Guidelines For Planning Scope of Site Investigation Works For Road Projects

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Abstract

Site investigation is an essential, part of geot-echnical design process. Intimate knowledge of Ihr,-; test techniques and possible geotechnical problems arise from ground conditions with part rular' reference to problems on stability and df:formation or displacement of slopes and founrations are essential for planning the scope of site investigation (SI) works. This paper intends to suggest some guidelines for planning the scope of SI for road projects. Only general principles and rationale underlying the site investigation practice are presesited.

General

Site Investigation (SI) is the exploration or discovery of the ground conditions to enable engineers to make informed design decisions. This will avoid or reduce the likely risks of unexpected hazards being encountered during and after construction. The main purpose of SI is to determine within practical limits, the depth, thickness, extent & composition of each distinct subsoil stratum; the depth & composition of ground water; the strength, compressibility properties of soil/rock stratum and other ground features information as required by geoieahnical engineers to perform appropriate cost effective design.

All site investigation (SI) works should comply with BS 5930, BS 1377 and JKR Standard, Specification for SI works. All deep boring should be rotary wash boring with adequate capacity and accessories to perform the works specified. The extent of site investigation mainly depends on the character and variability of the subsoil and ground water, and the amount of existing information available. However it should be noted that subsoil conditions of a road alignment are very sensitive to geological conditions, and so the spacing and location of boreholes/test pits/types of tests should be more closely related to the detailed geology of the project area and the geotechnical problem/analysis required to be carried out.

The planning of SI works should be carried out by suitably qualified geotechnical engineers after review of the project brief/route location: desk study and a preliminary field inspection. All the quality SI works should be closely directed, monitored, supervised and reported by geotechnical e,igineers. Additional scope of SI may be found necessary after some preliminary SI results are made available.

Filling Areas

The purpose of SI in filling areas is mainly to check bearing capacity and assess settlement of the ground, overall slope stability and provide necessary soil data for design of ground treatment works (if found necessary).

For filling areas where embankment is high (> 6 m) or the ground is swampy and consists of compressible soils, adequate number of boreholes and other relevant field tests should be carried out to determine the subsoil condition with particular reference to:-

- the geometry of the subsoil strata both transversely and longitudinally, (usually one or two borehoies in addition to three or more Deep Sounding (DS) or piezocones are used to determine the generalized sub soil profile for deposited formation at each stretch of soft ground. For residual soils areas, hand augering (HA) and deep boring (DB) plus JKR probes are performed instead of DS).

- the nature of these subsoil strata, their basic physical properties or index proper ties (moisture content, liquid limit, plastic limit, sieve analysis, SG, organic content), shear strength (Cu, C', o') and compress ibility (Cc, Cv, Mv). At least two undis turbed samples per distinct soft strata per borehole plus field & lab testing are pre ferred.

Stationary piston samplers should be used for taking samples from soft strata. Additional penetration vane shear and pressure meter tests are invaluable to obtain representative strength and consoli dation properties of the soft ground. The extent of site investigation in embankment areas should be sufficient to produce ade quate characterization of site conditions and properties to assess slope stability, to predict amount and rate of settlement and to design the necessary cost effective ground treatment.

- regime of ground water (and seepage). and its variation (by HA/DB and piezometers) . In, the case of sizeable project on subsoil consisting of very compressible organic clay, instrumented trial embankments incorporated with ground improve-ment techniques may 1-iave to be carried out to ensure the design is cost effective.

- Generally, the depth of boreholes should extend through all compressible or unsuit able soil or unstable laminated weathered rock at shallow depth (< 6 m) which is likely to encounter instability and settle ment problems due to the surcharge load of the filling. A a practical guide, boreholes should only ba terminated after reaching very stiff/dense strata ('two consecutive SPT values exceeding 20) for soft ground areas such as in coastal alluvial soils. In residual soil areas, at least one borehole should be extended until very hard/very dense strata (SPT value exceeds 50).

  For filling on steep sloping ground, more boreholes should be carrie=d out to deter mine the presence of unstable so;f/rock horizons, i.e. the character and orientaVon of all structural discontinuities, e.g. joints, sheared zones, laminated bedding, foliation etc. Detailed geological mapping may also be required.

  For low embankment in res:dual soil areas, one or two hand augering plu,: a few JKR probes are sufficient for design.

Cut Areas

The purpose of SI in cut areas is to procure geological information (soil/rock, interface), soil properties and water table conditions 'far slope stability checking and design of slope stabilization works when necessary. The SI for cut areas to be pontential borrow areas is to determine soil properties, (compaction properties) and assess the suitability as construction material specified.

For cut areas, adequate soil investigation should be carried out to determine the type of soils (soil classification, index and strength properties from on quality samples etc.) and ground water level and its uariation and fluctuation (by Casangrande stand-pipe or pneumatic piezometer). Infiltration, erosion and terrain characteristics aspects are very important for slope design. This is for assessment of the stability of slopes and drainage requirements.

Exploration to a minimum depth of 2 m to 3 m below the proposed formation level is necessary for ;proper assessment of possible subgrade strength and drainage conditions. For sedimentary rock areas, in addition to geological mapping, at least three boreholes per major hill should be carried out to determine the stratigraphical formation, the presence of defective or unstable geological structural discontinuities and its strength properties. Seismic survey may have to be carried out for major road projects passing through mountainous areas involving massive and deep excavation This is to ensure that more geo logical information are made available for slope stability assessment and also the quantity of rock excavation can be estimated with reasonable accuracy. Foam drilling and Mazier sampling are only required for high quality undisturbed samples in deter mining the shear strength of the residual soils.

For generalized subsoil profile purpose of the whole alignment (including in filling areas), the spacing of boreholes or hand augering for highway projects should be 60 m - 600 m. For road alignment passing through the same type of geological formation, less number of boreholes are required or spacing should be 500 m

interval or more. For road alignment passing through complex, variable/different geological formations, more borehofes at closer spacing are necessary. JKR probes should be carried out near the HA positions and filling areas to verify the consistency of the subsoil.

At least one test pit (2 m deep or more) should be carried out at each major cut area which form major sources for filling. Bulk sampling for classification test, CBR, dispersion and compaction test should be carefully planned for study on suitability and availability of filling materials.

Bridges and Structures

For major structures like bridges, major culverts and retaining walls, at least two Deep Boring should be carried out at each site or minimum one borehole per pier or abutment or maximum spacing of borehole should be 60 m. Additional boreholes should be allowed for bridge approach embankments especially on soft ground or high embankment areas. Other basic requirements are as follows:-

- **Bore Depth**

  All boreholes should be rotary wash bor ing. Boring shall only be terminated after 5 consecutive SPT exceeds 50 OA 5 consec utive SPT exceeds 30 if the bore depth also exceeds 60 m or refer to designer for advice and direction. Boring also can be terminated if rock is encountered:-

* *Suitable triple tube core barrel of NMLC or NMLC sizes should be used for rotary rock coring.*

- **Field Test**

  SPT shall be carried out at 1.r rn interval unless otherwise stated by the designer. In case of soft ground, vane shear test shall toe carried out instead of SPT and interval of testing should be 'm interval.

- Undisturbed samples, (UD samples) or preferable stationary piston samples shall be taken at, soft clay strata (alternate to SPT/vane test) for consolidation/shear test especially for boreholes at abutment/ approach to abutment.

- At least 3 water samples (from river and or from UD samples) shall be taken for chemical test (pH, So4 & chloride con tents).

- All soil classification test (natural moisture content, Atterberg limits, & sieve analysis etc.) shall be carried out for all typical dis turbed sample at various distinct strata.

- Photographs (at least 5 nos.) shall be taken to give general site conditions, access (ter rain and vegetation etc.), river/stream bank, & water flow conditions, boring machine set up, typical soil/ rock samples.

SI Report

The factual. SI report should be prepared and checked by a suitably qualified engineer. The report should include but not limited to the following:-

- Terms of Reference, purpose and scope of SI. Methodology, procedure & equipment (Type, model etc.) used.

- General relevant information (geological setting, topography, vegetation & other rel evant surface features).

- Record of time & date of bo, ing operation and ground water observation.

- Borelogs (field borelogs shah be corrected, checked & certified by geotechnical engi neer).
- Piezometer records.

- Summary of lab testing results.

- Photographs showing general site condi tions, typical soil and rock samples..

- Plan showing actual boreholes/te st loca tions with coordinates or chainages & A.L.

- Generalized subsoil profile along the align ment showing soil strata, ground water, lab and field test results, rock etc.

* *Logging of bore logs should be prepared*

by a suitably qualified technician or geologist! or engineer. Soil and rock description should be strictly according to BS 5930.

Common SI Methods

(a) JKR Probes

Results are used to determine thickness of unsuitable material to be removed and also for preliminary design of embankments. Usually carried out near HA or DB posi tions and filling areas to verify the consis tency of subsoil of medium strength up to maximum of 12 m deep.

(b) Hand Augering (HA)

Used in soft to stiff cohesive soils or sandy soils above water table. Usual spacing is 60 m - 600 m. Maximum depth is about 5 m. Very extensively used for road projects because extensive samples along the align ment can be obtained at a relatively fast and cheap price for the basic and index properties; used for identification, classifi cation and correlation of engineering prop erties such as permeability, strength and deformation etc.

(c) Deep Boring (DB)

Boreholes are advanced by power rotary drilling. Borehole sizes of NW or HW are preferred. Invaluable to determine strati graphical formation and subsoil properties in cut and filling areas.

Usual spacing is 60 m - 600 m. Field tests such as SPT vane shear, (for soft to stiff strata) permeability & pressure meter tests can be carried out in the boreholes. Disturbed and undisturbed samples can be taken for various laboratory tests to deter mine strength and deformation properties. Piezometers can also be installed in the borehole to monitor the ground water con ditions. SPT tests are usually carried out at 1.5 m interval. For soft clay and residual soils strata, stationary piston and Mazier samplers are respectively used to take quality undisturbed samples for laboratory strength tests.

Continuous soil sampling (Swedish or Delft Samplers) is specified if identifica tion of soil fabric or depth of changes in distinct strata & properties are required. For uniform subsoil, more sampling for lab tests; but for erratic subsoil more field tests should be carried out.

(d) Deep Sound(DS) - 100 kN/200 kN capacity

This is the static Dutch Cone Penetrometer Test. It is usually used to supplement Deep Boring results in filling areas which are fluvial or soft formation. Not suitable for boulder or gravel abundant subsoil. The results can be used to correlate and ascer tain strength & deformation properties etc. of the subsoils. Useful and adequate to determine subsoil profile. Piezocone tests is preferred.

(e) Test Pit & Bulk Sampling

Usually up to 2 m deep. For visual inspec tion of subsoil strata, soil type and strength (by pocket penetrometer). Bulk sampling for lab tests (soil classification, CBR & compaction tents). Undisturbed block sam ples also Grin be obtained for strength tests in the laboratory.

Concluding Remarks

It is hoped that the above suggested brief guidelines are useful and helpful to road engi-neers to plan their scope of site, investigation. It is vital to identify and understand adequately the possible associated risks and geotechnical problems to b-:~ encountered before planning a proper SI scheme for a road project. Purpose and scope of tests can only be determined after the possible geotechnical problems are known. Scope of Si works when planned by different engineers tend to be varied ')ecause there are an infinite number of conditions to be met and the process of planning also leaves many areas where individual engineering judgement, knowledge and experiences must be applied. Therefore it is important to realize that it is impossible to provide an exhaustive step by step guidelines applicable to all possible cases for engineers who are not familiar with geot-

echnical design.

References

a) BS 5930 (1981) SITE INVESTIGATION
b) BS 1377 (1990) METHODS OF TEST FOR SOILS FOR CIVIL ENGINEERING PURPOSES.
c) JKR STANDARD SPECIFICATION FOR SITE INVESTIGATION WORKS (1990).
d) NEOH C A (1990), IKRAM LECTURE NOTES ON SITE INVESTIGATION.