

**Surface and Sub-surface
Geotechnical Exploration**

2400

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2401. GENERAL

2401.1. The objective of sub-surface exploration is to determine the suitability or otherwise of the soil or rock surrounding the foundation and soil parameters and rock characteristics for the design of foundation by in-situ testing or testing of samples/cores taken out of exploration. The sub-surface exploration shall be planned in such a way that different types of soil upto the desired depth and their profile for the full proposed length of the bridge can be recorded and other information such as mechanical and physical properties like grain-size distribution, sensitivity, any existence of deleterious material in soil or ground water, etc., are determined alongwith soil parameters and rock characteristics. The sub-surface exploration shall also throw light on porosity of rock and subsidence due to mining, ground water level, artesian condition, if any, likely sinking and driving effort, likely constructional difficulties, etc.

2401.2. Field Investigation

Field investigations of sub-surface has. usually three phases :

- i) Reconnaissance
- ii) Preliminary Explorations
- iii) Detailed Explorations

2401.2.1. Reconnaissance includes a review of available topographic and geological information, aerial photographs and data from previous investigations and site examination.

2401.2.2. Preliminary investigation shall include the study of existing geological information, previous site reports, geological maps, air photos, etc. and surface geological examination. For large and important structures the information may be supplemented by geophysical methods. In some cases where no previous sub-strata data are available, exploratory geophysical investigation may need to be supplemented by resorting to a few bore-holes. These will help to narrow down the number of sites under consideration and also to locate the most desirable location for detailed sub-surface investigation like bore or drill holes, sounding probes, etc.

2401.2.3. The scope of detailed investigation for bridges may be decided based on data obtained after preliminary investigation. Based on data obtained after preliminary investigations, the bridge site, type of

structure with span arrangement and the location and type of foundations, shall be tentatively decided. Thereafter, the scope of detailed investigation including the extent of exploration, number of bore-holes, type of soundings, type of tests, number of tests, etc., shall be decided, so that adequate data considered to be necessary for the detailed design and execution, are obtained.

2401.2.4 The width of exploration : One purpose of detailed exploration for high embankments is to ascertain the average shear strength of each strata. The other purpose is to ascertain the compressibility of the clayey strata. It is, therefore, necessary that detailed and well illustrated description of the characteristics of stratification should be prepared. After the general shape and trend of the boundaries of the various soil deposits have been determined and rough assessment of their strength has been made by sub-surface sounding, with or without sampling in exploratory boring, the location of bore-hole(s) for undisturbed sampling shall be decided. At least one representative undisturbed sample should be collected from each strata. When the homogeneous strata is very thick, one representative sample shall be collected for each 3 m thickness of the strata.

2401.3. Soil investigation for foundations shall contain a programme for boring and retrieval of samples. The field work shall consist of excavation, drilling of bore-holes for the purposes of collection of undisturbed and disturbed samples, standard penetration tests, in-situ vane tests, static and dynamic cone penetration tests, other field tests, as specified by the Engineer and preparation of bore-logs. Collection and preservation for testing of disturbed and undisturbed samples from bore-holes, borrow pits, etc., as specified by the Engineer shall form a part of the above. All in-situ tests shall be supplemented by laboratory investigations. Relevant Indian Standards such as IS:1498, IS:1888, IS:1892, IS:2131, IS:2132, IS:2720, IS:4434 and IS:4968 and Appendix I of IRC:78, etc., shall be followed for guidance.

2401.4. The soundings by dynamic method shall be carried out in bore-holes using a standard sampler as specified in IS:2131.

2402. PRELIMINARY INVESTIGATION

2402.1. Foundations

2402.1.1. Preliminary exploration shall be carried out to determine the soil profile showing the boundaries between the different soil types and between loose and dense parts in the same type of deposits.

For guidance reference may be made to IRC:75. For this purpose, as a first step, a suitable type of sub-surface sounding (e.g. static or dynamic cone penetration test) shall be carried out. As many soundings as necessary should be made, until the penetration data is complete enough to leave no doubt concerning the general shape and the trend of boundaries of the various soil deposits. Exploratory drill holes should then be made at one or two locations where average condition prevails and near those few points where the penetration diagrams indicate maximum deviations from the average.

2402.1.2. The exploration shall cover the entire length of the bridge and also extend at either side for a distance about twice the depth below bed of the last main foundations. If there is any necessity for designing investigation for approaches particularly on soft soil or with high embankment or there is a possibility of considering alternatives between viaduct or earthen embankment, the extended length and location of the borings beyond the proposed location of abutment should be determined and executed.

2402.1.3. The depth of exploration should be at least $1\frac{1}{2}$ times the minimum width of foundation below the proposed foundation level. Where such investigation end in any unsuitable or questionable foundation material the exploration shall be extended to a sufficient depth into firm and stable soils or rock but not less than four times the minimum depth of foundation below the earlier contemplated foundation level. In case of good sound rock the stipulation of minimum depth may be decreased based on difficulty to conduct core drilling and the minimum depth may be restricted to 3 metres.

2402.2. Guidebund and Embankment

The depth of exploration should include all strata likely to affect stability of the embankment, guide bund and/or cause undesirable settlement. In general, the requirement of settlement governs the depth of exploration for high embankments in particular. However, borings can be terminated at shallower depths when firm strata or bed rock is encountered. Ordinarily, the boring shall be taken to a depth of at least 1.5 times the height of embankment and guidebund. However, where highly compressible strata are encountered, the boring may have to be taken deeper. In order to ensure that firm strata is sufficiently thick, the boring should extend 3 metre into the firm strata.

2403. DETAILED EXPLORATION

2403.1. The exploration shall cover the entire length of the bridge and also extend at either end for a distance of about twice the depth below bed of the last main foundation to assess the effect of the approach embankment on the end foundations. Generally the sub-surface investigations (preliminary and detailed) for bridges shall extend to a depth below the anticipated foundation level equal to about one and a half times the width of the foundation. However, where such investigations end in any unsuitable or questionable foundation material, the exploration shall be extended to a sufficient depth into firm and stable soils or to rock.

2403.2. The type and extent of exploration shall be divided into the following groups as per requirement of foundation design and likely method of data collection :

- i) Foundation requiring shallow depth of exploration
- ii) Foundation requiring large depth of exploration
- iii) Fills behind abutments and protection works

2403.3. Location Boring

Where the data made available by detailed exploration indicates appreciable variation or where variations in a particular foundation are likely to appreciably affect the construction (specially in case of bridge foundations resting on rock), it will be necessary to resort to additional bores/soundings to establish complete profile of the underlying strata. The additional borings /soundings shall be decided depending upon the extent of variation at a particular foundation location and should cover the entire area of the particular foundation.

2403.4. Construction Stage Exploration

Whenever a change in the sub-soil strata/rock profile is encountered during construction, explorations shall be resorted to establish the correct data for further decisions.

2403.5. Logging of bore-holes by radio-active methods shall be done for detailed investigations as specified in the contract or in special provisions.

2403.6. For bridge works, the investigations shall be comprehensive enough to, enable the designer to estimate or determine the following :

- i) the engineering properties of the soil/rock,

- ii) the location and extent of soft layers and gas pockets, if any, under the hard founding strata,
- iii) the geological condition like type of rock, faults, fissures or subsidence due to mining, porosity etc.,
- iv) the ground water level,
- v) artesian conditions, if any,
- vi) quality of water in contact with the foundation,
- vii) the depth and extent of scour,
- viii) suitable depth of foundation,
- ix) the bearing capacity of the foundation,
- x) probable settlement and probable differential settlement of the foundations,
- xi) likely sinking or driving effort, and
- xii) likely construction difficulties.

2404. EXPLORATION FOR BRIDGE FOUNDATIONS RESTING ON ROCK

2404.1. Investigation and interpretation of data for rock is a specialised work. To arrive at the characteristic strength of rock mass, reliance shall be placed more on in-situ tests in comparison to laboratory tests. An engineering geologist shall also be associated in the exploration programme.

2404.2. Identification and classification of rock types for engineering purposes may in general be limited to broad, basic geological classes in accordance with accepted practice. Strength of parent rock alone is of limited value because overall characteristics depend considerably on character, spacing and distribution of discontinuities of the rock mass, such as the joints, bedding planes, faults and weathered seams. An important factor affecting the behaviour is the weathered zone at top.

2404.3. Basic Information Required from Explorations

- i) Depth of rock strata and its variation over the site,
- ii) Whether isolated boulder or massive rock formation,
- iii) Extent and character of weathered zone,
- iv) Structure of rock - including bedding planes, faults, fissures, solution cavities etc.,
- v) Properties of rock material-strength, geological formation, etc.,
- vi) Erodibility of rock to the extent possible,
- vii) Colour of water.

2404.4. Exploration Programme

If preliminary investigations have revealed presence of rock within levels where the foundation is to rest, it is essential to take up detailed investigation to collect necessary information mentioned in clause 2404.3. The exploratory bore-hole shall be drilled into the rock to a depth of about 3 metres to distinguish a boulder from a continuous rock formation.

2404.5. The extent of exploration shall be adequate enough to give a complete picture of the rock profile both in depth and across the channel width to assess the constructional difficulties in reaching the foundation levels.

2404.6. The depth of boring in rock depends primarily on local geology, erodibility of the rock, extent of structural loads to be transferred to foundation etc. Normally, it shall pass through the upper weathered or otherwise weak zone, well into the sound rock. Minimum depth of boring in sound rock shall be 3 metres.

2404.7. Detailed Investigation for Rock

2404.7.1. This covers sounding, boring and drilling. An adequate investigation programme shall be planned to cover the whole area for general characteristics and in particular the foundation location, to obtain definite information regarding rock-depth and its variation over the foundation area. The detailed programme of exploration will depend on the type and depth of over-burden, the size and importance of the structure, etc. To decide this, geophysical methods adopted at the preliminary investigation stage will be helpful, this data being supplemented by sounding, bore-holes and drill holes.

2404.7.2. Drilling through rock is a very specialised work and every care shall be taken to notice and record any small change during drilling. The time required to drill through a certain depth, amount of core recovery, physical condition, length of pieces of core, joints, colour of water residue, weathering and evidence of disturbance and other effects shall be carefully noticed and entered in the drilling log. For guidance, IS:5313 may be referred to. The data shall be presented in accordance with IS:4464.

2404.7.3. The cores shall be stored properly in accordance with IS:4078.

2404.7.4. The rock cores obtained shall be subjected to following laboratory tests :

- i) Visual identification for texture, structure, composition, colour and grain size.
- ii) Laboratory tests shall be done for specific gravity, porosity and moisture content.

2404.7.5. In-situ tests shall be made in accordance with IS:7292; IS:7317; and IS:7746. In addition, laboratory tests can also be made on samples.

2404.7.6. Use of in-situ tests for measuring strength and deformation characteristics shall be made. Use of bore-hole photography will be desirable to evaluate the presence of faults, fissures or cavities, etc.

2404.8. Special Cases

2404.8.1. Investigation for conglomerate : A drill hole shall be made same as for rock. The samples collected shall be subjected to suitable tests depending upon the material, special care shall be taken to ascertain erodibility of the matrix. Where possible, specially for shallow foundation, Plate Load Test shall be conducted.

2404.8.2. Investigation for laterites : The investigation shall be generally similar to that required for cohesive soils, use of penetration tests shall be preferred, if suitable correlation charts are available. This may be static or dynamic penetration tests or vane shear tests. In the case of hard laterite, recourse may have to be made to core drilling as for soft rocks. For laterites at shallow depths, use of Plate Load Test may be advantageous.

2404.9. Caution

2404.9.1. The interpretation of laboratory results on rock samples depends upon the relationship of the specimens tested to the overall rock characteristics, enumerated in Appendix 1 of IRC:78. For this purpose, care shall be exercised in the choice of specimen size and its orientation in relation to the joint pattern.

2404.9.2. In some cases, the foundation behaviour will be dominated by a possible mode of failure involving movement along some joint surface, fissures or weak layer within a generally strong rock system and also by possible weathering. In-situ shear tests may be conducted wherever feasible, as such tests are likely to give more representative data than the shear tests conducted on core samples.

2404.10. Presentation of Data

The data shall be given in diagrammatic form in 3 sheets giving the following details :

Sheet 1 : Plan showing the position of bore-holes clearly marked so as to fix the position at a future date.

Sheet 2 : This shall contain the bore-log chart and test results of the samples separately for each bore-hole/pit etc.

Sheet 3 : This shall contain pictorial representation of the bore-log data to get an overall picture of the soil profile at the cross-section of the river.

NOTE : For guidance, refer to IRC:78.

2405. BORING

Boring shall be done by any of the following methods depending on the soil type and types of samples required for the investigation:

- i) Auger Boring
- ii) Shell and Auger Boring
- iii) Percussion Boring
- iv) Wash Boring
- v) Rotary Boring

For preliminary and detailed sub-surface investigation only rotary drills shall be used. The casing shall also be invariably provided with diameters not less than 150 mm upto the level of rock, if any. However, use of percussion or wash boring equipment shall be permitted only to penetrate through bouldery or gravelly strata for progressing the boring but not for the collection of samples. While conducting detailed borings, the resistance to the speed of drilling i.e. rate of penetration, core loss, etc., as already specified in Appendix 3 of IRC:78 shall be carefully recorded to evaluate the different types of strata and to distinguish specially sand from sandstone, clay from shale, etc.

2406. RECORDS OF BORINGS AND TRIAL PITS

2406.1. The field records for the preliminary and detailed exploration shall contain the date when the boring was made, the location of the boring with reference to a permanent system of co-ordinates and the elevation of the ground surface with respect to a permanent bench mark. They shall include elevation at which the water table and the upper boundary of each of the successive soil strata were encountered,

the investigator's classification of the layer on the basis of general information obtained from field examination (refer to Appendix 2.1 of IRC:75) and the value of the resistance obtained by means of Standard Penetration Test. The type of tools used for borings shall be recorded. If the tools were changed, the depth at which the change was made and the reason thereof shall also be noted. Incomplete and abandoned borings shall be described with no less care than successfully completed drill holes. The notes shall contain everything of significance observed on the job such as the elevation at which wash water was lost from the hole.

2406.2. For all borings and trial pits, necessary information as detailed below shall be given. A site plan showing the disposition of the bore holes shall also be attached :

- a) Agency
- b) Location with reference map
- c) Pit/Bore-hole number
- d) Reduced level (R.L.) of ground surface or other reference point
- e) Dates of starting and completion
- f) Name of supervisor
- g) Scales of plans and sections
- h) Dimensions, methods of advancing exploration such as by hand tools, blasting, boring, etc.
- i) General description of strata met with and RLs at which they are met
- j) Position and altitude of contacts, faults, strong joint, slicken sides, etc.
- k) Inflow of water, methods of controlling the water, required capacity of pumps for dewatering
- l) The level at which the sub-soil water is met with
- m) Dip and strike of bedding and of cleavage.
- n) Visual description of strata
- o) Results of field tests e.g. SPT, in-situ vane shear test etc.
- p) Any other information and remarks.

2406.3. Upon removal of sampling tube, the length of the sample in the tube and the length between the top of the tube and the top of the sample in the tube shall be measured and recorded.

2407. METHODS OF SAMPLING

There are two types of samples viz. (a) Disturbed sample (b)

Undisturbed sample. The usual methods for sampling conforming to IS:1892 and IS:2132 are given below :

Nature of Ground	Type of Sample	Method of Sampling
Soil	Disturbed	Hand Samples Auger Samples Shell Samples
	Undisturbed	Hand Samples Tube Samples
Rock	Disturbed	Wash Samples from percussion or rotary drilling
	Undisturbed	Cores

2408. PROCEDURE FOR TAKING SAMPLES

2408.1. For proper identification of sub-surface material, sample should be recovered containing all the constituents of the materials in their proper proportion. In clayey deposits such samples could be collected by split spoon samplers. In the case of sandy deposits, sampling spoons shall be fitted with suitable devices for retaining samples. All data required for soil identification (Appendix 2.1 of IRC:75) should be collected from the samples so extracted when undisturbed samples, which are more desirable for collection of some of the data, are not available. Penetration test should be carried out with the standard split-spoon sampler or penetrometers if the soil is coarse grained. When it is known in advance that the soil profile is fairly regular, preliminary and detailed investigation may be combined. Tube samplers can be used in place of split spoon samplers for collecting samples in clayey strata.

2408.2. Disturbed Soil Samples

2408.2.1. Disturbed samples of soil shall be obtained in the course of excavation and boring. For procuring samples from below the ground water level, where possible, special type of sampler shall be used. Where Standard Penetration Test is conducted, representative samples shall be obtained from the split spoon. While collecting disturbed samples from borrow areas it shall be ensured that the samples collected represent all types of borrow materials to be used in the construction of embankment and sub-grade.

2408.2.2. The size of sample generally required shall be as given in Table 2400-1.

TABLE 2400-1 SIZE OF SOIL SAMPLE REQUIRED

S. NO.	PURPOSE OF SAMPLE	SOIL TYPE	WEIGHT OF SAMPLE REQUIRED Kg
1.	Soil identification, natural moisture content tests, mechanical analysis and index properties, chemical tests	Cohesive soils Sands and Gravels	1 3
2.	Compression tests	Cohesive soils and sand	12.5
3.	Comprehensive examination of construction material and borrow area soil including soil stabilisation	Cohesive soils and sands Gravelly soil	25 - 50 50 - 100

2408.2.3. While taking out disturbed soil samples, Standard Penetration Test may also be conducted to find out the bearing capacity of the sub-soils at specified levels.

2408.3. Undisturbed Soil Samples

2408.3.1. The location of the bore-hole shall be as indicated on the drawing or given by the Engineer.

The depth of the bore-hole shall be as indicated on the drawing or shall be governed by the criteria given therein or as directed by the Engineer.

2408.3.2. Samples shall be obtained in such a manner that their moisture content and structure do not get altered. This may be ensured by careful protection and packing and by use of correctly designed sampler.

2408.3.3. Standard Penetration Test may have to be conducted in each case to obtain additional data as directed by the Engineer. In soft clay, in-situ vane shear test as per IS:4434 may have to be conducted. Where all the three operations have to be carried out in one layer, the sequence shall be undisturbed soil sampling followed by in-situ vane shear test, followed by Standard Penetration Test.

2408.3.4. For compression test samples, a core of 40 mm diameter and about 150 to 200 mm length may be sufficient, but for other laboratory tests, a core of 100 mm diameter and 300 mm length

shall be taken as far as possible, unless otherwise specified by the Engineer.

2408.3.5. The upper few millimetres of both types of sample shall be rejected as the soil at the bottom of the bore hole usually gets disturbed by the boring tools.

2408.4. Rock Samples

2408.4.1. Disturbed samples : The sludge from percussion borings or from rotary borings which have failed to yield a core, shall be collected for a disturbed sample. It may be recovered from circulating water by settlement in a trough.

2408.4.2. Undisturbed samples : Block samples taken from the rock formation shall be dressed to a size of about 90 x 75 x 50 mm.

For core samples - cores of rock shall be taken by means of rotary drills fitted with a coring bit with core retainer, if warranted.

2408.4.3. In case of rock at shallow depths which can be conveniently reached, test pits or trenches are the most dependable and valuable methods since they permit a direct examination of the surface, the weathered zone and presence of any discontinuities. It is also possible to take representative samples for tests. For guidance, IS:4453 may be referred to.

2409. PROTECTION, HANDLING AND LABELLING OF SAMPLES

2409.1. Care shall be taken in handling and labelling of samples so that they are received in a fit state for examination and testing and can be correctly identified as coming from a specified trial pit or boring.

2409.2. The disturbed material in the upper end of the tube shall be completely removed before applying wax for sealing. The length and type of sample so removed should be recorded.

2409.3. The soil at the lower end of the tube shall be reamed to a distance of about 20 mm. After cleaning, both ends shall be sealed with wax applied in a way that will prevent wax from entering the sample. Wax used for sealing should not be heated to more than a few degrees above its melting temperature. The empty space in the samplers, if any, should be filled with moist soil, saw dust, etc., and the ends covered with tight fitting caps.

2409.4. Labels giving the following information should be affixed to the tubes :

- a) Tube number
- b) Job designation
- c) Sample location
- d) Boring number
- e) Sample number
- f) Depth
- g) Penetration
- h) Gross recovery ratio

The tube and boring numbers should be marked in duplicate.

Duplicate markings of the boring number and sample number on a sheet which will not be affected by moisture should be enclosed inside the tube.

2410. TESTS FOR EXPLORATION OF SHALLOW FOUNDATIONS OF BRIDGES

2410.1. Test pits or trenches are the most dependable and valuable methods of exploration since they permit direct visual examination and more reliably the type of soil and their stratification. This will also allow in-situ tests like plate bearing tests, shear tests and uni-axial jacking tests, etc.

2410.2. Tests shall be conducted on undisturbed samples, which may be obtained from open pits. The use of Plate Load Test (as per IS:1888) is considered desirable to ascertain the safe bearing pressure and settlement characteristics. A few exploratory bore holes or soundings shall be made to safeguard against presence of weak strata underlying the foundation. This shall extend to a depth of about $1\frac{1}{2}$ times the proposed width of foundation.

The laboratory results shall correlate with in-situ tests like Plate Load Tests and Penetration Test results.

2411. TESTS FOR EXPLORATION FOR DEEP FOUNDATIONS OF BRIDGES

2411.1. The tests to be conducted at various locations for properties of soil, etc., are different for cohesive and cohesionless soils. These are enumerated below and shall be carried out, wherever practicable, according to soil type.

2411.1.1. Cohesionless soil

- a) Classification tests, density, etc.
- b) Field tests.
 - Plate Load test as per IS:1888.
 - Dynamic Penetration test as per IS:2131 and Use of Dynamic Cone penetration test as per IS:4968 (Part 1 or Part 2) may be conducted where considered appropriate
- c) Laboratory tests : Shearing strength test - triaxial or box shear test - in case of the possibility of rise of water table, the tests shall be done on saturated samples.

2411.1.2. Cohesive soils

- a) Classification tests, density, etc.
- b) Field tests :
 - Plate Load Test.
 - Unconfined Compression Test as per IS:2720 (Part 10).
 - Vane Shear Test as per IS:4434.
 - Static Cone Penetration Test (IS:4968 Part 3).
- c) Laboratory tests : Shearing strength test - triaxial tests (IS:2720 Part 9). Consolidation Test (IS:2720 Part 15)

Note : Where dewatering is expected, samples may be tested for permeability (IS:2720 Part 17).

2411.2. The sub-surface exploration for bridge works can be divided into 3 zones :

- i) between bed level and upto anticipated maximum scour depth (below H.F.L.)
- ii) from the maximum scour depth to the foundation level.
- iii) from foundation level to about $1\frac{1}{2}$ times the width of the foundation below it.

2411.3. The sub-soil water shall be tested for chemical properties to ascertain the hazard of deterioration to foundations. Where dewatering is expected to be required, permeability characteristics shall be determined.

2411.4. For the different zones categorised in para 2411.2 the data required, such as soil classification, particle size distribution, shearing strength characteristics, method of sampling disturbed and undisturbed samples, testing, including particle size distribution, shear strength, unconfined compression test, shall be complied with.

2412. TESTING OF MATERIAL FOR GUIDE BUND AND HIGH EMBANKMENT AND ITS FOUNDATIONS

2412.1. The soil properties for the embankment foundation shall be as specified in particular specifications and shall be got verified

prior to construction operation. In case the actual soil properties do not match the particular specification, then embankment design shall be revised.

2412.2. Field investigation for the embankment material should be carried out to collect general information as indicated in IRC:75. For details refer to Clause 305.

Field investigations for sub-soil strata shall consist of taking minimum two bore holes for each approach to a bridge along centre line of the alignment at a distance of 50 m and 120 m behind the abutment positions on both sides. The depth of bore holes below the ground level may ordinarily be 2.5 times the maximum height of the embankment subject to minimum depth of 20 m. Thin walled sampling tubes of 100 mm internal diameter and 450 mm minimum length conforming to IS:2132 shall be used for collecting undisturbed samples from bore-holes at an interval of 2.5 to 3.5 m. Standard penetration test should be conducted immediately after undisturbed sample is collected.

2412.3. In addition to the relevant identification tests, mentioned in IRC:75, it shall be necessary to conduct some of the following tests on the undisturbed samples collected from the sub-strata. The choice of test is primarily determined by the type of soil, type of stability analysis (vide Table 2400-2), availability of apparatus and cost of investigation.

TABLE 2400-2 SHEAR STRENGTH TESTS FOR STABILITY ANALYSIS

S. No.	Stage in Life of Embankment	Strength Parameters	Shear Test	Type of Analysis
1.	(a) During construction or immediate post-construction	c_{uu}, ϕ_{uu}	Unconsolidated undrained triaxial shear test on undisturbed samples and on compacted embankment material	Total stress analysis
1	(b) — do —	S_u	Unconfined compression test in laboratory or vane shear test	— do —
1	(c) During construction or immediate post-construction	$C\phi'$	Consolidated undrained test with pore-pressure measurement on as compacted soil samples of embankment materials and on undisturbed samples	Effective stress analysis
2.	Long term stability	$C\phi'$	— do —	— do —

2412.4. Laboratory Investigations of Embankment Material

2412.4.1. The following tests should be conducted on representative samples of embankment material :

S. NO.	TEST	TEST METHOD
i)	Gradation Test (Sieve Analysis)	IS:2720 (Part 4)
ii)	Atterberg Limit Test	IS:2720 (Part 5)
iii)	Standard Proctor Test	IS:2720 (Part 7)
iv)	Natural Moisture Content	IS:2720 (Part 2)

2412.4.2 In addition to the above, there is need for shear strength tests on compacted samples of the fill material. For this purpose, the relative compaction should be 95 per cent of the Standard Proctor maximum dry density and moisture content, same as that likely to prevail in the embankment during the period covered by the stability analysis or to be used in the field during construction. Undrained test shall be run on cohesive soils and shear strength parameters should be ascertained for the ranges of normal pressures which are likely to be experienced in the field. In cases where effective stress analysis is required to be done, pore-pressure measurements should also be made during the undrained tests and effective strength and pore-pressure parameters should be found out. For fill material of cohesionless soils, a direct shear box test (IS:2720-Part 13) may be conducted to ascertain shear strength of soil.

2412.4.3. The results of reconnaissance, field and laboratory investigations for embankments shall be consolidated into a well-knit report. The record of findings and recommendations, if any, may be presented in the form of written test, graphs, figures and tables, as appropriate for different types of data and findings.

Information and data to be contained in the report should include general location map, pertinent geological information on reconnaissance observations, sub-soil profile (Fig. 2.1 of IRC:75), boring logs and summary of sub-soil properties (Fig. 2.2 of IRC:75), graphs and tables related to laboratory investigations, results of borrow area investigations (Fig. 2.3 of IRC:75) and recommendations, if any.

The undisturbed samples shall be collected from each layer of sub-soil unless the stratum is such that undisturbed samples cannot be collected using ordinary sampler. Where indicated by the Engineer, undisturbed samples shall be collected using piston sampler or core-cutter or such special devices. In thick layers undisturbed samples shall be collected at 3 m interval.

2413. MEASUREMENTS FOR PAYMENT

In case of bridge and road structures, the work of boring and trial pits shall be considered as incidental to the foundation works and nothing extra shall be paid unless otherwise specified in the contract. In cases where it is specified to be paid separately, like contract for soil investigation, the work shall be measured in running metres for boring, in cubic meters for trial pits, in number of samples for collection of disturbed and undisturbed samples and in number of tests for each type of test.

2414. RATE

The contract unit rate shall include the cost of all labour, materials, tools and plant and equipment required for doing the boring or making pits as per these specifications, taking out and packing the samples, sending and getting them tested in approved laboratories and making available the test report as specified or directed by the Engineer inclusive of all incidental costs to complete the work as per the specifications.
