GUIDELINES FOR SITE INVESTIGATION WORKS

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1.0 INTRODUCTION

A process of the site exploration consisting of site inspection, boring, sampling and testing to obtain necessary properties for ground characterization, geotechnical evaluation and design.

To determine within practical limits, the depth, thickness, extend and compositions of each soil stratum; the depth, type and condition of rock; the depth and composition of ground water; the strength, compressibility and hydraulic characteristic of soil strata as required by geotechnical designers.

Adequate knowledge of subsoil conditions is very crucial in the design of foundation for a structure including the design of temporary works. Absence of proper Site Investigation (SI) results invariably will lead to produce a geotechnical design which is either unnecessarily over designed or dangerously inadequate.

Site Investigation generally ranges from 0.1% to 5.0% of the construction cost depending on the extent and scope of SI required for the project, which in place depend very much on the possible geotechnical problems identified, the character and variability of the subsoil properties, the type and nature of project, the experience of the designer and the existing information available.

2.0 THE IMPORTANCE OF SITE INVESTIGATION (SI)

2.1 The purposes of carrying out a site investigation are as follows:

a) To study the general suitability of the site for an engineering project (Feasibility studies).

b) To enable a safe, practical and economical evaluation and design of foundation, earthwork, construction method.

c) To determine the possible difficulties and problems that may be encountered by a specific construction method.

d) To study the properties or suitability of construction material (soils or rocks).

e) To determine the cause of failure (civil works) or failure investigation and subsequently prepare the necessary remedial works.

2.2 Without SI or inadequate SI, geotechnical design is incomplete and it has been identified as a main factor accounting for many geotechnical failures, significant delay and increase in construction cost when the design has to be revised or amended

3.0 WORKS PROCEDURE FOR SITE INVESTIGATION

3.1 Works procedure for SI are as follows:-

a) Desk study to collect all relevant data and preliminary information.

b) Site reconnaissance to familiarize general site condition and review of information available from desk study and site inspection report.

c) Planning programmed and scope of site investigation. Need, purposes and possible geotechnical problems of the project must be identified clearly first before the scope snd extent of SI including the number and locations, of boring, sampling and testing can be decided.

d) Prepare specification, BQ & necessary documents for tender/quotation.

e) Tender evaluation and appoint suitable/competent contractor to carry out the ground exploration; boring, sampling and testing under close supervision of experienced engineer.

f) Carry out laboratory testing after the study of the bore logs.

g) Preparation of Site Investigation interpretative report.

h) Geotechnical analysis and design.

i) Review during construction and monitoring or instrumentation works.

3.2 The following preliminary information/details facilitating site investigation planning should be prepared when planning site investigation works:-

a) Location Plan – showing the location of the project concerned. Latest developments in the area involving in earthwork or piling works etc. if any, should be indicated

b) Site Plan – showing the layout of the proposed structures, utility pipes and cables, nearby structures/buildings/rivers, other potential hazardous conditions if any, should also be indicated

c) Other Details – like topographical map, loading conditions and preliminary site inspection/ investigation reports if any should be included. According to KPKR 's circular Ref.(20)dlm.KPKR/PP/79/11 dated 21/12/79, JKR District has to carry out at least 6 JKR probes for each building and fill up Form SI 2/71 Rev. 79 and send to designer for further action. JKR probes need not be carried out if the building is likely to have piled foundation.

4.0 PLANNING OF SITE INVESTIGATION WORKS

4.1 Site investigation includes three parts namely:-

a) Surface investigation - Site inspection or walk-over survey to access the general site conditions and identify the possible changes that may arise in the

ground and environmental conditions, either naturally or as a result of the works, and the effect of such changes on the works, on adjacent works and on the environment in general.. Usually soil engineer is required to inspect the site to appreciate actual site and ground problems with particular reference to terrain, vegetation, swamps, water runoff, stratigraphical formation where they are exposed.

b) Subsurface investigation - Ground or soil investigation by means of boring, sampling, testing etc. so as to determine stratigraphy and pertinent properties of soil underlying the project site.

c) Construction monitoring/ observation and feedback.

4.2 Planning scope of SI means:-

a) Select type of testing and methods of site investigation. Important considerations are; terrain features and accessibility, geological conditions, possible geotechnical problems, types of samples and test required. An understanding of geology of the site is crucial for identification of possible geotechnical problems and subsequent proper planning and interpretation of SI.

b) Estimate cost and time requirement.

c) Determine the number and spacing of boreholes or other field tests. (location and procedure of test, criteria to terminate a borehole should be clearly specified)

d) Determine frequency and types of in-situ testing and sampling in each borehole.

e) Determine extent of supervision on testing and boring.

f) Prepare list of special precautions for the site investigation supervisor, if any.

g) Prepare scheme of laboratory testing after analysis of field bore logs.

4.3 Guidelines for Planning Scope of Works for Road Projects (Refer Appendix C)

4.4 Guidelines For Planning Site Investigation For Building Projects

4.4.1 For building projects, JKR probes are usually carried out first. The results are sufficient for shallow foundation design if all the following conditions are complied:-

a) Results are reasonably consistent

b) Good bearing layer is above water table and available at about 2m below the ground and the subsequent strata has better bearing capacity up to at least 3m below the proposed founding level or 1.5 times the width of footing whichever is larger.

c) No footings are on filled ground.

d) Design pressure is 100 KN/m^2 or less.

e) Building is a low rise building (column load less than 1000 KN/column)

f) Designer has some knowledge about the site condition

Otherwise further SI has to be carried out. This includes one or two or more of the following methods of soil investigation:-

i. Hand Augering to determine the water table; type and consistency of soil
ii. Motorised Hand Boring
iii. Deep Boring (for any soil where piling is anticipated)

iv. Deep Sounding (mainly for alluvial soils where piling is anticipated; also used to supplement DB results)

v. Plate bearing or pressuremeter tests (for shallow foundation using high bearing capacity, say 100KN/m^2 or more or in fractured rock or soft rock)

vi. Test pit and bulk sampling (shallow foundation or deep excavation)

4.4.2 Spacing of borehole

- Spacing of boreholes for multistory building should be 15m-45m (depending on the uniformity of strata, geologic conditions and foundation type)
- Two boreholes for a block of low rise building on flat land is sufficient.
- For problematic and erratic soil formation like limestone areas, uncontrolled filled ground or boulder abundant areas, or structures sensitive to settlement more boreholes are necessary.
- For erratic and very variable subsoil condition, more field and boring tests; but less laboratory testing and little undisturbed sampling is required.
- For more uniform soil considerable lab testing and minimum field testing is required.

4.4.3 Depths of Boreholes

- All boring should extend through unsuitable/compressible strata to dense or hard strata.
- Required depth of boreholes depends on purpose of SI, the size and type of structures, characteristic and sequence of subsoil strata.
- Boring should be terminated after 5 consecutive SPT exceed 50 or 5 consecutive SPT exceed 30 if the borehole also exceeds 60m.
- At least one borehole per site to be drilled up to 3m or more into bedrock
- When rock is encountered, it should be proved by coring to minimum of 3m into rock having an average core recovery of at least 50% or at least 6m if the rock is limestone.

- The depth of borehole should extend through any unsuitable or weak soil to a sufficient depth of soil stratum which is firm or strong and unlikely to undergo settlements due to the load of the building.

4.4.4 In-situ testing and sampling practice

- SPT test/ samples should be taken at 1.5m intervals or at change in materials.
- For very soft or soft cohesive soil, vane shear test and piston samplers should be used
- For the site where shallow foundation is feasible or deep excavation is expected, SPT should be carried at 1.0m interval.
- Test pits are also relevant for bearing tests, undisturbed sampling for shear strength test, water table conditions etc.

4.4.5 Water Table (WT) should be taken:-

- During boring,
- At completion of borehole, and
- A min of 24hr after completion of borehole

More accurate WT is crucial for deep excavation and stability analysis and can only be obtained by installation of piezometer and long term monitoring.

4.4.6 a) Disturbed Samples

- Mostly obtained from the split barrel sampler used in SPT, are used for identification and classification tests.
- Some approximate strength and compressibility properties can be obtained from classification test results based on some correlations.

b) Undisturbed Samples

- Structural disturbance is kept to minimum and mainly used for consolidation and strength test
- Common undisturbed soil samplers are piston sampler, thin wall samplers, hydraulic sampler and Mazier samplers

4.5 Factor Influencing Selection of SI Methods

In planning process of site investigation, the following factors that may influence the selection of site investigation methods have to be considered:-

4.5.1 Geological nature of the site

- For alluvial fluvial deposit formation, Deep Sounding is generally suitable; but need to determined the soil type and ground water table (by Hand Augering or Deep Boring (DB)/Motorised hand boring(MHB))
- For residual soils, DB or MHB are more suitable; but only DB can do rock coring (not MHB).
- Trial pits are only practicable in firm or compact soils or in soft rock, above water table.
- For limestone areas, boulder abundant areas and uncontrolled filled ground, DB have to be used.
- SPT is appropriate for all soils except soft or very soft clay where vane shear test is more appropriate.
- Sampling for undisturbed samples by thin-walled sampler or piston sampler is only appropriate for cohesive soil with SPT value of about 10 or less.
- Disturbances in sampling for soils with SPT value exceeding 15 are unacceptable unless special measures are taken or Denison or Mazier samplers are used.

4.5.2 Topographical nature of the site

- Terrain and access condition are important considerations from the point of view of moving site investigation equipment about.

- In hilly or steep inclined sites, headings driven (horizontal or inclined drilling) may be more convenient than vertical boring machine or alternatively use small portable boring machine.
- In waterlogged or swampy areas, some preliminary work to prepare working platforms or staging are necessary

4.5.3 Type of information required

a) Type of SI methods required to be done depend very much on the type of information and analysis required or geotechnical problems identified based on the assessment of preliminary information available.

b) If a construction such as road embankments or building formation is on soft or swampy ground, the important geotechnical problems or concerns are the amount and rate of settlements, stability analysis, foundation design, negative friction on piles etc. Hence the required important information are:-
   - Subsoil profile showing the various thickness of compressible/hard strata water table (by DS/DB/Piezo cone/continuous sampling)
   - Compressiblility properties for settlement analysis (by undisturbed sampling using piston samplers for conso test, Cv, Mv, Cc etc.
   - Shear strength properties for stability analysis and ground treatment and pile design (vane shear tests, SPT, strength values can be from correlations with index properties etc.)

4.5.4 Financial constraints and time restriction

a) More extensive site investigation means more cost and more time.

b) Deep Sounding (DS) is usually cheaper and faster when compared to Deep Boring (DB); but when in swampy areas with very soft ground, DS can be as expensive as DB due to difficulty in getting anchorage load

c) Cost of SI is usually within the range of 0.1% to 5% of the construction cost; therefore to reduce the scope of SI for financial reasons alone is seldom justified

d) Three possible approaches can be taken when planning SI works:-

- Method 1: Carry out limited SI and adopt high FOS (Factor of Safety) in design. (Usually the design is unnecessarily over conservative or dangerously inadequate)
- Method 2: Carry out limited SI for design. Allow instrumentation works and additional SI during construction stage to verify the design. (Acceptable if the designer is very experienced and followed through during the construction stage, but the cost may not be cheap)
- Method 3: Carry out detailed SI for design (Usually cost effective if the designer has adequate experience, but it needs longer time for the SI)

APPLICABILITY OF COMMON FIELD OR INSITU TESTS

	FIELD TESTS	Soil Type	Soil Profile	Rock		SOIL TYPE					SOIL PARAMETERS				
				H.Rock	S.Rock	Gr	Sand	Silt	Clay	Peat	Ø	Cu	Mv	Cv	K
1.	Penetrometer														
	1.1 JKR Probe	X	C	X	X	C	B	B	B	B	X	B	X	X	X
	1.2 SPT	A	B	X	B	B	A	A	A	A	B	B	X	X	X
	1.3 DS (CPT)	B	A	X	X	B	A	A	A	A	C	B	C	C	X
	1.4 Pliezocone (CPTU)	A	A	X	X	A	A	A	A	A	B	B	A	A	B
	1.5 Flat Dilatometer	B	A	X	X	C	A	A	A	A	B	B	C	C	X
	1.6 Resistivity Probe	C	C	X	X	C	A	A	A	A	B	C	X	X	X
2.	Vane Shear	B	C	X	X	X	X	B	A	B	X	A	X	X	X
3.	PB Pressuremeter	B	B	C	A	B	B	B	A	B	X	B	B	C	X
4.	SB Pressuremeter	B	B	C	B	B	B	B	A	B	B	B	B	B	B
5.	Continuous Soil Sampling	A	A	X	B	B	A	A	A	A	C	B	B	B	C

Legends:-

A	=	suitable/useful	O	=	effective friction angle	K	=	coef. of permeability
B	=	moderate	Cu	=	undrained strength			
C	=	doubtful	Mv	=	coef. of volume compressibility			
X	=	not suitable	Cv	=	coef. of consolidation			

Appendix C

Guidelines For Planning Scope of Site Investigation Works For Road Projects

1.0 General

Site investigation (SI) is the exploration 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 and composition of each distinct subsoil stratum; the depth and composition of ground water; the strength, compressibility properties of soil/rock stratum and other ground features information as required by geotechnical engineers to perform appropriate cost effective design.

The extent of the SI 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 geotechnical problem/analysis required to be carried out.

2.0 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.

For filling area where embankment is high (> 6m) or the ground is swampy and consists of compressible soils, adequate number of boreholes and other

relevant field test should be carried out to determine the subsoil condition with particular reference to:-

a) The geometry of the subsoil strata both transversely and longitudinally

- Usually one or two boreholes in addition to three or more Deep Sounding (DS) or piezocones are used to determine the generalized subsoil 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.

b) The nature of these subsoil strata, their basic physical properties or index properties (moisture content, liquid limit, plastic limit, sieve analysis, SG and organic content)shear strength (Cu, C' and Ø') and compressibility (Cc,Cv and Mv). At least two undisturbed samples per distinct soft strata per borehole plus field & lab testing are preferred. Additional penetration vane shear and pressure meter tests are invaluable to obtain representative strength and consolidation properties of the soft ground.

The extent of site investigation in embankment areas should be sufficient to produce:-

- adequate characterization of the site conditions and properties to assess slope stability,
- to predict amount and rate of settlement, and
- to design the necessary cost effective ground treatment.

c) Regime of ground water (and seepage) and its variation (by HA/DB and piezometers).

d) The depth of boreholes should extend through all compressible or unsuitable soil or unstable laminated weathered rock at shallow depth (<6m) which is likely to encounter instability and settlement problems due to the surcharge load of the filling. As a practical guide, boreholes

should only be 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).

e) For filling on steep sloping more boreholes should be carried out to determine the presence of unstable soil/rock horizons.

f) For low embankment in residual soil areas, one or two hand augering plus a few JKR probes are sufficient for design.

3.0 Cut Areas

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

b) 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 lavel and its variation and fluctuation (by Casangrande stand pipe or pneumatic piezometer). Infiltration, erosion and terrain characteristics aspects are very important for slope design. This is for assessement of the stability of slopes and drainage requirements.

c) Exploration to a minimum depth of 2m to 3m 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 geological 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 determining the shear strength of the residual soils.

d) 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 60m – 600m.
- For road alignment passing through the same type of geological formation, less number of boreholes are required or spacing should be 500m interval or more.
- For road alignment passing through complex, variable/different geological formations, more boreholes 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.

e) At least one test pit (2m 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.

4.0 **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:-

a) Bore Depth

All boreholes should be rotary wash boring. Boring shall be terminated after 5 consecutive SPT exceeds 50 or 5 consecutive 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:-

Rock Type	Min. Core Length
Igneous rocks (granite) & bore depth <24m or Recovery Ratio R/r <50%	4.5m
Igneous rocks, bore depth <24m	3.0m
Shale/schist/slate/sandstone Recovery Ratio R/r <50%	6.0m
Shale/schist/slate/sandstone Recovery Ratio R/r >50%	3.0m
Limestone R/r >50% and no cavity	6.0m
Limestone R/r <50% or with cavity	9m – 21m
Other rock R/r >50%	4.5m
Other rock R/r <50%	6.0m

b) Field Test

SPT shall be carried out at 1.5 m interval unless otherwise stated by the designer. In case of soft ground, vane shear test shall be carried out instead of SPT and interval of testing should be 1 m interval.

c) Undisturbed samples, (UD samples)

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.

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

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

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