Rail Baltica
Coordinated by RB Rail

SPECIFICATION

REQUIREMENTS FOR SITE INVESTIGATIONS (GEOLOGICAL AND HYDROGEOLOGICAL INVESTIGATIONS)

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ACRONYMS AND ABBREVIATIONS

A full list of acronyms and abbreviations can be found in RBR Glossary of Abbreviations. The following acronyms and abbreviations are used throughout this document:

Abbreviation	Definition
BEP	BIM Execution Plan
BIM	Building Information Modelling
BIM EIR	Building Information Management Employers Information Requirements
CAT	Cable Avoidance Tool
CCS	Control-Command and Signalling
CPT(U)	Cone Penetration Tool (with pore pressure readings)
DG	Design Guidelines
DPH	Dynamic Probing Heavy
DPL	Dynamic Probing Light
DPM	Dynamic Probing Medium
DPSH	Dynamic Probing Super Heavy
DSR	Design Site Representative
ENE	Energy subsystem related to the feeding/controlling of traction facilities
ERT	Electrical Resistivity Tomography
GDR	Geotechnical Design Report
GI	Geotechnical Investigations
GIR	Ground Investigations Report
GPR	Ground Penetrating Radar
HWL	Highest water level
RB	Rail Baltica
RBR	RB Rail AS
RQD	Rock Quality Designator
SI	Site Investigations
SCR	Solid Core Recovery

SPT	Standard Penetration Test
TCR	Total Core Recovery
UCS	Unconfined Compressive Strength
UXO	Unexploded Ordnance

1 Introduction

1.1 Investigation methodology

The geotechnical and hydrogeological investigations described in this document shall be carried out with the purpose of providing information for the improvement, renovation and new construction of the construction elements mentioned below.

The results of the investigations shall enable the appointed Consultants geotechnical design team to provide recommendations and proposals for structures such as bridges/underpasses, retaining walls, noise barriers, culverts, drainages, hydraulic structures, ecoducts, earthwork structures (embankments/cuttings), power distribution systems sites, ENE traction stations, paralleling posts (PP)/switching posts (SWP) etc. within the corridor of RBR mainline. The investigations must also account for the retrofitting and integration of existing infrastructure, which is in close proximity to, or connecting with, the RBR alignment via reconstruction/improvement. The investigations shall contribute to informing the design assumptions with regards to:

(a) Representative and direct parametric derivation to inform stability/ deformation calculations as well as to verify the use of indirect correlations

(b) Spatial mapping of soft soil and Peat

(c) Total extent of possible soil replacement (areas of unstable or weak stratum)

(d) Material classification and site won reuse

(e) Possible soil improvement

(f) Type of foundation

(g) Depth of foundation

(h) Frost penetration and susceptibility analysis

(i) Foundation and embankment construction methodology

(j) Permissible load bearing capacity of the soil

(k) Estimates on expected settlement for defined loads

(l) Construction excavation methods and temporary support requirements

(m) Groundwater management

(n) Ground risk analysis, including the identification and mapping of potential geohazards (e.g., Karst features, faulting, landslides, UXO, made ground, soft soil etc.)

(o) Risk to the durability of the structure as well as the construction personnel with respect to ground contamination

(p) Monitoring proposals

To enable the geotechnical designer to assess the aforementioned aspects, the investigations need to obtain information so that the designer can gain site-specific information via field and laboratory testing. It should be noted that it is the responsibility of the Consultant to ensure that the stratum is suitably logged, classified and parameterised in order to produce well informed and optimised design solutions. The following list outlines the minimum requirements for sub-surface data acquisition and is not exhaustive:

For soils (shall include but is not limited to):

(a) Soil identification and classification in accordance with EN1997-2, ISO 14688-1 & 2, UIC 719R (QS classification).

(b) Particle size analysis and consistency limits according to EN 1997-2 and ISO 17892 parts 4 & 12.

(c) Water sensitivity classification according to Design Guidelines (MBF value).

(d) Frost susceptibility according to ISSMGE TC-8 criteria.

(e) Water content, natural in accordance with EN 1997-2 and ISO 17892-1.

(f) Bulk density in accordance with EN 1997-2 and ISO 17892-2.

(g) Particle density in accordance with EN 1997-2 and ISO 17892-3.

(h) Density index in accordance with EN 1997-2 and ISO 22476 parts 2 & 3).

(i) Necessary strength properties (both total and effective) in accordance with EN 1997-2, ISO 17892 parts 7 to 10 and ISO 22476 [all relevant parts].

(j) Necessary compressibility and deformation properties in accordance with EN 1997-2, ISO 17892 parts 5, 7 to 10 and ISO 22476 [all relevant parts].

(k) Permeability in accordance with EN 1997-2, ISO 17892-11, and ISO 22282 [all relevant parts].

(l) Shrinking and swelling indices in accordance with EN1997-2, ISO 17892-5 ISRM 2007.

(m) If necessary (e.g., for concrete and steel structures), additional chemical characterization shall be evaluated according to EN 1997-2, ISO 18400 [all relevant parts], ISO 10694, ISO 10693, ISO 11048, ISO 10390, BS 1377-3 (or equivalent) (e.g., measurements of organic content, carbonate content, sulphate content, pH value, acidity or alkalinity and chloride content etc.);

(n) Installation and monitoring in accordance with EN1997-2 and ISO 18674 [all relevant parts].

For rockmass (shall include but is not limited to):

(a) Classification, identification and description in accordance with EN 1997-2, ISO 14689 and ISRM 2007.

(b) Water content, density and porosity in accordance with EN 1997-2 and ISRM 2007.

(c) Intrinsic strength properties in accordance with EN 1997-2, ISRM 2007, ASTM D5731, ASTM D4543, ASTM D7012, ASTM D2936.

(d) If required, discontinuity strength testing in accordance with ISRM 2007 and ASTM D5607.

(e) Intrinsic deformation testing in accordance with ISRM 2007, ASTM D7012, ASTM D4543, ASTM D7070.

(f) If required, swelling properties in accordance with EN 1997-2 and ISRM 2007.

(g) Rock mass permeability in accordance with EN1997-2, ISO 22282-3 ASTM D5084, ASTM D4525.

(h) Discontinuity spacing and orientation.

(i) Rock quality designators (e.g., RQD, TCR, SCR and fracture index) in accordance with EN1997-2, ISO22475-1, ASTM STP984.

(j) Overall, Rock Mass Rating, testing and kinematic stability (e.g., ISRM 1978, ISRM 1974-2006 and 2007-2014).

(k) Characterisation and determination of aggregate suitability in accordance with EN1997-2, all relevant parts of EN 932, EN 933, EN 1097, EN 1367, EN 1744 and EN 13286.

The geotechnical and hydrogeological investigations shall be planned and carried out according to the rules and recommendations set out within EN 1997 parts 1 and 2 and ISO 22475-1. Furthermore, the Consultant shall take into account the national recommendations and mandatory legislation.

The Consultant shall collect all available information from the previous geotechnical investigation studies and can use this as supplementary information, if approved by the Client. It should be noted that the preliminary and historical investigations shall not substitute the required full scope of investigations set out within later sections of this document.

The Consultant shall produce all geotechnical data used for the design in a native digital format that is easily interrogated and compatible across all proprietary mapping and visualisation platforms such as arcGiS, holeBASE, openground, leapfrog etc.

The ground investigation works shall be planned with a degree of flexibility with close supervision by the Consultant. The Consultant shall appoint a design site representative (DSR) to be the local point of contact and liaison between the Consultants design team and the Client. It shall be the responsibility of the DSR to make decisions on behalf of the Consultants geotechnical design team with respect to the day-to-day investigation activities. The DSR shall supervise and maintain control of site investigation works and shall be ready to alter the investigation plan in light of unforeseen conditions. The DSR shall have a direct point of contact with the Clients geotechnical team in order to comply with the requirements outlined in the following sections.

2 SPECIAL ISSUES

2.1 Hydrogeology

In some areas, the water level may rise above ground level due to high or confined groundwater and/or during the heavy precipitation events. This must be taken into account for all considerations, also for drilling and planning of the works. These include rivers that can overflow their banks due to flooding. These areas can vary greatly locally and must be estimated and planned by the Consultant. For this reason, investigations for groundwater conditions must be made.

Groundwater investigations must provide all essential information needed for geotechnical design and construction. The following outlines the minimum level of information that shall be recorded:

(a) Depth, thickness, extent and permeability of the aquifers in the subsoil and the fissures in the rock.

(b) Total head of the free groundwater level or pressure level of aquifers, the evolution over time, and the current groundwater levels with the possible extremes and their annual exceedance probabilities.

(c) Distribution of pore water pressure.

(d) Chemical composition and temperature of groundwater.

The test results must be sufficient to answer the following questions:

(a) Highest water level (according to DG).

(b) Possible groundwater lowering solutions.

(c) Possible harmful effect of groundwater on excavations or embankments (e.g., hydraulic heave, frost susceptibility, stability).

(d) Any kind of measures that are necessary to protect the structure (e.g., groundwater drainage).

(e) Effect of groundwater lowering (including neighbouring areas and structures).

(f) The capacity of the water, which can occur during the construction.

(g) Chemical interaction between groundwater and structures (e.g., concrete aggressiveness).

All groundwater measurements and sampling must be carried out according to EN ISO 22475-1. Furthermore, the rules and recommendations of EN 1997-2 are mandatory requirements.

2.2 Drilling in rivers or lakes

The investigation for foundations crossings large bodies of water might necessitate the need to drill in the water. Depending on the river or lake, permission to navigate the river should be obtained by the Consultant from the national and local authorities if necessary, and in accordance with national legislation. The Consultant shall propose a viable solution for carrying out the necessary investigations in rivers, ponds, dikes or lakes at the required location of the investigation. The depth of exploration and the type of drilling and casing should be chosen depending on the geology. For drillings in rivers and lakes, the safety and environmental requirements shall conform to the national and local legislation. For example, certification for oil-tightness of the equipment used may be necessary. This is the responsibility of the Consultant to ensure site reinstatement to its previous condition without.

2.3 Tunnels

If tunnel sections are envisaged along the proposed alignment route, the consultant shall carry out at least one (1 No.) investigation per 50m of the tunnel alignment alternating left and right of the centre line as part of the first stage investigations. The depth of the investigation shall be advanced to no less than 6m below the proposed base of the tunnel. If the vertical or horizontal alignment of the tunnel changes the consultant shall amend the investigation to comply with these requirements at all stages of the design phase. An investigation offset tolerance of <15m from the alignment centreline may be accepted by the Client on a case-by-case basis in relation to access constraints or alignment alterations. The Client must be notified in a timely manner for approval.

If the tunnel is situated within a known geohazard area or voids are detected below the base of the tunnel, the investigation must extent sufficiently to prove competent ground. The Client shall be informed immediately by the Consultant in the event that the investigation works encounter problematic ground or voids in order to agree on a suitable investigation amendment. Geohazards must be recorded early in order to ensure the design solution or alignment choice is well informed.

Additional boreholes, wireline or surface geophysical logging may be implemented in addition to the base investigation requirement. Geophysical methods may be implemented based on desk and site reconnaissance information gathered by the Consultant prior to intrusive works.

2.4 Sub-surface voids

Prior to the investigation areas of potential sub-surface void zones shall be investigated by means of suitable wireline or surface geophysical survey methods. The planning of investigations shall be informed by examination of historical desk-based information and geomorphological landform features (historical sink holes, surface depressions or erosion features etc.) from site walk overs. The Consultant shall also liaise with the national geological survey to utilise local knowledge on such geohazards at the commencement of the project.

If larger cavities are encountered during drilling or if drilling fluid loss occurs, then this must be reported to the Client immediately via the DSR. If the drilling method is chosen incorrectly, the drill string may be lost. The Client shall not be responsible for any such loss.

In addition, it should be noted that in areas with limestone, the gypsum layers may exist, which can, if incorrectly reinstated, lead to long term and large-scale deformations due to surface water ingress. This imposes a risk of damaging infrastructure and buildings associated to the railway and neighbouring structures.

2.5 Peat and soft soil

There is a significant coverage of peat, soft-soil and wetland geomorphologies within the Baltics. Peat cells can be localised and sporadic, as well as present as large raised or blanket bogs. The alignment may cross or pass close to such areas which inherently exhibit very weak and highly compressible behaviour. The planning of investigations shall be informed by examination of historical desk-based information/ mapping and geomorphological landform features from site walk overs. The Consultant shall also liaise with the national geological survey to utilise local knowledge on such geohazards at the commencement of the project.

Accessibility into these areas shall require plant that exerts low bearing pressures, the use of light equipment or bog matting should be considered. Rig instability and site safety is paramount, therefore well-informed planning and quick communication between the Client and the Consultant is required.

Strength as well as primary and secondary deformation properties of Peat and soft soil stratum is essential to understanding the behaviour under a net load increase. Therefore, in-situ or suitable sampling methods shall be employed. It is difficult to recover true undisturbed Peat samples, the consultant shall consider piston or block sampling methods (ISO 22475-1) to try to achieve quality class 1 samples (EN1997-2).

Standard penetration or dynamic probing methods may allow insight into the overall depth of the soft stratum. However, it is deemed not suitable to provide any useful information regarding strength or deformation. The consultant shall employ the use of in-situ shear vane measurements and/ or suitably calibrated CPTu for parametric profiling with depth, in addition to class 1 laboratory samples.

Geophysical surveys may also be implemented to effectively profile the extends of the soft-soil zones as well as aid in the parametric interpretation.

It is extremely important that these areas are thoroughly investigated and classified, therefore planning and access into bogs, densely forested areas and river channels is priority in order to achieve the most suitable and feasible design solution.

2.6 Competent rock

If competent rock is encountered (i.e., UCS ≥0.6MPa), unweathered, no unfavourable joint set or fracturing and there is no presence of karst or void features within the zone investigated, the investigation depth below the foundation formation level or rock head can be reduced to 5m into rock. If large voids are detected, depths should be advanced until competent rock is proven over a continuous 5m core run or termination is agreed between the Client and the Consultant.

2.7 Environmental requirements

When operating machinery with internal combustion engines, additional measures shall be taken to reliably prevent seepage of oil and fuel into the subsoil.

When encountering contaminated soil and/ or groundwater, the Client shall be notified immediately to determine further measures.

The Consultant shall comply with the relevant local, national and EU environmental protection laws, e.g.:

(a) Any Water protection

(b) Nature conservation

(c) Nature and landscape protection

(d) Tree protection

(e) Soil and national monument protection

The relevant authorities shall be notified prior to the commencement of drilling operations. The notification must be submitted in the contractually agreed and legally prescribed form. Storage areas, repair areas, sanitary facilities, etc. are to be set up without the possibility of contamination of groundwater or open waters.

Customary conditions, such as the transport and use of clean water for the drilling fluid, the collection and disposal of unloaded flushing and pumped water, as well as the disposal of surplus cuttings, shall be considered.

2.8 Investigation in Quarries

Investigations in operating Quarries shall be carried out in order to verify the usability of locally produced aggregates for railway construction including railway and road overpasses.

When carrying out the investigation in Quarries Consultant shall account for the following:

(a) Sampling of the aggregate products shall be collected and documented according to appropriate standard (e.g., EN 932-1)

(b) While sampling, it must be warranted that the minimum weight of the collected material is suitable to conduct all the required laboratory tests and analyses as stated in the appropriate standards. At least three bulk samples shall be taken for testing per product, and these shall be taken at three distinct locations from the stockpile

(c) Separate samples (not to be mixed) shall be collected in case there are two or more products produced in the Quarry

(d) For every sampled product appropriate Declaration of Performance or Declaration of Conformity shall be collected

3 METHODOLOGY

The Client will provide the Consultant with any project specific historical geological/geotechnical reports carried out for the project (preliminary investigation). If the consultant wishes to use the preliminary information to supplement their investigations, then the Consultant shall compare and validate the preliminary GI data with the current investigations carried out under the supervision of the Consultant. A technical evaluation of the validity of the preliminary geological/geotechnical reports shall be provided to the Client. The validity of preliminary investigations must be assessed in terms of its compliance to the RBR DG, EN 1997 Parts 1 and 2 as well as national regulations if the data from the preliminary investigations is to be considered for the application in the design. The Consultant shall be responsible to use the reports for design purposes and the preliminary data shall not be used to replace the requirements set out within this document.

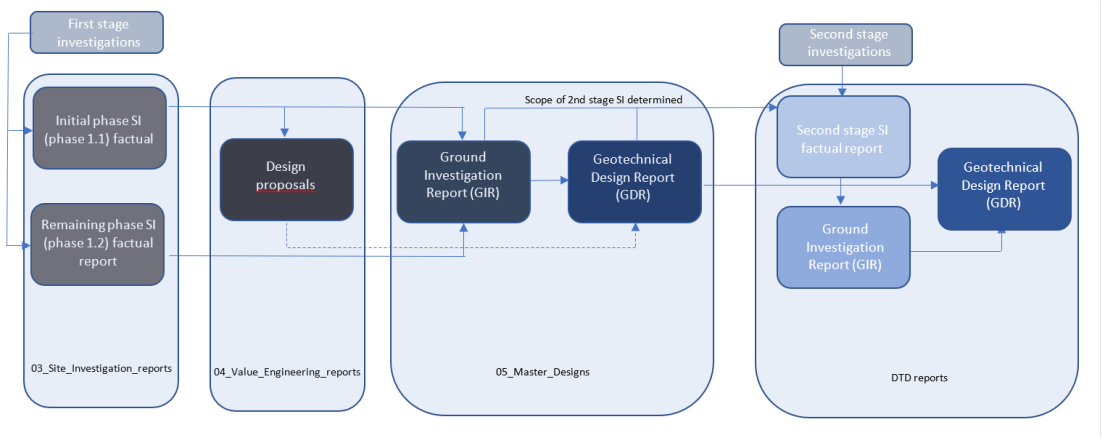
The Consultant is encouraged to use the preliminary investigation results, local and archived information as well as direct site reconnaissance to aid in the planning and execution of the ground investigation campaign as well as the identification of potential geohazards. The aim of this is to foresee the ground conditions that may potentially limit the contractor's capability of reaching the drilling location or target depths as well as identifying constraints to the design solutions. Therefore, a proactive approach is encouraged with respect to the selection of the investigation type and accessibility methods early in the procurement and award phases.

The Consultant shall use a two-stage investigation approach consisting of the following:

(a) First stage (Phase 1) GI shall be split into two sub-phases to inform the progression from the design proposal phase (Phase 1.1) to the master design phase (Phases 1.1+1.2)

(b) Second stage (Phase 2) GI shall be used in areas requiring more refinement of conditions and parameters, identified in the master design process and shall be implemented during the detailed technical design phase if necessary

The following schematic is provided in order to clarify the staged approach:



The second stage (Phase 2) investigation campaign shall be carried out in cooperation with Client if:

(a) There are late changes in the alignment profile and/or the design of the engineering structure or the foundation design requires additional information that can only be gathered by means of additional investigations and associated field tests

(b) There is a decision about the final track alignment that needs more concentrated investigations and field tests

(c) The applicable standards and requirements for the design or investigations change during the course of the project, which in turn necessitates additional investigations

(d) The total available data from the existing geological/geotechnical reports and the first stage investigation campaign is not sufficient for a cost effective and safe design of the construction in question

(e) Ground risks are identified which require a higher resolution on spatial extents, behaviour and parametric understanding

(f) Additional and/or control investigations are mandatory according to national legislation and geotechnical category of the structure[1]

The Consultant is responsible for the selection of the most appropriate methodology of investigation to achieve the requirements set out within this document. The Consultant's investigations, together with the existing investigations, shall fulfil EN 1997 Parts 1 and 2 rules and recommendations as well as national applicable standards and legislation. If the national legislation requirements do not comply with the EN 1997 Parts 1 and 2 then Consultant shall comply with the higher standard that is recognised under EU law.

4 BASIC CONDITIONS

4.1 Permission for drilling

The Consultant shall obtain all public-law permits (e.g., traffic-related permits, water-related permits, night work, etc.) and all private-law permits (including access authorizations / owner notifications) prior to commencement of the works and carry out all necessary disclosure requirements.

[1] This is applicable for Lithuania only. For determination of geotechnical category refer to STR 1.04.02: 2011, section VI. For requirements of additional – control investigations refer to STR 1.04.02: 2011, section VII

4.2 Unexploded ordnance (UXO)

The Consultant shall obtain all information available from the local and regional authorities with regards to the likelihood of UXO within the area of investigation. Before the commencement of all intrusive works, the Consultant must prove to the Client that all the necessary and legally required steps to ensure the safety of the site staff and the surrounding area has been implemented. It is the consultant's responsibility to become familiar with the national and local laws and regulations. UXO risk areas represent a critical component of site investigations. No additional reimbursement shall be foreseen in UXO areas indicated in publicly available sources and databases.

4.3 Underground services: Utilities, cable and pipe crossings

It is the responsibility of the Consultant to contact the utility owners and get the information about the location, depth and type of the utilities. The location shall be fixed on the field by geodetic survey. Consultant shall follow all requirements stated by the affected parties before commencing geotechnical investigation.

This work shall be done before the commencement of all intrusive works so that the activities can be carried out safely regarding the cables and pipes in the immediate area of the investigation works. Also, the Consultant must comply with all regulations regarding safety zones, especially for but not limited to high voltage cables and high-pressure gas pipelines. It is recommended that the following steps are carried out prior to drilling in areas known to have buried services and/or in the absence of reliable records:

(a) Cable avoidance tools (CAT) and Genny used to scan an area of 1.5m by 1.5 around the proposed drilling position

(b) Hand digging to 1.2m with regular CAT checking

(c) Commencement of intrusive investigations

It is the Consultants responsibility to cover the costs and safety considerations associated to damages caused resulting from a utilities strike.

4.4 Construction site logistics

It is the responsibility of the Consultant to become familiar with the conditions of the investigation sites and to assess the accessibility to all foreseen investigation points. Consultant shall be responsible for mitigation of any accessibility issues. The Consultant shall liaise with the Client in a timely manner to agree on mitigation proposals. The Consultants DSR shall be the point of immediate contact with the Client.

The impact on the natural and/or built environment shall be kept to a minimum. The site setup must comply with the environmental protection laws and regulations, as well as with the national health and safety requirements for each country.

4.5 Two-stage approach investigation methodology

4.5.1 Investigation point identification

The Consultant shall provide a unique identification numbers or labels for the investigation points. The unique number or label shall provide information about the type, exact location of the investigation and investigation campaign. The Consultant shall provide a list with all planned and carried out investigation that also includes information on:

(a) Location with coordinates

(b) Absolute height

(c) Planned and actual depth

(d) Date of execution

(e) Photos from material samples with landscape background and coordinates (Note: It is important to prove borehole depth with photos).

4.5.2 Investigation schedule

The following chapters set out the investigation minimum requirements. The investigation schedule shall be fulfilled in two stages.

The first stage (Phase 1) investigation schedule shall provide all the necessary information to:

(a) verify the existing investigations that are supplied by the Client

(b) enable the designer to make the design decisions, such as alignment and type of foundation, geotechnical characterisation and material reuse etc.

Investigations together with the verified existing investigations must be sufficient to fulfil the rules and recommendations outlined within EN 1997 Part 1 and 2 and provide all the information necessary for the design.

(a) Phase 1.1 geological investigations

Phase 1.1 investigations shall carry out at least 1 borehole per 300m for any alignment option (including any late alignment changes) and additionally 2 investigation points[2] per structure (bridges, road viaducts, railway viaducts, eco ducts, grade separated pedestrian crossings, retaining walls, tunnels and underpasses, systems sites, ENE traction stations, paralleling posts (PP)/switching posts (SWP)). An investigation offset tolerance of ±15m from the alignment centreline may be accepted by the Client on a case-by-case basis in relation to access constraints or minor alignment alterations.

For culverts with a width ≥2m, the Consultant shall carry out at least 1 borehole.

The choice of the investigation methods listed below shall be selected with the aim to assess the foundation types and depths for structures and technical solutions according to requirements described in Design Proposals.

(b) Phase 1.2 geological investigations.

The remaining first stage investigations (phase 1.2) shall be conducted according to this technical specification (Ch. 4.5.3) and EN1997-2 as well as the informative Annex B stated in Chapter 2.4.3 of this Technical specification.

Results from phase 1.1 shall be taken into account when choosing remaining borehole locations.

4.5.3 First stage investigation compliance requirements (combined phase 1.1 and 1.2)

4.5.3.1 Track

Based on Eurocode 7: Geotechnical design – Part 2: Ground investigation and testing, national legislation and applicable standards given in Chapter 1.1, the Client requires one investigation point not less than every 100 meters along the proposed alignment, alternating on the left and right side of the track. Depending on the type of investigation, equipment and ground conditions, more than one investigation point may be necessary at specific locations. The selection of types of investigations must be based on the geotechnical properties of

[2] A field test (CPT, DPSH, DPM etc.) may be considered as a separate investigation point only if it is linked to visual identification and sampling by drilling or excavating. The distance between the two (between the borehole and field test) shall be ≥2 to ≤15 m. Suitable depth compliance must be considered when proposing a field test.

the soil or rock that needs to be checked according to the geotechnical category[3]. These properties must be acquired in intervals not larger than 200 m.

Based on the validity of the preliminary investigations, the Consultant shall propose new locations in between the preliminary investigation points with the spacing between the new investigations not less than 100m.

Preliminary stage investigation data can be used in the design only if they are properly validated and their compliance is deemed acceptable by the Client in accordance with the requirements outlined within this technical specification, EN1997 and the project Design Guidelines.

For embankments and cuttings, the larger value of the following conditions should be met (Figure 1).

(a) For embankments:

- $0{,}8h < z_a < 1{,}2h$
- $z_a \geq 6$ m

where

"h" is the embankment height,

"za" is the investigation depth below the formation level of the embankment

(b) For cuttings:

- $z_a \geq 2{,}0$ m
- $z_a \geq 0{,}4h$

where

"h" is the dam height or depth of cutting,

and "z_a" is the investigation depth below the formation level cutting

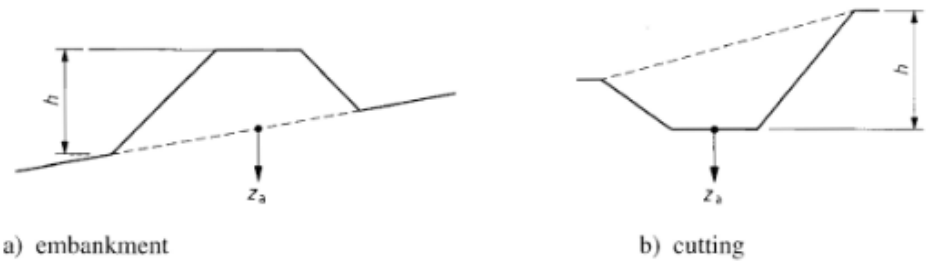


Figure 1 Determination of investigation depths for embankments and cuttings (EC 7)

4.5.3.2 Tunnels

The planned tunnels that are proposed to be executed as cut and cover tunnels can be treated as deep cuts. Due to the higher cost and associated higher risks the investigation points frequency shall be one point per 50 m, alternating between left and right track. The depth of the investigations shall be no less than 6m below the base of the tunnel. Also see section 2.3.

4.5.3.3 Structures

Based on Eurocode 7: Geotechnical design – Part 2: Ground investigation and testing, the investigation depth depends on the type of foundation. Given that at the start of a design campaign the foundation types and dimensions are likely to be not properly defined, it is recommended that the Consultant overestimates the initial investigation depths to establish an overall understanding of the geological structure and to identify any

[3] Refer to EN 1997-1, clause 4.3.1 & national regulations (if applicable)

hazards which may be within the likely stressed zone imposed by the structure. The description of the general determination of the investigation depth for different foundations is provided below.

For structures, the larger value of the following conditions should be applied (Figure 2, type a)

- $z_a \geq 6$ m
- $z_a \geq 3{,}0b_F$

where

"b_F" is the smaller side of the foundation and

"za" is the investigation depth below the formation level of the structure's foundation

For raft foundations and structures with several foundation elements, whose effects in deeper strata are superimposed on each other:

- $z_a \geq 1{,}5b_B$

where

"b_B" is the smaller side of the structure, (Figure 2, type b) and

"z_a" is the investigation depth below the formation level of the structure's foundation

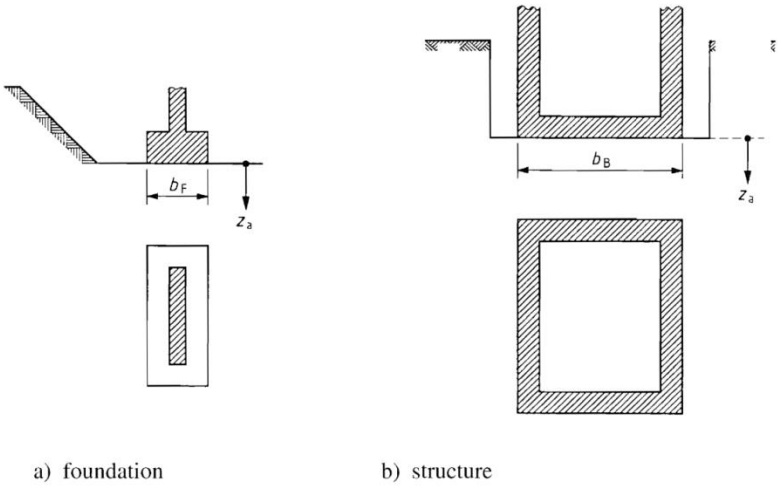


Figure 2 Determination of investigation depths for structures and foundations (EC 7)

For piles, the following three conditions should be met (Figure 3):

$z_a \geq 1{,}0b_g$

$z_a \geq 5{,}0$ m

$z_a \geq 3D_F$

where

"D_F" is the pile base diameter; and

"b_g" is the smaller side of the rectangle circumscribing the group of piles forming the foundation at the level of the pile base

"z_a" is the investigation depth below the formation level of the structure's foundation

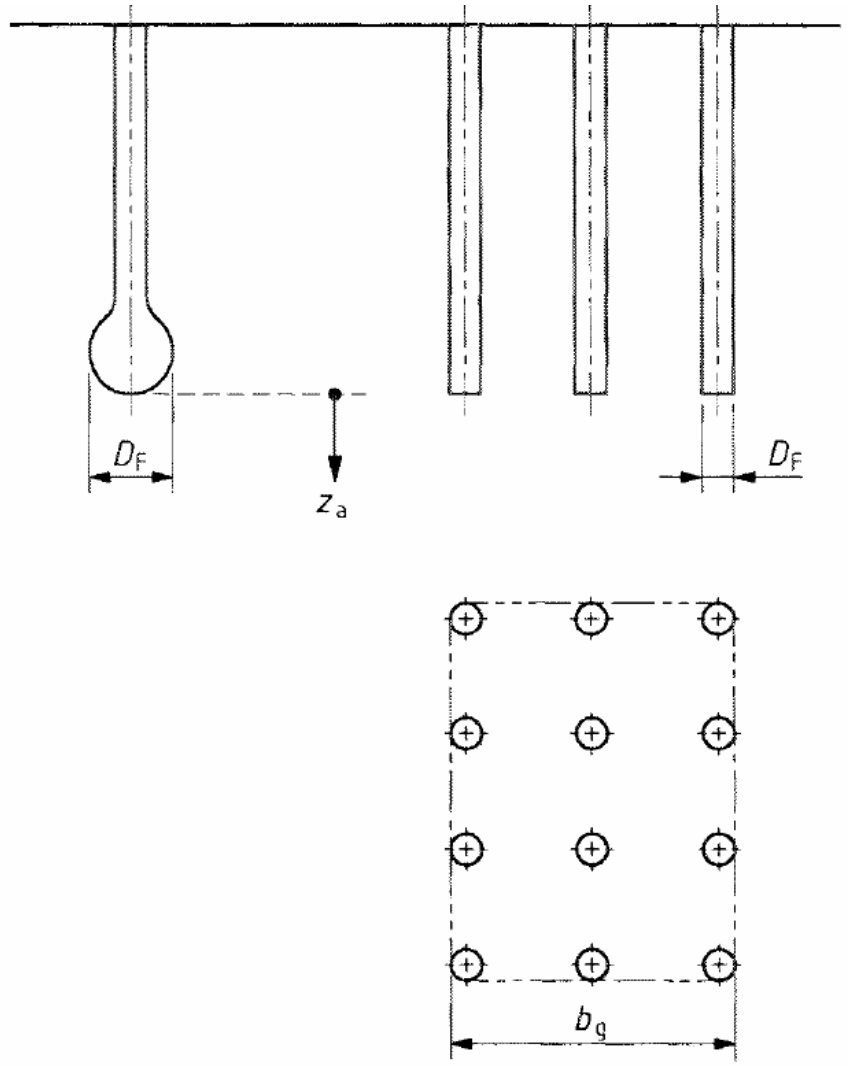


Figure 3 Determination of investigation depths for piles (EC 7)

It is the Consultants responsibility to ascertain if the investigations carried out shall fulfil the requirements of the local authorities, the operators and owners of the engineering structures or earthworks. It is up to the Consultant to decide which type of investigation method shall be used depending on the proposed design and required depth and method of the investigation.

During Phase 1.2 investigations, the Consultant shall carry out at least 2 investigation points per foundation for the structure with a depth of 25m or more (depending on the depth of proposed foundation or understanding of the geological structure). In case of field test, the termination depth is the same as for borehole unless the termination criteria defined by the relevant standard is reached at shallower depths.

For culverts in width ≥2m the Consultant shall carry out at least 2 investigation points of a depth of between 6m to 10mbgl or za≥1.5bB below the base of the culvert formation level whichever is deeper.

For culverts in width ≤2m the Consultant shall carry out at least 1 borehole of a depth of between 6m to 10mbgl or za≥1.5bB below the base of the culvert formation level whichever is deeper.

The general investigation methodology and minimum requirements for different structures and foundations is presented below. Additional investigation requirements may be set by the infrastructure owner or operator.

Piled structures (Investigation points per abutment / pier):

(a) Field test (SPT, DPH, CPT etc.) the greater depth of between 25 m or as per the requirements set out in Annex B of EN1997-2, unless standard termination criteria (refusal) is reached

(b) Core drilling (See Ch. 4.6.6) the greater depth of between 25 m or as per the requirements set out in Annex B of EN1997-2

Note 1: in case DPH or CPT terminates shallower than target depth, borehole SPTs (see Ch. 4.6.5) are recommended at every change of stratum within the zone of influence or;

Note 2: Other in-situ field tests (such as high-pressure dilatometers or pressuremeters etc.) may be specified where required or in the event probing cannot achieve sufficient depth for direct parameter profiling.

Structures on raft / frame foundation (Investigation points per foundation when the frame/ raft is narrower than 60m):

(a) Field test (SPT, DPH, CPT etc.) the greater depth of between 25 m or as per the requirements set out in Annex B of EN1997-2, unless standard termination criteria (refusal) is reached. Positioned at the two opposite corners of the frame/ raft.

(b) Core drilling (See Ch. 4.6.6) the greater depth of between 25 m or as per the requirements set out in Annex B of EN1997-2. Positioned at the two opposite corners of the frame

Note: in case DPH or CPT terminates shallower than target depth, borehole SPTs (see Ch. 4.6.5) are recommended at every change of stratum within the zone of influence or;

Note 2: Other in-situ field tests (such as high-pressure dilatometers or pressuremeters etc.) may be specified where required or in the event probing cannot achieve sufficient depth for direct parameter profiling.

Structures on raft / frame foundation (Investigation points per foundation when the frame is wider than 60m):

(a) Field test (SPT, DPH, CPT etc.) the greater depth of between 25 m or as per the requirements set out in Annex B of EN1997-2, unless standard termination criteria (refusal) is reached. Positioned at two opposite corners of the frame and one centrally, in addition to as many as necessary in between so that the spacing between investigation points does not exceed 60m

(b) Core drilling (See Ch. 4.6.6) the greater depth of between 25 m or as per the requirements set out in Annex B of EN1997-2. Positioned at two opposite corners of the frame and one centrally, in addition to as many as necessary in between so that the spacing between investigation points does not exceed 60m

Note: in case DPH or CPT terminates shallower than target depth, borehole SPTs (see Ch. 4.6.5) are recommended at every change of stratum within the zone of influence or

Note 2: Other in-situ field tests (such as high-pressure dilatometers or pressuremeters etc.) may be specified where required or in the event probing cannot achieve sufficient depth for direct parameter profiling.

4.5.3.4 CCS/ENE Facilities/Sites

The scope of geotechnical investigations for CCS/ENE facilities/sites including system facilities, ENE traction substations and paralleling posts (PP)/switching posts (SWP) shall be planned based on the proposed area/ location of the sites.

Preliminary foundation proposals for energy distribution structures following the alignment (i.e. catenary masts, paralleling and switching posts etc.) shall be based on the track investigations (see section 4.5.3.1). Note that site-specific foundation investigations of these structures may be completed by the responsible contractor if deemed necessary to clarify or confirm ground/ hydrogeology conditions.

With respect to CCS/ENE facilities, the quantity of investigation points for large area sites shall not exceed a 60m-by-60m grid with at least 1 field test (SPT, DPH, CPT etc.) and 1 borehole for sampling within the footprint of the proposed area. For sites spanning more than 60 m in any direction, as many sets of investigation points consisting of 1 field test and 1 point for sampling by drilling or excavating as necessary shall be conducted so that the entire area is covered by a grid pattern of investigation points spaced out not more than by 60 m. The requirements according to EC7-2 Annex B.3 large area structures shall be implemented.

The depth of investigations for CCS/ENE facilities/sites shall be based on the recommendations of EC7-2 Annex B section B.3 (5). The minimum depth of the investigation shall be at least 6m below the foreseen formation level of the structure. However, ground level may be adopted as the preliminary reference level if the design formation level is unknown. The responsible contractor may complete additional foundation specific investigations to prove stratigraphy and or behaviour if required.

NOTE 1: the purpose of these investigations is to provide information on preliminary ground conditions. In subsequent design stages more complex individual structures with different foundation options might be designed within CCS/ENE site boundaries which shall require additional geotechnical investigations. These shall be covered by CCS/ENE contractors during deployment process of respective subsystem.

Note 2: It is important that the preliminary investigations define and fully classify the broad stratigraphic composition and general geomechanical behaviour of the underlying site, lithological framework, structural features as well as the groundwater conditions.

4.5.4 Second stage investigations (Phase 2)

The second stage (Phase 2) ground investigations are optional. However, they shall be accounted for in the costing during the bid process. Payment of the second stage (phase 2) shall be separate from phase 1 and paid in the event the second stage is required. The Consultant together with the Client shall assess zones requiring a higher resolution of ground data and propose the quantity, type, location and depth of additional investigation works. The Consultant shall submit the proposal to the Client for approval. The proposal shall include a justification, type of investigations to be implemented and plan layout. The Consultant cannot proceed with the second stage (phase 2) investigations without the approval from the Client.

During the second stage (phase 2) investigations, the concentration of investigation points is locally increased in zones identified by the Consultant. The information from the preliminary and phase 1 ground investigations shall be consolidated, highlighting the need for additional investigations. The aim of the second stage (phase 2) is provided within section 4.5 of this technical specification. All proposed investigations shall comply with sample quality class, probing and depth requirements set out within the relevant code of practice as outlined above.

The maximum number of additional boreholes to be accounted for within the scope of the second stage (phase 2) is 250 and shall also include scope for laboratory testing. The costing shall assume 25% are conducted to a depth of 6m, 25% to a depth of 10m, 25% to a depth of 25m and the remaining 25% to a depth of 50m.

Note: The scope of the investigations is not limited to intrusive boreholes, the Consultant may later propose alternative works which include advanced field testing/ instrumentation that is covered by the cost estimates based on 250 additional intrusive boreholes.

When planning the second stage (phase 2) the Consultant shall submit a proposal of works in a tabulated format, the following table provides an example.

Table 1-1: Example of proposal of works quantities table

Type of investigation	Volume (Boreholes)
Percussion gouge drilling, m	

Dynamic probing heavy, m	
Core drilling, m	
Cone Penetration Test, m	
Standard Penetration Test, m	
In-situ field tests (pressuremeter, HPDs, field vane tests, geohydraulic etc.) No.	
Geophysics (GPR, ERT, seismic, magnetometry etc.) m	
Instrumentation (Piezometer, standpipe etc.) No.	

4.6 Sampling

4.6.1 Quantity

For Percussion gouge drilling mentioned in chapter 4.6.2 a continuous recovery of bulk samples is expected. For these methods at least one sample shall be taken, and classification tests conducted for each visual change in stratum or every 3 m in homogenous soil. Samples shall be placed in containers of relevant type and capacity, which have an airtight cover or seal so that the natural moisture content of the sample can be maintained.

The date of investigation, the unique investigation number or label and the depths of the collected sample shall be recorded on the container.

For core drillings mentioned in chapter 4.6.6 involving continuous core sample recovery, the cores shall be extruded from the barrel and placed in core boxes immediately after recovery. Care must be taken to ensure that they lie in their correct sequence and immediately photographed. All cores should be protected from dehydration and frost in the core boxes by covering or wrapping them in plastic wrap.

For core drillings at least one sample shall be taken, and classification tests conducted for each visual change in stratum or every 3 m in homogenous soil / rock. Undisturbed samples for advanced testing shall be taken according to geotechnical category to fulfil EN 1997-2 requirements. Undisturbed samples shall be stored within a rigid sampling tube to ensure locked-in stresses and stress history is preserved as much as reasonably possible. The sampling tube shall be capped, and wax sealed only to be opened for test preparation at the laboratory.

The depths shall be recorded on core boxes at intervals of at least one metre and at the end of each core run. Additionally, each core box shall be marked externally to show the borehole investigation designation, the depth range and also direction of drilling.

For core losses in rock, the drill cuttings and/or sieve residue shall be collected in a container.

4.6.2 Quality

The quality of soil samples is classified according to the degree of disturbance in terms of the soil mechanics parameters and properties, which can be determined according to EN ISO 22475, chapter 6.2.

The quality of samples gathered by means of percussion gauge drilling shall be grade 3-5 depending on the type of stratum encountered (EN ISO 1997-2 and 22475-1). The quality of samples gathered by means of core drilling methods shall be at least class 3 in soil and class 2 in rock (EN ISO 1997-2 and 22475-1), unless where sampling for strength and deformation testing is required then class 1 shall be achieved

4.6.3 Special samples

To recover special samples from boreholes, the drilling process shall be interrupted. Special samples shall be taken from each stratum containing organic soil or pollutant. For recovering special samples from boreholes, the general information (material/dimension) in EN ISO 1997-2 and 22475-1 chapter 6.4.2 shall be observed.

For groundwater sampling, clean sample bottles with an airtight cover, a pump, water sampler, thermally insulated box for the transport of sample bottles and a thermometer is required. The samples shall be taken from groundwater which has freshly entered to the investigated horizon. Care must be taken to ensure that any stagnant or contaminated water is pumped out prior to sampling. To ensure proper sampling from boreholes, measures shall be taken to prevent the inflow of water from the surface or from other aquifers or ingress of air by the action of drilling tools.

Water can be extracted by submersible pumps, water sampler or by vacuum bottles in cohesive soils (EN ISO 1997-2 and 22475-1 chapter 8.3).

4.7 Borehole filling and sealing

All boreholes must be backfilled. compacted and sealed with a clay plug after finishing the drilling. If drilling is conducted on a hard standing of asphalted surface, reinstatement to previous conditions shall be carried out. Care must be taken to reconstruct at least the condition prior to reconnaissance in terms of stability (e.g., compression) and dimensions (e.g., clean sealing). The associated costs must be included into the contract.

4.8 Groundwater monitoring well

The entire groundwater monitoring must be carried out as described in chapter 1.2.1 to fulfil the required aims.

If boreholes are used for groundwater pumping wells, then a minimum drill diameter of 300 mm is required to create a pumping well (DN 125). In contrast to pumping well, observation wells serve to measure the GW-level and to take samples. They can be designed as a DN 80. Pumping wells may be required for the execution of groundwater pumping tests in the second phase of the investigation.

4.9 In-situ field experiments

4.9.1 Pumping test (ISO 22282-4)

This chapter describes a pumping test with continuous measurement and digital recording of the water level, the flow rate and quantity and the quality criteria. These must be planned according to geology, hydrogeology, and the pumping well. For each pumping test, a sampling protocol with a minimum information about the head data of the measuring point, type and technique of sampling, organoleptic findings, continuous control of lowering and pumping rate with regulation and adjustment of the pumping rate must be carried out. After ending the experiment, the measurement of the recharge of the groundwater level in relation to the time of the start of the experiment, the end of the experiment and changes in the experimental set-up have to be noted.

To carry out a pumping test, a pump is required, which is placed at least 3 meters below the water surface and can deliver at least 10 l/min. As a result, pumping is carried out with a defined withdrawal quantity until stationary conditions are established. The lowering of the groundwater shall be measured in the pump well and, if present, at groundwater measuring points. The pumped water must be discharged with a hose at least 50 m from the sampling point. The withdrawal quantity and the reduction to be achieved depends on the type of aquifer.

The evaluation of the experiments is carried out depending on the boundary conditions of the aquifer. In this case, the hydraulic permeability and the storage coefficient must be determined.

4.9.2 Open end test (ISO 22282-2)

The “open end test” is carried out in boreholes to determine the local hydraulic permeability. In the experiments, date and time of the experiment and the amount of water entered over the time to maintain the

water level must be recorded. The test should always be performed on the planned bottom of the infiltration basin, with the remainder of the drill hole being sealed by the experimental apparatus.

4.10 Reporting of results

Reporting of all results shall be in hardcopy and digital format. The digital format for text and tables shall be generally acceptable file formats (e.g., docx, xlsx, etc.). The digital format for drawings and map-based results shall be ".dxf/.dwg" format. The relevant ISO standards shall be consulted which outline the "mandatory" reporting requirements for borehole logs, field, and laboratory testing.

Factual reports dedicated to each sub-stage of investigations (initial first stage investigations, remaining first stage investigations and second stage investigations) shall be submitted to introduce with the scope of works and factual data collected during the investigations. Factual reports must include the following (in accordance with EN1997-2 section 6.2):

Brief description of the project

(a) Consultants and Sub-contractors involved in the works

(b) Dates when the investigations were conducted

(c) Groundwater observations

(d) Site investigation plan

(e) Field investigation logs

(f) Laboratory test results

(g) Photos of soil / rock recoveries

(h) Longitudinal geological profile

After the first stage site investigations are completed and factual reports accepted by the Client, the Consultant shall submit the ground investigation report (GIR) in accordance with the EN 1997-2, section 6, including:

(i) Purpose and scope of the geotechnical investigation, including a discussion on the extent and scope of the investigation

(j) Brief description of the project for which the geotechnical report is being compiled, giving information about the location of the project

(k) Geotechnical category

(l) Consultants and Sub-contractors involved in the works

(m) Dates when field and laboratory investigations were performed

(n) Detailed description of methods used for the field work with reference to the accepted standards followed, and with discussion on rationale used to determine type, spacing, frequency and locations of the tests

(o) Types of field equipment used

(p) Presentation of field observations which were made by the supervising field personnel during the execution of the sub-surface explorations

(q) The principal geological and topographical features of the area, with an appraisal of the terrain and hydrogeological conditions

(r) A map showing the location by number of each investigation point in a scale of 1:1000 Each location and level of each of the investigation location should be accurately defined by geodetic survey to an accuracy of 10 cm horizontal and 10 cm vertical

(s) A description of the investigation methodology, standards and scope of testing including an account of any site constraints encountered

(t) A summary of each proposed construction item (earth- or engineering work) showing a minimum of:

- the types of materials including their extent and variability, all test results the location and extent of any soft/wet areas
- the presence and extent of any boulders, weathered rock and "rock excavation materials"
- the factual excavation characteristics of the various materials

(u) Data on fluctuations of ground water table with time in the boreholes during the performance of the fieldwork and in piezometers after completion of the fieldwork

(v) Areas of existing instability and geohazards

(w) Historical land use

(x) Seismicity and faulting

(y) Areas of existing mineral extraction and mining as well as the identification of local borrow pits

(z) Ground and groundwater contamination

(aa) Compilation of all individual boring logs including groundwater and executed field test at a vertical scale of 1:100

(bb) Geotechnical cross-sections for each earth or engineering structure at a scale of 1:100 vertical and 1:500 horizontal

(cc) Geotechnical long sections along the alignment at a scale of 1:1000

(dd) Grouping and presentation of field and test results in appendices and as summary tables

(ee) List of samples (disturbed and undisturbed) with information on

- Sampling location
- Sample type
- Sampling method
- Depth of sample (from… to… [m below ground level and absolute heights])

(ff) List and map in a scale of 1:1000 for the investigations that have to be carried out in the second investigation campaign

(gg) photo-documentation of field work, which includes photos of every investigation point and observations made during the execution of exploration

(hh) Report outlining the need for each investigation location for the second investigation campaign

(ii) Compiled field and laboratory test results

Once second stage site investigations are completed the results must be compiled in factual report and GIR supplemented with the new data.

5 References

Ref:	Document Number:	Document Title:

1.	ASTM D2936	Standard Test Method for Direct Tensile Strength of Intact Rock Core Specimens
2.	ASTM D4525	Standard Test Method for Permeability of Rocks by Flowing Air
3.	ASTM D4543	Standard Practices for Preparing Rock Core as Cylindrical Test Specimens and Verifying Conformance to Dimensional and Shape Tolerances
4.	ASTM D5084	Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
5.	ASTM D5607	Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force
6.	ASTM D5731	Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classifications
7.	ASTM D7012	Standard Test Methods for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures
8.	ASTM D7070	Standard Test Methods for Creep of Rock Core Under Constant Stress and Temperature
9.	ASTM STP984	Rock Classification Systems for Engineering Purposes
10.	BS 1377-3	Methods of test for soils for civil engineering purposes Chemical and electro-chemical testing
11.	EN 932	Tests for general properties of aggregates
12.	EN 933	Tests for geometrical properties of aggregates
13.	EN 1097	Tests for mechanical and physical properties of aggregates
14.	EN 1367	Tests for thermal and weathering properties of aggregates
15.	EN 1744	Tests for chemical properties of aggregates
16.	EN 1997	Eurocode 7: Geotechnical design
17.	EN 13286	Unbound and hydraulically bound mixtures
18.	ISO 10390	Soil, treated biowaste and sludge
19.	ISO 14688	Geotechnical investigation and testing — Identification and classification of soil
20.	ISO 14689	Geotechnical investigation and testing — Identification, description, and classification of rock
21.	ISO 10693	Soil quality — Determination of carbonate content — Volumetric method
22.	ISO 10694	Soil quality — Determination of organic and total carbon after dry combustion (elementary analysis)
23.	ISO 11048	Soil quality — Determination of water-soluble and acid-soluble sulfate
24.	ISO 17892	Geotechnical investigation and testing — Laboratory testing of soil
25.	ISO 18400	Soil quality — Sampling

26.	ISO 18674	Geotechnical investigation and testing — Geotechnical monitoring by field instrumentation
27.	ISO 22282	Geotechnical investigation and testing — Geohydraulic testing
28.	ISO 22475	Geotechnical investigation and testing — Sampling methods and groundwater measurements
29.	ISO 22476	Geotechnical investigation and testing — Field testing
30.	RBDG-MAN-030-0105_BIM_EIR	Building Information Management (BIM) Employer's Information Requirements
31.	UIC 719R	Earthworks and track bed for railway lines