

CONSTRUCTION STANDARD
FOR
EARTHWORKS

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1. SCOPE

This Standard deals with earthworks forming part of general civil engineering construction such as highways, railways and airfields, bulk excavation for major structures and excavation in pits, shafts and trenches for foundations, pipelines and drainage works.

The Standard is written in general terms and its application to any particular branch of civil engineering or to any particular construction project may be subject to the special requirements of the work under consideration.

This Standard also includes some general information about the operation of construction plant for earthworks, together with a brief description of the said, construction plants in the form of an Appendix.

2. REFERENCES

In this Standard the following standards and publications are referred to and to the extent specified, form a part of this Standard.

BS 1377:1975	"Methods of Test for Soils for Civil Engineering Purposes"
BS 5607:1988	"Code of Practice for Safe Use of Explosives in the Construction Industry"
BS 5930:1981	"Code of Practice for Site Investigations"
BS 6031:1981	"Code of Practice for Earthworks"
BS 8004:1986	"Code of Practice for Foundations:"
ASTM D653:1987	"Terms and Symbols Relating to Soil and Rock"
IPS-E-CE-110	"Soil Engineering"

3. DEFINITIONS AND TERMINOLOGY

Engineering geology and rock mechanics terms are defined in various published works. For the purpose of this Standard reference shall be made to definitions given in ASTM D 653 and BS 6031. Definition of terms related to soil testing are given in BS 1377.

4. SAFETY PROCEDURES

Persons responsible for the safe operation of any construction works should not only be conversant with all the relevant legislations, but should also actively encourage a safe approach to the work in hand.

The principal causes of accidents, which apply at any stage of the works, are categorized as follows:

- falls of persons into the works;
- falls of materials (e.g. collapse of the sides of excavations, fall of material into the excavation from spoil tips, etc.);
- unintentional collapse of the whole or any part of a structure and of structures erected as temporary works (includes the effect of excavations alongside existing buildings and inadequate timbering of excavations);
- lifting operations associated with the works and unfenced machinery;
- fires and explosions;
- electrical, including damage to underground cables and other electrical services;
- trespass by the public (including children) onto construction sites;

- miscellaneous accidents due to lifting and carrying equipment and materials, poor means of access for vehicles and operatives into excavations, collisions with obstructions such as projecting reinforcement, mis-placed or inadequate barriers and randomly stacked materials, and reversing accidents or other collisions involving earth-moving equipment and transport.

For more detailed information refer to Clause 4 of BS 6031:1981.

5. SITE PREPARATION

Before all or any part of the site is occupied adequate fences should be erected on the boundaries of the site to define its limits, to restrict construction plant to the site of the works, to protect the public and prevent farm or other animals from straying onto the site or onto adjoining roads. Following this and before any earthworks operations are commenced pre-earthwork drainage, if required, should be put in hand.

Site preparation may involve one or more of the following activities:

- site clearance
- stripping topsoil
- treatment of ditches and watercourses
- treatment of underground and man made cavities
- treatment of subsoil

For more detailed information refer to Clauses 8.2.2 to 8.2.6 of BS 6031.

6. CUTTINGS

Excavation of cuts shall be made so that drainage is provided. All loose stones, boulders, roots, stumps and unstable ground shall be removed. Where soft, unstable or otherwise unsuitable materials are encountered at the bottom of cut, excavation shall continue to suitable soil and the cut then refilled to the required elevation with materials specified for backfill and compacted as specified for embankments.

Where the nature of the project allows, the position and alignment of a cutting in plan and the geometry of the cutting in cross section should take the following factors into account:

- potentially unstable ground in the vicinity;
- the stability of the cutting slope itself;
- wind effects, including snow drifting, sand deposition and scouring;
- maintenance;
- visual and other amenity aspects.

Drainage may be required at the top of a cutting slope to intercept surface water flowing towards the excavation, and so to prevent the water from discharging down the slope. This drainage can take the form of open channels, ditches or piped drains.

Pipe drains should not be less than 150 mm in diameter.

When acting as subsoil drain they are laid with open joints and may be bedded on concrete.

Where cuttings are constructed in soil containing sulfates injurious to Portland cement, concrete or mortar, the use of a sulfate-resisting cement should be considered for all concrete work and earthenware, or PVC pipes should be used instead of concrete pipes.

Where the available width between the toe of a cutting and the site boundary is insufficient to accommodate a safe slope for the full height of the cutting, it is necessary to introduce support in the form of a retaining wall in order to reduce the slope, or to adopt some other means of artificially creating a steepened slope.

Suitable forms of retaining walls to give support to a cutting slope are:

- gravity walls in mass concrete, brickwork, or stone masonry
- reinforced concrete walls of L or T-shape
- reinforced concrete buttress walls
- reinforced concrete counterfort walls
- reinforced concrete diaphragm walls (cantilevered or anchored)
- reinforced earth walls
- steel sheet piling (cantilevered or anchored)
- crib walls, e.g. precast concrete sections, disused rubber vehicle tyres
- gabions (stone-filled wire mesh baskets)

For more information about retaining walls refer to IPS-E-CE-140.

Other methods of support include but are not limited to the following:

- Ground Anchors
- Rock Bolting
- Dental treatment of rock faces
- Improvements to soil parameters

For more detailed information refer to Clause 6.5.5 of BS 6031: 1981.

7. EMBANKMENTS AND GENERAL FILLING

7.1 General Factors

Embankments should be constructed in layers. The specified thickness of each layer varies from 150-300 mm. Compaction of each layer may be accomplished with steel rollers, rubber-wheel rollers, sheepfoot rollers, vibrating rollers etc., depending on the materials being used. In some cases, extra-heavy compactors are employed.

When the available excavated material is not sufficient for the embankments, material from outside borrow pits must be brought to the site.

Before embankments are placed, it is necessary to strip off organic topsoil. Excessive future settlement can be avoided by compacting the existing ground before placing new fill. When new embankment lies against a slope, slippage can be avoided by benching, which is done by plowing flat slopes or terracing steep slopes.

Frequent soil tests should be made as compaction proceeds to insure that the minimum specified compaction value is obtained.

When necessary, the fill should be moistened by watering equipment. Water content of the fill material is less critical in granular fills than in fills having fine materials such as silts and clays. Such fills may be rejected when the water content cannot be brought to the specified optimum value because of uncontrollable factors such as wet climate.

7.2 Materials

The strength, deformation and moisture susceptibility of foundation and fill material should be established by means of:

- in-situ testing as part of site investigation;
- laboratory tests;
- instrumental field trials.

In the case of large rock embankments field trials, should be carried out in order to determine the best procedures for forming a satisfactory embankment.

Factors which may give rise to settlement problems within the foundation materials include:

- cohesive soils of high compressibility;
- peat;
- changes in ground water levels due to extraction by pumping or natural causes;
- underground voids such as old mine workings or natural cavities;
- active mining including salt extraction by pumping. The site investigation should be directed towards the discovery of such features.

For more detailed information refer to Clause 7.3.2 of BS 6031: 1981 and IPS-E-CE-110 "Soil Engineering".

7.3 Drainage

Drainage systems to deal separately with subsoil water and surface water run-off are essential from both the construction point of view and for the future stability of the embankment or general filled area.

Generally these systems consist of pre-earthworks drainage, temporary drainage during construction, drainage measures to improve and maintain the stability of embankment or general filling which include vertical and horizontal drainage and permanent drainage.

When drains are constructed before completing the fill, the remaining fill in the vicinity of the pipes should be placed and compacted in such a way as not to overstress the pipe.

7.4 Special Site Conditions

The various conditions affecting embankments or general fill are:

- 1) fill deposited in water;
- 2) embankments on soft ground;
- 3) embankments on sloping ground;
- 4) embankments over quarried ground;
- 5) embankments on existing filled ground, and
- 6) embankments over mine workings and other underground voids.

The above site conditions and their remedies are discussed in Clause 7.5 of BS 6031:1981.

8. EXCAVATION AND FILLING

8.1 General Considerations

Routes and vehicles should be selected and loads restricted or distributed, so that no unnecessary damage is caused to highways and bridges by the movement of plant and materials by extraordinary traffic to and from the project.

Where access is required to and from the public highway, its size and form has to be agreed with the authorities of Ministry of Roads and Transportation. All existing highways should be kept clean and clear of all dust, mud or other debris and the requirements of the highway authority in this respect should be complied with.

8.2 Location of Borrow Areas

Borrow areas should be sited as near as possible to the area to be filled, so that direct access to the site can be achieved as far as possible without use of public roads. Proper site investigation should be carried out so that the quality of the materials is correctly ascertained and the quantities available estimated to within reasonable limits. It is important to ensure in the siting of borrow pits that landslides or other movements are not initiated or reactivated.

8.3 Excavation

Method of excavation suitable for a particular site depends on several factors of which the most important are the nature of the materials to be excavated, the prevailing weather conditions, and the type of transport to be used. In general, excavations may be divided into the following categories:

- excavation in cutting or borrow pit areas ;
- excavation below water;
- excavation in rock.

8.4 Types of Excavations

Classification of excavations with respect to type of excavated material is as follows:

- Topsoil excavation
- Earth excavation
- Muck excavation
- Rock excavation
- Unclassified excavation

8.5 Classification of Excavation in Accordance with the Purpose

Excavation also may be classified in accordance with the purpose of the work as follows:

- Stripping
- Roadway excavation
- Drainage excavation
- Bridge excavation
- Channel excavation
- Footing excavation
- Barrow excavation

8.6 Earth Moving

The excavated material should be moved as quickly and economically as possible to its final destination which may be on or off the construction site.

For further details refer to Clause 8.4 of BS 6031: 1981.

8.7 Deposition and Spreading

The excavated material should be deposited in layers, spread as evenly as practicable and compacted. The thickness of the layers depends on the type of material and its behavior under compaction and on the compacting equipment available.

8.7.1 Filling

Fill shall be built up evenly over the full width of the area with a slope sufficient to allow efficient surface drainage of rain water and prevent ponding.

The placing of fill shall not commence until the area to be filled has been inspected and approved by the AR*.

* AR= Authorized Representative of the owner.

8.7.2 Rockfill

Rockfill should be placed in layer thicknesses compatible with the available rock moving plant, compaction plant and the properties of the rock itself.

Unsuitable materials, including weathered rock and rock susceptible to deterioration, should be removed prior to commencing rockfill operation.

9. COMPACTION

9.1 General

The degree of compaction necessary is determined by the engineering properties required for the fill to carry out its design function. It can be specified in terms of any of the following properties of the compacted material:

- minimum dry density;
- maximum air voids associated with a maximum moisture content;
- minimum percentage of the maximum dry density obtained from a standard laboratory test;
- minimum shear strength.

9.2 Test for Compaction of Earthworks

The tests which are normally carried out in connection with earthworks compaction are mentioned in IPS-E-CE-110.

They enable shear strength and density/moisture content relationship both in the field and in the laboratory to be established.

9.3 Methods of Compaction

The objective of the operation is to achieve the required degree of compaction by the most economical means.

The method of compaction employed depends upon:

- soil type, including its grading and moisture content at the time of compaction;
- specified compaction requirements;
- total quantity of material and rate at which it is to be compacted;
- geometry of proposed earthworks;
- environmental restrictions (e.g. noise);

The various types of compaction plant which are commonly available are described in clause 10 and a guide to their suitability for different soil types is given in Table 1.

TABLE 1 - TYPICAL COMPACTION CHARACTERISTICS FOR NATURAL SOILS, ROCKS AND ARTIFICIAL MATERIALS USED IN EARTHWORK CONSTRUCTION

The information in this Table should be taken only as a general guide. When the material performance cannot be predicted, it may be established by earthwork trials. This Table is applicable only to fill placed and compacted in layers. It is not applicable to deep compaction of materials in-situ.

Material	Major divisions	Subgroups	Suitable type of compaction plant	Minimum number of passes for satisfactory compaction	Maximum thickness of compacted layer (mm)	Remarks
Rock-like materials	Natural rocks	All rock fill (except chalk)	Heavy vibratory roller not less than 180 kg per 100 mm of roll Grid roller not less than 800 kg per 100 mm of roll Self-propelled tampering rollers	4 to 12	500 to 1500 depending on plant used	If well graded or easily broken down then this can be classified as a coarse grained soil for the purpose of compaction. The maximum diameter of the rock fragments should not exceed two-thirds of the layer thickness
		Chalk	See remarks	3	500	This material can be very sensitive to weight and operation of compacting and spreading plant. Less compactive effort is needed than with other rocks
Artificial	Waste material	Burnt and unburnt colliery shale	Vibratory roller Smooth wheeled roller Self-propelled tampering roller	4 to 12 depending on weight of plant	300	
		Pulverized fuel ash	Vibratory roller Self-propelled tampering roller Smooth wheeled roller Pneumatic tyred roller			Includes lagoon and furnace bottom ash
		Broken concrete, bricks, steelworks slag, etc.	Heavy vibratory roller Self-propelled tampering roller Smooth wheeled roller			Non-processed sulphide brick slag should be used with caution
Coarse soils	Gravel sand gravelly soils	Well graded gravel and gravel/sand mixtures: little or no fines	Grid roller over 540 kg per 100 mm of roll	3 to 12 depending on type of plant	75 to 275 depending on type of plant	
		Well graded gravel/sand mixtures with excellent clay binder	Pneumatic tyred over 2000 kg per wheel Vibratory plate compactor over 1100 kg/m ² of baseplate Smooth wheeled roller Vibratory roller Vibro-tamper Self-propelled tampering roller			
Sands and sandy soils	Sands and sandy soils	Gravel with excess fines, silty gravel, clayey gravel, poorly graded gravel/sand/clay mixtures				
		Well graded sands and gravelly sands, little or no fines Well graded sands with excellent clay binder				

(to be continued)

TABLE 1 - (continued)

Material	Major divisions	Subgroups	Suitable type of compaction plant	Minimum number of passes for satisfactory compaction	Maximum thickness of compacted layer (mm)	Remarks
Coarse soils (continued)	Uniform sands and gravels	Uniform gravels; little or no fines	Smooth wheeled roller below 500 kg per 100 mm of roll	3 to 16 depending on type of plant	75 to 300 depending on type of plant	
		Uniform sands; little or no fines Poorly graded sands, little or no fines Sands with fines, silty sands, clayey sands Poorly graded sand/clay mixtures	Grid roller below 540 kg per 100 mm of roll Pneumatic tyred roller below 1500 kg per wheel Vibratory roller Vibrating plate compactor Vibro-tamper			
Fine soils	Soils having low plasticity	Sils (inorganic) and very fine sands, rock silty or clayey fine sands with slight plasticity Clayey sils (inorganic) Organic sils of low plasticity	Sheepsfoot roller Smooth wheeled roller Pneumatic tyred roller Vibratory roller over 70 kg per 100 mm of roll Vibratory plate compactor over 1400 kg/m ² of base plate Vibro-tamper Power rammer	4 to 8 depending on type of plant	100 to 450 depending on type of plant	If moisture content is low it may be preferable to use a vibratory roller Sheepsfoot rollers are best suited to soils at a moisture content below their plastic limit
		Silty and sandy clays (inorganic) of medium plasticity Clays (inorganic) of medium plasticity Organic clays of medium plasticity				
	Soils having medium plasticity					Generally unsuitable for earthworks
Soils having high plasticity		Micaceous of diatomaceous fine sandy and silty soils, plastic silts Clay (inorganic) of high plasticity, fat clays Organic clays of high plasticity				Should only be used when circumstances are favorable
						Should not be used for earthworks

Note:

If earthworks trials are carried out the number of field density tests on the compacted materials should be related to the variability of the soils and the standard deviation of the results obtained.

9.4 Soil Compaction Characteristics

9.4.1 General

For compaction purposes, soils can be classified into the groups described in 9.4.2 to 9.4.5.

9.4.2 Rockfill

Rockfill should be compacted in thick layers with the maximum diameter of the rock fragments not exceeding two thirds of the layer thickness.

9.4.3 Granular soils

Granular soils are generally defined as non-cohesive or coarse soils with high permeability containing a small percentage of fines (say less than 10% smaller than 0.06 mm).

9.4.4 Cohesive fine soils

9.4.4.1 Silts

The moisture content has a great influence on both the strength and compaction characteristics of silty soils.

9.4.4.2 Clays

The compaction characteristics of clay are highly dependent on moisture content in that a greater compactive effort is required as the moisture content reduces. It may be necessary to adopt thinner layers and more passes by heavier compaction plant, specifically sheep foot rollers, than required for granular materials. Where clays are compacted at the upper limit of moisture content feasible for compaction, there is a danger of instability as a result of excess pore water pressures caused by such compaction.

9.4.5 Special fills-waste materials

Such materials are by their nature extremely variable and should always be subject to site trials to determine the compaction specification.

9.5 Control of Compaction in the Field

The following operations, which influence the degree of compaction, should be monitored:

- forming the correct depth of layer for each material type;
- segregation of materials where different compaction required;
- routing of earth-moving plant to avoid uneven compaction of any area of the fill;
- correct number of passes being given to each layer of fill by compaction plant;
- filling being placed correctly to enable full compaction of the edge of the embankment to be achieved;
- correct operation of compaction plant, particularly vibratory plant;
- maintenance of a free-draining surface during fill placement.

In addition the moisture content and the density and/or shear strength of the resulting earthworks should be periodically checked.

9.6 Compaction Adjacent to Structures

Earthworks operations adjacent to structures are frequently carried out separately from the main earthworks operations and can be considered in the following categories:

9.6.1 Culverts

Filling should be brought up and compacted uniformly on both sides of culverts to avoid unequal loading of the structure. Filling over the top should be carried out under close supervision to avoid unacceptable point loading's due to construction plant or fill containing material which may damage the structure.

9.6.2 Abutments and retaining walls

It is essential that the material placed behind structures is of a type that can be compacted to such a degree that only insignificant differential settlement occurs subsequently. This frequently necessitates the exclusion of naturally arising cohesive materials and certain weak rocks such as chalk.

9.6.3 Special types of fill

The Engineer should specify special types of fill, such as selected granular materials, pulverized fly ash or lean concrete in the immediate area of the structure. Satisfactory compaction to reduce to a minimum differential settlement between backfill and structure is important enough to warrant the additional expense. Both the type of compaction plant and the method of compaction may have to be modified from those used in general embankment construction. The possible development of horizontal forces on foundations or on piles should be considered.

9.6.4 Obstructions

These can take the form of manhole shafts, piers for bridges, columns etc., or temporary obstructions such as poles or towers supporting overhead cables or settlement monitoring equipment.

In order to obtain the required compaction around the obstruction, it is usually necessary to employ suitable supplementary compaction plant which is able to operate efficiently in these conditions without damage to the obstruction.

10. THE OPERATION OF CONSTRUCTION PLANT FOR EARTHWORKS

10.1 Classification of Plant

The various types of plant are described briefly in Appendix A in relation to the conditions and soils most appropriate to their use.

10.2 Particular Factors Affecting Earth-Moving Plant

The total quantity of material requiring to be excavated should be considered in terms of the following:

- quantities arising from individual excavations and the times at which these excavations can be carried out;
- the individual destinations for the material from each excavation;
- the haulage routes and the likely variation in condition of each haul road from the point of excavation to the point of deposition;
- the nature of the material, whether it is in a loose or dense state, whether it is weather-susceptible and whether it will be necessary to lower the water table in order to excavate it;

- the feasibility of excavating material by equipment standing or running across the area, or only by equipment on prepared foundations or on stable soil at ground level;
- the suitability of the material for rubber-tyred plant (the ground may be abrasive to tyres or so soft that only tracked plant can operate);
- the depth of the excavation, access into the excavation and methods of support, if any, around the perimeter of the excavation.

10.3 Preparation for Excavation

The extent of the work should be assessed, the perimeter details decided and then the excavation area and perimeter set out. Reference pegs and profiles should be established clear of the excavations and associated works so that the position of the operation is never in doubt, and in such a way that the operators of the plant and those in attendance on them can readily assess the formation level and other details of the shape to be achieved. It is necessary to take steps to avoid stoppages. These stoppages may occur because of the presence of obstructions in the ground, usually at higher level, or the accumulation of water. Possible obstructions include tree stumps and heavy roots, foundations of buildings or other structures which have been demolished, large boulders, and waste deposits. It is usually preferable to take steps before commencing the main excavation to remove these obstructions so that the plant may proceed without hindrance.

10.4 Excavation and Earth-Moving Plant

Construction plant suitable for excavation is described in Appendix A of BS 6031: 1981. The most commonly employed method of earth-moving is by the use of lorries, dumpers and the like. The choice is influenced in part by any need to travel along public highways and/or the need to dispose of material away from the site which it arises. For hauls over 1000 m, large dump truck or lorry transport are usually employed.

Earth-moving can also utilize transport by rail, barge or ship. When barges or ships are used the material is normally unloaded by grabs. Bottom-dumping barges are economical for placing fill in standing water.

10.5 Compaction Equipment

The types of compaction plant in common use are described in Appendix A of BS 6031: 1981.

11. TRENCHES, PITS AND SHAFTS

11.1 Temporary Support of Excavations

For temporary supports timber, steel sections or precast reinforced concrete can be used. The selection of the method of support is largely influenced by the type of ground encountered and type of the plant used for excavation. The amount of re-use expected from the components are also factors to be considered. All supported excavations should be provided with guard-rails, hand rails, walkaways, staging and ladders in accordance with construction requirements. The following types of support are commonly used:

- Poling boards [Figs. 1 and 2, 3(d) and 4(a)]
- Horizontal sheeting (Fig. 5)
- Runners (Fig. 3)
- Sheet piling (Figs. 6 and 7)
- Movable shoring systems (Figs. 1, 2, 3, 6 and 7)

11.2 Effect of Width

The following methods for supporting the sheeting, walings or soldiers can be used depending on the width of the excavation.

- I) Trenches up to about 6 m wide can be strutted from side to side by single timber or steel struts;
- II) Trenches exceeding about 6 m in width require the use of king piles or soldiers to permit the use of two or more single lengths of timber to span the width of the trench thereby reducing the effective length of the strut. Alternatively trenches 6 m or more in width can be strutted with steel or reinforced concrete members with or without the need for restraint by king piles;
- III) For excavations which are so wide that support of the sheeting by walings and struts would be uneconomical, one of the following methods can be used:
 - 1) Cutting of earth faces to a slope so that they are stable without timbering.
 - 2) Supporting the sheeting by raking shores taking their reaction from the ground slab concrete previously constructed within the interior of the excavation.
 - 3) Tying back the walings or soldiers by means of anchors restrained by the ground behind the excavation face. Where cast-in-place concrete walls are used the anchors can be connected directly to the walls without the need for horizontal walings.
 - 4) Constructing the permanent earth support in a trench around the perimeter of the excavation. This acts as retaining wall subsequently allowing the ground in the interior of the excavation (the dumping) to be removed without further temporary support.

The retaining wall should be designed to be self-supporting at this stage, and should not rely for stability on a basement floor or ground floor slab constructed at a later stage of the work.

- 5) Constructing permanent support across the full width of the excavation in the form of the ground floor slabs or intermediate lower ground floor slabs of a deep basement. Strutting by this method is followed by removing the soil from below the slabs through openings left for this purpose. Restraint to buckling of the slabs is normally required and this can consist of the permanent columns of the building, or temporary bracing can be provided.

This method is most economical when used in conjunction with permanent support to the sides of an excavation by means of in-situ concrete, diaphragm walls or contiguous bored and cast-in-place piling.

11.3 Supports for Excavations

For full information and description of the following supports for excavations refer to Clauses 13.1 to 13.1.9 of BS 6031: 1981.

- I) Support by poling boards or steel trench sheets
- II) Support by horizontal sheeting
- III) Support by runners
- IV) Sheet piling of excavations
- V) Adjustments of supports to enable the permanent work to be constructed
- VI) Maintenance of supports
- VII) Striking of supports

11.4 Backfilling

When excavated material is used for backfilling its moisture content and density, after compaction, should be as near as possible to that of the undisturbed soils, particularly with clays which may dry out or conversely become wet and soft when in the spoil heaps. Such material cannot be compacted satisfactorily and it is desirable to replace it by granular backfill or lean concrete wherever load-bearing capacity or minimum settlement are important. The compaction of the imported backfill has to be undertaken with care, each layer being well rammed or vibrated as described in Clause 9. Space left by drawing timbers should be properly filled in.

Where it is necessary to place fill through water, only coarse granular material should be used. Concrete placed in bags can be used where load-bearing capacity is required from underwater fill.

In water-bearing ground the space between the backfilled excavation and the permanent structure may act as a reservoir in which ground water can accumulate.

The effect of such impounded water on the permanent structure or on existing adjacent works should be considered, and drainage should be undertaken to control ground water levels. Existing land drainage systems intersected by the excavation should be properly reinstated or diverted around permanent underground structures before the backfilling is completed.

If fill of suitable quality is not available it may be advisable to use lean concrete instead. Consideration should also be given to the use of flexible joints in new pipework or in connections to existing pipework to accommodate settlement in the backfill or from the permanent structure.

11.5 Trenches

11.5.1 General

In adopting the method of excavation the following factors should be considered;

- 1) Purpose and location of the trench
- 2) Size of the trench
- 3) Trench opening
- 4) Nature of ground
- 5) Removal of ground water
- 6) Statutory obligations
- 7) Obstructions

For more detailed information refer to clause 12 of BS 6031: 1981.

11.5.2 Excavation procedure

11.5.2.1 Methods available

The principal ways in which a trench may be excavated are:

- a) a short section of trench is opened at a time and the work is carried out by a single gang. This is the normal method for small pipes and sewers;
- b) a longer section of trench is kept open to enable a number of gangs to carry out all stages of the work concurrently. This spread method of working applies to pipelines in open country;
- c) the excavation for the full length of the trench proceeds stage by stage from top to bottom, frames being added as required until the final depth is reached. This is the normal method employed in digging for foundations at a considerable depth on a confined site, particularly in areas where there is surrounding property which must not be disturbed, when consideration should also be given to the need for underpinning the existing foundations.

11.5.2.2 Trenches with sloping sides

Any width or depth of trench may be constructed with sloping sides, provided that;

- a) the nature of the ground is suitable and the sides of the trench can stand up at a stable angle without support for the required time;
- b) dewatering of the ground can be effectively carried out to prevent the sides slipping or the trench flooding. This applies especially to water-bearing granular soils; and,
- c) the permanent work can be installed safely in the trench. In this connection it should be appreciated that the permanent work, e.g. a pipeline, may be subject to greater vertical loading and have less lateral support in a trench with sloping sides than in one with vertical sides;

If these conditions apply, all the excavation can be carried out mechanically by dragline, backacter, or scraper. This type of trench involves excavating and storing considerably more spoil than trenches with supported sides, but saving in cost and time can be made when using such mechanical equipment. A support-free trench is advantageous where long pipes are to be laid or where large cast-in-situ culverts or similar works have to be constructed. Fig. 9 (a) shows a trench of this type up to 5 m deep, and Fig. 9 (b) a similar trench between 5 m and 10 m deep. The dewatering system shown in this illustration would be adopted only if the trench were excavated below ground water level in a granular soil.

11.5.2.3 Trenches with vertical sides

Supports should be provided for all vertically sided trenches more than 1.2 m deep which men are required to enter. Supports should be inserted in a manner that does not involve risks to operatives due to instability of the sides of the trench. In bad or wet ground it may be necessary to drive sheet piles or poling boards before commencing the excavation.

If spoil is to be deposited alongside the trench as the work proceeds, it should be done in such a manner that it does not form a hazard in itself, or cause the trench sides to become unstable.

11.5.2.4 Bottoming of trenches

Whatever the permanent work, some hand trimming is usually necessary in the trench bottom. In most soils, therefore, the main excavation should cease above formation level, leaving the remainder to be trimmed and shaped accurately to line and level. During this operation it is desirable to avoid trampling or otherwise disturbing the soil at the formation level, particularly in clays, silts and fine sands. Depending upon the purpose of the trench it may be helpful in such soils, therefore, to lay gravel, broken stone or weak concrete as soon as the formation is exposed to form a protective layer. Ground water should meanwhile be kept below formation level.

In rock it is usually necessary to excavate to below formation level and then to place uniformly compacted sand or other fine granular material, or concrete, to produce a true bottom. Where the longitudinal gradient is steep, the material has to be sufficiently coarse to resist erosion by a permanent flow of ground water along the base of the trench.

11.5.3 Mechanical excavation of trenches

When mechanical excavating machines as described in Appendix A are used, the full depth and width of a trench is made in one cut from the surface to the bottom of the excavation, but the final trimming to levels is usually completed by hand. Temporary supports to the sides of the trench should be placed as quickly as possible as excavation proceeds. Operatives should not enter the trench until adequate protection has been provided. Ladders should be available at frequent intervals to allow safe access to the trench and easy egress in an emergency.

11.5.4 Hand excavation of trenches

When conditions make it impracticable to excavate mechanically, hand excavation becomes necessary. Such conditions include the following:

- ground too steep for a machine, or working space restricted (as in narrow streets);
- road and railway crossings where a machine would interfere with traffic;
- sites where cables, mains, drains and other obstructions are known to exist;
- paved surfaces or lawns where damage to the surface by a machine cannot be tolerated;
- very bad ground which is incapable of supporting the weight of a machine;
- when the job is small or where for any other reason it is more economical to use hand labor.

11.5.5 Methods of dewatering trenches

The various methods of removing water from excavations referred to in 12.2.3.3. of BS 6031:1981 are generally applicable to trenches.

11.5.6 Installation of permanent work or materials in trenches

Small drains or pipes and small quantities of concrete are usually lowered and placed by hand. Heavier units can be placed with the help of tripods or traveling gantries fitted with hand-operated chain blocks and tackle; with very long pipes "soldiering" arrangements are made in the timbering for the temporary removal of struts to allow the pipes to be lowered and placed in position (see Fig. 10). Alternatively the timbering system can be designed to permit the insertion of long pipes without the need to remove members.

Heavy items may be placed with mobile power-driven cranes traveling alongside the trench.

11.5.7 Backfilling

Refer to Clause 11.4 of this Standard.

11.6 Pits and Shafts

11.6.1 General

Pits and shafts are usually constructed on the principles described in Clause 13 of BS 6031:1981. Methods of excavation are governed by the confined space and by obstructions caused by timbering. These reduce the effectiveness of mechanical plant and may necessitate the adoption of specially designed equipment. Hand excavation followed by loading the spoil into buckets or trays may be more economical than machine excavation in small pits and shafts.

11.6.2 Methods of support of excavations

The choice of poling boards, runners, horizontal sheeting or sheet piling depends on the depth of excavation, the soil or rock conditions, and the purpose for which the pit or shaft is being dug. The top of the pit or shaft should be made large enough to allow for the combined set-in of all the waling frames where runners, or combined poling boards and runners, are used. Guard rails, hand rails or other safety measures are necessary around the pit or shaft at ground level. [See Figs. 4 (a) and 4 (b)].

11.6.3 Drainage

The various methods of removing water from excavations referred to in 12.2.3 of BS 6031 are generally applicable to pits and shafts. In water-bearing ground the most favorable working conditions are achieved by maintaining one or more temporary pumping sumps about 0.5 m below the general level of the excavation at all stages.

These methods of lowering ground water are described in BS 8004:1986.

11.6.4 Striking of supports and backfilling

These operations generally follow large excavation practice as described in 13.1.9 of BS 6031 and Clause 11.4 of this Standard. Care should be taken to avoid unbalanced loading either of the permanent structure or of the support.

11.6.5 Alternative methods of sinking

Medium and deep pits and shafts can often be sunk economically by one or a combination of the methods described below:

- well sinking;
- underpinning with segmental lining;
- cast-in-place concrete lining;
- steel lining installed by drilling methods;
- use of ground treatment processes.

For detailed information refer to BS 8004:1986.

12. EXCAVATION IN ROCK

12.1 General

Methods of breaking, loosening and excavating rock or other hard materials should be chosen according to the conditions prevailing, the hardness of the rock, the volume of excavation and the equipment available.

Drilling and blasting is usually the most effective and economical method of excavating a hard, massively bedded rock formation. Reference should be made to BS 5607. Blasting should not be used where:

- the site is enclosed or built up to an extent that protective measures against damage to buildings, services or other property through blast, vibration, flying material, and other hazards are not practicable;
- the site is adjacent to thoroughfares where blasting would cause undue inconvenience to the public or stoppage of traffic;
- the site adjoins buildings such as hospitals and schools where annoyance or health hazard would be caused to the occupants;
- blast or vibrations might cause instability of slopes;
- damage might be caused to excavation supports.

12.2 Rock Excavation by Mechanical or Hand Methods

Rock can be loosened by means of mechanical impact devices such as air-hydraulic, or diesel-operated hammers with chisel points, mounted on the bucket arm of an excavator or suspended from a crane.

Hand methods of loosening rock formations include the use of pneumatic breakers, picks, and wedges. When using mechanical hammers or handled pneumatic breakers it is desirable to excavate in the form of shallow benches. The levels of the benches may be governed by the bedding of the rock and the mechanical equipment available.

12.3 Rock Excavation by Drilling and Blasting

In the case of excavations for trenches, pits and shafts, the main requirement is to produce an effective blast with the minimum of explosive and the minimum of disturbance to the rock surrounding the completed excavation.

Care should be taken to cause the minimum noise and vibration and to avoid flying rock.

Maximum effectiveness is achieved using delay detonators in each row with the delay increasing with increasing distance from the face, thus keeping the burden or distance between the charge and the face to the optimum value for each row of holes (Fig. 12). The use of delayed charges also minimizes the noise and vibration.

When excavating in pits and shafts the center holes (cutholes) are fired first to blow the rock upwards. Then the concentric rings of holes are fired using delay detonators to blow the rock towards the crater formed by the cut hole charges. Finally the trimming hole charges around the periphery of the excavation are fired (Fig. 13), unless pre-splitting has been used previously to maintain the shaft profile.

In large pit excavations it is advantageous to keep the center of the excavation at a lower level than the surrounding area, thus forming circular benches from which the rock is blasted towards the center for removal by grab or shovel.

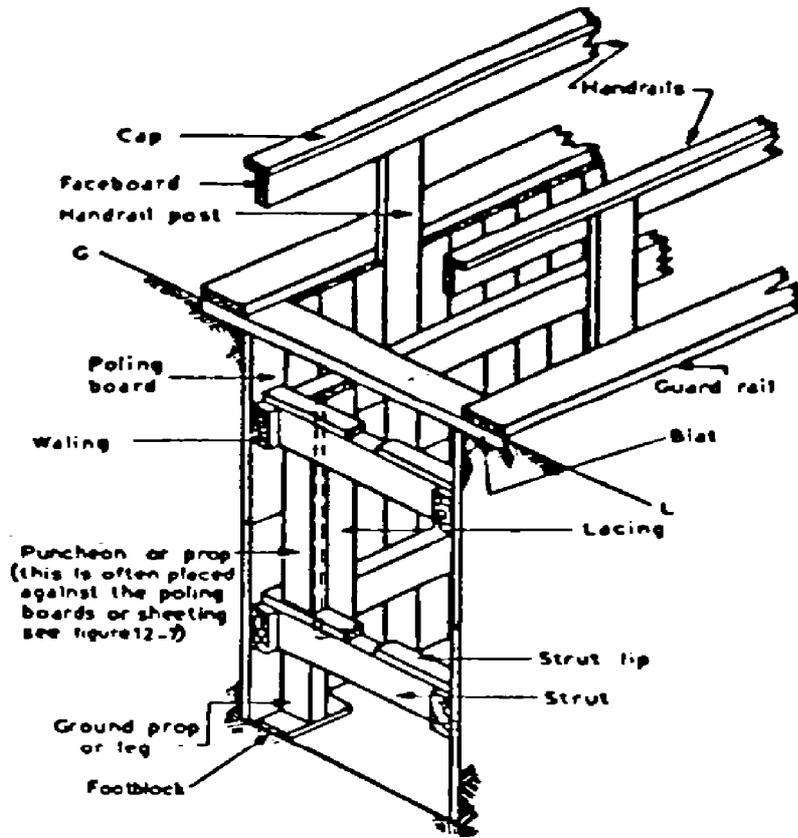
The storage and handling of explosive, the loading of shot holes, and the connecting and firing of the charges is to be undertaken with full regard to the safety of the operatives and the public and in compliance with the legislation governing the use of explosives.

In confined surroundings the ground surface over the charge should be covered with mats fabricated from sleepers, heavy wire netting, rope coils, or chains to prevent damage by flying rock. Adequate warning arrangements should be provided for all persons working in or passing through the danger zone, with control of vehicular traffic as necessary.

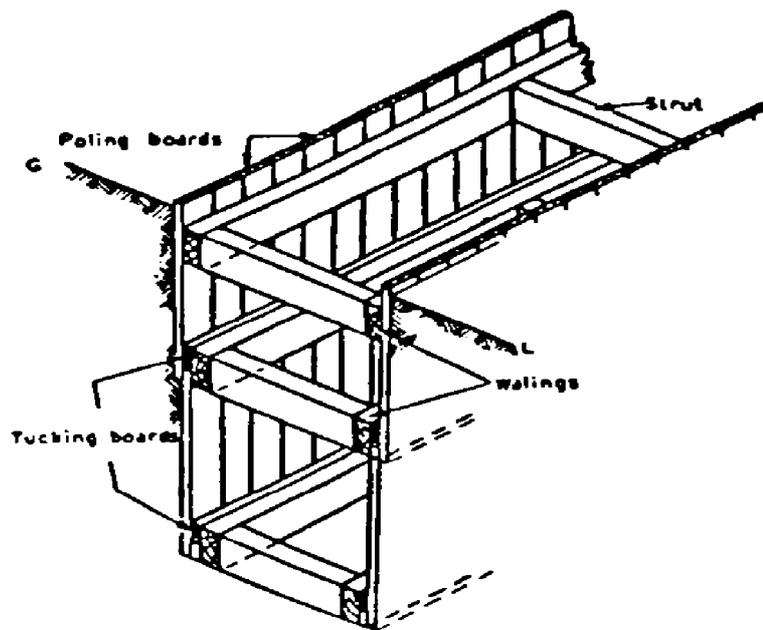
12.4 Removal of Loosened Rock

The rock loosened by ripping, by mechanical or hand-operated breakers or by explosives is removed by normal earth-moving equipment. Loosened rock in trenches is removed by backacter excavator, and in pits and shafts by grabbing.

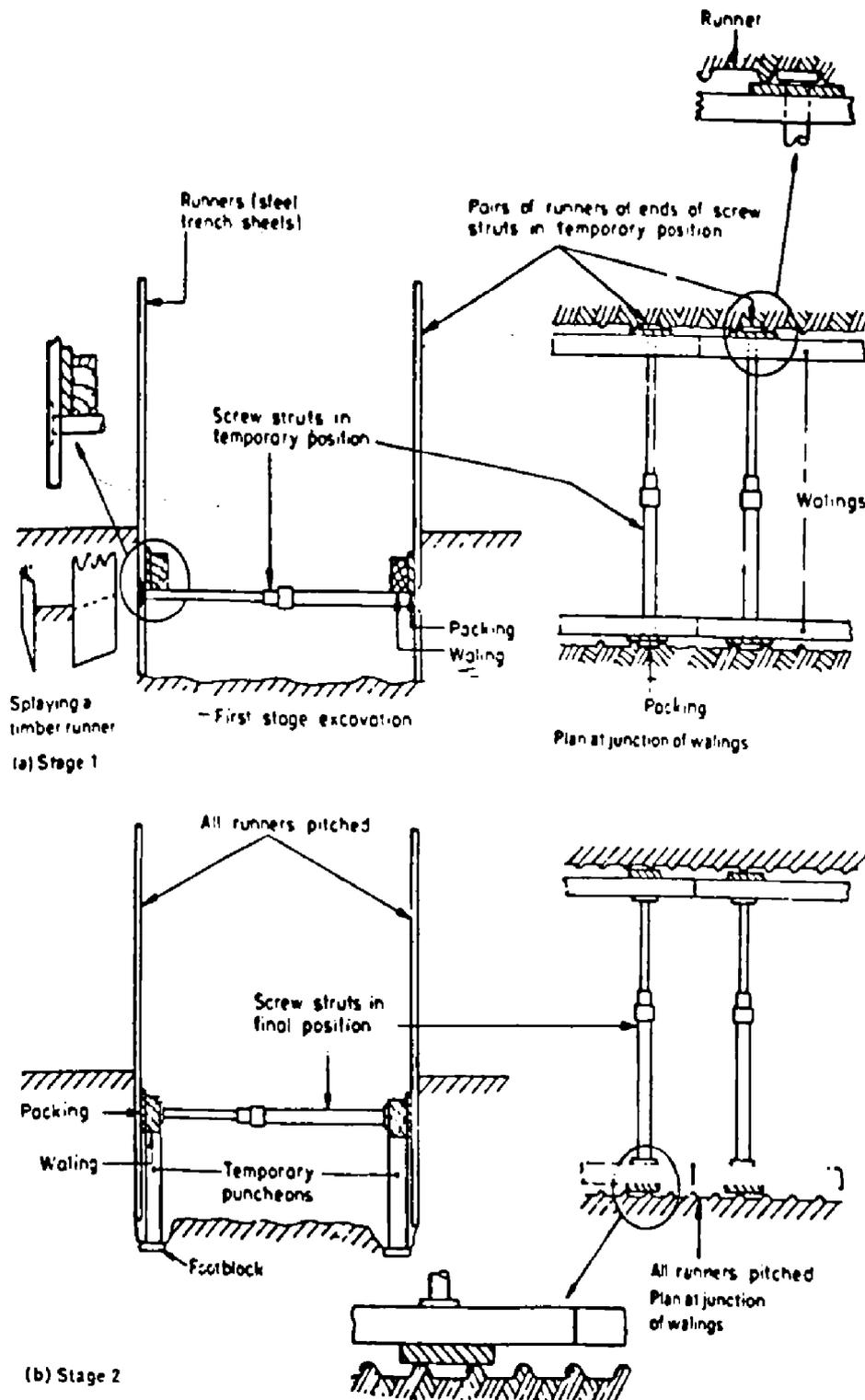
Loosened rock in large excavations is removed by front-end loading shovel or face shovel with suitable means of protecting operatives against material falling from the face. Alternatively it can be removed by dragline excavator standing on the bench above the cut.



TYPICAL SINGLE OR CENTER WALING POLING FRAME
Fig. 1

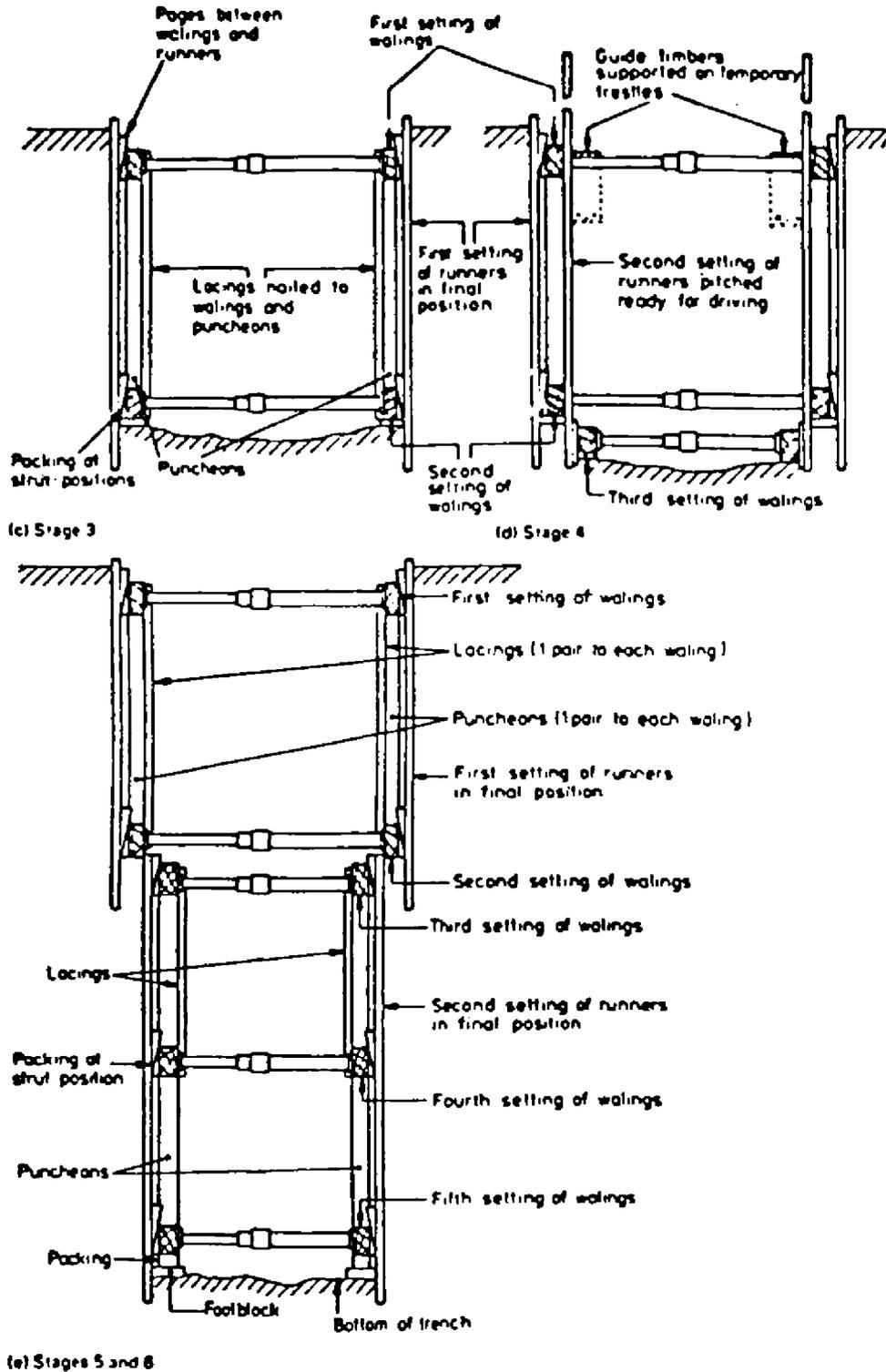


CLOSE POLING WITH TRUCKING FRAMES
Fig. 2

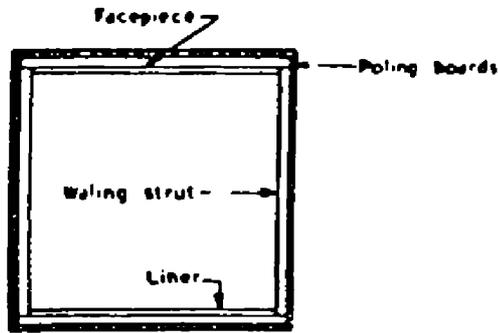


TRENCH EXCAVATION USING STEEL TRENCH SHEETS AS RUNNERS
Fig. 3

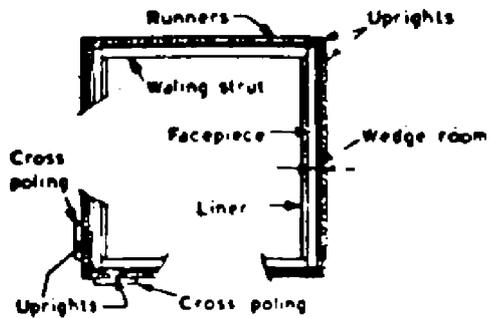
(to be continued)



TRENCH EXCAVATION USING STEEL TRENCH SHEETS AS RUNNERS
Fig. 3

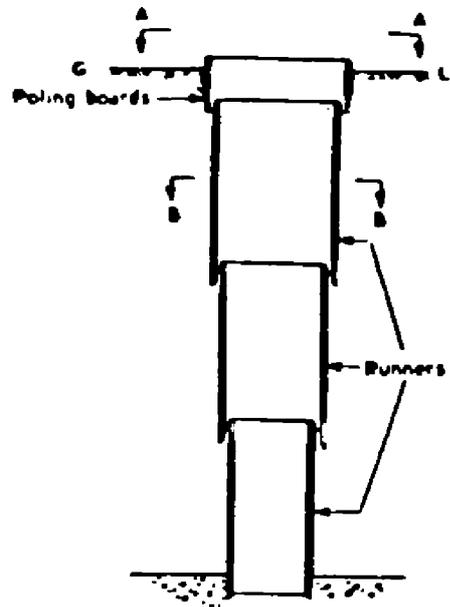


Plan on A-A
Pit or shaft frame for poling boards



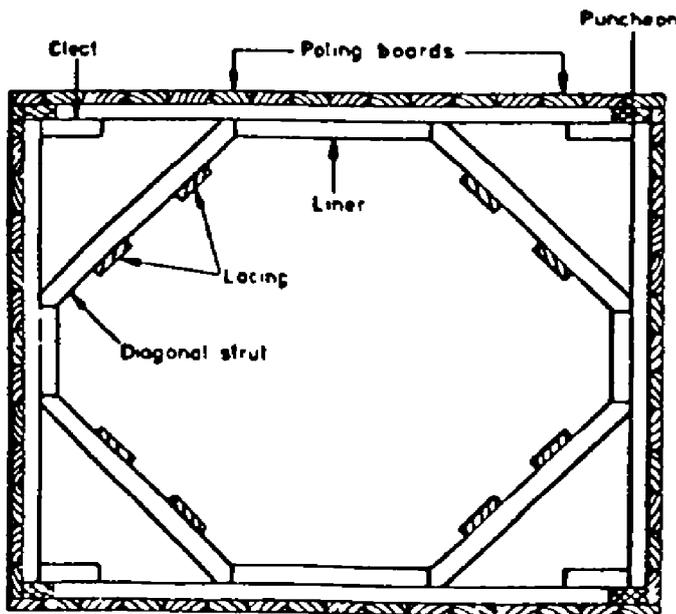
Plan on B-B
Pit or shaft frame for runners

The bottom left-hand corner detail shows position of uprights when ground is loose. corner uprights cannot be placed first, and cross poling is necessary



Waling and struts omitted for clarity

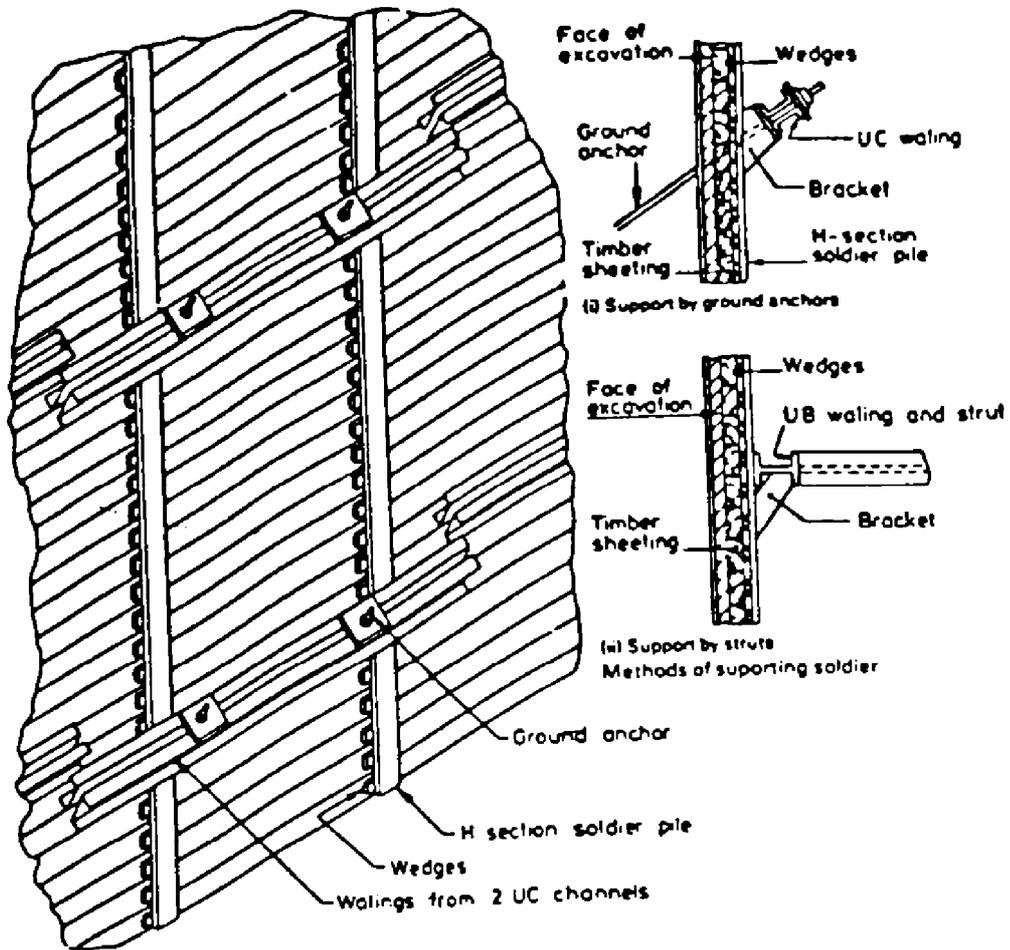
(a)



(b)

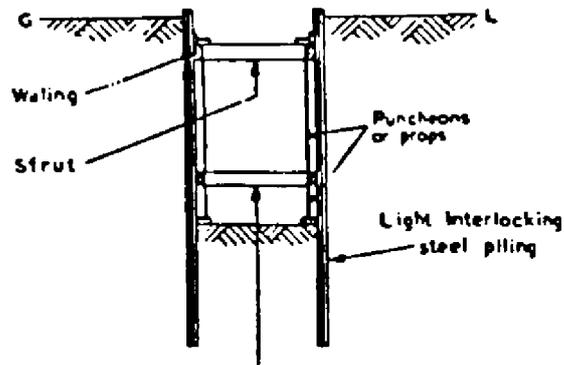
METHOD OF EXCAVATING ISOLATED PITS AND SHAFTS

Fig. 4

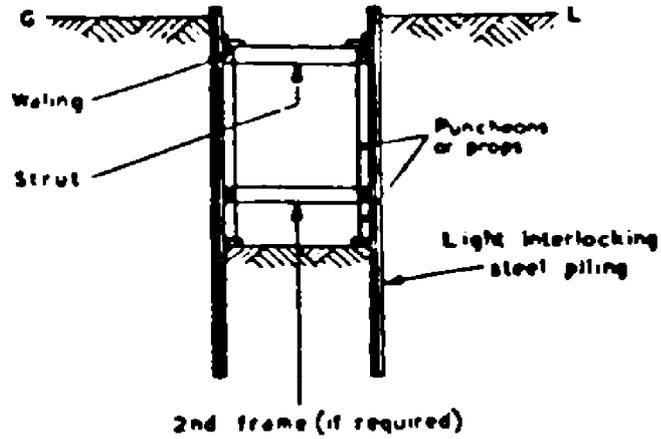


SUPPORT OF DEEP EXCAVATION BY HORIZONTAL SHEETING AND SOLDIER PILES

Fig. 5

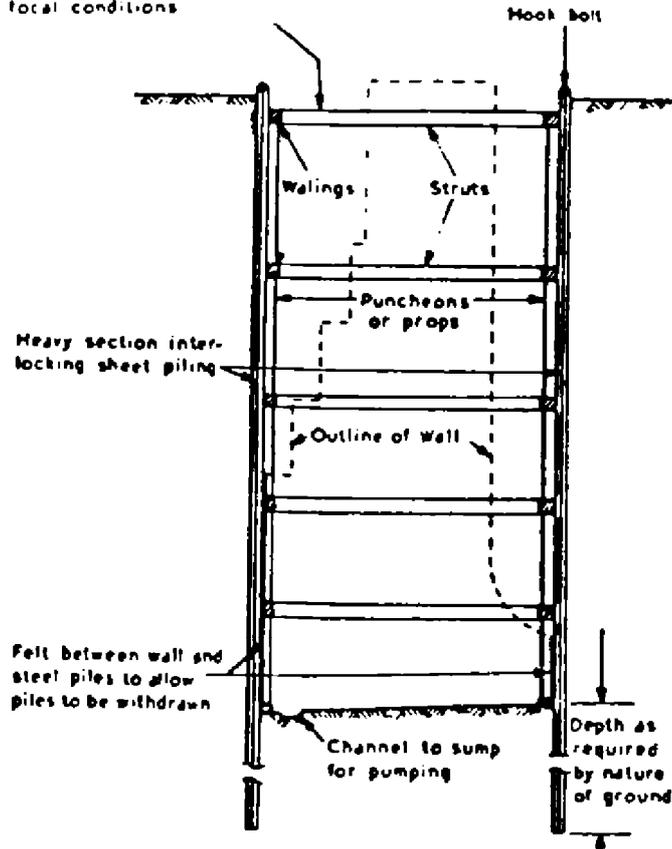


TYPICAL MEDIUM-DEPTH TRENCH WITH STEEL SHEET PILING IN BAD GROUND
 Fig. 6

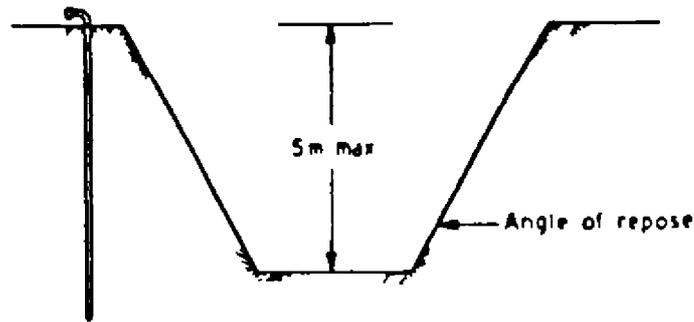


WIDE AND DEEP TRENCH USING STEEL SHEET PILING
 Fig. 7

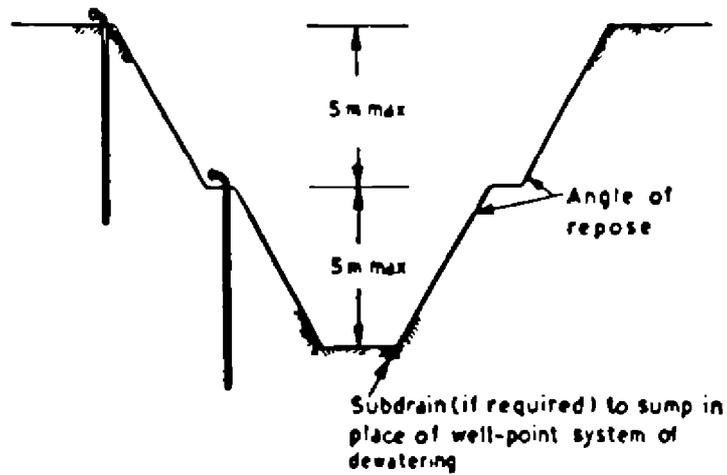
spacing of struts dependent
 on strength of steel piling used
 and nature of ground and
 local conditions



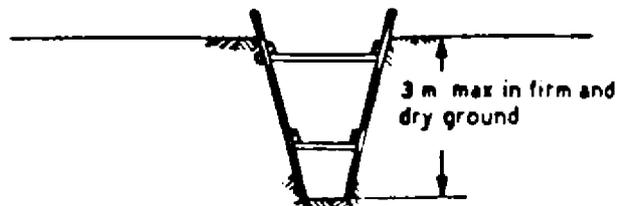
BLOCKINGS, CHOCKS OR CHOGS
Fig. 8



(a) Well-point dewatering Single stage (both sides if necessary)

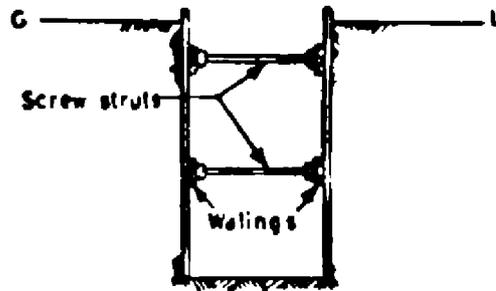


(b) Well-point dewatering Two stage (both sides if necessary)

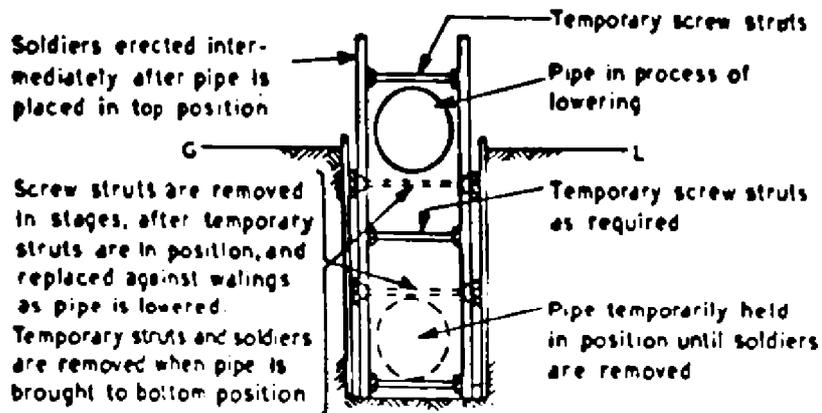


(c) Frames composed of suitable boards at appropriate centres

TRENCHES WITH SLOPING SIDES
Fig. 9

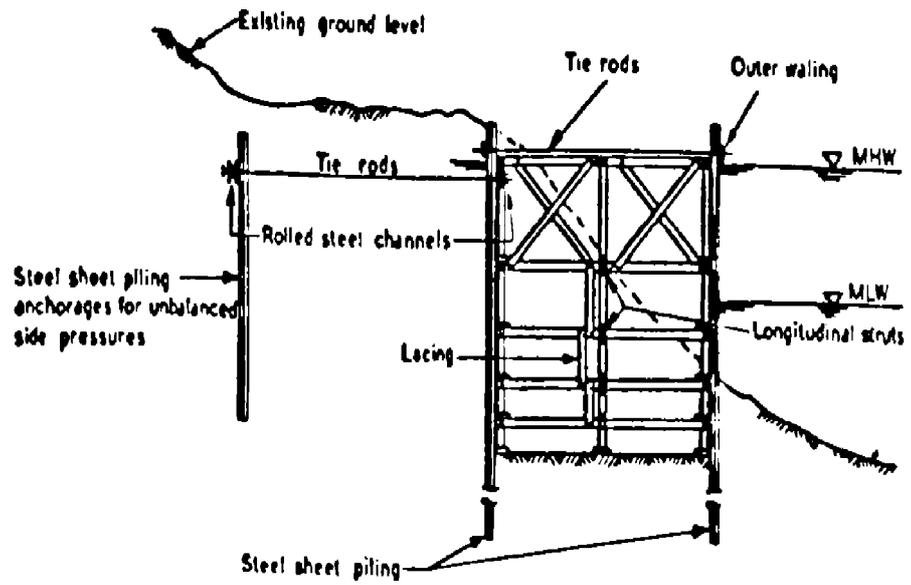


(a) Trench excavated and timbered

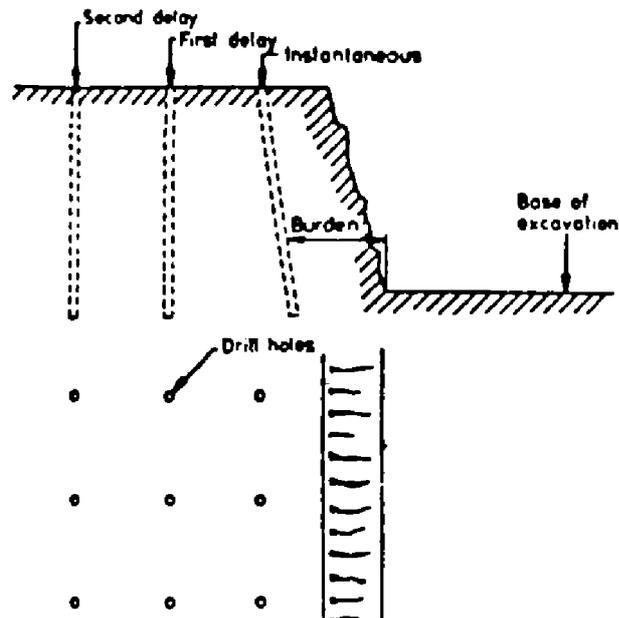


(b) Use of temporary soldiers and struts during lowering of pipe

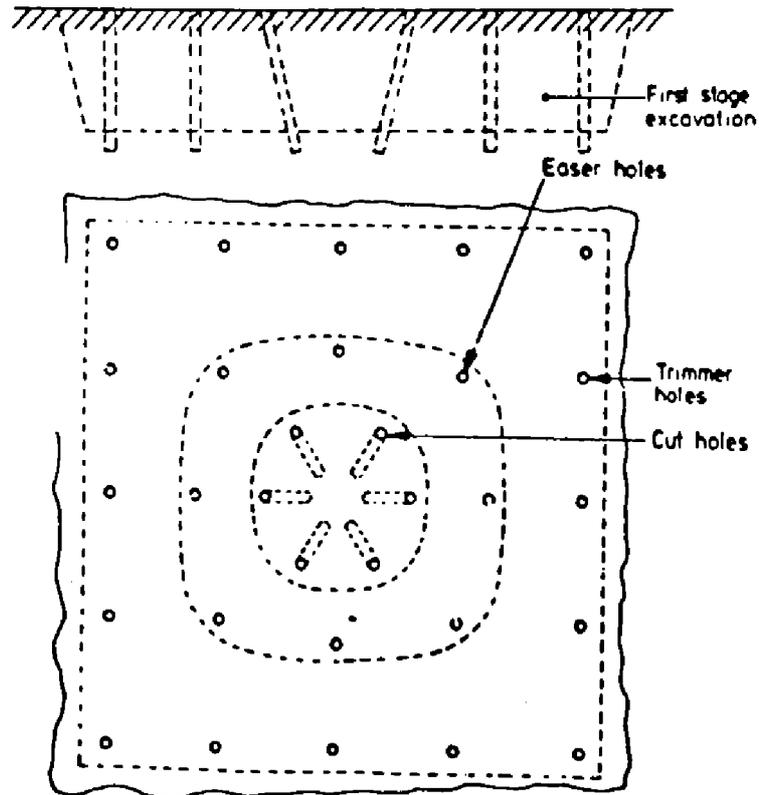
METHOD OF LOWERING LONG STEEL PIPES BY USE OF TEMPORARY STRUTTING
Fig. 10



TRENCH TIMBERING FOR QUAY WALLS, ETC.
Fig. 11



ROCK EXCAVATION BY DRILLING AND BLASTING: GENERAL EXCAVATION
Fig. 12



ROCK EXCAVATION BY DRILLING AND BLASTING: PITS AND SHAFTS
Fig. 13

APPENDICES

APPENDIX A

SELECTION OF CONSTRUCTION PLANT FOR EARTHWORKS

In selecting basic equipment to be used for earthworks the following should be considered;

- Types of material to be excavated
- Type and size of hauling equipment to be used
- Load-supporting ability of original ground
- Load-supporting ability of material to be excavated
- Volume of excavation to be moved
- Volume to be moved per unit of time
- Length of haul
- Type of haul road
- Type and volume of material to be used for compaction

Table 2 gives a summary on construction plant for earthworks. For more detailed information refer to Appendix A of BS 6031:1981.

TABLE 2 - SUMMARY OF CONSTRUCTION PLANT FOR EARTHWORK

DESCRIPTION		MAIN CATEGORIES	REMARKS
EXCAVATION PLANT	GENERAL PURPOSE EXCAVATORS	- DRAGLINE - BACKHOE - FACE SHOVEL - SKIMMER - GRAB - BACKACTER	REFER TO A.1.1 OF BS 6031: 1981
	FRONT END LOADERS		REFER TO A.1.2 OF THE ABOVE MENTIONED STANDARD
	TRACTORS AND SCRAPERS	- RUBBER TIRED SCRAPERS - BULLDOZERS	REFER TO CLAUSE A.1.3 OF BS 6031: 1981
	CONTINUOUS TRENCHING MACHINES		REFER TO CLAUSE A.1.4 OF BS 6031: 1981
	BUCKET WHEEL EXCAVATORS		REFER TO CLAUSE A.1.5 OF BS 6031: 1981
COMPACTION PLANT	- SMOOTH-WHEELED ROLLERS - PNEUMATIC-TYRED ROLLERS - GRID ROLLERS - SHEEPSFOOT ROLLERS - TAMPING ROLLER		REFER TO CLAUSES A.2.1 TO A.2.5 OF BS 6031: 1981
COMPACTION PLANT	VIBRATORY ROLLERS	- SINGLE ROLL PEDESTRIAN-CONTROLLED ROLLERS - DOUBLE ROLL PEDESTRIAN-CONTROLLED ROLLERS - TANDEM VIBRATING ROLLERS - DOUBLE-VIBRATING ROLLERS - TOWED VIBRATING ROLLERS - SELF PROPELLED VIBRATING ROLLERS - VIBRATING PLATE COMPACTORS AND TAMPERS	REFER TO SUBCLAUSE A.2.6.1 TO A.2.6.8 OF BS 6031: 1981