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CODE OF PRACTICE FOR SUBSURFACE INVESTIGATION FOR FOUNDATIONS

(*First Revision*)

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Indian Standard
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Indian Standard

CODE OF PRACTICE FOR SUBSURFACE INVESTIGATION FOR FOUNDATIONS

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 28 December 1979, after the draft finalized by the Soil Engineering and Rock Mechanics Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 A detailed investigation for site is essential before a design can be finalized. The object of subsurface and related site investigation is to provide the engineer or architect with as much information as possible about the existing conditions, for example, the exposed overburden, the course of a stream nearby, a rock outcrop or a hillock, vegetation, and other geological features of the area. It is equally important to know the subsoil conditions below a proposed structure.

0.2.1 The methods of subsurface investigation enable vertical sections of the strata to be drawn and samples to be tested, on the site or in a laboratory for determining shear strength parameters, bearing capacity of the soil, permeability, water table, type classification and other geophysical information in the field. This information, together with the normal topographical survey, provides the engineer with complete details of the site and enables him to prepare economical designs for the foundations.

0.2.2 Proper inspection and guidance in boring operations and investigations are essential to ensure that the required data are obtained.

0.3 Because of the complexity of natural deposits, no one method of exploration is best for all situations. The choice depends upon the nature of the material and on the purpose of the exploratory programme. This code is intended to summarize in a convenient form the information available so that the desirable information may be obtained. The code has been prepared in relation to conditions and practices existing in India. This standard was published in year 1962. Based on further data collected in past 18 years, this revision has been prepared.

0.4 Though this code is mainly intended to cover subsurface investigation for foundations of multi-storeyed buildings, most of the provisions are generally applicable to other civil engineering works, such as roads, air fields, bridges, marine works, etc. The following codes have been published so far to cover special aspects of investigation for specific works:

*IS : 4078-1980 Code of practice for indexing and storage of drill cores (*first revision*).

*IS : 4453-1980 Code of practice for exploration by pits, trenches, drifts and shafts (*first revision*).

*IS : 4464-1967 Code of practice for presentation of drilling information and core description in foundation investigation (*first revision*).

IS : 4651 (Part I)-1974 Code of practice for planning and design of ports and harbours : Part I Site investigation (*first revision*).

*IS : 5313-1980 Guide for core drilling observations (*first revision*).

*IS : 6926-1972 Code of practice for diamond core drilling for site investigation for river valley projects.

*IS : 6955-1973 Code of practice for subsurface exploration for earth and rockfill dams.

0.5 In the formulation of this standard, due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960†. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This code deals mainly with subsurface investigations for foundations of multi-storeyed buildings to determine,

a) Sequence and extent of each soil and rock stratum in the region likely to be affected by the proposed work,

b) Nature of each stratum and engineering properties of soil and rock which may affect design and mode of construction of proposed structures and their foundations, and

c) Location of ground water and possible corrosive effects of soil and water on foundation materials.

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*These relate to multi-purpose river valley projects.

†Rules for rounding off numerical values (*revised*).

1.1.1 Aspects relating to procuring representative samples of the soils and rocks, obtaining general information on geology, seismicity of the area, surface drainage, etc, and subsurface investigations for availability of construction materials are also mentioned briefly.

1.1.2 Most of the provisions of this code are also applicable to subsurface investigation of underground and overhead water tanks, swimming pools and (abutments of) bridges, roads, air fields, etc.

2. GENERAL

2.1 In areas which have already been developed, advantage should be taken of existing local knowledge, records of trial pits, bore holes, etc, in the vicinity, and the behaviour of existing structures, particularly those of a nature similar to that of the proposed structure. In such cases, exploration may be limited to checking that the expected soil conditions are those as in the neighbourhood.

2.2 If the existing information is not sufficient or is inconclusive the site should be explored in detail so as to obtain a knowledge of the type, uniformity, consistence, thickness, sequence and dip of the strata and of the ground water conditions.

2.2.1 *Site Reconnaissance* — Site reconnaissance would help in deciding future programme of field investigations, that is, to assess the need for preliminary or detailed investigations. This would also help in determining scope of work, methods of exploration to be adopted, field tests to be carried out and administrative arrangements required for the investigation. Where detailed published information on the geotechnical conditions is not available, an inspection of site and study of topographical features are helpful in getting information about soil, rock and ground-water conditions. Site reconnaissance includes a study of local topography, excavations, ravines, quarries, escarpments; evidence of erosion or landslides, behaviour of existing structures at or near the site; water level in streams, water courses and wells; flood marks; nature of vegetation; drainage pattern, location of seeps, springs and swamps. Information on some of these may be obtained from topographical maps, geological maps, pedological and soil survey maps, and aerial photographs.

2.2.1.1 Data regarding removal of overburden by excavation, erosion or land slides should be obtained. This gives an idea of the amount of pre-consolidation the soil strata has undergone. Similarly, data regarding recent fills is also important to study the consolidation characteristics of the fill as well as the original strata.

2.2.1.2 The type of flora affords at times some indication of the nature of the soil. The extent of swamp and superficial deposits and peats will usually be obvious. In general, such indications, while worth noting, require to be confirmed by actual exploration.

2.2.1.3 *Ground-water conditions* — The ground-water level fluctuates and will depend upon the permeability of the strata and the head causing the water to flow. The water level in streams and water courses, if any, in the neighbourhood, should be noted, but it may be misleading to take this as an indication of the depth of the water table in the ground. Wells at the site or in the vicinity give useful indications of the ground-water conditions. Flood marks of rivers may indicate former highest water levels. Tidal fluctuations may be of importance. There is also a possibility of there being several water tables at different levels, separated by impermeable strata, and some of this water may be subject to artesian head.

2.2.2 *Enquiries Regarding Earlier Use of the Site* — In certain cases the earlier uses of the site may have a very important bearing on proposed new works. This is particularly so in areas where there have been underground workings, such as worked-out ballast pits, quarries, old brick fields, coal mines and mineral workings. Enquiries should be made regarding the location of shafts and workings, particularly shallow ones, where there may be danger of collapse, if heavy new structures are superimposed.

2.2.2.1 The possibility of damage to sewers, conduits and drainage systems by subsidence should also be investigated.

2.2.3 Geophysical investigations of the site may be conducted at the reconnaissance stage since it provides a simple and quick means of getting useful information about stratifications. Depending on these information, detailed subsoil exploration should be planned. Important geophysical methods available for subsoil exploration are:

a) electrical resistivity method, and
b) seismic method.

2.2.3.1 *Electrical resistivity method* — The electrical resistivity method, in which the resistance to the flow of an electric current through the subsurface materials is measured at intervals of the ground surface, may be useful for the study of foundation problems and particularly for finding rock strata under deep soil cover.

2.2.3.2 *Seismic method* — The seismic method makes use of the variation of elastic properties of the strata which affect the velocity of shock waves travelling through them, thus providing a usable tool for dynamic elastic moduli determinations in addition to the mapping of the subsurface horizons. The required shock waves can be generated by hammer blows on the ground or by detonating a small charge of explosives. This method is quite useful in delineating the bedrock configuration and the geological structures in the subsurface.

2.3 Outline of Procedure

2.3.1 *Number and Disposition of Trial Pits and Borings* — The disposition and spacing of the trial pits and borings should be such as to reveal any major changes in thickness, depth or properties of the strata over the base area of the structure and its immediate surroundings. The number and spacing of bore holes or trial pits will depend upon the extent of the site and the nature of structures coming on it. For a compact building site covering an area of about 0·4 hectare, one bore hole or trial pit in each corner and one in the centre should be adequate. For smaller and less important buildings even one bore hole or trial pit in the centre will suffice. For very large areas covering industrial and residential colonies, the geological nature of the terrain will help in deciding the number of bore holes or trial pits. Cone penetration tests may be performed at every 50 m by dividing the area in a grid pattern and number of bore holes or trial pits decided by examining the variation in the penetration curves. The cone penetration tests may not be possible at sites having gravelly or boulderous strata. In such cases geophysical methods may be useful.

2.3.2 *Depth of Exploration* — The depth of exploration required depends on the type of proposed structure, its total weight, the size, shape and disposition of the loaded areas, soil profile, and the physical properties of the soil that constitutes each individual stratum. Normally, it should be one and a half times the width of the footing below foundation level. In certain cases, it may be necessary to take at least one bore hole or cone test or both to twice the width of the foundation. If a number of loaded areas are in close proximity the effect of each is additive. In such cases, the whole of the area may be considered as loaded and exploration should be carried out up to one and a half times the lower dimension. In weak soils, the exploration should be continued to a depth at which the loads can be carried by the stratum in question without undesirable settlement and shear failure. In any case, the depth to which seasonal variations affect the soil should be regarded as the minimum depth for the exploration of sites. But where industrial processes affect the soil characteristics this depth may be more. The presence of fast growing and water seeking trees also contributes to the weathering processes.

NOTE — Examples of fast growing and water seeking trees are Banyan (*Ficus bengalensis*), Pipal (*Ficus religiosa*) and Neem (*Azadirachta indica*).

2.3.2.1 An estimate of the variation with depth of the vertical normal stress in the soil arising from foundation loads may be made on the basis of elastic theory. The net loading intensity at any level below a foundation may be obtained approximately by assuming a spread of load of two vertical to one horizontal from all sides of the foundations, due allowance being made for the overlapping effects of load from closely spaced footings. The depth of exploration at the start of the work may be decided as given in Table 1, which may be modified as exploration proceeds, if required.

2.4 Importance of Ground-Water Tables

2.4.1 For most types of construction, water-logged ground is undesirable because of its low bearing capacity. On sites liable to be water-logged in

TABLE 1 DEPTH OF EXPLORATION

(*Clause* 2.3.2.1)

SL No.	TYPE OF FOUNDATION	DEPTH OF EXPLORATION (D)
i)	Isolated spread footing or raft	One and a half times the width (B) (*see* Fig. 1)
ii)	Adjacent footings with clear spacing less than twice the width	One and a half times the length (L) of the footing (*see* Fig. 1)
iii)	Adjacent rows of footings	*See* Fig. 1
iv)	Pile and well foundations	To a depth of one and a half times the width of structure from the bearing level (toe of pile or bottom of well)
v)	1. Road cuts	Equal to the bottom width of the cut
	2. Fill	Two metres below ground level or equal to the height of the fill whichever is greater

wet weather, it is desirable to determine the fluctuation of the water table in order to ascertain the directions of the natural drainage, and to obtain a clue to the design of intercepting drains to prevent the influx of ground water on to the site from higher ground. The seasonal variation in the level of water table should also be noted.

2.4.2 If in the earlier stages of investigations, dewatering problems are anticipated a detailed study should be carried out to ascertain the rate of flow and seepage.

2.4.3 For deep excavation, the location of water-bearing strata should be determined and the water pressure observed in each, so that necessary precautions may be taken during excavation, for example, artesian water in deep strata may give rise to considerable difficulties unless precautions are taken. An idea of the steady level of water should be obtained. Bore holes, which have been driven, may be used for this purpose, but since water levels in bore holes may not reach equilibrium for some time after boring, these should be measured 12 to 24 h after boring and compared with water levels in wells that may be available in the area. It is seldom necessary to make detailed ground-water observations in each one of a group of closely spaced bore holes but sufficient observations should be made to establish the general shape of the ground-water table; however, observations should always be made in the first boring of the group. The minimum and maximum ground-water levels should be obtained from local sources and wells in the area would also give useful information in this regard.

NOTE — For methods of determination of water level in a bore hole, IS : 6935-1973* and for methods of determination of permeability of overburden, IS : 5529 (Part I)-1969† may be referred.

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*Method of determination of water level in bore hole.

†Code of practice for *in-situ* permeability tests: Part I Tests in overburden.

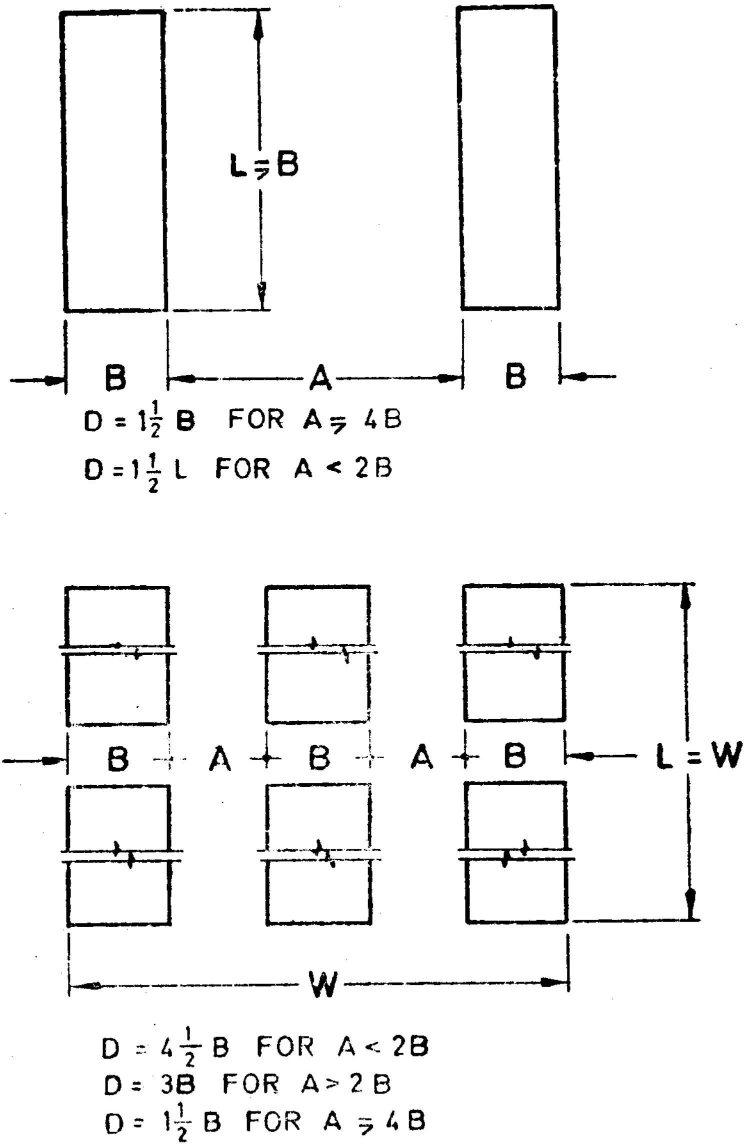

FIG. 1 DEPTH OF EXPLORATION

2.4.4 In making ground-water observations, it should be remembered that in some localities there may be one or more isolated bodies of water or perched ground-water tables above the main ground-water table. The formation of perched ground-water tables is caused by impervious strata which prevent the water from seeping down to the main body of ground water. The difference in water levels in bore holes spaced reasonably close to one another would indicate a perched water table.

2.5 Corrosive Soils, Waters and Effluents — In certain localities, ground water and soil may contain constituents in amounts sufficient to cause damage to foundations of structures. Cement concrete is liable to be attacked by water containing sulphates. Some soils have a corrosive action on metals, particularly on cast iron, due to either chemical or bacterial agency, and enquiry should be made in the locality to find if such corrosion has previously occurred. In such cases a chemical analysis of the soil should be made to assess the necessity of special precautions. Ground water may be tested for its salt content, alkalinity or acidity, etc, for its effect on foundations. For the purpose of chemical analysis about 5 litres of water should be collected from as near the bottom of the bore hole or trial pit as possible and not from the top. Water in the bore hole should be pumped out completely and after 24 h the water which is collected in the bore hole should again be pumped out and sample of water obtained as near to the bottom as possible. This will prevent erroneous collection of water utilised in wash boring which is not the natural ground water. The water samples should be collected in plastic jerry cans filled up to the brim and should be air tight for the purpose of chemical analysis in laboratory.

2.5.1 In industrial areas, corrosive action may arise from industrial waste products that have been dumped on the site. Samples of such individual waste products should be collected and chemically analysed in the laboratory.

2.6 Soil and Rocks — As the engineering classification deals mainly with soil as a material of construction, soil may be defined as that which comprises accumulations of solid particles, loose or cohesive deposits, such as gravel, sand, silt, clay or any combination thereof which is loose enough to be removed with a spade or shovel in a dry or saturated state. Their depths may vary from deep lying geological deposits to agricultural surface soils. Correspondingly, the term ‘ rock ’ may be applied to materials other than the above, that is, natural beds or large hard fragments or original igneous, sedimentary or metamorphic formations.

2.6.1 *Classification and Identification of Soils* — For this purpose IS : 1498-1970* should be referred.

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*Classification and identification of soils for general engineering purposes (*first revision*).

3. METHODS OF SITE EXPLORATION

3.1 General — Subsurface explorations should generally be carried out in two stages, that is, preliminary and detailed.

3.1.1 *Preliminary Exploration* — The scope of preliminary exploration is restricted to the determination of depths, thickness, extent and composition of each soil stratum, location of rock and ground water and also to obtain approximate information regarding strength in compressibility of the various strata. When reconnaissance is not possible it is essential to carry out preliminary investigation to decide the method of approach of investigation. During preliminary investigation, geophysical methods and tests with cone penetrometers and sounding rods are useful guides.

3.1.2 *Detailed Exploration* — Detailed investigation follow preliminary investigation and should be planned on the basis of data obtained during reconnaissance and preliminary investigations. This plan may require review as the investigations progress. The scope of detailed exploration is ordinarily restricted to the determination of engineering properties of strata which are shown by preliminary exploration to be critical. The object of detailed exploration is to determine shear strength and compressibility of all types of soils, density, density index, natural moisture content, and permeability. It may also be necessary to determine the preconsolidation pressure of the strata from oedometer tests and to determine the consolidation characteristics beyond preconsolidation pressure. Appropriate shear tests should also be conducted on samples subjected to ambient pressures beyond the preconsolidation range also. The detailed investigation includes boring programme and detailed sampling to determine these properties. Field tests which may be performed are *in-situ* vane shear tests and plate load tests. The field permeability test and the test for the determination of dynamic properties of soils may also be conducted where necessary. More advanced methods of logging of bore holes by radioactive methods fall under the category of detailed investigations. All *in-situ* tests are to be supplemented by laboratory investigations. The various phases of currently used methods of exploration and their mode of application are indicated in Appendix A.

3.2 Geophysical Investigations — Geophysical surveys make use of differences in the physical properties like electrical conductivity and elastic moduli, density and magnetic susceptibility of geological formations in the area to investigate the subsurface. These methods may be employed to get preliminary information on stratigraphy or complement a reduced boring programme by correlation of stratigraphy between widely spaced bore holes. Of the four methods of geophysical surveys, namely seismic, electrical, magnetic and gravity surveys, only seismic refraction and electrical resistivity surveys are widely used. Magnetic methods are occasionally used for detecting buried channels, dykes, ridges, and intrusions in the subsurface rocks. A brief outline of the seismic method and electrical resistivity method is given in Appendix B.

3.3 Open Trial Pits — The method of exploring by open trial pits consists of excavating trial pits at the site and thereby exposing the subsoil surface thoroughly, enabling undisturbed samples to be taken. The undisturbed samples may be obtained by driving sharp-edged thin-wall tubes into the ground by gently hammering or pressure. Alternately, hand-cut samples known as chunk samples can be obtained. In sufficiently cohesive soil, undisturbed sample can be cut out and trimmed to regular shapes, say a cube or a cylinder. Wrap the chunk samples with plastic cloth, plastic paper (polythene film) or a waxed paper painted on the outside with molten wax. Two additional layers of cloth and wax are required to perfectly seal the sample. If a soil is easily disturbed, a firmly constructed wooden box, with lid and bottom removed, is kept around the protruding sample block so as to leave a space of about 25 mm between the sample and sides of the box. The space between the sample and the sides of the box is packed with moist saw dust or similar packing material. The top of the sample is cut to size, cloth or paper and wax are applied and then the lids are fitted. This method should generally be used for small depths (up to 3 m), but for greater depths (over 6 m) and below ground-water table, the method becomes expensive due to the expense of sheet piling or caissons which are required in such cases. Deep trial pits may be used to investigate open fissures, or to explore zones of weak rocks which would break up in the core barrel and are incapable of being recovered intact.

3.4 Subsurface Soundings — The geophysical methods of reconnaissance are sometimes supplemented by penetrometer tests by cones. The cone penetrometer, apart from its use for delineation of rock strata, may also be utilized for correlation with more detailed borings of soil characteristics like density, bearing capacity, etc. Sounding methods consist of measuring the variation in the resistance of the soil with depth by means of a penetrometer and may be conducted either by the static or the dynamic methods [*see* IS : 4968 (Part I)-1976*, IS : 4968 (Part II)-1976† and IS : 4968 (Part III)-1976‡]. The soundings by dynamic method may also be carried out in bore holes using a standard sampler. The sampler used and the procedure adopted shall be as specified in IS : 2131-1963§. The static cone penetration methods are not suitable for exploration of boulderous or gravelly strata and in very stiff cohesive soils. However, dynamic cone penetration methods may be conducted in such areas to give an idea about the compactness of strata.

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*Method for subsurface sounding for soils: Part I Dynamic method using 50 mm cone without bentonite slurry (*first revision*).

†Method for subsurface sounding for soils: Part II Dynamic method using cone and bentonite slurry (*first revision*).

‡Method for subsurface sounding for soils: Part III Static cone penetration test (*first revision*).

§Method for standard penetration test for soils.

3.5 Exploratory Drilling — Preliminary borings by augers, either power or hand driven, are quick and economical up to a depth of about 6 m in alluvial deposits. They are difficult to operate below the water table. When detailed information is not required, wash boring with chopping and jetting may be utilized in cohesive and non-cohesive soils up to great depths. In the absence of casing, the sides of the holes, where required, should be stabilized with drilling fluid consisting of drilling mud (*see* **3.6.5.1**). In sandy soils, bentonite slurry in the bore hole should be maintained at a level of 1 to 1·5 m above the level of water table. In the wash boring method changes in stratification can be ascertained only by the rate of progress of the drill or change in the colour of wash water or both. As the formation hardens, rotary drills, using churning bits may be utilized. In gravelly materials, percussion drilling with simultaneous advance of casing is the only easy method of advance. In hard and cemented formation like rock, the hole is advanced with cutting edges using steel shots, hardened metal bits, tungsten carbide or diamond bits.

3.6 BORINGS

3.6.1 *Auger Boring* — An auger may be used for boring holes to a depth of about 6 m in soft soil which can stand unsupported but it may also be used with lining tubes if required. Mechanically operated augers are suitable for gravelly soils or where a large number of holes are to be made.

3.6.2 *Shell and Auger Boring* — A hand rig may be used for vertical boring up to 200 mm in dia and 25 m in depth. In alluvial deposits the depth of the bore hole may be extended up to 50 m with a mechanized rig. The tool consists of augers for soft to stiff clay, shells for very stiff and hard clay and shells or sand pumps for sandy strata, attached to sectional boring rods. Small boulders and thin strata of rock may be broken up by a chisel bit attached to the boring rods. The boring rods are raised or lowered by means of shear legs and a winch, and are turned by hand. The casing is advanced by driving by means of a 'monkey' suspended from a winch.

3.6.2.1 No water shall be added while boring through soft cohesive soils and cohesionless soils above water table. Bailers should be used to remove soil cuttings. In stiff cohesive soils it may be necessary to soak the bore hole before any progress can be made. While boring through cohesionless deposits below water table, water in the casing shall always be maintained at or above the water table. It is essential that the casing is kept full of water or with 5 percent bentonite slurry up to the top level. Special care should be taken while withdrawing the shell to avoid sand boiling. Start pouring the slurry into the casing pipe so that the sand boiling is avoided in the vacuum created by withdrawing the shell. While boring, care shall be taken to minimise disturbance to the deposits below the bottom of the bore hole. Disturbed soil of the deposits with all the constituent parts should be recovered at regular intervals or whenever there is a change of strata. These samples are suitable for conducting various identification tests in the laboratory.

3.6.3 *Percussion Boring* (*see* Fig. 2) — This method consists of breaking up of the formation by repeated blows from a bit or a chisel. Water should be added to the hole at the time of boring, and the debris baled out at intervals. The bit may be suspended by a cable or rods from a walking beam or spudding device.

Where the boring is in soil or into soft rocks and provided that a sampler can be driven into them, cores may be obtained at intervals using suitable tools; but in soils, the material tends to become disturbed by the action of this method of boring and for this reason, the sample may not be as reliable as by the shell and auger method. As these machines are devised for rapid drilling by pulverizing the material, they are not suitable for careful investigation. However, this is the only method suitable for drilling bore holes in boulderous and gravelly strata.

3.6.4 *Wash Boring* (*see* Fig. 3) — In this method, water is forced under pressure through an inner tube which may be rotated or moved up and down inside a casing pipe. The lower end of the tube, fixed with sharp edge or a tool, cuts the soil which will be floated up through the casing pipe around the tube. The slurry flowing out gives an indication of the soil type. In this method heavier particles of different soil layers remain under suspension in the casing pipe and get mixed up, and hence this method is not suitable for obtaining samples for classification. Whenever a change in strata is indicated by the slurry flowing out, washing should be stopped and a tube sampler should be attached to the end of the drill rod or the inner tube. Samples of the soil should be obtained by driving the sampler into the soil by hammering or jacking. Jacking or pulley method should be used when undisturbed samples are required. Initially fish-tail bit or pistol bits are used for drilling bore hole up to weathered material. These bits should be replaced by tungsten carbide or diamond bits. Double tube-core barrels are recommended for drilling in weathered rock stratum, with seaming shells and core catcher as required.

3.6.5 *Rotary Boring*

3.6.5.1 *Mud-rotary drilling* (*see* Fig. 4) — In this system, boring is effected by the cutting action of a rotating bit which should be kept in firm contact with the bottom of the hole. The bit is carried at the end of hollow, jointed drill rods which are rotated by a suitable chuck. A mud-laden fluid or grout is pumped continuously down the hollow drill rods and the fluid returns to the surface in the annular space between the rods and the side of the hole, and so the protective casing may not be generally necessary. In this method cores may be obtained by the use of coring tools.

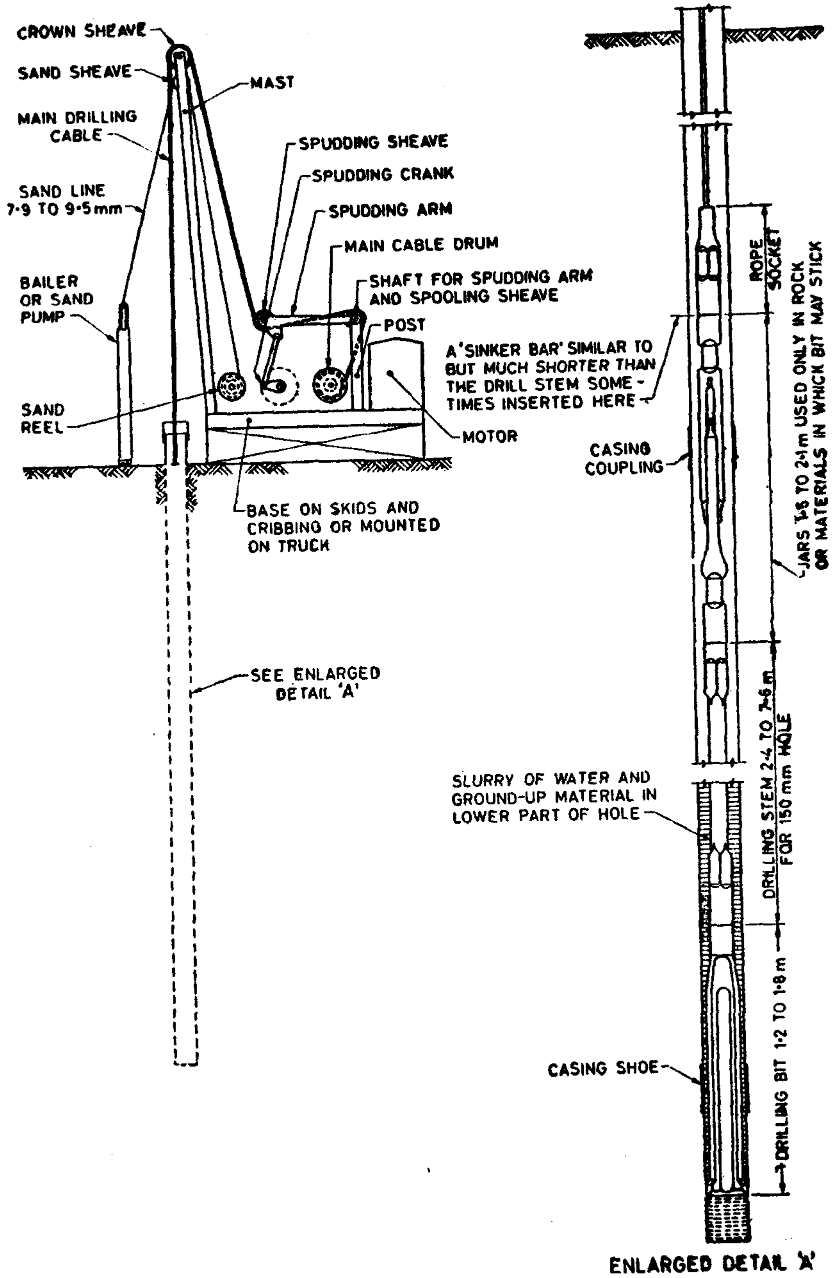


FIG. 2 TYPICAL ARRANGEMENT OF PERCUSSION DRILLING

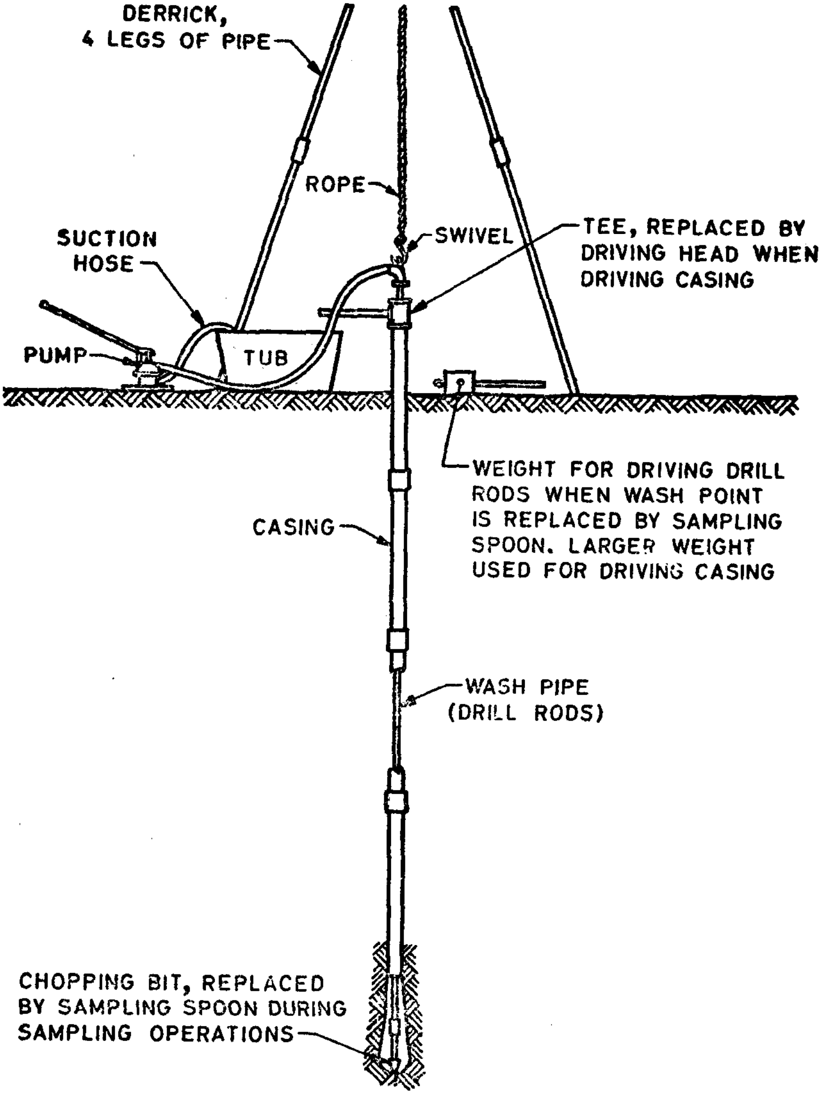


FIG. 3 TYPICAL ARRANGEMENT FOR WASH BORING

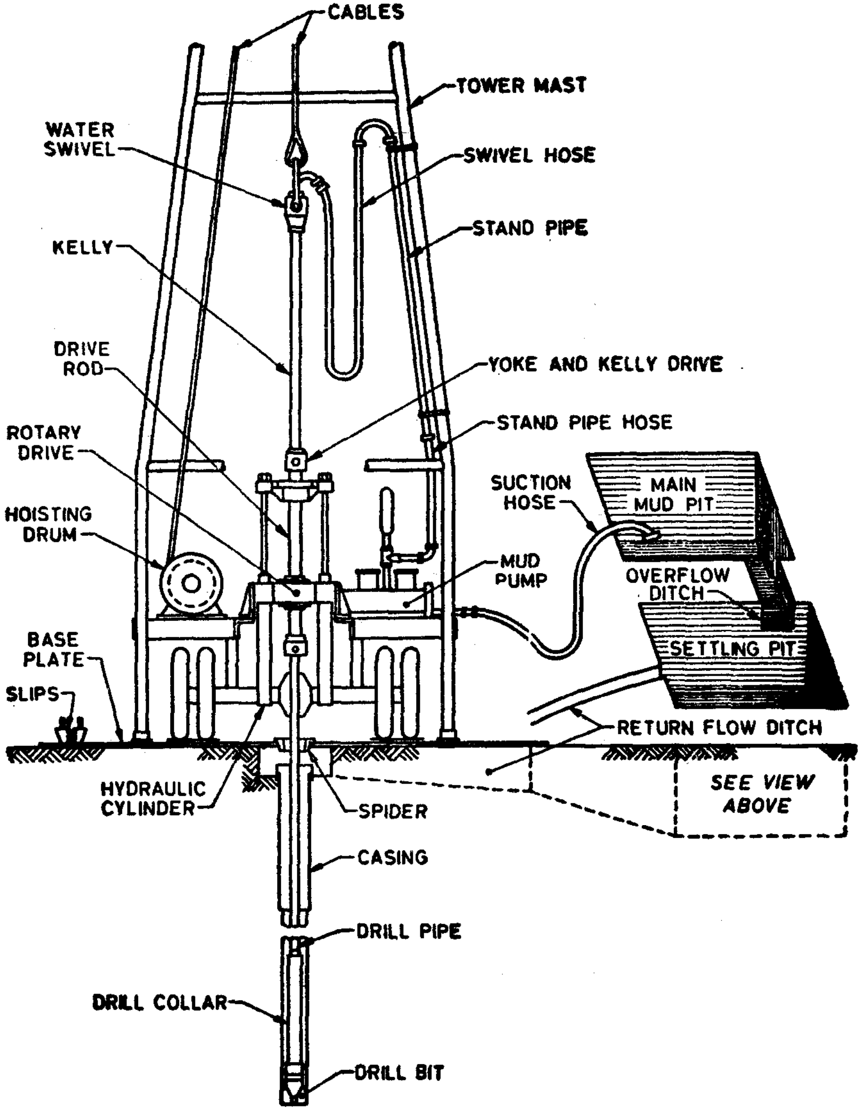


FIG. 4 TYPICAL ARRANGEMENT FOR ROTARY DRILLING

3.6.5.2 *Simplified mud-boring method* — In this method the boring is advanced by a cutter fixed to drill rods which are rotating by means of pipe wrench. Bentonite is pushed simultaneously by a double piston pump. The slurry flowing out of cutter bottom, mixes up with the cut soil and flows to the bore hole surface, settling tank and back to the slurry tank. The process is continuous and the same slurry can be used several times. The drilling tool is lowered slowly with the help of manually operated winch fixed on a tripod. After the boring is advanced up to the desired depth, pumping of the slurry should be continued for 10 to 15 minutes.

In case gravel and kankar are encountered, a gravel trap fitted with stays around the drill rod, a little above the cutter, may be used. The trap consists of 80 to 100 cm long hollow cylinder having a conical shape at bottom. Holes of 3 mm diameter are also drilled in the drill rod within the trap as well as in the conical portion of the trap. During boring, gravel and kankar rise a little and then settle into the trap. With the provision of holes, no finer materials settle in the trap.

The small silt-sand stone or hard beds may be broken using conical or chisel-ended bits connected with drill rod. The broken pieces can subsequently be removed by means of the gravel trap.

3.6.5.3 *Core drilling* — Core drills shall be so designed that in sound rock, continuous recovery of core is achieved. Water is circulated down the hollow rods, which returns outside them, carrying the rock cuttings to the surface as sludge. These shall be retained as samples in traversing friable rock where cores cannot be recovered. It is important to ensure that boulders or layers of cemented soils are not mistaken for bed rock. This necessitates core drilling to a depth of at least 3 m in bed rock in areas where boulders are known to occur. For shear strength determination, a core with diameter to height ratio of 1 : 1 is required. Rock pieces may be used for determination of specific gravity and classification.

3.6.5.4 *Shot drilling* — The system is used in large diameter holes, that is over 150 mm. Due to the necessity of maintaining the shots in adequate contact with the cutting bit and the formation, holes inclined over 5° or 6° cannot be drilled satisfactorily. This system is different from other types of core drilling because the coarser cuttings do not return to the surface but are accumulated in a chip cup immediately above the bit and here the chilled shot is used as an abrasive in place of the drilling head.

3.7 Pressure Meter — A pressure meter (*see* Fig. 5) applies a uniform radial stress to the bore hole at any desired depth and measures consequent deformation. The test involves lowering of an inflatable cylindrical probe to the test depth in a bore hole. The probe is inflated by applying water pressure from a reservoir. Under pressure it presses against the unlined wall of the bore hole and causes volumetric deformation. The stress on the

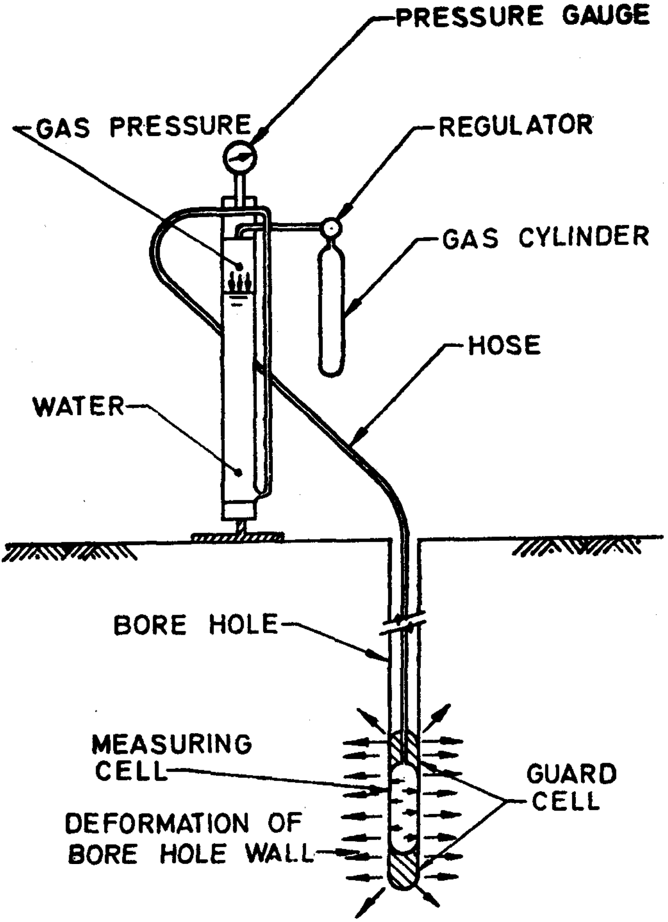
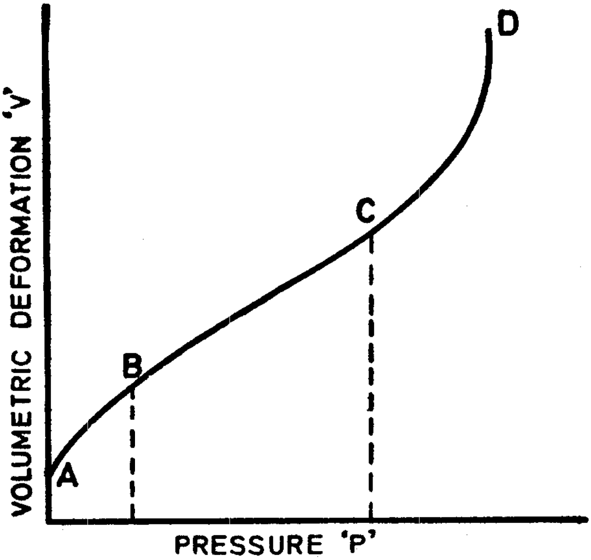


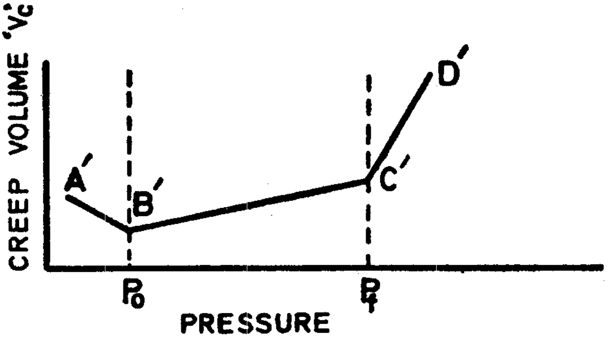
FIG. 5 PRINCIPLE OF PRESSURE METER

bore-hole wall is the pressure of water applied. The deformation of the bore hole is read in terms of volume corresponding to fall in water level of the reservoir. The readings are plotted as shown in Fig. 6.

3.8 Field Tests — Certain tests, if required, are to be carried out on materials without actual removal of the material from its existing position. Dilatancy, consistency, density, structure, colour and field identification should be carried out during reconnaissance at preliminary investigation stage.



6A Typical Pressure Meter Curve



6B Corresponding Creep Diagram

FIG. 6 PRESSURE AND CREEP CURVES

3.8.1 *Tests Which Measure Properties of the Soil* — These tests are:

a) Vertical loading tests (*see* IS : 1888-1971*)

b) Deep penetration tests — Standard penetration test (*see* IS : 2131-1963†) and Cone penetration tests [*see* IS : 4968 (Part I)-1976‡), IS : 4968 (Part II)-1976§ and IS : 4968 (Part III)-1976||]

c) Vane shear tests (*see* IS : 4434-1978¶)

d) Measurement of density of the soil [*see* IS : 2720 (Part XXVIII)-1974** and IS : 2720 (Part XXIX)-1975††]

e) Pressure meter test

A brief note on the tests (a), (b) and (c) is given in Appendix C.

3.9 Choice of Method — The choice of the method depends on the following factors:

a) *Nature of Ground*

1) *Soils* — In clayey soils borings are suitable for deep exploration and pits for shallow exploration. It is possible to take representative undisturbed samples in both cases.

In sandy soils, boring is easy but special equipment such as, Bishop or Osterberg piston samplers, should be used for taking undisturbed samples below the water table. Such samples can however be readily taken in trial pits provided that, where necessary, some form of ground water lowering is used.

2) *Rocks* — Borings are suitable in hard rocks and pits in soft rocks. Core borings are suitable for the identification of types of rocks but they provide braited data on joints and fissures. NX bore hole camera is useful to photograph the stratification in drilled bore holes.

b) *Topography* — In hilly country the choice between vertical openings (for example, borings and trial pits) and horizontal openings

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*Method of load tests on soils (*first revision*).

†Method for standard penetration test for soils.

‡Method for subsurface sounding for soils: Part I Dynamic method using 50 mm cone without bentonite slurry (*first revision*).

§Method for subsurface sounding for soils: Part II Dynamic method using cone and bentonite slurry (*first revision*).

||Method for subsurface sounding for soils: Part III Static cone penetration test (*first revision*).

¶Code of practice for *in-situ* vane shear test for soils (*first revision*).

**Methods of test for soils: Part XXVIII Determination of dry density of soils in-place by the sand replacement method (*first revision*).

††Methods of test for soils: Part XXIX Determination of dry density of soils in-place by the core cutter method (*first revision*).

[for example, exploratory drifts (*see* IS : 4453-1980*)] may depend on the topography and the geological structure. Steeply inclined strata and slopes are most effectively explored by drifts or inclined borings and low dipping strata or gentle slopes by trial pits or vertical borings.

Swamps and areas overlain by water are best explored by borings which may have to be put down from floating craft.

c) *Cost* — For deep exploration, borings are usual as deep shafts are costly. For shallow exploration in soil, the choice between pits and borings will depend on the nature of the ground and the information required for shallow exploration in rock; the cost of bringing a core drill to the site will only be justified if several holes are required; otherwise trial pits will be more economical.

3.9.1 *Trial Pits and Shallow Bore Holes* — Trial pits are preferable to shallow bore holes, since they enable sand and single strata to be seen in their undisturbed state and give a more accurate idea of timbering and pumping that may be required. Trial pits in stiff fissured clays also give fairly accurate idea of the depth of open excavations or vertical cuts that can be carried out without shoring. They also give a better picture of the patchy ground where the soil lies in pockets. In case of gravels and sandy soils fines tend to be washed out and the various layers are apt to become mixed as a result of 'piping'. Hence it is difficult in such cases to obtain representative samples and unless proper precautions are taken a misleading impression may be obtained. The best procedure is to obtain samples from trial pits dug after the ground water has been lowered by means of wells or sumps with suitable filter linings.

4. SAMPLING TOOLS

4.0 General — To take undisturbed samples from bore holes properly designed sampling tools are required. These differ for cohesive and non-cohesive soils and for rocks.

4.1 The fundamental requirement of a sampling tool is that on being forced into the ground it should cause as little displacement, remoulding and disturbance as possible. The degree of disturbance is controlled by the following three features of its design:

a) Cutting edge,

b) Inside wall friction, and

c) Non-return value.

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*Code of practice for exploration by pits, trenches, drifts and shafts (*first revision*).

4.1.1 *Cutting Edge* — A typical cutting edge is shown in Fig. 7. It should embody the following features:

a) *Inside clearance* (C_I) — The internal diameter (D_c) of the cutting edge should be slightly less than that of the sample tube (D_s) to give inside clearance. The inside clearance, calculated as follows, should be between one percent and 3 percent of the internal diameter of the sample tube. This allows for elastic expansion of the soil as it enters the tube, reduces frictional drag on the sample from the wall of the tube and helps to retain the core:

$$C_I = \frac{D_s - D_c}{D_c}$$

where

C_I = inside clearance,
D_s = inside diameter of the sampling tube, and
D_c = inside diameter of the cutting edge.

b) *Outside clearance* (C_0) = The outside diameter (D_w) of the cutting edge should be slightly larger than the outside diameter (D_T) of the tube to give outside clearance. The outside clearance should not be much greater than the inside clearance. This facilitates the withdrawal of the sampler from the ground. The outside clearance should be calculated as follows:

$$C_o = \frac{D_w - D_T}{D_T}$$

where

C_o = outside clearance,
D_w = outside diameter of the cutting edge, and
D_T = outside diameter of the sampling tube.

c) *Area ratio* (A_r) — The area ratio, calculated as follows, should be kept as low as possible consistent with the strength requirements of the sample tube. Its value should not be greater than about 20 percent for stiff formations; for soft sensitive clays an area ratio of 10 percent or less should be preferred. Where it is not possible to provide sufficient inside clearance, piston sampler should preferably be used:

$$A_r = \frac{D^2{}_w - D^2{}_c}{D^2{}_c} \times 100 \text{ percent}$$

where

A_r = area ratio,
D_w = outside diameter of the cutting shoe, and
D_c = inside diameter of the cutting shoe.

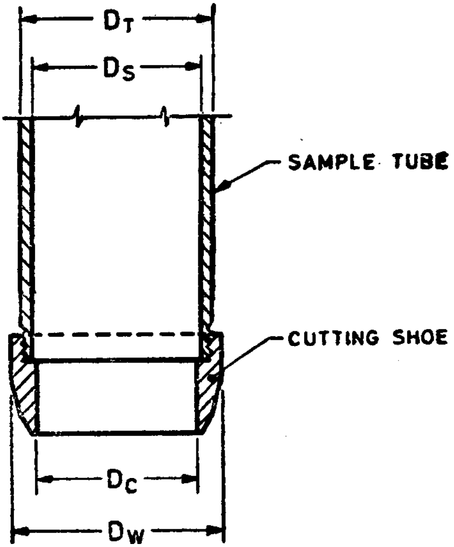

FIG. 7 DETAILS OF CUTTING EDGE

4.1.2 *Wall Friction* — This can be reduced by:

a) suitable inside clearance,

b) a smooth finish to the sample tube, and

c) oiling the tube properly.

4.1.3 *Non-return Valve* — The valve should have a large orifice to allow the air and water to escape quickly and easily when driving the sampler.

4.1.4 *Recovery Ratio* — For a satisfactory undisturbed sample, taking into consideration the influence of the inside clearance [*see* **4.1.1** (a)] when excess soil is prevented from entering the tube, the recovery ratio calculated as follows should be between 98 to 96 percent.

$$R_r = \frac{L}{H}$$

where

R_r = recovery ratio,
L = length of the sample within the tube, and
H = the depth of penetration of the sampling tube.

4.2 Types of Samplers

4.2.1 *Cohesive Materials*

4.2.1.1 *Open tube sampler* — The open tube sampler is an ordinary seamless steal tube with its lower edge chamfered to make penetration easy. Subject to the requirements of undisturbed sampling, an open tube sampler with a separate cutting shoe may also be used. The sampler head which connects the tube to the boring rod is provided with vents to permit water to escape when sampling under water and check valve to help to retain the sample while withdrawing the sampler (*see* IS : 2132-1972*).

4.2.1.2 *Split spoon sampler* — Split spoon sampler is a modified form of the open tube sampler, in which the sampling tube is split into two halves held together by the cutting edge and the sampler head. This sampler makes the removal of the sample easier.

The split spoon sampler driven as specified in IS : 2131-1963†, may be used in foundation investigations to collect samples for visual identification and preliminary laboratory tests. This penetration results may be utilized to correlate *in-situ* properties like density, shear strength and bearing capacity.

4.2.1.3 *Piston sampler* — A piston sampler consists of two separate parts, (a) the sample cylinder and (b) the piston system; the latter which is actuated separately, fits tightly in the sampler cylinder.

The single important control in the operation of the piston sampler is the separate actuation of the piston system. It may be done by separate drilling rods, or by a liquid pressure device or by a special lock and wire-rope system.

During the driving and till the start of the sampling operation, the bottom of the piston should be flush with the cutting edge of the sampler. At the desired sampling elevation, the piston should be fixed in relation to the ground and the sampler cylinder forced independently into the ground, thus punching a sample out of the soil.

The piston prevents water and dirt from entering the tube during the lowering operation. It also serves to keep the recovery ratio constant during the punch. As the sampler tube slides past the tight fitting piston during the sampling operation, a negative pressure is developed above the sample, which holds back the sample during withdrawal.

Both the sample cylinder and piston system, should be finally withdrawn with the sample remaining in the sample cylinder.

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*Code of practice for thin-walled tube sampling of soils (*first revision*).

†Method for standard penetration test for soils.

4.2.2 *Cohesionless Materials*

4.2.2.1 In the case of either cohesionless materials such as silts and sands, or soft soil strata, sampling operations are confronted with the possibility of the sample falling out of the sampler due to lack of cohesion; this is specially so with increasing diameter of sampling tubes. Hence some form of positive control should be incorporated at the top and/or bottom of the sampling device. This is affected in the following manner:

a) *Control at the top of the sampler* — A reduction of pressure on the sample is brought about by providing a ball valve in the sampler head or a properly packed free or stationary piston in the sampling tube.

b) *Control at the bottom of the sampler* — This control is achieved by:

   1) incorporating core retainers in the form of concealed springs, multiple flap valves, claw-shell valves in the sample shoe or introducing core retainers attached to an auxiliary barrel pushed down the sampler after the drive; this will however disturb the samples to certain extent; and

   2) maintenance of slight pressure below the sampler by the injection of compressed air into the space below the sampler formed by the introduction of an auxiliary core barrel; Bishop sampler may be used.

c) *Solidification by the introduction of chemicals or emulsions* — The solidification may be done at the bottom of the sampling tube after driving, or a sufficient volume of the strata to be sampled may be solidified before the sampling operation starts.

4.2.3 *Rocks* — Cores of rock should be taken by means of rotary drills with a coring bit. Other types of drills, such as shot drills may also be used. All types of rotary drills should be fitted with core barrels and core catchers which break off the core and retain it when the rods are withdrawn. Double tube core barrels should be used for ensuring better core recovery and picking up soft seams or layers in bed rocks.

5. METHODS OF SAMPLING

5.1 Samples are of two types:

a) *Disturbed Samples* — These are taken by methods which modify or destroy the natural structure of the material, though with suitable precautions the natural moisture content can be preserved.

b) *Undisturbed Samples* — These are taken by methods which preserve the structure and properties of the material. Such samples are easily obtained from most rocks, but undisturbed samples of soil can only be obtained by special methods.

The following table indicates the methods that are usually employed:

NATURE OF GROUND	TYPE OF SAMPLE	METHOD OF SAMPLING
Soil	Disturbed	Hand samples Auger samples (for example, in clays) Shell samples (for example, in sand)
	Undisturbed	Chunk samples Tube samples
Rock	Disturbed	Wash samples from percussion or rotary drilling
	Undisturbed	Cores

In cohesive soils of all types it is possible with most strata to procure undisturbed samples which are very satisfactory for examination and testing purposes. Undisturbed sampling of sand below the water table is not always an easy matter, but special methods have recently been developed for this purpose and used satisfactorily.

6. PROCEDURE FOR TAKING SAMPLES

6.1 Disturbed Soil Samples — Disturbed samples of soils may be obtained in the course of excavation and boring. The taking of disturbed samples of clay may result in the remoulding of the material and may render it unsuitable for shear strength measurements unless it is required for fill. Such samples are suitable for mechanical analysis and tests for index properties. These samples may not be truly representative, specially when taken from below the ground-water level. This is more so in the case of gravels containing a portion of fine sand, since the finer fractions tend to be washed off the sampler by the water. For procuring true samples, where possible, the ground-water level may be lowered by means of pumping from filter wells before procuring samples, or special type of samplers used (*see* **4.2.2**). The quantity of sample generally required for testing purposes is given in Table 2 [*see also* IS : 2720 (Part I) - 1972[*]].

6.2 Undisturbed Soil Samples — Samples shall be obtained in such a manner that moisture content and structure do not get altered. These may be attained by careful protection and packing and by the use of a correctly designed sampler.

6.2.1 *Clay* — If strength of soft clay is to be known, the sampling procedure may be supplemented by *in-situ* tests like vane shear test (*see* IS : 4434-1978[†]) which gives a measure of the shear strength of the soil.

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[*] Methods of test for soils: Part I Preparation of dry soil samples for various tests (*first revision*).

[†] Code of practice for *in-situ* vane shear test for soils (*first revision*).

TABLE 2 QUANTITY OF SOIL SAMPLE REQUIRED

(*Clause* 6.1)

Sl No.	Purpose of Sample	Soil Type	Weights of Sample Required kg
i)	Soil identification, natural moisture content tests, mechanical analysis and index properties	Cohesive soils	1
	Chemical tests	Sand and gravels	3
ii)	Compaction tests	Cohesive soils and sands	12·5
		Gravelly soils	25
iii)	Comprehensive examination materials including soil stabilization	Cohesive soils and sands	25 to 50
		Gravelly soils	50 to 100

6.2.1.1 *Chunk samples* — Chunk samples may be taken where clay is exposed in excavation. A block of clay should be carefully removed with a sharp knife taking care that no water is allowed to come into contact with the sample and that the sample is protected from exposure to direct sun and wind. The chunk sample should be coated with molten wax so that the layer of wax prevents escape of moisture from the sample. Chunk samples are not suitable if those are to be transported to long distances because in such cases the samples will get disturbed in transit. Undisturbed samples may also be obtained by means of a sampling tube of 10 cm internal diameter provided with a cutting edge. In this procedure the soil surrounding the outside of the tube should be carefully removed while the tube is being pushed in.

6.2.1.2 *Core samples* — The sampler should be lightly oiled or greased inside and outside to reduce friction. It should then be attached to the boring rods and lowered to the bottom of the bore hole or trial pit. The sampler should be pushed into the clay by hand or by jacking. Where this is not possible, the sampler may be driven into the clay by blows from a 'monkey'.

The distance to which the sampler is driven should be checked, because if driven too far, the soil will be compressed in the sampler. A sampling head with an 'overdrive' space will allow the sample tube to be completely filled without damaging the sample. After driving thero ds, the sampler should be rotated to break off the core and the sampler should be steadily withdrawn. In soft clays and silty clays where samples are required from below the water table, with water standing in the casing pipe, a piston sampler may be used with advantage.

6.2.1.3 For compression test samples, a core of 40 mm diameter and about 150 to 200 mm long may be sufficient; but for other laboratory tests, a core of 75 mm to 100 mm diameter and preferably 300 mm long is necessary. The upper few mm of both types of sample should be rejected as the soil at the bottom of the bore hole usually gets disturbed by the boring tools.

6.2.2 *Sand* — Comparatively undisturbed samples of moist sand above ground-water level may be taken from natural exposures, excavations or borings by gently forcing a sampling tube into the soil. Undisturbed samples of sand below ground-water table may be obtained by the use of a compressed air sampler, which enables the sample to be removed from the ground into an air chamber and then lifted to the surface without contact with the water in the bore hole. This may be done by another method which involves the use of a thin walled piston sampler and bentonite or other types of drilling mud. The use of bentonite or other drilling mud obviates the need for casing pipes with thin wall samplers. In all methods it is essential to maintain the water or drilling mud in the boring tube at or slightly above ground-water level. This prevents any disturbance of the structure of the sand by the flow of water into the bore hole.

6.3 Rock Samples

6.3.1 *Disturbed Samples* — The sludge from percussion borings, or from rotary borings which have failed to yield a core, may be taken as a disturbed sample. It may be recovered from circulating water by settlement in a trough. The rock type may be deduced by examining the material of which the sludge is composed.

6.3.2 *Undisturbed Samples*

6.3.2.1 *Block samples* — Such samples taken from the rock formation shall be dressed to a size convenient for packing to about 90 × 75 × 50 mm.

6.3.2.2 *Core samples* — Cores of rock shall be taken by means of rotary drills fitted with a coring bit with core retainer, if warranted. Good core recovery (*see* **4.1.4**) depends upon the correct operation and careful use of the equipment.

6.3.2.3 *Frequency of sampling* — In intermittent sampling, undisturbed soil samples are obtained at every change in stratum and at intervals not exceeding 1·5 m within a continuous stratum. On important investigations such as the foundations for an earth dam, continuous core sampling in any soft clay layers may be necessary.

6.4 Water Samples — If a trial pit has been excavated or a well exists near about the site of exploration, the collection of water samples does not present any difficulty. However, if it is to be collected from a bore hole made at the site, some difficulty is apprehended on account of the narrowness of the bore, caving-in of the sides, etc. In the latter case, therefore, it should suffice to collect the water sample from the bore hole with the help of a common suction pump having a hose pipe, rubber tubing, etc, which can be conveniently lowered down into the bore hole, connected at the suction end. The water may then be collected into a clean vessel, allowed to settle and the supernatant liquid poured out into a clean well-rinsed glass or polythene bottle. The water samples may then be sent to the laboratory for chemical analysis.

6.5 Records of Borings and Trial Pits

6.5.1 *Borings* — In recording exploratory work in connection with borings necessary information should be given, preferably on a record sheet of the type given in Appendix D. A site plan showing the disposition of the borings should be attached to the records. Where a deep boring has deviated from line, a plan and section should accompany the record.

6.5.2 *Trial Pits* — Plans and sections, drawn to the largest convenient scale, should be provided. The following information should also be given:

a) Agency;

b) Location with map and plan reference;

c) Pit number;

d) Reduced level (RL) of ground surface, or other reference point;

e) Dates, started and completed;

f) Supervision;

g) Scales of plans and sections;

h) Dimensions, types of sheeting and other materials of stabilization, method of advancing the exploration, such as, by hand tools, blasting, boring, etc;

j) General description of strata met with;

k) Position and attitude of contacts, faults, strong joints, slicken-sides, etc;

m) Inflow of water, methods of controlling the water, required capacity of pumps;

n) The level at which the subsoil water table is met with;

p) Dip and strike of bedding and of cleavage; and

q) Any other information and remarks.

7. PROTECTION, HANDLING AND LABELLING OF SAMPLES

7.1 Care should be taken in protection and handling of samples and in their full labelling, so that samples can be received in a fit state for examination and testing and can be correctly recognized as coming from a specified trial pit or boring. Suitable methods are given in Appendix E.

7.2 Extrusion of Samples — Undisturbed samples of soil retained in a liner or seamless tube sampler which arrive in the testing laboratory, sealed with wax at both ends, have to be taken out of the liners or tubes for actual testing. This should be done very carefully without causing any disturbance to the samples themselves. The wax may be chipped off by a penknife. This may also be done by slightly warming the sides of the tube or liner at the ends when the wax will easily come off. If the tubes or liners are oiled inside before use, it is quite possible for samples of certain moisture range to be pushed out by means of suitably designed piston extruders. If the extruder is horizontal, there should be a support for the sample as it comes out from the tube so that it may not break. For screw type extruders, the pushing head must be free from the screw shaft so that no torque is applied to the soil sample in contact with the pushing head. All extruding operations must be in one direction, that is, from cutting edge to the head of the sample tube. For soft clay samples pushing with an extruder piston may result in shortening or distortion of the sample. In such cases the other alternative is to cut the tube by means of a high speed hacksaw in proper test lengths and fill the testing moulds, by placing the cut portions directly over the moulds and pushing the sample in, with a suitable piston. After the sample is extruded, it should be kept either in humidity chamber or in a desiccator and taken out only when actual testing is carried out, to avoid possible loss of moisture.

8. EXAMINATION AND TESTING OF SAMPLES

8.1 The samples of soils and rocks are to be tested in the laboratory for determining their engineering properties. The various tests that are usually necessary for different phases of exploration are given in Table 3.

TABLE 3 TESTS FOR DIFFERENT PHASES OF EXPLORATION

(*Clause* 8.1)

PHASE OF EXPLORATION	TESTS NECESSARY ON A SAMPLE	
	Type of Test	Detailed Tests
i) Reconnaissance exploration	—	Visual classification (*see* IS : 1498-1970[1])
ii) Detailed exploration	Physical tests	Liquid and plastic limits [*see* IS : 2720 (Part V)-1970[2]]
		Grain size analysis [*see* IS : 2720 (Part IV)-1975[3]]
		Specific gravity [*see* IS : 2720 (Part III)-1980[4]]
		Natural moisture content [*see* IS : 2720 (Part II)-1973[5]]
		Unit weight [*see* IS : 2720 (Part III)-1980[4]]
		Consolidation test (including pre-consolidation pressure) [*see* IS : 2720 (Part XV)-1965[6]]
		Shear strength:
		Unconfined compression [*see* IS : 2720 (Part X)-1973[7]]
		Triaxial compression [*see* IS : 2720 (Part XI)-1971[8]]
		Direct shear permeability test [*see* IS : 2720 (Part XIII)-1972[9]]
	Chemical tests	Soluble salt content:
		Chlorides and sulphates [*see* IS : 2720 (Part XXVII)-1977[10]]
		Calcium carbonate content (if warranted) [*see* IS : 2720 (Part XXIII)-1976[11]]
		Organic matter content (if warranted) [*see* IS : 2720 (Part XXII)-1972[12]]
	Ground water	Chemical analysis including *p*H determination [*see* IS : 2720 (Part XXVI)-1973[13]]
		Bacteriological analysis (if necessary)
	Rock drilling	Visual examination Unit weight Water absorption Porosity Petrographic analysis Compressive strength Shear strength

[1] Classification and identification of soils for general engineering purposes (*first revision*).

[2] Methods of test for soils: Part V Determination of liquid and plastic limits (*first revision*).

[3] Methods of test for soils: Part IV Grain size analysis (*first revision*).

[4] Methods of test for soils: Part III Determination of specific gravity (*first revision*).

[5] Methods of test for soils: Part II Determination of water content (*second revision*).

[6] Methods of test for soils: Part XV Determination of consolidation properties.

[7] Methods of test for soils: Part X Determination of unconfined compressive strength (*first revision*).

[8] Methods of test for soils: Part XI Determination of shear strength parameters of a specimen tested in unconsolidated undrained triaxial compression without the measurement of pore water pressure.

[9] Methods of test for soils: Part XIII Direct shear test (*first revision*).

[10] Methods of test for soils: Part XXVII Determination of total soluble sulphates (*first revision*).

[11] Methods of test for soils: Part XXIII Determination of calcium carbonate (*first revision*).

[12] Methods of test for soils: Part XXII Determination of organic matter (*first revision*).

[13] Methods of test for soils: Part XXVI Determination of *p*H values (*first revision*).

APPENDIX A

(*Clause* 3.1.2)

CURRENT METHODS OF SUBSOIL EXPLORATION

Sl No.	Method	Mode of Operation	Type of Formation
(1)	(2)	(3)	(4)
		A. RECONNAISSANCE METHODS	
		i) *Geophysical*	
1)	Electrical resistivity method (ac or dc)	Measurement of variations in the apparent resistivity as measured on the ground	Alluvial deposits weathered and fissured rock, buried channels and ground water
2)	Seismic refraction method	Measurement of velocities of compressional waves from the travel time curves of seismic waves	do
		ii) *Sounding*	
3) a)	Standard penetration test (*see* IS : 2131 - 1963[*])	Variations in the stratification is correlated with the number of blows required for unit penetration of standard penetrometer by a drive hammer	Non-cohesive soils without boulders
b)	Static cone penetrometer test [*see* IS : 4968 (Part III)-1976[†]]	The cone penetrometer is advanced by pushing and the static force required for unit penetration is correlated to the engineering properties like density, bearing capacity, settlement, stratification, etc	Primarily used in cohesive soils
c)	Dynamic cone penetrometer test [*see* IS : 4968 (Part II)-1976[†]]	The cone is driven by a standard hammer and the rest is as in (b) above	Primarily used in cohesive soils
		B. EXPLORATORY METHODS	
		i) *Drilling*	
4)	Shell and auger	Using auger for soft clays and shell for firm to stiff clays; in sand to be used with casing for lining and with bentonite; for boring at depths if more than 25 m power operator winches are used	All types of soils specially soils of mixed type

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[*] Method for standard penetration test for soils.

[†] Method for subsurface sounding for soils: Part III Static cone penetration test (*first revision*).

[‡] Method for subsurface sounding for soils: Part II Dynamic method using cone and bentonite slurry (*first revision*).

Sl No.	Method	Mode of Operation	Type of Formation
(1)	(2)	(3)	(4)
5)	Hand auger	The auger is power or hand operated with periodic removal of the cuttings	All soils except sands and gravels above water table
6)	Simplified mud boring	Manual rotation of cutter fixed with drill rods by means of pipe wrench; simultaneously pumping of bentonite slurry by manually operating a double piston pump. Chisel and gravel trap used for hard bed, gravel and *kankars*	Silts and sands or mixed soils specially below water table
7)	Wash boring	Light chopping, strong jetting and removal of cuttings by circulating water. Change of stratification could be guessed from the rate of progress and colour of the wash water	Soft to stiff cohesive soils and fine sand except gravel and boulders
8)	Percussion drilling	Power chopping, hammering and periodic removal of the slurry with bailers. The strata could be identified from the slurry	Rocks and soils with boulders, except clay or loose sand
9)	Rotary drilling	Power rotation of the coring bit which may vary from metal bits to tungsten carbide or diamond bits depending upon the hardness of formation (*see* IS : 6926-1973* *and* IS : 5313-1980†)	Rocks, fissured rock and all soils except cobbles and boulders
		ii) *Exploratory Sampling*	
10)	Open tube sampler and split tube sampler	Driving standard sampler by a hammer weighing 65·0 kg through a drop of 750 mm (*see* IS : 2131-1963‡)	Cohesive soils and silts
11)	Double tube core barrels	Used with a rotary machine; non-rotating inner barrel of swivel type slips over the sample and retains it as the outer bit advances (*see* IS : 6926-1973*)	Coarse sand and gravels; most suitable for soft rocks like shale and any weathered rock formation
		C. DETAILED INVESTIGATIONS	
		i) *Undisturbed Sampling*	
12)	Thin walled tubes 50 to 125 mm	The tubes are jacked into a cleaned hole under a static force (*see* IS : 2132-1972§)	Soils of medium strength

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*Code of practice for diamond core drilling for site investigation for river valley projects.

†Guide for core drilling observations (*first revision*).

‡Method for standard penetration test for soils.

§Code of practice for thin-walled tube sampling of soils (*first revision*).

SL No.	METHOD	MODE OF OPERATION	TYPE OF FORMATION
(1)	(2)	(3)	(4)
13)	Piston type sampler	The tubes are jacked into a cleaned hole under a static force	Clays and silts
14)	Samplers with special core retainers	do	do
15)	Sand sampler	The tubes are jacked into a cleaned hole under a static force (*see* IS: 8763-1978*)	Sand without boulders
16)	Solidification methods	Solidification at the bottom of the sampler after jacking the sampler into soils	do
17)	Open cuts and trenches	The sample is cut from the sides and bottom of a trench and sealed in a wooden box	All types of formations
		ii) *Bearing Capacity Tests*	
18)	Plate load test (soils)	Loading a steel plate at desired elevation and measuring the settlement under each load, until a desired settlement takes place or failure occurs (*see* IS: 1888-1971†)	Clay and sandy formations
19)	Load test (rocks)	Loading two discs placed diametrically opposite each other on two sides of a trench, by means of a jack and measuring the deflection near the sides	Rocks
20)	Vane shear test	Advancing a four-winged vane into a fresh soil at desired elevation and measuring the torque developed in rotating the vane (*see* IS: 4434-1978‡)	Soft and sensitive clays
		iii) *Logging of Bore Holes by Geophysical Methods*	
21)	Electrical logging	Measuring the potential and resistances of formation by an electrode system at various elevations	--
22)	Neutron logging	Measuring the intensity of scattered radiation from a system at desired elevation	--
23)	Gamma ray logging	Measuring the intensity of scattered gamma radiation from a system at desired elevation	--

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*Guide for undisturbed sampling of sands.

†Method of load tests on soils (*first revision*).

‡Code of practice for *in-situ* vane shear test for soils (*first revision*).

APPENDIX B

(*Clause* 3.2)

OUTLINE OF SEISMIC AND ELECTRICAL RESISTIVITY METHODS

B-1. SEISMIC METHOD

B-1.1 In this method shock waves are created into the soil, at ground level or at a certain depth below it, by striking a plate on the soil with a hammer or by exploding small charges in the soil. The radiating shock waves are picked up by the vibration detector (geophone), where the time of travel gets recorded. Either a number of geophones are arranged in a line, or the shock producing device is moved away from the geophone to produce shock waves at given intervals. Some of the waves, known as direct or primary waves, travel directly from the shock point along the ground surface and are picked up first by the geophone. If the subsoil comprises of two or more distinct layers, some of the primary waves travel downwards to the lower layer and get refracted at the surface. If the underlying layer is denser, the refracted waves travel much faster. As the distance from the shock point and the geophone increases, the refracted waves reach the geophone earlier than the direct waves. Fig. 8 shows the diagrammatical travel of the primary and refracted waves. The results are plotted on a graph as shown in Fig. 9, between distance *versus* time of travel. The break in the curve represents the point of simultaneous arrival of primary and refracted waves and its distance is known as critical distance which is a function of the depth and the velocity ratio of the strata. This method is effective when the velocities successively increase with depth.

The various velocities for different materials is given below as a guide:

MATERIALS	VELOCITY, m/s
Sand and top soil	180 to 365
Sandy clay	365 to 580
Gravel	490 to 790
Glacial till	550 to 2 135
Rock talus	400 to 760
Water in loose materials	1 400 to 1 830
Shale	790 to 3 350
Sandstone	915 to 2 740
Granite	3 050 to 6 100
Limestone	1 830 to 6 100

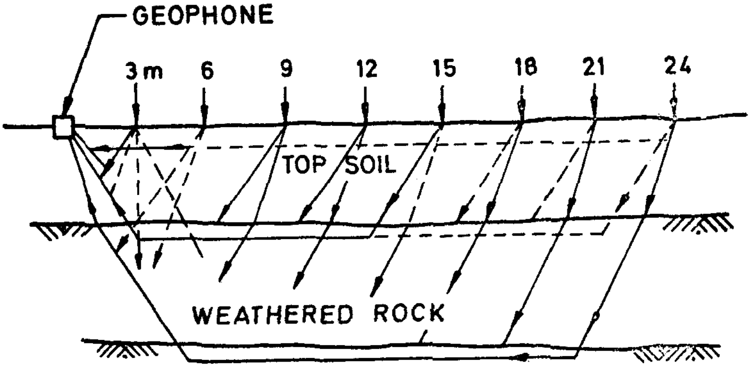

FIG. 8 WAVE REFRACTION PRINCIPLE

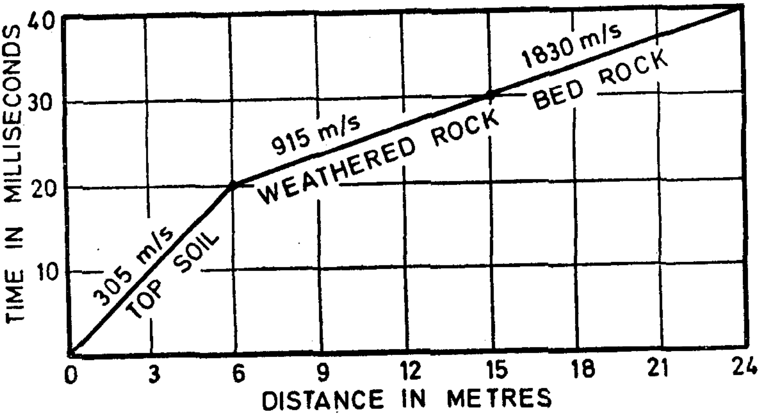

FIG. 9 TIME-DISTANCE GRAPH

B-2. ELECTRICAL RESISTIVITY METHOD

B-2.1 The electrical resistivity method is based on the measurement and recording of changes in the mean resistivity or apparent specific resistance of various soils. The resistivity (ρ ohm.cm) is usually defined as the resistance between opposite phases of a unit cube of the material. Each soil has its own resistivity depending upon water content, compaction, and composition; for example, the resistivity is low for saturated silt and high for loose dry gravel or solid rock. The test is conducted by driving four metal spikes to serve as electrodes into the ground along a straight line at equal distances (*see* Fig. 10).

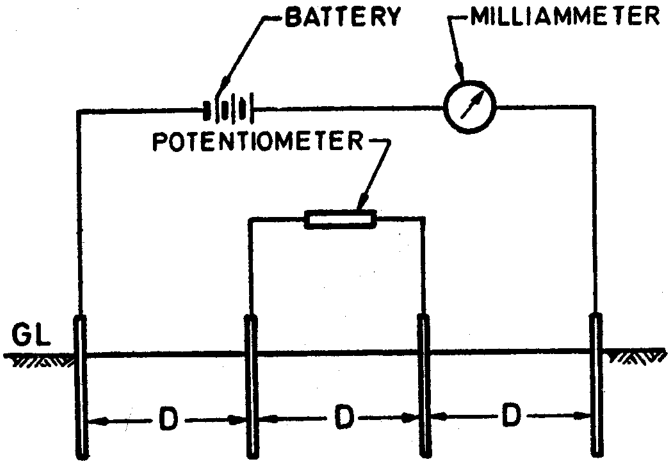

FIG. 10 POSITION OF ELECTRODES

B-2.1.1 A direct voltage is imposed between the two outer potentiometer electrodes and the potential drop is measured between the inner electrodes. The mean resistivity is given by the following formula:

$$\rho = 2\pi D \frac{E}{I}$$

where

ρ = mean resistivity (ohm.cm)
D = distance between electrodes (cm)
E = potential drop between inner electrodes (V)
I = current flowing between outer electrodes (A)

B-2.1.2 To correctly interpret the resistivity data for knowing the nature and distribution of soil formations, it is necessary to make preliminary trial on known formations. Average values of resistivity ρ for various rocks and minerals are given below:

MATERIAL	MEAN RESISTIVITY, ohm.m
Limestone (marble)	10^{12}
Quartz	10^{10}
Rock salt	10^{6} — 10^{7}
Granite	5 000 — 10^{6}
Sandstone	35 — 4 000
Moraines	8 — 4 000
Limestones	120 — 400
Clays	1 — 120

APPENDIX C

(*Clause* 3.8.1)

FIELD TESTS TO MEASURE PROPERTIES OF SOIL

C-1. VERTICAL LOADING TESTS

C-1.1 Loading tests may be used to determine whether the proposed loadings on foundations and subgrades are within safe limits, and subject to certain limitations, to assess the likely settlement of a structure. The greater, the uniformity of the strata tested, the more reliance may be placed on the results obtained.

Table 4 gives guidance regarding the methods of estimating bearing capacity and settlement of structures for various types of soils:

TABLE 4 METHODS OF ESTIMATION OF BEARING CAPACITY AND SETTLEMENT

Sl No.		Type of Strata	Methods of Estimation	
			Ultimate Bearing Capacity	Settlement of Structures
1)	a)	Hard rocks	L	L
	b)	Soft rocks, such as shales, weak limestones and sand stones	FL	L
	c)	Non-cohesive soils	FL	F
	d)	Soft compressible soils	LF	LF
	e)	Stiff, fissured clays	LF	LF
2)		Soft, compressible stratum overlying hard stratum	LF	L
3)		Hard stratum overlying compressible stratum	LF*	L
4)		Very variable strata varying in type, thickness and arrangement	Each case to be dealt with on its merits	

NOTE — Methods are given in order of preference:

F = Field load test

L = Laboratory tests: Compression and shear tests on undisturbed samples. Consolidation test on undisturbed samples. Elastic modulus tests on undisturbed samples.

*Tests should be made on each stratum.

C-1.2 The method of conducting load tests on soils is described in IS : 1888-1971*.

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*Method of load tests on soils (*first revision*).

C-2. DEEP PENETRATION TESTS

C-2.1 Penetration Tests in Bore Holes — These tests consist of measuring the resistance to penetration under static or dynamic loading of different shaped tools.

C-2.1.1 All the tests are empirical and their value lies in the amount of experience behind them.

C-2.1.2 Dynamic penetration tests in bore holes are the more usual and provide a very simple means of comparing the results of different bore holes on the same site and for obtaining an indication of the bearing value of non-cohesive soils which cannot easily be assessed in any other manner. The standard penetration test is the most widely used of these tests (*see* IS : 2131-1963*).

C-2.2 Sounding Tests — Deep sounding tests are carried out by means of apparatus consisting of an outer tube and an inner mandrel, which can be driven by means of a hammer or caused to penetrate steadily by an increasing dead load or by jacking. Measurements are made of the resistance to penetration as the depth of penetration increases and the technique involves separate measurement of the direct toe resistance and the skin resistance [*see* IS : 4968 (Part I)-1976†, IS : 4968 (Part II)-1976‡ *and* IS : 4968 (Part III)-1976§].

The method is used to determine the resistance to the driving of bearing piles and as a rapid means of preliminary site exploration and to supplement information obtained from borings.

C-3. VANE TESTS

C-3.1 The vane test has been shown to be a promising non-empirical method of measuring the shear strength of soft clay *in-situ*, at all depths from the surface to at least 30 m. It is particularly useful in the measurement of strength in deep beds of soft sensitive clays.

C-3.2 The shear strength of soft clays can be measured *in-situ* by pushing into the clay a small four-bladed vane, attached to the end of a rod and then measuring the maximum torque necessary to cause rotation. To a close approximation this torque is equal to the moment developed by the shear strength of the clay acting over the surface of the cylinder with a radius and height equal to that of the vanes. The method of conducting vane test is given in IS : 4434-1978‖.

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*Method for standard penetration test for soils.

†Method of subsurface sounding for soils: Part I Dynamic method using 50 mm cone without bentonite slurry (*first revision*).

‡Method of subsurface sounding for soils: Part II Dynamic method using cone and bentonite slurry (*first revision*).

§Method of subsurface sounding for soils: Part III Static cone penetration test (*first revision*).

‖Code of practice for *in-situ* vane shear test for soils (*first revision*).

APPENDIX D

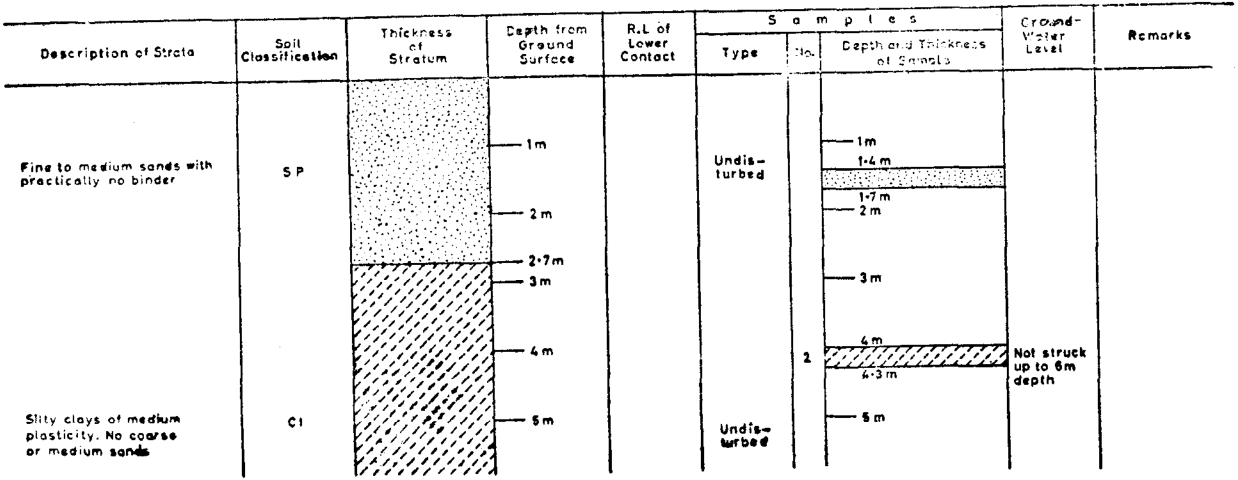
(*Clause* 6.5.1)

RECORD OF BORING

Name of Boring Organization

Bored for:..
Ground surface level:........................
Type of boring: Wash boring
Diameter of boring:........................
Inclination: Vertical
Boring:..

Location: Site
Boring No:..
Soil sampler used:.............................
Date started:.....................................
Date completed: ....
Recorded:...



APPENDIX E

(*Clause* 7.1)

HANDLING AND LABELLING OF SAMPLES

E-1. HANDLING OF SAMPLES

E-1.1 Disturbed Samples of Soil — Where samples are required for testing, or where it is desirable to keep them in good condition over long periods, they should be treated as follows:

a) Immediately after being taken from the bore hole or trial pit, the sample should be placed in a cloth bag or tin preferably in a glass jar of at least 0·5 kg capacity, and it should fill this container with a minimum of air space. The container should have an air-tight cover. In this way the natural water content of the sample can be maintained for one or two weeks without appreciable change.

b) The containers should be numbered and a label as described in E-2 should be placed immediately under the cover in a container.

c) The containers should be carefully packed in a stout wooden box (preferably with separate partitions) with saw dust or other suitable material, to prevent damage during transit.

d) Where necessary, the samples should be tested for natural water content immediately on arrival at the laboratory and an accurate description made of the sample. In such a case proper precautions should be taken to preserve the natural water content during sampling. During the interval while the samples are awaiting transport, they should be stored if possible in a cool room.

E-1.2 Undisturbed Samples of Soil — The following conditions of handling and protection of undisturbed samples are to be regarded as a minimum requirement for samples taken by the usual methods; in special cases it may be necessary to take more elaborate precautions:

a) Samples which are retained in a liner or which are retained in a seamless tube sampler should receive the following treatment:

Immediately after being taken from the boring or trial pit, the ends of the sample should be cut and removed to a depth of about 2·5 cm (or more in the top to cover any obviously disturbed soil). Several layers of molten wax should then be applied to each end to give a plug about 2·5 cm thick. If the sample is very porous, a layer of waxed paper should first be placed over the ends of the sample.

Any space left between the end of the liner or tube and the top of the wax should be tightly packed with saw dust or other suitable material, and a close-fitting lid or screwed cap be placed on each end of the tube or liner. The lids should, if necessary, be held in position by adhesive tape. If the longitudinal joint of the liner is not air-tight, this should be waxed and protected by adhesive tape in the same way as the lid.

b) Samples which are not retained in a tube should be wholly covered with several layers of molten paraffin wax immediately after being removed from the sampling tool, and then placed in a suitable metal container, being tightly packed in the container with saw dust or other suitable material. The lid of the container should be held in position by adhesive tape. If the sample is very porous, it may be necessary to cover it with waxed paper before applying the molten wax.

c) A label bearing the number of the sample, preferably of the type shown in **E-2**, should be placed inside the container just under the lid. It should be placed at the top of the sample. In addition, the number of the sample should be painted on the outside of the container, and the top or bottom of the sample should be indicated.

d) The liner or containers should be placed in a stout wooden box, preferably with separate partitions, and packed with saw dust, paper, etc, to prevent damage during transit.

e) It is desirable to test the undisturbed samples within two weeks of taking them from the boring or trial pit, and during the interval while awaiting transport and test, they should be stored, if possible in a cool room, preferably with a high humidity, say 90 percent.

E-1.3 Samples of Rock

E-1.3.1 *Block Specimens* — The reference number of the sample should be recorded on it either by painting directly on the surface of the specimen, or by attaching to the specimen a small piece of surgical tape on which the number is written in Indian ink or indelible pencil. Samples should then be wrapped in several thicknesses of paper and packed in a wooden box. It is advisable to include in the wrapping a label of the type described in **E-2**.

E-1.3.2 *Cores* — In the case of small diameter drill cores, it is usual to preserve the whole core. This is best done in core boxes which are usually 1·5 m long and divided longitudinally by light battens to hold 10 rows of cores. The box should be of such depth and the compartments of such width that there can be no movement of the cores when the box is closed. The lid of the box should be adequately secured (*see* IS : 4078-1980*).

E-1.3.2.1 Great care should be taken, in removing the core from the core barrel and in placing it in the box, to see that the core is not turned end for end, but lies in its correct position. Depths below the surface of

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*Code of practice for indexing and storage of drill cores (*first revision*).

the ground should be indicated at 1·5 m intervals by writing the depth in indelible pencil on a small block of wood which is inserted in its correct position in the box. The exact depth of any change of strata should be shown in the same way. Where there is a failure to recover core, this should be recorded in the same way.

E-1.3.2.2 Where specimens are required for examination or analysis, short lengths of core may be split longitudinally by means of a special tool known as core splitter. One-half of the specimen should remain preserved in the box. Large diameter drill cores are usually too heavy to be treated in this way. As a rule, they are laid out in natural sequences for examination on the ground. Specimens required for detailed work may be treated as block specimens (*see* **E-1.3.1**).

E-1.3.2.3 The properties of hard clays and soft rocks depend to some extent on their moisture content. Representative samples should therefore be preserved by coating them completely with a thick layer of wax after removing the softened skin.

E-2. LABELLING OF SAMPLES

E-2.1 All samples should be labelled immediately after being taken from the bore hole or trial pit.

Records should be kept on a sheet of the type shown as below. These sheets are serially numbered and bound in book form in duplicate. Each sheet carries a portion which may be detached along a line of perforations and which is used as a label [*see* **E-1.1**(b) *and* **E-1.2**(c)]. On this portion the serial number of the sheet is repeated three times, so that the chance of its being defaced is diminished.

Bound at This Edge	Perforated Here	Tear Off Slip

No: 1 100	No: 1 100
SAMPLE RECORD	
Location........................Date..................	
Boring No............R.L. of ground surface..........	
Position of sample, from...........................	
to..............................below ground surface	No: 1 100
Container No.........................Type of Sample	
Disturbed/Undisturbed	
Remarks:	
Signed:	No: 1 100

(*Continued from page 2*)

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4968 (Part II)-1977	Method for subsurface sounding for soils: Part II Dynamic method using 50 mm cone and without bentonite slurry (*first revision*)
4968 (Part III)-1977	Method for subsurface sounding for soils: Part III Static cone penetration test (*first revision*)
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