor construction is more liable to occur on flat ground, where the temptation is strong not to dig out more than seems necessary, and not to dig deep enough side ditches to keep the road construction dry. But once the proper precautions are taken the road will stand up and need little more than regrading and rolling from time to time to keep the surface in good condition and able to shed rainwater.

13.7 Trenching for pipelines

The hydraulic hoe or backacter is the machine most widely used for trench excavation for pipelines. In hard ground or rock, the trenching machine might be used, which has been described in Section 13.2. Depths for water and gas pipelines are usually the pipe diameter plus 1 m. For sewers, greater depths are often required to maintain falls. When flexible plastic pipes are used, especially in the smaller diameters, pipe joints can be made above ground, the pipe being snaked in. Bottoming of the trench can be achieved by using a straight-edged bucket without teeth, and the backhoe can also place soft material or concrete into a trench on which to bed pipes or fully surround them. Provided no men are allowed in the trench, timbering can thus be avoided. When large-diameter steel pipes with welded joints have to be laid, a string of several pipes may be welded up alongside the trench, and dozers equipped with side-lifting booms can lower the string of pipes into the prepared trench. This reduces the amount of timbering and excavation of joint holes necessary, which need only be arranged where successive strings have to be jointed together.

The principal defects occurring on pipelines come from defective joints and pipe fracture due to settlement of a pipe on a hard band, large stone or lump of rock in the base of the trench. The use of the hydraulic hoe makes the preparation of an even bed for the pipe easier to achieve, especially on suitable selected soft granular fill. However, the base of the trench along each length of pipe must be carefully boned in before the pipe is lowered, to ensure that each pipe is fully supported along its body.

For non-flexible pipes of ductile iron, asbestos cement, steel or concrete it will be necessary to joint them after laying. Sufficient access is then required for the jointer to make the joint properly, and support to the trench sides will be essential in every case where there is not absolute certainty there can be no slip of material into the trench. Falls of material into trenches are a major hazard in civil engineering, and adoption of a consistent, rigorously applied safety approach is the only way to prevent accidents. The damaging weight of even a small fall of earth must be borne in mind.

While it will be obvious that gravity sewers must be laid to a fall, it is sometimes not appreciated that trunk water mains should be laid to a minimum rise or fall. The preferred minimum gradients are 1:500 on a rising grade in the direction of flow; and 1:300 on a falling grade. The former would be to an air release valve, the latter from the air valve to a washout or hydrant. Thus the levels of ground ahead of the pipelaying must be prospected to locate suitable high and low points, and intermediate points where an increase or decrease of grade is necessary. The pipeline between such predetermined points should follow an even grade. In flat ground it may not be possible to comply with the foregoing grades, but it is still advisable to give uniform rises to air valves and falls to washout positions. In built-up areas, pipelines can generally follow the requisite cover below ground surface because branches and connections will release air, and hydrants will be used as washouts.

Backfill to pipes should always be of selected soft or fine granular material to 150 mm above the crown of the pipe. Few contractors in UK would fail to do this, but on some contracts overseas the resident engineer may need to stop the contractor from dozing the excavated hard material straight back into the trench irrespective of the rocks it contains, which would damage the sheathing to pipes.

13.8 Thrust blocks and testing pipelines

The resident engineer may have to ensure that thrust blocks to pipes are adequate. A block acts primarily to transfer pipe thrust to the natural ground against which the block abuts. Hence the nature of the ground is important. The force to be resisted on a bend with push in joints is shown in Fig. 13.1. The internal water pressure taken should be the maximum static pressure occurring, plus an allowance for surge pressure. The block bearing area against the natural ground has to be sufficient to mobilize adequate resistance from the soil against pipe thrust. Where a bend points down, a weight block below the upper joint is usually necessary, the joint being strapped down to it. Particular care has to be taken when a bend down is required at the bank of a river or stream. There may then be very little ground resistance to prevent the bend blowing off if the joint is the usual push-in type: hence the upper joint of the bend may require tying back to a suitable thrust block to resist the hydraulic force tending to push the bend off.

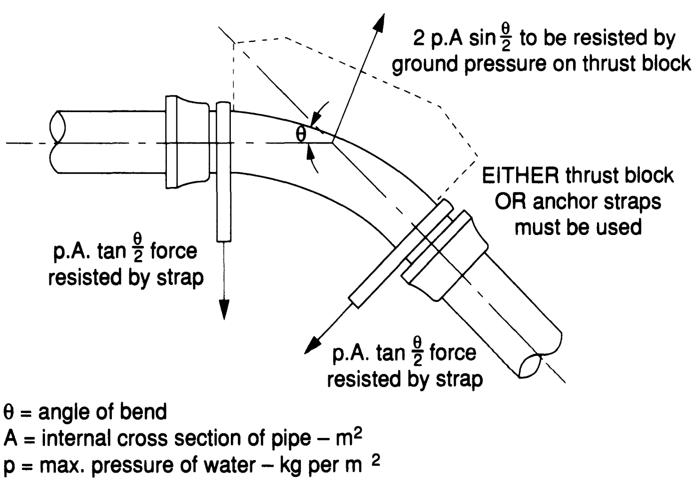


Fig. 13.1 Thrust on a pipe bend. The maximum pressure taken should be maximum static plus an allowance for surge

The watertightness test for a pipeline should be prescribed in the specification. Care must be taken to fill the pipeline slowly to ensure release of all air. The usual practice is to fill from one end, having all washouts and hydrants open. The latter are progressively closed along the line when they cease to emit air or mixed air and water. This may take a considerable time, as air pockets may get trapped and only slowly disperse. A satisfactory test cannot be achieved if an air pocket is left in the pipeline. After filling, the pipe should stand under pressure for 24 hours before testing. This permits pipe expansion and absorption of water by asbestos cement or concrete pipes or by any mortar lining of steel or iron pipes. Normally pipelines are tested between valves, but on a trunk main these may be so far apart that temporary stop ends may be needed to test the pipeline in reasonable lengths. Especial care is needed in testing partly completed pipelines to ensure that they are properly restrained against the high test pressures.

An experienced pipelaying contractor will know that care in making joints on a pipeline is rewarded many times over when the pipeline test shows the line is satisfactory. It is rarely possible to leave joints exposed before testing, so if a test fails it may take much time and trouble to find the leak causing it. When finally found, it may be as simple as a twisted rubber ring in a push-fit joint. It is not easy to make clean, perfect joints in a muddy trench. The contractor can save himself money if he gives the jointer every facility to make a good joint: easy access to see the underside of the pipe spigot, buckets of water and plentiful clean rags to ensure that joint faces and joint ring are scrupulously clean before the joint is assembled. No grease or jointing compounds should be permitted other than that which the pipe manufacturer recommends. Welders also need sufficient room and good lighting to make sure welds are adequate, and should not be expected to weld up badly aligned pipes.

13.9 Handling and jointing large pipes and fittings

All ductile iron or steel pipes and fittings must be handled with proper wide lifting slings to prevent damage to their sheathing or coating. The use of chains or wire ropes 'blocked off' pipes with pieces of wood should not be permitted by the resident engineer. Apart from possible damage to the coating, the packing pieces may slip out when the chain or wire rope slackens and the pipe may fall. Handling of heavy pipes and fittings must be done with every precaution. The crane handling a heavy pipe must not slacken off until the pipelaying foreman is certain it is safe to do so, and no man would be put in danger if the pipe should move. Timber props, packings and wedges in adequate numbers should be available to secure the pipe before it is finally moved into position for jointing by slow jacking or barring to get it into position, the wedges being continuously adjusted to keep the pipe from moving unexpectedly.

Where large diameter pipes and fittings such as bends have to be fitted together, there is often difficulty in getting them set so that their joints match accurately, especially when a bend must be fixed at an angle to the horizontal. Before lowering such a bend into position it is worth while measuring it to find and mark, on the outside of the pipe at both ends, the diameters on the true axis of the bend and at 90 degrees to it. These should be accurately marked with a chiselled or indelible pencil line on white paint, not marked with chalk, which will rub off. It is quite difficult to locate the axis of a bend accurately, even when the bend is above ground; and can be frustratingly difficult when the bend is laid in some trench or basement. It is also good practice to put a mark round the spigot end of a pipe showing how far it must be inserted into a socket. The relationship of this line to the socket face indicates whether the alignment is satisfactory. Spigot and socket pipes need to be lined up within one degree to achieve a good joint; pipe flanges have to be lined up exactly parallel, with the bolt holes exactly matching, and as close as possible after insertion of the necessary joint ring before final drawing together of the flanges by progressive tightening of the bolts. To set a 1.2 m diameter 45 degree bend accurately to join a horizontal pipe at one end and an inclined pipe at the other may take a gang of four men and a crane driver two or three hours. If things do not go well it may take much longer.

14

Site concreting and reinforcement

14.1 Development of concrete practice

Although many contractors now use ready-mix concrete where it is convenient and economic, there are still many projects on which concrete is mixed on site. On remote sites and sites overseas there may be no ready-mix suppliers. If large pours are required it may be more economic for a contractor to produce concrete on site. In other cases a contractor may fear that a ready-mix supplier would not be able to cope with variations in his site requirements. Traffic hold-ups can cause delay to delivery lorries, and create 'bunching' of deliveries. No contractor likes to see a partially completed pour of concrete moving towards its initial set when no further ready-mix lorries arrive. Concrete produced on site is under his control: he can start concreting as soon as formwork is ready, and can stop concreting in an organized manner if some difficulty arises in placing. Such problems are the contractor's; but if he proposes to use ready-mix, the resident engineer should check that the supplier can meet the specified requirements for concrete. Some ready-mix suppliers, for instance, may not supply a 40 mm (1.5 in) size coarse aggregate.

On most construction sites the concrete used is made of natural aggregates such as gravel, sand and crushed rock mixed with water and ordinary Portland cement to BS 12:1978. For many years the 'standard mixes' shown in Table 14.1 have been used and continue being used today. They are as specified in British Standard Code of Practice CP 114:1969 *The structural use of reinforced concrete in buildings*, which covers design according to the elastic theory.* A 1:2:4 mix was commonly adopted for ordinary structural reinforced concrete, the 1:1:3 mix being used for water-retaining work. The works cube compressive strengths quoted

*BS 8110:1985 *The structural use of concrete* was intended to supersede CP 114 but, in response to a large number of objections from engineers, CP 114 has been retained and is still widely used. BS 8110 supersedes the previous CP 110:1972 and, like that Code of Practice, deals with reinforced concrete design according to the load factor theory. It incorporates the majority of CP 110 provisions, so the latter continues to be used, particularly as the cost of BS 8110: 1985 is £219.50 (1994).

Table 14.1

British Standard CP 114: Standard mixes by weight

Equivalent volume mix proportions	Works cube at 28 days	Dry weight of aggregates per 50 kg cement.				
		Sand	Coarse aggregates 19 mm max		Coarse aggregates 38 mm max	
			Workability		Workability	
	N/mm²		Low kg	Medium kg	Low kg	Medium kg
1:1:2	30	65	145	110	165	135
1:1:3	25.5	80	165	135	200	165
1:2:4	21	90	190	155	225	190
Compaction factor			0.32–0.880	0.88–0.94	0.82–0.88	0.88–0.94
Slump (mm)			12–25	25–50	25–50	50–100

Note: Weights are based on use of Zone 2 sand (see Table 14.4.) aggregates of relative density of about 2.6. If Zone 3 sand (finer) is used, reduce sand weights by about 10 kg and increase coarse aggregate by same amount. If the sand is crushed rock, reduce weight of coarse aggregate by 10 kg.

could be expected to be achieved with proper control of the quality of materials and the mixing.

Since the production of CP 114, a need for higher-strength concretes, coupled with more detailed studies of the chemistry of concrete and the advantages of using different types of aggregates, cements and admixtures to meet varying conditions, has led to requiring concrete mixes to be designed to meet some specific strength together with such other requirements as are considered necessary. BS 5328:1991 *Methods for specifying concrete* sets out the main current requirements; while a number of other British Standards cover the use of special aggregates, special cements, and additives. When any of these special ingredients are to be used, the procedures to be followed should be detailed in the specification, or else provided to the resident engineer by the engineer. In the material which follows, only the ordinary matters that the resident engineer will be expected to deal with are described.

14.2 Standards for concrete quality

The specification should define the grades of concrete required and in what parts of the works each grade is to be used. BS 5328: 1991 details three classes of concrete mixes: **prescribed mixes**, **designed mixes** and **standard mixes**. The last is for low-strength mixes used for unreinforced concrete in mass filling, strip footings, blinding concrete, trench filling etc. Ordinary prescribed mixes are defined

Table 14.2

BS 5328: 1981 Ordinary prescribed mixes

Grade of concrete	Weight of aggregate to be used per 100 kg of cement			
	Max size 40 mm workability		Max size 20 mm workability	
	Medium kg	High kg	Medium kg	High kg
C20P	660	600	600	530
C25P	560	510	510	460
C30P	510	460	460	400

by the proportions of aggregates to be used per 100 kg of cement, as shown in Table 14.2. A C25P grade mix means a prescribed mix in accordance with Table 14.2 that achieves a **characteristic strength** of 25 N/mm². Designed mixes specify only the characteristic strength, e.g. C25 grade, the maximum size of aggregate, and minimum cement content.

The characteristic strength of a mix is defined as 'that value of strength below which 5 per cent of... strength measurements... are expected to fall'. On a statistical basis, cube strength test results on a given mix are found to follow a normal distribution: that is, 50 per cent of test results are above the mean, *X*, and 50 per cent below. If only 5 per cent of results are to fall below a required value *P*, then the mean strength *X* must obviously be higher than P. From the characteristics of a normal distribution curve, *X* has to be 1.64*S* higher than *P* to achieve not more than 5 per cent results below *P*, where *S* is the standard deviation[†] of the test results obtained. If only 2.5 per cent of results are to fall below *P*, then *X* must be (*P* + 1.96*S*).

Reliable values of *S* cannot be obtained unless enough sample results are available. BS 5328 requires a minimum of thirty tests to be made before assessing *S*; and for $n = 30$ to 100 tests, the value has to be taken as $[0.86 + \sqrt{(2/n)}]S$, with a minimum value of 6 N/mm². The DoE manual *Design of normal concrete mixes* (1988) recommends that for Grades C20 and above, *S* should be taken as not less than 8 N/mm until more than twenty test results are available, and a minimum value of 4 N/mm² should apply however many tests are taken. For trial mixes, values of 2*S* would also normally be taken (rather than 1.64*S*) to give a further margin of safety. However, a less exacting approach is also allowed, as described in the next section.

[†]The standard deviation *S* is defined by

$$S = \sqrt{\frac{(X - x_1)^2 + (X - x_2)^2 + \ldots (X - x_n)^2}{(n-1)}}$$

where there are *n* test results $x_1, x_2, \ldots, x_n$, and *X* is their mean value.

14.3 Practical compliance with concrete standards

It can be seen that although designing a trial mix to meet a given grade can be done within a reasonable time using recommended minimum *S* values, the proving of a mix by statistical analysis of cube strengths is a lengthy business. At least twenty batches of concrete would have to be made up (preferably thirty or more) and at least two cubes from each batch tested at 28 days. (BS 5328 requires the mean of two cubes to be taken in each case.) The statistical method is therefore mainly used to monitor concrete quality when large quantities have to be placed, and is not practicable for small sites. However, BS 5328 lays down simpler criteria, namely(for concrete of grades C20 and above):

- the average strength of four consecutive samples must exceed the characteristic strength by 3 N/mm^2; and
- no single test shall be more than 3 N/mm less than the characteristic strength.

Thus four batches tested are the minimum requirement for testing of a trial mix. As an example, a trial mix for Grade C25P characteristic strength would be satisfactory if samples from each of four batch mixes should give a mean strength of not less than 28 N/mm^2, with no single cube strength under 22 N/mm^2.

The specification may also set other requirements, such as minimum cement content, minimum density of concrete, and minimum tensile strength under bending. BS 1881:1981 *Methods of testing concrete* describes (*inter alia*) standard methods of sampling mixes, making and curing test specimens, density testing, and tensile testing – the latter labelled 'determination of flexural strength'. Cubes are usually tested in an off-site laboratory. A density test can be carried out on site provided it is defined as on 'fresh, fully compacted concrete' (*see* Section 14.8 below). The requirement for the flexural test is shown in Fig. 14.1. A test apparatus

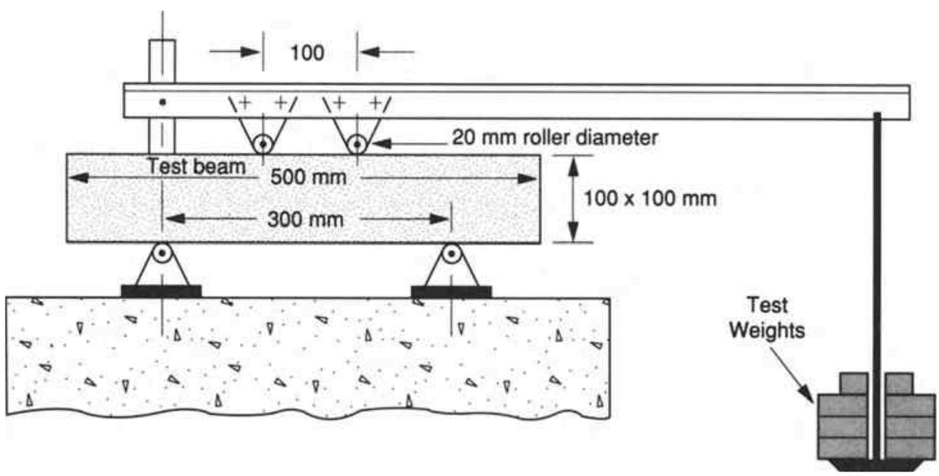
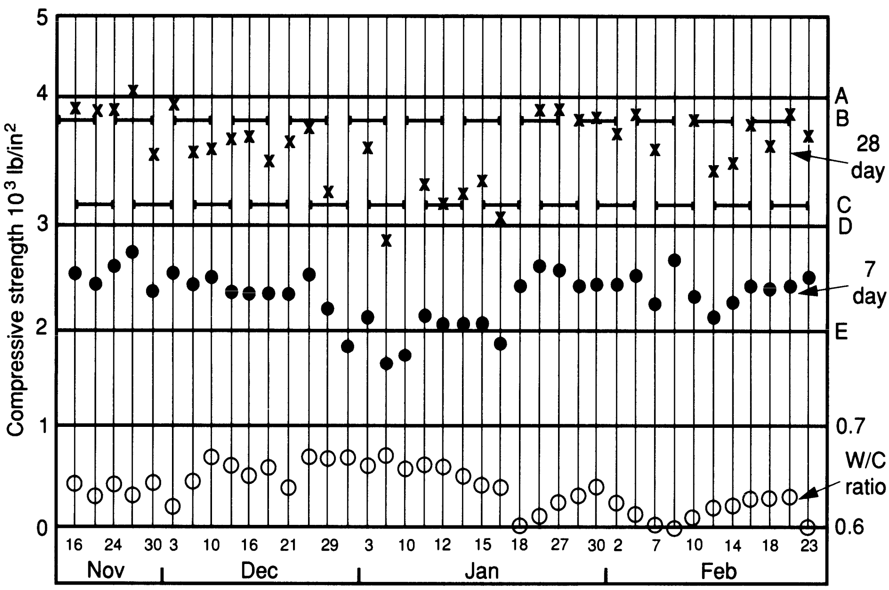


Fig. 14.1 Flexural test as BS 1881 on concrete beam for 20 mm max. aggregate size. For simple site testing (see text) it may suffice to use a single central roller to apply the load

is simple to make on site, and the tensile strength of the concrete is easily calculated from the value of the central load that causes failure of the beam. This tensile strength is important in water-retaining concrete, and can be helpful in deciding when support props can be removed from slabs and beams if the test beam is cured alongside and in the same manner as such slabs and beams. However, a margin of safety must be allowed for possible differences in compaction between the test beam and the *in situ* concrete.

To keep a watch on concrete quality during construction, a record of the type shown in Fig. 14.2 can be used, on which are plotted 7-day and 28-day concrete cube strength test results. The figure illustrates a decline in strength at 7 January, remedied later by reducing the water/cement ratio.



A – Upper action line 4200 lb/in² (29.0 N/mm²)
B – Upper warning line 4000 lb/in² (27.6 N/mm²)
C – Lower warning line 3200 lb/in² (22.0 N/mm²)
D – Lower action line 3000 lb/in² (20.7 N/mm²)
E – 7 day warning line 2000 lb/in² (13.8 N/mm²)

Each point mean value of five test results.

Fig. 14.2. Graphical check on concrete test results

Table 14.3

BS 5328; 1981 Percentage by mass of fine aggregate to total aggregate

Grade of concrete	Sand grade	Percentage Sand: Total aggregate			
		Max size 40 mm workability		Max size 20 mm workability	
		Medium	High	Medium	High
	Zone 1	35	40	40	45
C20P	Zone 2	30	35	35	40
C25P	Zone 3	30	30	30	35
C30P	Zone 4	25	25	25	30

Notes: 'The proportion given in the tables will normally provide concrete of the strength indicated.'
'Small adjustments in the percentage of fine aggregate may be required.'
'For Grades C20P, C25P and C30P . . . it is advisable to check that the percentage of fine aggregate stated will produce satisfactory concrete if the grading approaches the coarser limits of Zone 1 or the finer limits of Zone 4.'
(Grades C7.5P, C10P, C15P, and maximum aggregate sizes of 14 mm and 10 mm shown in BS 5328 Tables have been omitted.)

14.4 Grading of aggregates and their suitable mixing

The 1981 edition of BS 5328 provided a table showing the amount of fine aggregate in a prescribed mix, the grading of the fine aggregate being defined as given in BS 882: 1973, which gave the grading for four **zones** of fine aggregate. These two tables of information are useful in determining the ratio of fine to coarse aggregate required to make a dense mix, and so are reproduced in Tables 14.3 and 14.4. Zones 2 and 3 fine aggregates were the most used for forming suitable concrete mixes. Zone 1 grading (the coarsest) tended to give a harsh concrete and

Table 14.4

BS 882: 1973 Grading of fine aggregate

BS410 sieve mm	Percentage by weight passing BS sieves			
	Zone 1	Zone 2	Zone 3	Zone 4
10.0	100	100	100	100
5.0	90–100	90–100	90–100	95–100
2.36	60–95	75–100	85–100	95–100
1.13	30–70	55–90	75–100	90–100
0.60	15–34	35–59	60–79	80–100
0.30	5–20	8–30	12–40	15–50
0.15	0–10	0–10	0–10	0–15

also was often not procurable; and Zone 4 was usually avoided if possible because it contained too much fine material for producing the best concrete. A 1983 revision of BS 882 no longer quotes these four zones, but substitutes **gradings C**, M, and F (coarse, medium and fine), whose grading limits, however, are so wide they are not useful for mix design purposes.

In practice, samples of the fine and coarse aggregates proposed to be used should be sieved to find their typical grading. Sometimes it is found that the coarse aggregate contains a substantial proportion of fines (below 0.5 mm), while the fine aggregate may frequently be of a uniform size. Consequently, various ratios of coarse to fine aggregate must be tried out to see which gives the best mix. Envelopes of suitable grading curves for 20 mm (0.75 in) and 40 mm (1.5 in) max-

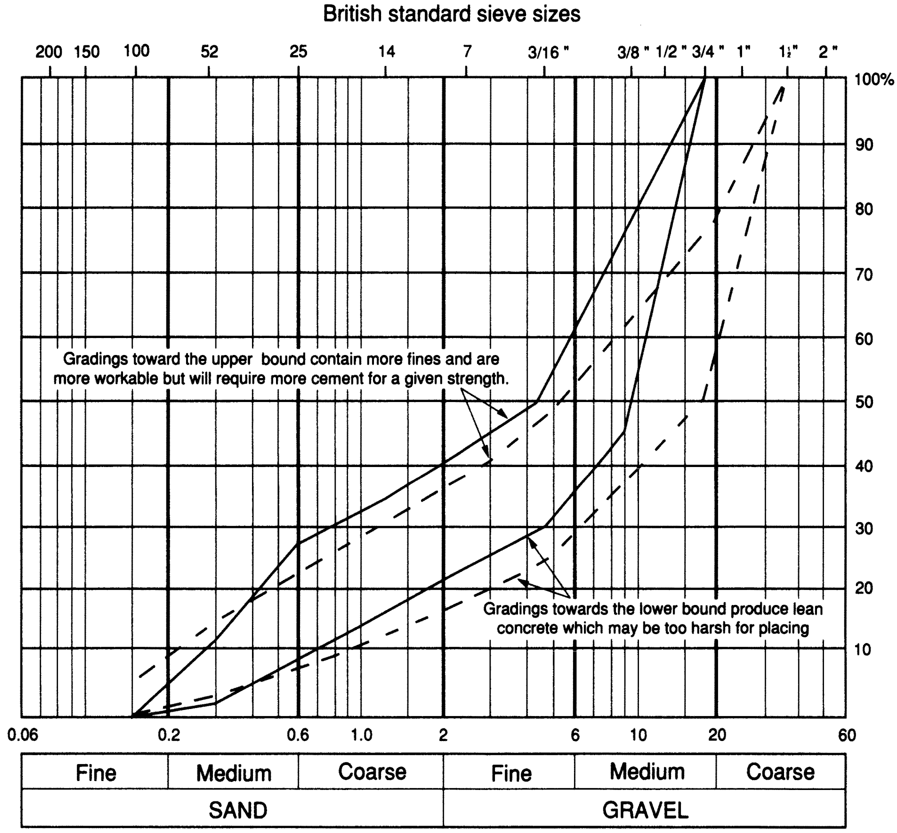


Fig. 14.3. Suitable range of aggregate gradings for concrete. (Based on modified versions of graphs by H M Walsh: *How to make good concrete*)

imum size aggregate are shown in Fig. 14.3. The first trial mix can adopt a ratio of fine to coarse aggregate that, as near as possible, gives a grading approximating to the centre of the appropriate envelope shown. Adjustment of the mix proportions for subsequent trial mixes will then show whether some improvement in the quality of the mix is possible. *Design of normal concrete mixes* published by the Building Research Establishment in 1975 is a useful guide.

14.5 Workability of concrete and admixtures

Workability requirements for a concrete mix tend to conflict with requirements for maximum strength, density and economy, since workability increases with increased fines, cement, or water in a mix, but increased fines and water reduce density and strength, and increased cement may increase shrinkage and liability to cracking as well as adding to the cost of a mix. It is therefore necessary to produce minimum satisfactory workability in order to keep the deleterious effects of too much fines, cement or water to a minimum.

Workability can be measured on site relatively easily by the well-known **slump test**, but it is not very accurate. A truncated metal cone, 300 mm high by 100 mm diameter at the top and 200 mm at the bottom, is filled in three equal layers with concrete, each being rodded with twenty-five strokes of a 16 mm rod, rounded at both ends. On removal of the cone the 'slump' or drop in level of the top of the concrete below the 300 mm height is measured. Another site test uses the **compacting factor apparatus**, which works on the principle of finding the weight of concrete that falls via a sequence of two hoppers into a cylinder. The compacting factor is the ratio of the weight of concrete falling into the cylinder as compared with the weight of concrete compacted to fill it. The higher this ratio is, the more workable is the concrete. These and other laboratory tests are described in BS 1881: 1983. In practice, workability need not be routinely measured on site by either of the above apparatuses as it can easily be judged by eye, as described in Section 14.6 below.

There is a substantial reduction of the workability of a concrete mix during the first 10 min after mixing, as anyone who has hand mixed concrete will know. This is primarily due to absorption of water by the aggregate, so that the reduction in workability is less if the aggregate is wet before use. On a construction site this reduction of workability is not usually noticeable, as more than 10 min usually passes before the concrete is placed. However, if samples for workability are taken, a time lapse of 10 min should be allowed before they are tested.

Admixtures to concrete are sometimes proposed by the contractor for approval, such as plasticizers or air-entraining agents to improve workability, or an accelerator to assist the contractor in striking formwork early. If the specification does not define which admixtures or special cement can be used, the resident engineer should not agree to any such proposal from the contractor, but pass it to the engineer for decision. There are many admixtures on the market, each having its own characteristics, some of which can be disadvantageous. For instance, the use of the accelerator calcium chloride is not permitted for steel-reinforced concrete under BS 8110 because it increases the risk of corrosion of the steel. Rapid-hardening cement can cause a high concrete temperature, leading to shrinkage and cracking; and air-entraining agents reduce the density and strength of concrete. This does not mean that no admixtures should be permitted, but that the complex reactions that they can cause make it necessary to call in specialist advice to ensure their safe use in any particular case. Very high strength concrete of up to 100 N/mm^2 strength or more, as used in high-rise buildings, is obtained primarily by use of a very low water/cement ratio. As a consequence, adequate workability has to be achieved by use of an admixture. The specification must state precisely what is required.

Special cements containing a proportion of ground granulated blast-furnace slag, pulverized fuel ash (pfa or 'fly ash') or other pozzolanic materials will normally be specified by the engineer for a particular purpose. They are advantageous in mass concrete because of their relatively low heat production without diminution of final strength. If not specified, any proposal by the contractor to use them should be referred to the engineer. Special aggregates for concrete usually comprise lightweight materials; they are mostly used only for particular building purposes (such as screeds for thermal or fire insulation), or in precast concrete products.

14.6 Practical points in producing good concrete

Provided certain simple rules are followed, good concrete can be achieved by methods varying from the 'bucket and spade' hand-labour method to use of the most sophisticated weigh-batching and mixing plant. The following shows the principal matters that should receive the resident engineer's attention.

First, choose **good aggregates**. The best guide is to use well-known local aggregates that have been and are being used satisfactorily on other jobs elsewhere. A reputable supplier will be able to name many jobs where his aggregate has been used, and the resident engineer will not be over-cautious if he visits one or two of these where the concrete is exposed to view. When the aggregates are being delivered on the job (not just the first few loads, but the loads when the supply has really got going), random loads as delivered should be examined. Handfuls of aggregate should be taken up and examined in detail, looking for small balls of clay, soft spongy stones, flaky stones, pieces of brick, soft shale, crumbly bits of sandstone, and whether clay or dirt is left on the hands after returning the handful. If the resident engineer finds more than one or two pieces of weak stone, or more than a single small piece of clay from a few handfuls, he should request the contractor to bring this to the notice of the supplier. He need not reject the load out of hand, but it will do no harm to let the supplier know that the aggregates are being watched. If a load contains numerous weak stones or several pieces of clay, it should be rejected.

Diagnosing whether an aggregate is likely to give rise to alkali–silica reaction (which can cause expansion and disruption of concrete in a few years in the presence of moisture) requires specialist knowledge. The most practical approach for the resident engineer is to ask the supplier if his aggregate has been tested for this; if not, structures built some years previously with the aggregate should be checked for signs of cracking due to alkali–silica reaction. Guidance and precautions are set out in certain publications,[1,2] but if it is proposed to use an aggregate not used before, the resident engineer should refer the problem to the engineer.

Second, choose **tested cement**. The same principle applies to cement as to the choice of aggregates: find the supplier of cement to other jobs and request a recent test certificate. Troubles can start when imported cement has to be used or cement from a variety of suppliers. Overseas it is not unusual for a small contractor to buy his cement a few bags at a time from the local bazaar. It is essential to test such cement on site before any concrete is placed in an important part of a structure. BS 12 provides methods for testing the compressive strengths of 1:3 mortar cubes or 1:2:4 concrete cubes but, if this is difficult to arrange, the flexural test mentioned in Section 14.3 can be applied on site.

Third, ensure the aggregates are **reasonably graded**. In delivery and stockpiling of coarse aggregate there is a tendency for the mix to segregate, the larger material remaining on top. Care has to be taken to ensure that certain batches are not made up from all the coarsest material and others from most of the fines. Crushed rock often has a considerable amount of dust in it; although this does not normally present a problem, one does not want a batch made up mostly from dust and fines taken from the bottom of a stockpile.

Fourth, always have **washed aggregates**. Unwashed aggregates suitable for concreting are rare: they usually comprise crushed clean homogeneous rock. Sometimes a river sand is supplied unwashed, it being assumed that the sand has already been 'washed' by the river. This should not be accepted as a fact, as a river also carries silts and clays. Sea-bed or beach sands must be washed in fresh water to remove the salt from them.

Fifth, mix the concrete properly and achieve the **right workability**. Mechanical mixers are seldom at fault with regard to mixing, and hand-mixing can also be quite satisfactory; but it is the water content of a mix that requires the most vigilant attention. The resident engineer should never let 'slop' be produced. Although the slump test and the compacting factor test are useful in defining the degree of stiffness of a mix, in practice judging the water content of a mix by eye is both necessary and possible. The right sort of mix should look stiff as it comes out of the mixer or when turned over by hand on mixing boards. It should stand as a 'heap' and not as a 'pool' of concrete. When a shovel is thrust into such a pile, the shovel-cut should remain open for some minutes. Such a mix will look quite different after it is discharged and worked into some wet concrete already placed. As soon as it is worked with shovels or vibrated, it will settle and appear to flow into and become part of the previously placed concrete.

The same characteristic makes it possible to judge the water content by noticing what happens if the freshly mixed concrete is carried in a dumper hopper to the point of discharge. The 'heap' of stiff concrete discharged from the mixer to the dumper hopper will appear to change to a pool of concrete as the dumper bumps its way round the usual site roads. When the dumper hopper is tipped, however, the concrete discharged should again appear stiff. But if, in transport, the concrete slops as a semi-fluid over the side of the dumper hopper, this shows that too much water has been added. A simple density test on freshly mixed concrete (*see* Section 14.8) may assist in finding if the mix has too much water.

Sixth, **ram the concrete well in place**. Properly shovelled, rodded, or vibrated, the concrete should be seen to fill the corners of shuttering and to easily wrap around the reinforcing bars. When hand shovelling or rodding is adopted, it is scarcely possible to over-compact the concrete. But when mechanical vibrators are used, the vibration should not be so prolonged as to produce a watery mix on the surface. Vibrators of the poker immersion type should be kept moving slowly in and out of the concrete. They should not be withdrawn quickly or they may leave an unfilled hole in the concrete; nor should they be left vibrating continuously in one location. Where vibrators are used, it is necessary for the contractor also to have available suitable hand rammers in case the vibrators break down in the middle of a pour.

Seventh, ensure that the mix has **sufficient cement** in it. Normally, contractors will use a little more cement than is theoretically necessary, and this is helpful, as batches of concrete vary. But if a contractor becomes too keen on cutting the cement to the bare minimum, a number of the cube-crushing tests may fail to reach the required strength, and much delay may be caused by conducting the investigations required to seek out the cause.

14.7 Some causes of unsatisfactory concrete

The two most common kinds of failure are:

- failure to get the required strength, the concrete being otherwise apparently good;
- structural failures, such as honeycombing, sandy patches, and cracking.

Failure to get the right strength in cubes taken from a concrete pour can sometimes have a very simple cause. Among such causes are the following.

- the cube was not compacted properly;
- it was left out all night in hard frost or dried out in hot sun;
- there was a mix-up of cubes, and a 7-day old cube was tested on the assumption that it was 28 days old;
- the cube was taken from the wrong mix.

Such simple errors are not unusual, and must be guarded against, because they cause much perplexity and waste of time trying to discover the cause of a bad test result. The concrete must be fully compacted in the mould, which is kept under damp sacking until the next day, when the mould can be removed and the cube marked for identity. It is then best stored in water at 'room temperature' for curing until sent to the test laboratory. If poor cube test results appear on consecutive batches, an error in the cement content of batches may be suspected, or else the quality of the cement itself.

Honeycombing is most usually caused by inadequate vibration or rodding of the concrete adjacent to the face of formwork. Sometimes too harsh a mix is used, so that there are insufficient fines to fill the trapped interstices between coarse aggregate and formwork, or the larger stones cause local arching. **Sand runs** – patches of sandy concrete on a wall surface which can be scraped away with a knife – can be due to over-vibration near a leaking joint in the formwork, which allows cement and water to pass out of the mix. One simple, and not infrequent, cause of poor concrete is use of the wrong mix due to a 'failure of communication' with the batching plant operator or ready-mix supplier. An experienced concreting foreman should be able to detect a 'wrong mix' the moment it is discharged.

14.8 Site checks on concrete quality

The defect of cube and beam tests on concrete is that results cannot be known until some days after the concrete has been placed. If weak concrete appears to have been placed in a structure a difficult situation arises. The resident engineer can ask for the offending concrete to be demolished and rebuilt, but this may pose such difficulty and delay that the decision ought not to be made on site without first discussing the problem with the engineer. The action taken depends upon how far the strength of the concrete falls short of the required strength, the load-bearing function of the under-strength concrete, and whether some alternative exists that does not involve breaking out the faulty concrete.

Frequent site checks of concrete quality can help to avoid such problems. Section 14.6 has already indicated that the water content of a mix can easily be judged by eye; and if the quality of the aggregate stocks held on site is kept under reasonable supervision, defects arising from aggregate quality or water content are unlikely to arise. Thus it is to the batching plant, and more particularly to the cement content, that checks should be directed.

One of the simplest on-the-spot tests that can be conducted is the **density** of freshly made concrete. This should be at least 2350 kg/m^3 (147 lb/ft^3) for a 1:2:4 mix and 2390 kg/m^3 (149 lb/ft^3) for a 1:1:2 mix on the assumption that the relative density of the aggregate is 2.65. The trial concrete mixes, however, should have revealed the typical densities expected for various grades of mix. The density can be obtained by filling and weighing an 0.015 m^3 (0.5 ft^3) container with freshly mixed and compacted concrete. An adequately dense concrete cannot be made with badly graded aggregate or with an excess of water.

If mixing takes place on site the accuracy of the weigh-batching plant should be checked regularly. Actual errors found on a typical hand-operated weight batcher were:

- zero error on scale: up to 15 kg;
- 20 mm stone: 78–106 per cent of required value;
- sand: 97–125 per cent of required value;
- cement (ex silo): 80–110 per cent of required value.

Allowance in a mix has to be made for the weight of the **moisture content** of the sand, which can be very variable when stocked in the open. Figure 14.4 shows the relationship between the bulking factor and moisture content. Some devices are available for measuring the moisture content of a sand, but measuring the moisture in every batch is not a practical proposition. Instead, typical samples of sand from the stockpile under varying weather conditions can be weighed, then dried and weighed again. This gives a guide as to the weights of fine aggregate to be

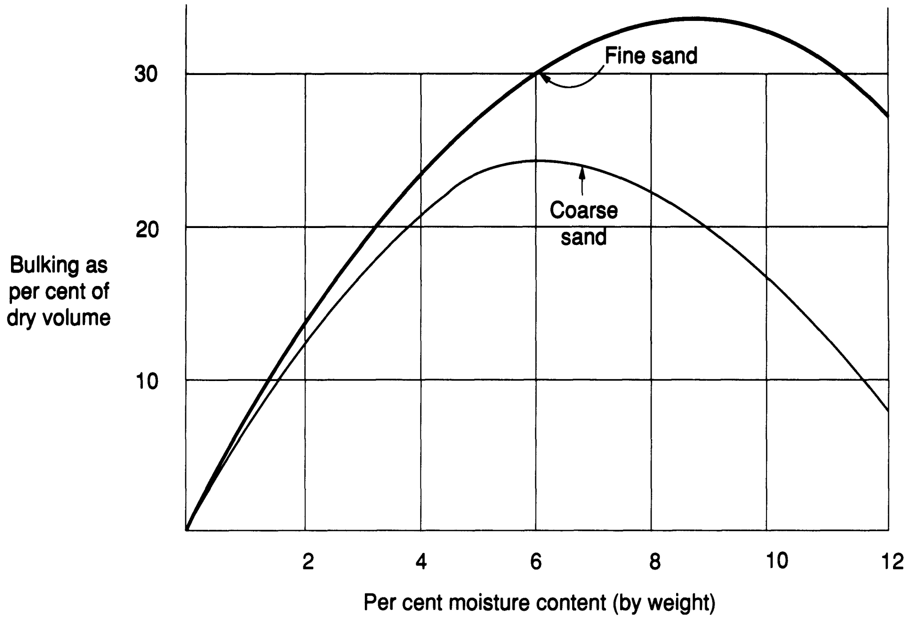


Fig. 14.4. Bulking of sand according to moisture content

used under 'dry', 'moist' or 'wet' conditions. The moisture content of the coarse aggregate is not usually checked, as it has little effect on the weight of the material.

Checking the **cement content** of the mix is particularly important if the cement is held in a silo. Serious under-weights of cement can occur due to machine faults with 'automatic' weighing equipment as well as with operator-controlled discharges from the silo. It is better if concrete batches are made up per bag or (more usually) per two 50 kg bags of cement, in which case only variations in the weight of aggregate affect the mix; but this method is only possible for relatively modest concrete outputs, not when large pours are required. The cement content of a mix cannot be directly tested; hence the importance of keeping watch on the batching plant accuracy. It would not be unreasonable for the resident engineer to ask the contractor to conduct regular tests at suitable times on the accuracy of the batching plant. A responsible contractor will realize that it is better to ensure his plant is accurate, than to face the difficulty of finding that concrete placed is below the required strength.

Occasionally on small sites or overseas, **volume batching** of concrete is used. The weight per unit volume of aggregates has to be obtained by weighing the amount required to loosely fill a measured container. Suitable wooden gauge boxes for aggregate, sand and cement then have to be made up for a given mix. Average weights of Portland cement are 1280 kg/m^3 (80 lb/ft^3) loose, or 1440 kg/m^3 (90 lb/ft^3) when shaken. If hand mixing is adopted, fairly large gauge boxes with no bottom can be used, as they are placed on a mixing platform, filled and lifted off. They would usually be sized for one bag (50 kg) of cement. The bulking of the sand according to its moisture content has to be allowed for.

14.9 Conveyance and placing of concrete

Specifications often contain clauses dealing with the **transport of concrete**, requiring remixing after transport beyond a certain limit, limiting the height through which concrete can be dropped, and requiring that no concrete be placed when more than a certain time has elapsed since mixing. In practice, problems of this sort seldom prove significant. Sometimes it may be necessary to insist that a contractor uses a closed chute to discharge concrete through a height in order to prevent segregation. Also, it may be desirable to ensure that mixed concrete is not left unplaced for too long. A requirement often found in specifications is that concrete must not be placed after it reaches its 'initial set', which for ordinary Portland cement concrete may take place 1 to 2 hours after mixing, dependent on temperature etc. However, a hardening on the outside due to surface drying can occur after about half an hour's standing, especially in hot weather. If this concrete is 'knocked up' again and shows that it can be satisfactorily placed it need not be rejected. However, if a delay is so lengthy that the concrete hardens into lumps, such concrete must be discharged to waste.

Pumped concrete usually poses more problems for the contractor than it does for the resident engineer, as only well-graded mixes relatively rich in cement are pumpable. Usually, several mortar batches must be sent through the pipeline to 'lubricate' it before the first batch of concrete is pumped through, and pumping must thereafter be continuous. It is not easy to pump concrete more than 300–400 m. If a stoppage of the flow of concrete occurs for any reason, the contractor has to take swift action to prevent concrete solidifying in the pipeline. Compressed air is used to force the final concrete batch through the line, followed by water to clean the pipes. Plasticizers are frequently used in pumped concrete; these increase its workability without requiring increased cement or water. There are a wide variety based on different chemicals; BS 5075: 1982 gives their main characteristics, but they should not be permitted by the resident engineer except to the extent allowed in the specification or sanctioned by the engineer.

Concrete can also be **blown** through a delivery pipe using a blower or compressed air. One batch at a time is blown through. The end of the delivery pipe must be directed into the area to be concreted, not against formwork, which may be dislodged by the force of the ejected concrete. Proper warnings must be given to personnel before each 'shot', because aggregate can rebound and be dangerous, especially when blowing concrete into closed spaces such as the soffit to a tunnel lining.

The **skip method** of placing concrete is widely used. Skips can be either bottom-opening or tip-over. In either case there can be a considerable bounce and sway of the skip when the concrete is discharged. The work should always be under the charge of an experienced ganger, who keeps a continuous watch over the safety of his men.

14.10 Construction and other joints

The resident engineer must agree with the contractor where **construction joints** should be placed; but he should not require them to be placed in impracticable positions, and must allow for the manner in which formwork must necessarily be erected. There are positions for construction joints that are 'traditional', even though the position may not seem to be the most desirable from a structural point of view. For instance, a construction joint usually has to occur at the base of a wall even though it cantilevers from a base slab, which is a point of maximum tensile stress in one face of the wall concrete. This joint is best sited 150 mm above the base slab so as to give a firm fixing for the wall shutters and the best possibility of achieving a sound joint. In water-retaining work it is important to keep the number of construction joints to a minimum.

The **bonding** of one layer of concrete to a previous layer is usually accomplished by cleaning the surface of the old concrete with a high-pressure water jet, and placing a layer at least 20 mm thick of mortar on the exposed surface immediately before the new concrete is placed. Sometimes a proprietary bonding mortar is used, especially when refilling cut-out portions of defective concrete. Wire brushing of the old surface is not so effective as water jetting, is laborious, and can seldom be properly done when reinforcement passes through a joint. A problem frequently encountered is that of finding debris on a construction joint at the bottom of erected formwork. Such debris must be removed before the mortar layer and new concrete is placed. Usually it is the job of the resident engineer's inspector to inspect formwork and the cleanliness of construction joints before permission is given to the contractor to start concreting. If the contractor runs 'quality assurance' one of his staff should act as inspector of formwork, but this does not relieve the resident engineer of his need to inspect on behalf of the engineer.

In **liquid-retaining structures** resilient plastic waterstops are usually provided at contraction joints. Fixing half their width in the stop-end shuttering to a narrow reinforced concrete wall often leaves a congested space for the concrete, which must therefore be most carefully vibrated in place to ensure that the waterstop is bedded in sound concrete. If the concrete face of the joint is to be bitumen painted before the next wall section is built, bitumen must not get on the waterstop.

Floor joint grooves need cleaning out by water jetting, then surface drying as much as possible with an air blower before the priming compound supplied by the manufacture of the joint filler is applied to the groove faces. It is essential that this primer is not omitted, and the filler must be pushed down to the bottom of the groove. Joint grooves are normally filled after the concrete has been allowed to dry out for two or three weeks, when most shrinkage on drying should have taken place (*see* Section 14.11).

Leaks from liquid-retaining concrete structures are most likely to occur from opening up of wall joints due to wall movement, especially at the corners of rectangular tanks, and puncturing of the floor joint filler under liquid pressure where the filler has not been solidly filled to the base of the groove.

14.11 Concrete finish problems

The skill required by carpenters to make and erect **formwork** for concrete is seldom fully appreciated. The formwork must remain 'true to line and level' despite substantial loading from the wet concrete. Column and wall faces have to be strictly vertical, and beam soffits strictly level, or any departure will be easily visible by eye. Formwork for concrete that is to remain exposed to view has to be planned and built as carefully as if it were a permanent feature of the building. Many methods have been tried to make the appearance of exposed concrete attractive but any of them can be ruined by honeycombing, a bad construction joint, or by subsequent weathering revealing that one pour of concrete has not been identical with adjacent pours, or that the amount of vibration used in compacting one panel has been different from that used in others. If concrete has to remain exposed to public view, then the resident engineer should endeavour to agree with the contractor what is the most suitable method for achieving the finish required if the specification or drawings do not give exact guidance on the matter. The problem is that if, through lack of detailed attention, a 'mishap' on the exposed surface is revealed when the formwork is struck, it is virtually impossible to rectify it. Sometimes rendering the whole surface is the only acceptable remedy.

Where concrete will not remain exposed to view, minor discrepancies can be accepted. 'Fins' of concrete caused by the mix leaking through butt joints in the formwork should be knocked off. Shallow honeycombing should be chiselled out, and a chase cut along any defective construction joint. The cut-out area or chase should be washed, brushed with a thick cement grout, and then filled with a dryish mortar mix. This rectifying work should be done as soon as possible so that the mortar mix has a better chance of bonding to the 'green' concrete.

Shrinkage cracking of concrete is a common experience. The shrinkage of concrete due to drying is of the order of 0.2–0.5 mm per metre for the first 28 days. Subsequently, concrete may expand slightly when wet and shrink on drying. The coefficient of temperature expansion or contraction is very much smaller: of the order of 0.007 mm per metre per degree Celsius of change. Rich concrete mixtures tend to shrink more than lean mixes. The use of large aggregate, such as 40 mm instead of 20 mm, helps to minimize shrinkage. To avoid cracking of concrete due to shrinkage, wall lengths of concrete should be limited to about 9 m if restrained at the base or ends. Heavy foundations to a wall should not be allowed to stand and dry out for a long period before the wall is erected, because the wall concrete bonding to the base may be unable to shrink without cracking. Concrete is more elastic than is commonly appreciated: for example, the unrestrained top of a 300 mm diameter reinforced concrete column 4 m high can be made to oscillate through nearly 10 mm by push of the hand.

14.12 Handling and fixing steel reinforcement

In best engineering practice the engineer will produce complete **bar-bending schedules** for use by the contractor. The engineer may not guarantee that such schedules are error free and may call upon the contractor to check them. But, as often as not, the contractor will fail to do this, so it is advisable for the resident engineer to check the schedules so that he can forewarn the contractor of any error present. In practice, few errors will be found, because the advantage of producing bar-bending schedules is that it applies a detailed check on the validity of the reinforcement drawings supplied to the contractor.

In some contracts the contractor is required to produce bar-bending schedules himself from the reinforcement drawings supplied under the contract. This is not such good practice; the engineer foregoes an opportunity to check the reinforcement drawings, and the contractor (or his reinforcement supplier) who produces the bending schedules will not necessarily be sufficiently acquainted with the design to notice some discrepancy that indicates a possible design error.

Reinforcement is now seldom bent on site, except on sites overseas. Deliveries of reinforcement should be supervised by the leading steelfixer, who should check the steel against the bar schedules and direct where bars should be stocked. Bars should be delivered with identifying tags on them, but sometimes these get torn off. The leading steelfixer should not allow withdrawals from stock without his permission. If the contractor does not pay sufficient attention to this and, for example, lets various steelfixers pick what steel they think is right, the resident engineer should forewarn the contractor that this is a recipe for ultimate chaos and delay.

Properly designed and bent bars can, in the hands of a good steelfixer, be as accurately placed as formwork. Crossings of reinforcement have to be wired together so that a rigid cage is built, able to withstand concrete placing without displacement. To ensure that the correct cover is given to bars, the contractor will need to prepare many small spacer blocks of concrete of the requisite cover thickness and about 25 mm square, which are wired on to the outside of reinforcement, keeping it the required distance from the formwork to give the specified cover. All wire ties should be snipped off close to the reinforcement so that their ends do not penetrate the concrete cover and form a path for corrosion of the reinforcement. The steelfixer will need to make and position spacer bars, generally U-shaped, which keep reinforcement layers the correct distance apart in slabs and walls. He may need many of these. They are not included in the bar-bending schedules, and the cost to the contractor of supplying and fixing them is usually included in the price for steelfixing. Figure 14.5 shows some points to watch when formwork and reinforcement is being erected.

Steel reinforcement stored on site rusts, but provided the rust is not so advanced that rust scales are formed, the rust does not appear to affect the bonding of the reinforcement to the concrete. A problem more likely to arise is the contamination of steel reinforcement with oil, grease or bitumen. If the contractor wishes to oil or grease formwork to prevent it sticking to concrete, he should do

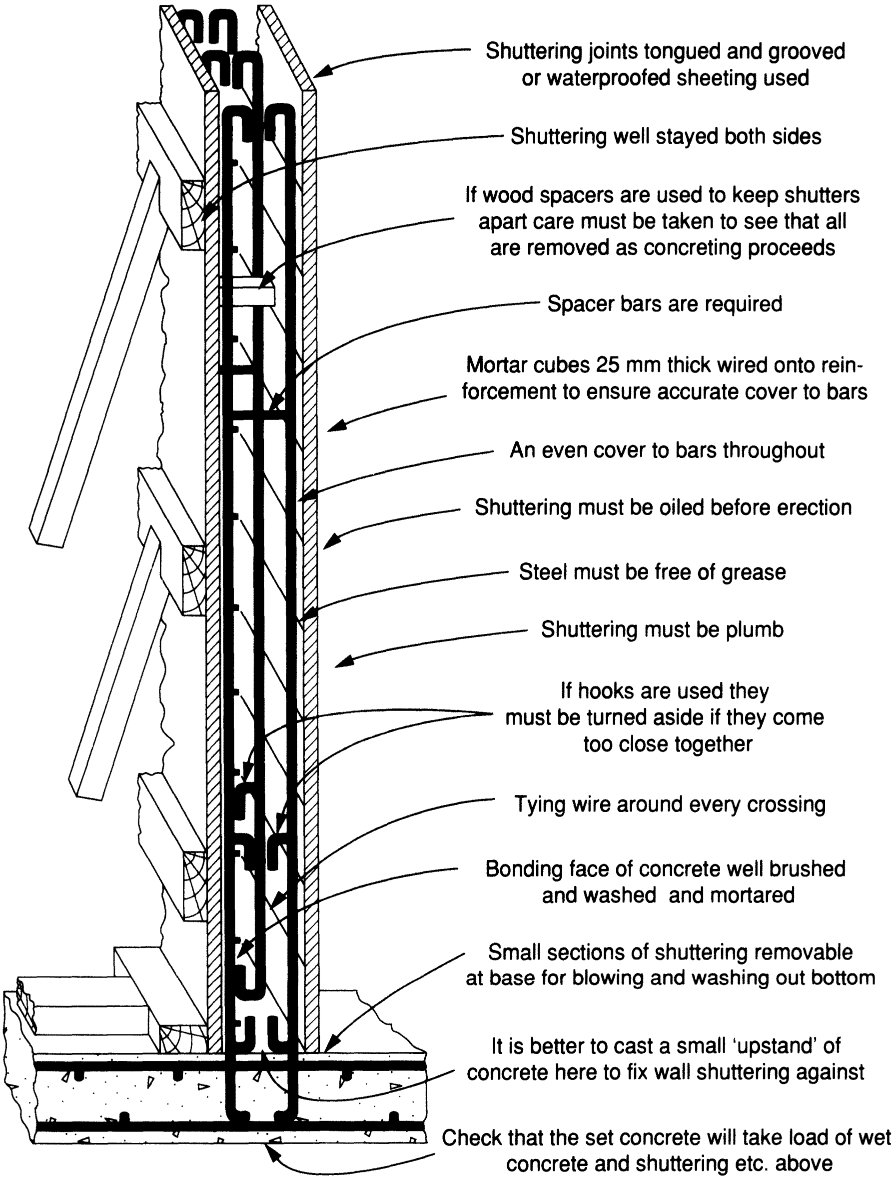


Fig. 14.5. Points to watch in erecting shuttering and reinforcement

so before the formwork is erected and not after it has been put in place. If the latter is attempted it will be almost impossible to prevent some oil or grease from getting onto the reinforcement. Similarly, if contraction joints are to be bitumen painted, care must be taken not to get bitumen on bars passing through such a joint.

The proper **design and detailing** of reinforcement makes a major contribution to the quality and durability of reinforced concrete. The designer must choose diameters, spacings and lengths of bars that not only meet the theoretical design requirements but which make a practical system for erection and concreting. Reinforcement to slabs must either be strong enough for the steel fixer to stand on, or spaced far enough apart for him to get a foot between bars onto the formwork below. Wall and column reinforcement must be of large enough diameter that it does not tend to sag under its own weight. Beam reinforcement should not be so congested that it will be difficult to get concrete to surround the bars without using a mix with too high a water content. The designer should consider options of design available to avoid heavy congestion of bars. An experienced designer who understands site erection problems will make as much use as possible of the four most commonly used bar diameters: 10, 12, 20 and 25 mm. He will appreciate that a 5 m long bar 25 mm diameter weighs about 20 kg, so that larger diameter or longer bars can be difficult for a steelfixer to handle on his own. For ease of handling, bars should not exceed 6–8 m length.

Bond laps have to be allowed for and should be at places which are convenient for the erection of formwork and for concreting. Starter bars in floor slabs are nearly always necessary for bonding to the reinforcement in walls. The length of their vertical arm should not be longer than is necessary to provide adequate bond length and support the wall reinforcement so that they present minimum impedance for slab concreting. If the designer wishes to use hooked bars, he should make sure that the thickness of slab or wall in which they are to be placed is sufficient to accommodate such hooks.

References

1. *Alkali–silica reaction: minimizing the risk of damage to concrete. Guidance notes and model specification clauses.* Technical Report No. 30. Concrete Society, October 1987.
2. *Alkali aggregate reactions in concrete.* Digest 330. Building Research Establishment, March 1988.

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