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6 LABORATORY TESTING

6.1 GENERAL

6.1.1 Scope

1 Geotechnical tests and testing procedures carried out in the laboratory or, when designated, on site.

2 Related Sections and Parts are as follows:

This Section

Part 1,..... General

Part 3,..... Soil Sampling

Section 6, Roadworks

Section 8, Drainage Works

Section 12, Earthworks Related to Buildings

6.1.2 References

1 The following standards and other documents are referred to in this Part:

AASHTO M145Standard Specification for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes

AASHTO T88Standard Method of Test for Particle Size Analysis of Soils

AASHTO T89Standard Method of Test for Determining the Liquid Limit of Soils

AASHTO T90Standard Method of Test for Determining the Plastic Limit and Plasticity Index of Soils

AASHTO T99Standard Method of Test for Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb.) Rammer and a 305-mm (12-in.) Drop

AASHTO T100Standard Method of Test for Specific Gravity of Soils

AASHTO T180Standard Method of Test for Moisture-Density Relation of Soils Using a 4.45-kg (10-lb.) Rammer and a 457-mm (18-in.) Drop

AASHTO T194Standard Method of Test for Determination of Organic Matter in Soils by Wet Combustion

AASHTO T208Standard Method of Test for Unconfined Compressive Strength of Cohesive Soil (ASTM Designation: D 2166)

AASHTO T215Standard Method of Test for Permeability of Granular Soils (Constant Head)

AASHTO T216Standard Method of Test for One-Dimensional Consolidation Properties of Soils

AASHTO T236Standard Method of Test for Direct Shear Test of Soils Under Consolidated Drained Conditions (ASTM Designation: D 3080)

AASHTO T258Standard Method of Test for Determining Expansive Soils

AASHTO T265Laboratory Determination of Moisture Content of Soils

AASHTO T288Standard Method of Test for Determining Minimum Laboratory Soil Resistivity

AASHTO T289Standard Method of Test for Determining pH of Soil for Use in Corrosion Testing

AASHTO T290Standard Method of Test for Determining Water-Soluble Sulfate Ion Content in Soil

AASHTO T291Standard Method of Test for Determining Water-Soluble Chloride Ion Content in Soil

AASHTO T296Standard Method of Test for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression

AASHTO T297	Standard Method of Test for Consolidated, Undrained Triaxial Compression Test on Cohesive Soils
ASTM D420.....	Site Characterization for Engineering, Design, and Construction Purposes
ASTM D422.....	Standard Test Method for Particle-Size Analysis of Soils
ASTM D512.....	Standard Test Methods for Chloride Ion In Water
ASTM D698.....	Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft ³ (600 kN-m/m ³))
ASTM D854.....	Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer
ASTM D1557.....	Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft ³ (2,700 kN-m/m ³))
ASTM D1883.....	Standard Test Method for California Bearing Ratio (CBR) of Laboratory-Compacted Soils
ASTM D2166/D2166M	Standard Test Method for Unconfined Compressive Strength of Cohesive Soil
ASTM D2434.....	Standard Test Methods for Measurement of Hydraulic Conductivity of Coarse-Grained Soils
ASTM D2435/D2435M	Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading
ASTM D2487.....	Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
ASTM D2488.....	Standard Practice for Description and Identification of Soils (Visual-Manual Procedures)
ASTM D2850.....	Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils
ASTM D2974.....	Standard Test Methods for Determining the Water (Moisture) Content, Ash Content, and Organic Material of Peat and Other Organic Soils
ASTM D2976.....	Standard Test Method for pH of Peat Materials
ASTM D3080/D3080M	Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions
ASTM D3282.....	Standard Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes
ASTM D4015.....	Standard Test Methods for Modulus and Damping of Soils by Fixed-Base Resonant Column Devices
ASTM D4230.....	Standard Test Method for Measuring Humidity with Cooled-Surface Condensation (Dew-Point) Hygrometer
ASTM D4318.....	Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D4546.....	Standard Test Methods for One-Dimensional Swell or Collapse of Soils
ASTM D4648/D4648M	Standard Test Methods for Laboratory Miniature Vane Shear Test for Saturated Fine-Grained Clayey Soil
ASTM D4767.....	Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils
ASTM D4959.....	Standard Test Method for Determination of Water Content of Soil By Direct Heating
ASTM D4972.....	Standard Test Methods for pH of Soils
ASTM D5084.....	Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
ASTM D5333.....	Standard Test Method for Measurement of Collapse Potential of Soils
ASTM G51	Standard Test Method for Measuring pH of Soil for Use in Corrosion Testing

ASTM G57	Standard Test Method for Measurement of Soil Resistivity Using the Wenner Four-Electrode Method
ASTM G187	Standard Test Method for Measurement of Soil Resistivity Using the Two-Electrode Soil Box Method
ASTM STP402	Testing Techniques for Rock Mechanics (ASTM STP402 Special Technical Publications No. 402)
BS 812.....	Testing aggregates;
.....	EN 932, Tests for general properties of aggregates;
.....	EN 933, Tests for geometrical properties of aggregates;
.....	EN 1097, Tests for mechanical and physical properties of aggregates;
.....	EN 1367, Tests for thermal and weathering properties of aggregates;
.....	EN 1744, Tests for chemical properties of aggregates.
BS 1377	Methods of test for soils for civil engineering purposes
BS 1377-2	Methods of test for soils for civil engineering purposes. Classification tests
BS 1377-3	Methods of test for soils for civil engineering purposes. Chemical and electro-chemical tests
BS 1377-4	Methods of test for soils for civil engineering purposes. Compaction-related tests
BS 1377-5	Methods of test for soils for civil engineering purposes. Compressibility, permeability and durability tests
BS 1377-6	Methods of test for soils for civil engineering purposes. Consolidation and permeability tests in hydraulic cells and with pore pressure measurement
BS 1377-7	Methods of test for soils for civil engineering purposes. Shear strength tests (total stress)
BS 1377-8	Methods of test for soils for civil engineering purposes. Shear strength tests (effective stress)
BS 1881-210	Testing hardened concrete, Part 210: Determination of the potential carbonation resistance of concrete – Accelerated carbonation method
BS 5930	Code of practice for ground investigations
EN 1997-2	Eurocode 7 - Geotechnical design - Part 2: Ground investigation and testing
Brown E.T. (Editor). Rock characterizations testing and monitoring. International Society for Rock Mechanics Suggested Methods. 1981. Pergamon Press.	
C2 through C25 and C27 through C31, Methods for examination of waters and associated materials, HMSO	
IRSM Commission on Testing Methods. Suggested method for determining Point Load Strength (revised version). <i>Int. J. Rock Mech. Min. Sci. and Geomech. Abst.</i> , 22, 51-60 (1985).	

6.2 SCHEDULE OF TESTS

- The Contractor shall prepare a schedule of tests for approval by the Engineer. It may be necessary to designate additional testing after the results of the original tests are available. Unless otherwise agreed, testing schedules are to be provided within six working days of the receipt by the Engineer of the relevant preliminary logs. The Contractor shall inform the Engineer within six working days from the receipt of the approved testing schedule if a sample referred to in the schedule is not available for testing.

6.3 TESTING PROCEDURES

6.3.1 General

- 1 Where applicable, all preparation, testing and reporting shall be in accordance with the relevant Qatar National Standard or British Standards or ASTM Standards. Where tests are not covered by these Standards, they shall be performed in accordance with the procedures in the references or as designated.
- 2 Calibration of load-displacement or other measuring equipment shall be carried out in accordance with the relevant standard (the preferred method) or the manufacturer's instructions by a calibration service approved by Qatar General Organization for Standardization (QS). Evidence of current calibrations shall be supplied to the Engineer.
- 3 Laboratory testing is a fundamental element of geotechnical engineering. The complexity of testing required for a particular project may range from a simple moisture content determination to specialized strength and stiffness testing. Since testing can be expensive and time consuming, the geotechnical engineer should recognize the project's issues ahead of time so as to optimize the testing program, particularly strength and consolidation testing.
- 4 The following minimum laboratory testing shall be carried out:-
 - (a) Particle size analysis (In trial pits: 1 test per soil type per trial pit. In boreholes: 1 test for each different soil strata per borehole).
 - (b) Moisture content (In trial pits: 1 per soil type per trial pit. In boreholes: 1 test for each different soil strata per borehole).
 - (c) Compaction tests to BS 1377 Part 4, including determination of moisture/ dry density relationship using heavy compaction test, 4.5 kg rammer methods. (In trial pits: 1 test per soil type per trial pit).
 - (d) California bearing ratio for soaked samples (In trial pits: 1 test per trial pit).
 - (e) Atterberg limits – each test shall report liquid limit [LL], plastic limit [PL] and plasticity index $[PI = LL - PL]$. (In trial pits: 1 test per soil type per trial pit. In boreholes: 1 test for each different soil strata per borehole).
 - (f) Chemical tests for soil and groundwater to determine: pH value, carbonate, sulphate, chloride and organic matter content (2 soil tests and 2 groundwater tests from selected trial pits/boreholes).
 - (g) Point load test (In boreholes: at 5m maximum intervals in rock and at every change in rock strata).
 - (h) Uniaxial compression tests on rock samples including deformation characteristics of the rock (In boreholes: at 5m maximum intervals in rock and at every change in rock strata).
 - (i) Consolidation (Oedometer) test on samples of clays, silts and other non- granular soils.
- 5 The laboratory tests and procedures are described in detail in relevant European (Euro code) and American (ASTM & AASHTO) Standards. Table 6.1 presents a summary list of AASHTO, ASTM and BS Standards for frequently used laboratory tests for soil.

Table 6.1:
AASHTO, ASTM and BS Standards for Frequently Used Laboratory Testing of Soils

Test Category	Name of Test	Test Designation		
		AASHTO	ASTM	BS
Visual Identification and Classification	Practice for description and identification of soils (Visual Manual Procedure).	-	D 2488	5930
	Test method for classification of soils for engineering purposes.	M145	D2487 D3282	5930
Index Properties	Test method for determination of water (moisture) content of soil by direct heating method.	T265	D4959	1377 (Part 2)
	Test method for specific gravity of soils.	T100	D854	1377 (Part 2)
	Method for particle-size analysis of soils.	T88	D422	1377 (Part 2)
	Test method for liquid limit, plastic limit, and plasticity index of soils.	T89 T90	D4318	1377 (Part 2)
Compaction	Test method for laboratory compaction characteristics of soil using standard effort (600kN-m/m ³).	T99	D698	1377 (Part 4)
	Test method for laboratory compaction characteristics of soil using modified effort (2,700kN-m/m ³).	T180	D1557	1377 (Part 4)
Chemical	Test method for pH of peat materials.	-	D2976	1377 (Part 3)
	Test method for pH of soils.	-	D4972	1377 (Part 3)
	Test method for pH of soil for use in corrosion test.	T289	G51	1377 (Part 3)
	Test method for sulfate content.	T290	D4230	1377 (Part 3)
	Test method for resistivity	T288	G57 G187	1377 (Part 3)
	Test method for chloride content.	T291	D512	1377 (Part 3)
	Test methods for moisture, ash, and organic matter of peat and other organic soils.	T194	D2974	1377 (Part 3)
Strength Properties	Unconfined compressive strength of cohesive soil.	T208	D2166/ D2166 M	1377 (Part 7)
	Unconsolidated, Undrained (UU) triaxial compression test on cohesive soils.	T296	D2850	1377 (Part 7)
	Consolidated-Undrained (CU) triaxial compression test on cohesive soils.	T297	D4767	1377 (Part 8)
	Consolidated Drained (CD) triaxial compression test for soils.	-	-	1377 (Part 8)
	Direct shear test of soils for consolidated drained conditions.	T236	D3080/ D3080 M	1377 (Part 7)
	Modulus and damping of soils by the resonant-column method (small-strain properties).	-	D4015	-
	Test method for laboratory miniature vane shear test for saturated fine-grained clayey soil.	-	D4648/ D4648 M	1377 (Part 7)
	Test method for CBR (California Bearing Ratio) of laboratory – compacted soils for highways.	-	D1883	1377 (Part 4)
Permeability	Test method for permeability of granular soils (constant head).	T215	D2434	1377 (Part 5)
	Test method for permeability of soils (falling head).	-	-	-
	Test method for measurement of hydraulic conductivity of saturated porous materials using a flexible wall permeameter.	-	D5084	1377 (Part 6)
Compression properties	Method for one-dimensional consolidation properties of soils (Oedometer test).	T216	D2435/ D2435 M	1377 (Part 5)
	Test methods for one-dimensional swell or settlement potential of cohesive soils.	T258	D4546	1377 (Part 5)
	Test method for measurement of collapse potential of soils.	-	D5333	1377 (Part 5)

6.3.2 Geotechnical Testing on Contaminated Samples

- 1 Where geotechnical testing is required on samples of suspected contaminated material, indicative chemical testing shall be carried out and a safe method of working approved by the Engineer before any such work is started. It should be noted that this may include but is not limited to the safe storage, transportation and handling of all suspect material.

6.3.3 Soil Testing

- 1 Soil testing shall be carried out and reported in accordance with BS 1377 or ASTM Standards unless otherwise designated.

6.3.4 Rock Testing

- 1 Rock testing shall be carried out and reported in accordance with the following references and as designated:
- (a) Classification.
 - (i) Natural water content - Brown (1981).
 - (ii) Porosity/density - Brown (1981).
 - (iii) Void index - Brown (1981).
 - (iv) Carbonate content - BS 1881.
 - (v) Petrographic description -Brown (1981).
 - (b) Durability.
 - (i) Slake durability index - Brown (1981).
 - (ii) Soundness by solution of magnesium sulphate - BS 812.
 - (c) Hardness.
 - (i) Shore sclerometer -Brown (1981).
 - (ii) Schmidt rebound hardness - Brown (1981).
 - (d) Aggregates.
 - (i) Aggregate crushing value - BS 812.
 - (ii) Ten percent fines - BS 812.
 - (iii) Aggregate impact value - BS 812.
 - (iv) Aggregate abrasion value - BS 812.
 - (v) Polished stone value - BS 812.
 - (vi) Aggregate frost heave - BS 812.
 - (e) Strength.
 - (i) Uniaxial compressive strength - Brown (1981).
 - (ii) Deformability in uniaxial compression -Brown (1981).
 - (iii) Tensile strength-Brown (1981).
 - Direct tensile strength.
 - Indirect tensile strength by the Brazilian method.
 - (iv) Undrained triaxial compression without measurement of porewater pressure-Brown (1981).
 - (v) Direct shear strength - Brown (1981).
 - (vi) Swelling pressure - Brown (1981).
 - Swelling pressure index under conditions of zero volume change.
 - Swelling strain index for a radially confined specimen with axial surcharge.
 - Swelling strain developed in an unconfined rock specimen.
 - (vii) Point load test - IRSM Commission on Testing Methods (1985).

- (f) Geophysical.
- (i) Seismic velocity-Brown (1981).

6.4 CHEMICAL TESTING FOR CONTAMINATED GROUND

1 Chemical testing for contaminated ground shall be carried out and reported in accordance with the following references and as designated:

- (a) Primary contaminants in soil.
 - (i) Arsenic total - C4.
 - (ii) Cadmium total - C2.
 - (iii) Chromium total - C2.
 - (iv) hexavalent chromium (undertaken if total chromium content >25 mg/kg dry
 - (v) Mass) -C2.
 - (vi) Lead total - C2.
 - (vii) Mercury total - C3.
 - (viii) Selenium total - C4.
 - (ix) Boron, water-soluble - C5.
 - (x) Copper total - C2.
 - (xi) Nickel total - C2.
 - (xii) Zinc total - C2.
 - (xiii) Cyanide total (alkali extraction methods) - C6.
 - (xiv) Cyanide complex - C6.
 - (xv) Cyanide free - C6.
 - (xvi) Thiocyanate - C6.
 - (xvii) (Tests xiii, xiv and xv undertaken if total cyanide >25 mg/kg dry mass. Methods shall follow alkali extraction.)
 - (xviii) Phenols total - C7.
 - (xix) Sulphide - C8.
 - (xx) Sulphate - total, acid, soluble - C9.
 - (xxi) Sulphate - water soluble, 2 : 1 extract - C9.
 - (xxii) Sulphur free - C10.
 - (xxiii) PH value - C9.
 - (xxiv) Toluene extractable matter - C11.
 - (xxv) Coal tar/polyaromatic hydrocarbons (undertaken if toluene extractable matter < 2000 g/kg dry mass of soil) - C12.
 - (xxvi) Asbestos. Asbestos content determination shall be carried out by visual examination and polarised light microscopy.
- (b) Secondary contaminants in soil.
 - (i) Antimony total - C13.
 - (ii) Barium total - C13.
 - (iii) Beryllium total - C15.
 - (iv) Vanadium total - C13.
 - (v) Cyclohexane extractable matter - C14.
 - (vi) Freon extractable matter - C15.

- (vii) Mineral oils - C31.
- (viii) Chloride - C9.
- (c) Contaminants in water.
 - (i) Arsenic - C4.
 - (ii) Cadmium - C2 and C23.
 - (iii) Chromium - C2 and C24.
 - (iv) Hexavalent chromium - C2.
 - (v) Lead - C2 and C25.
 - (vi) Mercury - C3.
 - (vii) Selenium - C4.
 - (viii) Boron - C5 and C6.
 - (ix) Copper - C2 and C27.
 - (x) Nickel - C2 and C28.
 - (xi) Zinc - C2 and C29.
 - (xii) Cyanide total - C6.
 - (xiii) Cyanide complex - C6.
 - (xiv) Cyanide free - C6.
 - (xv) Thiocyanate - C6.
 - (xvi) Phenols total - C7.
 - (xvii) Sulphide - C8.
 - (xviii) Sulphate - C9.
 - (xix) Sulphur free - C10.
 - (xx) PH value - C9.
 - (xxi) Polyaromatic hydrocarbons - C 12.
 - (xxii) Antimony-C13.
 - (xxiii) Barium-C13.
 - (xxiv) Beryllium-C15.
 - (xxv) Vanadium - C 13.
 - (xxvi) Chloride - C9.
 - (xxvii) Ammoniacal nitrogen - C16.
 - (xxviii) Nitrate nitrogen - C17.
 - (xxix) Chemical oxygen demand - C18.
 - (xxx) Biochemical oxygen demand - C19.
 - (xxxi) Total organic carbon - C20.
 - (xxxii) Volatile fatty acids - C21.
 - (xxxiii) Iron - C22.
 - (xxxiv) Manganese - C22.
 - (xxxv) Calcium - C31.
 - (xxxvi) Sodium - C31.
 - (xxxvii) Magnesium - C31.
 - (xxxviii) Potassium - C21.

- (d) Constituents of gas samples.
 - (i) Carbon dioxide - C30.
 - (ii) Hydrogen - C30.
 - (iii) Hydrogen sulphide - C30.
 - (iv) Methane - C30.
 - (v) Nitrogen - C30.
 - (vi) Oxygen - C30.
 - (vii) Ethane- C30.
 - (viii) Propane- C30.
 - (ix) Carbon monoxide - C30.

6.4.2 Laboratory Testing On Site

- 1 When designated, tests listed under laboratory testing shall be carried out on site.

6.4.3 Special Laboratory Testing

- 1 When designated, special laboratory testing shall be carried out.

END OF PART