

CHAPTER FOUR

Specification of Earthwork

THE majority of civil engineering projects entail a considerable amount of earthwork. Apart from general excavation, filling and the disposal of excavated material, some jobs require the execution of more specialised forms of excavation work, such as tunnel-work and dredging. In addition it is customary to include, under the general heading of 'Earthwork', specification requirements covering ancillary works such as timbering and keeping excavations free from water.

It will probably be useful at this stage to consider the matters that may require inclusion in an earthworks specification and to determine a logical sequence for them. The specification writer can then determine from this list the items which he needs to incorporate in the specification for his particular job.

PRELIMINARY WORK

- (1) Site investigation
- (2) Site clearance

EXCAVATION, FILL AND DISPOSAL

- (1) Excavation work generally
- (2) Excavation of pipe trenches
- (3) Excess excavation
- (4) Disposal of surplus excavated material
- (5) Backfilling
- (6) Fill
- (7) Trimming slopes
- (8) Restricted use of plant

CIVIL ENGINEERING SPECIFICATION

ANCILLARY WORK

- (1) Keeping excavations free from water
- (2) Timbering

SPECIALISED WORK

- (1) Tunnel work
- (2) Cofferdams
- (3) Dredging

The Codes of Practice on earthworks (CP 2003) and site investigations (CP 2001) contain a vast amount of detailed information on the methods which can be used in carrying out these classes of work. They can be useful guides to the Engineer in the drafting of specifications.

A wide selection of typical earthwork specification clauses follows, accompanied by explanatory notes, although it will be appreciated that the detailed requirements will vary considerably from job to job.

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PRELIMINARY WORK

Site investigation

Borings and ground information. Drawings showing details of the sub-strata obtained from borings are available for inspection at the offices of the Engineer. The Contractor is requested to examine these drawings and to make himself fully familiar with the conditions on site.

The information on these drawings is believed to be correct but is not guaranteed and is supplied for guidance purposes. The Contractor is responsible for obtaining such additional information as he considers necessary covering such matters as the nature of the ground, water levels, physical features of the site, etc.

It is customary to supply contractors with information on sub-strata and water-tables from borings, subject to the proviso that these details may not truly represent conditions over the whole area of the site. The onus is on the Contractor to obtain such further information as he deems necessary.

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Site levels. All levels shown on the Contract Drawings or mentioned in this document are related to Ordnance Datum at Newlyn.

Water levels. It is believed that the following truly represent the operative water levels, but their accuracy is not guaranteed.

Highest recorded water level
+15.27 O.D.
Mean high water spring tide
+10.31 O.D.
Mean low water spring tide
- 8.68 O.D.
Lowest low water -12.85 O.D.

Trial holes. The Contractor shall excavate all trial holes as required ahead of pipelaying work, and shall backfill and reinstate them and maintain the surfaces. The Contractor shall receive separate payment for this work provided he obtains prior consent of the Engineer, but he shall at his own expense take all other practicable measures to determine the location of other services.

Site clearance

Removal of hedges and brushwood. The Contractor shall uproot and burn all hedges and brushwood on the site of the Works.

Removal of trees and tree stumps. Where indicated on the Drawings or directed by the Engineer, trees shall be uprooted or cut down close to ground level and removed from the site. Stumps and tree

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It is the usual practice to relate all levels to Ordnance Datum, preferably a specific bench mark near the site.

With tidal work it is desirable that the Contractor should be supplied with the various water levels.

It is often necessary to determine accurately the location of other underground services before the lines of new sewers and mains can be established with certainty. It is not always possible to obtain sufficiently precise information from the statutory undertakers themselves.

These need to be uprooted, and burning on the site is usually the best method of disposal.

Here again, the removal of roots is essential. Entire trees can often be removed by a tree puller or a bulldozer (see Ministry of Agriculture pam-

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roots shall be grubbed up or blasted and burnt or removed from the site. Where directed by the Engineer the voids resulting from tree root removal shall be filled with approved excavated material in 225 mm (9 in.) consolidated layers.

Demolition of concrete wall. Demolish the concrete wall as indicated on the Drawings and retain the resulting debris on the site for use as filling under roads.

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phlet No. 101). Alternatively, trees should be cut off at a height not exceeding 1 m (3 ft) above ground and the stumps removed by winch gear or high-velocity explosives (subject to Home Office Regulations and local police requirements) or a combination of both methods.

With demolition work it is important to indicate whether the materials resulting from the demolition are to become the property of the Contractor or the Employer.

EXCAVATION, FILL AND DISPOSAL

General

Surface soil. Surface soil shall be stripped and deposited in temporary storage heaps, preparatory to being used for the soiling of slopes to cuttings and embankments and in the preparation of beds to receive trees and shrubs.

Turf. Where directed by the Engineer, turf shall be carefully cut 1 m × 300 mm × 40 mm (3 ft × 1 ft × 1½ in.) thick and it must be relaid within one week of cutting.

Where surface soil is to be retained, provision must be made for its stripping as a separate item from general excavation.

Turf is preferable to soiling and seeding in areas subject to constant and heavy wear, or where a grassed surface is required urgently.

Excavation

The excavation shall be carried out to the dimensions, levels, lines and profiles indicated on the Contract Drawings or

The Contractor is invariably required to excavate to the required dimensions in

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to such other dimensions as may be directed in writing by the Engineer. The excavations are to be performed in whatever material may be found, but extra payment will be made for excavation in rock. Rock is defined as material which, in the opinion of the Engineer, can be removed only by the use of compressed-air plant, wedges or explosives and is found in continuous beds exceeding 75 mm (3 in.) in thickness or in isolated stones exceeding 0.06 m³ (2 ft³) in volume.

The Contractor shall include for getting out the excavated material by hand or machine and for levelling and ramming surfaces prior to commencing any constructional work.

The faces and beds of all excavations, after being excavated to the required dimensions, shall be carefully trimmed to the required profiles and levels and cleaned of all loose mud, dirt and other debris. The bottom 150 mm (6 in.) of material in the beds of excavations shall not be removed until immediately prior to the execution of the permanent work.

Should slips of material occur during the execution of the Works or during the maintenance period, the Contractor shall be required to perform the remedial works at his own expense, unless the Engineer certifies that the slip occurred through no fault of the Contractor.

No excavation shall be refilled or built upon until the formation has been inspected and approved by the Engineer. Where the Contractor excavates below the required level in good ground, he shall make up the void in concrete (1:3:6) at his own expense.

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whatever material may be encountered. This clause will also contain any requirements as to the method of working, such as excavating to within 150 mm (6 in.) of formation in the first instance and removing the latter portion just before construction of the permanent works is commenced.

The choice of method of excavation is usually left to the Contractor and is influenced by a number of factors:

- (1) type of ground to be excavated;
- (2) ground-water conditions;
- (3) the period and height for which an excavated face will stand unsupported;
- (4) dimensions of trench.

Mechanical excavation of trenches is normally practicable to a depth of about 3 m (10 ft) in medium ground and 6 m (20 ft) in good ground, using various types of trencher. In wet or bad ground, it is necessary to install an efficient de-watering system before mechanical excavation proceeds.

Excavation of pipe trenches

Pipe trenches shall be excavated to the lines and levels shown on the Contract Drawings or as directed by the Engineer. The bottoms of all trenches shall be of such a width as to provide at least 150 mm (6 in.) clearance between the barrels of the pipes and the excavation or timbering, or such greater clearance as may be necessary to accommodate the concrete surround of the thickness prescribed.

This clause aims at securing pipe trenches of adequate width to allow for satisfactorily laying and jointing the pipes.

Disposal of surplus excavated material

All surplus excavated material shall be removed from the site to a tip to be provided by the Contractor. The site shall be kept as free as possible from accumulations of surplus material.

The responsibility for finding a method of disposing of surplus excavated material almost invariably falls upon the Contractor.

Backfilling

Backfilling of trenches and other excavations shall be carried out in layers not exceeding 225 mm (9 in.) in thickness and the filling shall be of material selected from the excavations and approved by the Engineer. This material must be carefully placed around foundations, etc., and be thoroughly consolidated, with care being taken to prevent any damage being caused to the permanent works. No backfilling shall be deposited until all silt, mud or other soft material has been removed.

In backfilling pipe trenches special care shall be taken to ram the fill at the sides of pipes. The filling material used

This clause aims at ensuring backfilling with suitable materials which are adequately consolidated to eliminate the source of much future trouble and expense. With pipe trenches, special precautions must be taken to prevent any possibility of damage to pipes during ramming of backfilled material.

The degree of compaction of backfilled material will depend on the nature of the work, i.e. on how much soil movement can be tolerated.

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beside pipes and for 300 mm (12 in.) above them shall be free from stones exceeding 25 mm (1 in.) gauge. The first ramming shall take place at half the height of the pipe. Where a mechanical rammer is used, the pipes shall be protected by at least 1 m (3 ft) of hand-rammed material.

Fill

Selected and approved excavated material may be used for fill, but certain additional material may have to be imported. Suitable imported material consists of stone, rubble, broken brick and slag, free from objectionable rubbish or trade waste and to the approval of the Engineer. Sample loads of filling material shall be approved by the Engineer before it is used in the Works. Any filling materials rejected by the Engineer shall be removed from the site immediately at the Contractor's expense.

General filling to embankments, etc., shall be thoroughly consolidated with a roller or crawler tractor weighing not less than 10,000 kg (9.84 tons). The fill is to be consolidated in layers not exceeding 300 mm (12 in.) consolidated thickness. Each layer shall extend over the full width of the embankment, and shall consist of reasonably well graded material, with all large voids suitably filled before the next layer is deposited.

The Contractor shall reconstruct to the proper level and profile any filled areas which may settle or spread during the execution of the work or the maintenance period. Where the settlement or

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Provision is made for the use of suitable material, adequately consolidated in layers in fill.

Code of Practice CP 2003: Earthworks gives guidance on the design and construction of embankments. Where embankments are to cross soft ground, undisturbed samples should be taken from the foundation at various depths and tested in a consolidation press. From the results of these tests an estimate can be obtained of the settlement that will occur under the fill at various depths.

Where the required height of bank is such that sheer failure of the foundation material might occur, it is advisable to construct the bank in stages, allowing sufficient time for the foundation material to consolidate under the weight of the first stage and so increase its strength before the second stage is added.

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spreading is, in the opinion of the Engineer, due to a cause within the control of the Contractor, then the cost of the remedial work shall be borne by the Contractor.

Trimming of side slopes

Side slopes shall be trimmed evenly to the inclinations shown on the drawings or to such other inclinations as the Engineer may direct. Earth slopes and verges, after trimming, shall be soiled to a depth of at least 150 mm (6 in.) with suitable vegetable soil, which shall be sown in the correct season with grass seed as specified at the rate of 0.05 kg/m² (1½ oz/yd²).

The contract rates for grass seed are to include for preparing and re-sowing bare patches either at the end of the maintenance period or within six months of sowing the seed, whichever is the longer, and for applying a suitable selective weed killer when the grass has become established.

Restricted use of plant

If for any reason the Engineer is of the opinion that it is undesirable that any excavator, mechanical digger or other plant used or proposed to be used by the Contractor for the purpose of excavation should be used or that any such plant is unsuitable for use on the Works or any part of them, the Engineer may order the Contractor not to use and/or to remove the plant from the site.

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In addition drainage may be required

- (1) in the bottom of cuttings;
 - (2) upon the slopes to intercept springs or seepage water;
 - (3) at the top of slopes to intercept surface water, either in the form of open channels or French drains.
- CP 2003: Earthworks contains a useful table covering the design of slopes in various types of rock.

Although the Engineer does not normally direct the Contractor as to the method in which he carries out the Contract Works or as to the plant which he shall use, nevertheless there may be a case on occasions for restricting the type of plant used to avoid undue annoyance or nuisance being caused to adjoining owners/occupiers.

ANCILLARY WORK

Keeping excavations free from water

All excavations shall be kept free from water at all times and adequate pumping plant, including special de-watering equipment, shall be provided by the Contractor, who shall also make his own arrangements for the disposal of all water encountered in the excavations. All sumps shall be located clear of excavations for permanent work, and when no longer required the sumps shall be filled in with suitable material or dealt with as directed by the Engineer.

The Contractor will not be permitted to carry out any concreting or other constructional work unless the excavations are dry, and the excavations shall be kept free from water until the concrete has set sufficiently so as not to be damaged by water.

Timbering

The Contractor shall supply and fix all necessary timbering, steel sheeting, strutting, shoring, etc., to support the sides of excavations so as to ensure the safety of workmen, freedom from damage of any structures or services and to prevent any movement of adjacent soil. All such supports shall be maintained until the constructional work is sufficiently advanced to permit the timbering, etc., to be withdrawn.

The Contractor is responsible for keeping all excavations free from water. Ground-water can often be excluded by surrounding the excavations with steel sheet piling or by the use of ground-water lowering; the injection of cement grouts, silicate solutions or bituminous emulsions can reduce the flow appreciably.

Ground-water lowering methods include shallow-well, well-point, deep-well and multi-stage.

The volume of water to be dealt with in excavations depends on:

- (1) the precautions taken to exclude water;
- (2) the nature of the ground;
- (3) the head causing water to flow into excavations.

The selection of the method of timbering to be used in excavation work is largely influenced by the type of ground encountered. Four types of sheeting are described in CP 2003: Earthworks, namely poling boards, horizontal sheeting, runners and sheet piling.

Sheet piles are frequently

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Where necessary, the excavations shall be close timbered or sheeted and the Contractor will receive no additional payment for this work, even although it may have been ordered by the Engineer.

Where the Contractor is required to leave in position timbering or sheeting on the order of the Engineer to safeguard adjoining buildings, etc., he will be paid the schedule price for the materials used. Any timbering or sheeting not ordered by the Engineer but left in for the convenience of the Contractor will not be the subject of any additional payment.

Any bridges, railways, buildings, walls, sewers, culverts, mains, cables, etc., likely to be damaged by the excavation shall be properly supported and the Contractor shall be held responsible for any damage arising in this connection. The Contractor shall be responsible for any damage to the permanent work due to inadequacy of timbering, etc., and any consequential damage caused by the removal of timbering, steel sheeting or other supports from excavations.

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interlocking rolled steel sections of various weights and strengths. This type of piling has the great advantage that it can be re-used many times.

Sheet piling is normally driven by a steam- or air-operated hammer. A pile frame or crane is used for pitching the piles and the size of crane or the height of frame required depends on the method to be used for pitching and driving and on the length of pile.

SPECIALISED WORK

Tunnel work

Excavation in tunnels and associated shafts shall be performed in a manner approved by the Engineer. All reasonable precautions shall be taken to prevent the subsidence or movement of the surrounding ground or disturbance of adjoining structures.

Where necessary or where directed, the Contractor shall closely timber the

With tunnel work it is imperative that the Contractor takes all necessary steps to prevent any movement of adjacent ground or buildings. Another essential requirement is the provision of adequate timbering. The accompanying specification clauses

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excavations to the satisfaction of the Engineer. When close timbering is not in use during driving of a tunnel, a set of timber ready cut and marked for boxing up the face shall be kept in close proximity to the work ready for immediate use should an emergency arise. Where support is required for the ground at the top and/or sides of a length during excavation, mild steel polings not less than 10 mm ($\frac{3}{8}$ in.) thick shall be inserted and left in.

indicate one way of doing this.

When driving operations cease, the face shall be closely timbered to the Engineer's satisfaction and if work ceases for 48 hours or more, the timbering shall be grouted at the Contractor's expense.

The Contractor shall include in his prices for all getting out, filling, wheeling, hoisting, handling, loading, transporting and disposal of the surplus spoil to the satisfaction of the Engineer.

Use of compressed air plant and equipment. The Contractor is required to comply with the regulations contained in the Report of the Committee on Regulations for the Guidance of Engineers and Contractors for Work carried out under Compressed Air, published by the Institution of Civil Engineers, and of the Regulations as to Safety, Health and Welfare in connection with Diving Operations and Work in Compressed Air, issued by the Ministry of Labour.

Special precautions are needed when tunnel work is to be performed in compressed air. The accompanying specification notes illustrate some of the principal matters to be considered. Above all, adequate precautions must be taken to ensure the safety of the workmen engaged in this class of work.

The Contractor shall install, maintain, operate and remove on completion, suitable air compressors, sufficient to supply adequate compressed air at the highest pressure that can be

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required, and allowing sufficient standby equipment of not less than one compressor nor less than 20 per cent of the total equipment.

The Contractor shall make arrangements for any alternative standby sources of electrical energy generation or other alternative means to maintain continuity in the event of breakdown of any of the services required for the safety of the workmen, or the Works, or for the prevention of any damage.

The whole of the plant and equipment for the supply of compressed air shall be brought on to the site, erected if possible, and tested before any work in compressed air is commenced.

After erecting and equipping the air locks but before work in compressed air is commenced, the works shall be subjected to a test under a pressure of 0.28 MN/m² (40 lbf/in²) maintained for not less than one hour. The Contractor shall supply, install and maintain in good working order a telephone system connecting the compressor houses, outside and inside of the air locks and tunnel faces, at all times that constructional work is proceeding in compressed air.

Shaft excavation. Under suitable conditions, shaft sinking may be performed by the orthodox underpinning method in free air; excavating, erecting and grouting each ring before the next is commenced. Where necessary, the shafts shall be sunk in compressed air with air locks.

Where steel sheet piling is used, it shall be supported in such a manner

This clause is particularly concerned with the sinking of shaft rings and the use of steel sheet piling to retain the sides of the excavation.

The Contractor may be given the opportunity to use other than orthodox methods subject to certain requirements.

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that the extreme fibre stress shall not exceed 155 MN/m^2 (10 tonf/in^2). With the consent of the Engineer, sheet piling supports may be in the form of rings of shaft lining, temporarily assembled and suitably packed. Annular space between the outside of the lining and the sheet piling shall be filled with concrete mix C in lifts not exceeding 1.2 m (4 ft) in height and with construction joints in the concrete not less than 150 mm (6 in.) distant vertically from the horizontal (circumferential) joints in the lining.

The Contractor shall include in his prices for all pumping, temporary sumps, etc. needed to control and remove the water entering the shafts.

Where the Contractor wishes to sink a shaft by a method other than that described, he shall submit his proposals to the Engineer, accompanied by adequate drawings and other information, including particulars of the items in the Bill of Quantities requiring adjustment.

Shield-driven work. The main tunnel lengths shall be driven using a hooded Greathead type shield, although tunnels may be driven open-faced for a distance not exceeding 6 m (20 ft) from the shaft break out. This work must be adequately timbered or otherwise supported to the satisfaction of the Engineer, and where directed the timbering or sheeting shall be left in position.

Where no water is encountered, the Contractor shall maintain an air pressure of 0.06 MN/m^2 or 55 kN/m^2 (8 lbf/in^2) in the tunnel, but where necessary the air pressure shall be increased to balance the hydrostatic head. Where there is insufficient loss of air at

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Concrete mix C would probably be 1:3:6.

It is frequently necessary to use a shield in tunnel work, to speed up the job, increase the safety of the workmen and reduce the loss of timbering. Even where shield-driven work is specified, it is customary to permit a short length of tunnel to be driven without a shield when breaking out from a shaft.

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the face to give adequate ventilation, the Contractor shall install suitable pipes or ducts for this purpose.

As the shield is driven, auger holes shall be driven in the top of the face for a distance of 600 mm (2 ft) to determine the nature of the ground.

Cofferdams

The Contractor shall provide, construct and maintain proper and sufficient cofferdams of steel sheet piling for dealing with water during the construction of the work adjoining the river bank, and shall remove the cofferdams at completion.

The price for cofferdams shall include for all steel sheet piles, angle and junction piles, struts, cleats, walings, puncheons, tie rods, anchors, etc., and for all labour in driving and fixing and for all clay puddle and other material necessary to make the cofferdams sound and watertight. The method of construction is at the discretion of the Contractor, who is entirely responsible for keeping the cofferdams watertight, but in no case shall the sheet piles be driven to a depth of less than 3 m (10 ft) below the new dredged or excavated levels. The tops of cofferdams shall be not less than 600 mm (2 ft) above flood level.

The Contractor shall be paid billed rates for any steel sheet piling which is left in position on the order of the Engineer.

The cofferdams shall be designed to withstand all pressure conditions obtaining at high and low tides both before and after excavation work has been

The responsibility for the design, provision, maintenance and removal of cofferdams usually rests with the Contractor. They form one of the most important and costly items of temporary works and the accompanying specification clauses list some of the more common requirements.

There is a continual emphasis on the need for watertightness to permit the permanent works within the cofferdam to be constructed in the dry. All responsibilities in connection with cofferdams fall upon the Contractor. The only extra payment he will receive is for sheet piling left in position on the order of the Engineer.

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carried out. The cofferdams must be maintained in a stable and satisfactory condition for such periods as are necessary for the performance of the Works, and they are not to be removed without the Engineer's written consent.

In the event of a cofferdam failing, the Contractor is to replace it at his own expense and to the satisfaction of the Engineer. Notwithstanding that the Engineer may have accepted the cofferdam designs submitted by the Contractor, the Contractor will be held entirely responsible for the adequacy and safety of the cofferdams and shall satisfy all claims for damage to new works, damage to property or injury to persons arising out of the failure of the cofferdams and shall indemnify the Employer therefrom.

The Contractor shall keep all cofferdams free from water from any source and shall provide all temporary pumping plant, pumping sumps, subdrains, pipes, channels, etc., and shall fill in any spaces left by the removal of any such works in a manner approved by the Engineer.

No concreting or other constructional work will be permitted unless the excavations are dry and they shall be kept free from water until the concrete has set sufficiently to prevent any possibility of damage by water.

Dredging

The dredging shall be performed to the lines and levels shown on the Contract Drawings or to such other lines and levels as may be directed by the Engineer.

Due to the cumbersome machinery used and the fact that the excavation is carried out below water level, it is customary for tolerances

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The work shall be undertaken with a suitable dredger and the excavated material shall be removed to a site approved by the River Authority.

Dredging shall be paid for on the basis of measurement in barge. The Contractor will be permitted a tolerance of 300 mm (12 in.) on horizontal surfaces and 600 mm (24 in.) on sloping surfaces, below the specified dredged levels. The volume of any excess dredging over this tolerance will be deducted from the barge quantities.

The Engineer and the Contractor shall undertake and agree a joint post-dredging survey to determine the final dredged levels.

below specified dredged levels to be allowed. Measurement of dredged quantities is usually by barge or hopper, but a check on final dredged levels by soundings will need to be made.