

6	EARTHWORKS AND ROADWORKS SPECIFICATION.....	2
6.1	GENERAL PRINCIPLES	2
6.1.1	General.....	2
6.1.2	References	3
6.2	EMBANKMENTS.....	3
6.2.1	Foundations.....	3
6.2.2	Slope Stability and Erosion Control.....	3
6.2.3	Cuts.....	4
6.3	EXECUTION	4
6.3.1	General.....	4
6.3.2	Excavations	5
6.3.3	Excavation for Structures.....	5
6.3.4	Backfill	5
6.3.5	Compaction	5
6.4	EARTHWORKS FOR EMBANKMENT CONSTRUCTION (INCLUDING SUB BASE OR PROTECTION LAYERS).....	6
6.4.1	Excavations for Embankment Foundation.....	6
6.4.2	Construction equipment.....	7
6.4.3	Compaction of the base of the embankment.....	7
6.4.4	Compaction of the embankment	8
6.5	ROADWORKS.....	8
6.5.1	General.....	8
6.5.2	Execution.....	8
6.6	GROUND IMPROVEMENT	8
6.6.1	General.....	8

6 EARTHWORKS AND ROADWORKS SPECIFICATION

6.1 GENERAL PRINCIPLES

6.1.1 General

- 1 This chapter is applicable for the design of earthworks bearing the railway track, either with sloping side slopes or with vertical slopes supported by retaining walls, and shallow cuts for the foundation of bridges. Deep cuts for the construction of cut-and-cover structures and various types of tunnels are covered in other sections of this specification.
- 2 Earthworks Construction Specifications
 - (a) All project related earthworks shall be according to QCS - Section 12 and EN 1997.
- 3 Method Statement
 - (a) The Contractor shall submit a method statement giving full details of proposed materials, plant and operations involved in the construction of earthworks to the Engineer for a SONO. It shall include but not be limited to
 - (i) Type of the excavation;
 - (ii) Sequence of excavation and placing of material;
 - (iii) Methods of ground water handling within and outside of the excavations and disposal of groundwater; and
 - (iv) Methods of testing, monitoring and reporting on the performance of the earthworks.
 - (b) The Contractor's method statement shall include the construction objectives (target compaction, density, moisture content, lift thickness, etc.) and the methods (procedures, tests, frequency etc.) used for ensuring that the target objectives are achieved. This document shall also specify the corrective measures to be taken if the target objectives are not achieved.
- 4 Embankments and similar structures shall be designed in accordance with the following standards:
 - (a) EN1990 Basis of structural design;
 - (b) EN1991 Actions on structures;
 - (c) EN1997 Geotechnical design; and
 - (d) UIC 719R Earthworks and Track-bed layers for Railway Lines.
- 5 Issues not covered in sufficient detail by the above standards shall be designed according to the relevant British Standards (BS):
 - (a) BS 6031 : Code of Practice for Earthworks;
 - (b) BS 1377 : Methods of Test of Soils for Civil Engineering Purposes; and
 - (c) UIC Standards.
- 6 Protection of the slope surfaces from storm-water erosion shall be provided for Temporary and Permanent Works.

6.1.2 References

- 1 The following standards are approved and/ or referred to in this Section:
 - American Association of State Highway and Transportation Officials (AASHTO) Standards
 - BS 1377Methods of test for soils for civil engineering purposes
 - BS 6031Code of practice for earthworks
 - EN 1990Eurocode - Basis of structural and geotechnical design
 - EN 1991Eurocode 1: Actions on structures:
 - EN 1997Eurocode 7 - Geotechnical design:
 - EN 1997-2Eurocode 7 - Geotechnical design - Part 2: Ground investigation and testing

- UIC - International union of railways Standards
- UIC CODE 719Earthworks and track bed for railway lines

6.2 EMBANKMENTS

6.2.1 Foundations

- 1 The embankments' foundation conditions shall be assessed on the basis of the shear strength and deformability characteristics of the local subsoil conditions, and design considerations shall be made for the embankments' construction materials
- 2 Design considerations related to foundation drainage and / or groundwater lowering shall be determined on the basis of the evaluated long-term groundwater conditions.
- 3 The design of the embankments' foundations shall include but not be limited to:
 - (a) Short – term and long-term settlement estimation;
 - (b) Measures to accelerate settlement;
 - (c) Ground improvement techniques;
 - (d) Liquefaction checks of potential subsurface fully saturated loose granular soils.

6.2.2 Slope Stability and Erosion Control

- 1 The design of embankments shall include, but not be limited to, the following:
 - (a) Ultimate width of top of embankment;
 - (b) Loading on top of embankment;
 - (c) Geotechnical properties of the foundation and fill materials;
 - (d) Restrictions on width of land available; and
 - (e) Special conditions to which the embankment would be subject to. This includes for example, tidal waters, active mining operation and natural cavities, and environmental and other economic factors which may influence the final choice of cross section.

- 2 The inclination of the slopes of embankments shall be adequate to ensure safety against slope stability failure, long-term deformations and erosion.
- 3 The proposed anti-erosion protection measures shall consider but not be limited to:
 - (a) Planting;
 - (b) Installation of geosynthetics (e.g. geocells, geogrids) with hydroseeding, etc.
- 4 If the embankment is founded on relatively impermeable materials and the groundwater table is high, both undrained and drained conditions shall be checked in the slope stability analyses.
- 5 Both local and global stability shall be checked. Local stability checks the embankment slope while global stability also considers potential failure surfaces passing through the foundation soils.
- 6 Adequate drainage shall be provided at the gutters of the top of the embankment to prevent uncontrolled flow of rain-water towards the slopes of the embankment and thus invigorating surface erosion processes.

6.2.3 Cuts

- 1 The inclination of the cut slopes shall be adequate to ensure safety against slope stability failure both in the short – term and long – term, as well as control of ground deformation, Cut stability checks shall include but not be limited to:
 - (a) Permanent Cuts
 - (i) Long – term static conditions, assuming the worst case groundwater conditions
 - (ii) Long – term earthquake conditions
 - (b) Temporary Cuts
 - (i) Short – term static conditions, assuming the corresponding groundwater conditions
- 2 In case of rock cut slopes where stability is controlled by the existence of unfavourably oriented discontinuities, the frequent mapping of the exposed surfaces is necessary. Possible modifications in the cut slopes design shall be considered (if necessary) on the basis of the evaluation of the mapping results.

6.3 EXECUTION

6.3.1 General

- 1 The Contractor shall carry out all earthworks in such a manner as to prevent erosion or slips and shall limit working faces to safe slopes and heights. The Contractor shall ensure that all surfaces have at all times sufficient gradients to enable them to shed water without causing erosion.
- 2 The Contractor shall provide all necessary equipment to keep the earthworks free from water.
- 3 Construction traffic on the final formation level shall be minimized to prevent damage and/or softening of the subgrade.

- 4 Surfaces of excavations or filling shall be protected against erosion and climatic influences.
- 5 Surfaces of excavations or filling, on which plain (unreinforced) or reinforced concrete will be formed, shall be prepared with a layer of lean concrete or in such other manner to provide a suitable surface.

6.3.2 Excavations

- 1 Demolition materials shall not be used for backfilling.
- 2 The final level of all excavations shall be free from mud and water, trimmed clean, thoroughly compacted and consolidated.
- 3 Trench excavation shall be executed by the use of suitable equipment, in such a manner so as to minimise disturbance to the required finished sides and bottom of the excavation.

6.3.3 Excavation for Structures

- 1 This work shall consist of all excavation for structures, culverts, headwalls, catch basins, manholes, inlets, and retaining walls and shall include all necessary clearing and grubbing, all necessary bailing, drainage, pumping, sheeting, strutting and the construction of coffer dams or cribs, also the disposal of all material obtained from such excavation and backfilling; it shall include the removal of that portion of existing structures below the ground which is necessitated by the construction of the new structure.
- 2 Any loose or improperly compacted soil below the structural foundation levels, shall be completely removed, and the void backfilled with suitable material as determined by BS 1377. Any previous excavations shall be excavated and backfilled.
- 3 All rock or other hard foundation material shall be cleaned of all loose material and cut to a firm surface, either level, stepped, or serrated. All open cracks and discontinuities shall be cleaned and grouted. All loose rock shall be removed.

6.3.4 Backfill

- 1 Top soil shall not be used for structural backfill.
- 2 When the weather conditions would adversely affect the placing of backfill, all such work shall be stopped.

6.3.5 Compaction

- 1 Backfilling around structures shall be made by selected filling material as per EN 1997, thoroughly compacted in layers.
- 2 Except in the vicinity of structures, excavations shall be backfilled with suitable material, compacted in layers of 300 mm maximum loose thickness to achieve a density of at least 95% of the maximum dry density.
- 3 Field density shall be carried out by in-situ tests in accordance with EN 1997-2.

6.4 EARTHWORKS FOR EMBANKMENT CONSTRUCTION (INCLUDING SUB BASE OR PROTECTION LAYERS)

6.4.1 Excavations for Embankment Foundation

- 1 Required excavation for the foundation of embankments shall include:
 - (a) Materials classified as A-7 or A-6 according to AASHTO Specifications;
 - (b) Unstable materials incapable of being compacted to the specified density at optimum moisture content using ordinary compaction methods for the equipment being used for compaction. Such materials may include, but not be limited to, organic and highly compressible soil;
 - (c) Material too wet to be compacted and prevented from drying in place prior to incorporation into the Works. Such materials may include mud from tide flats and coastal marshes; and
 - (d) Materials which are otherwise unsuitable for use in or under the embankment.
- 2 Where embankments are constructed across wadis, marshlands, tidal flats, or wet ground, which is soft and compressible and will not support the weight and forces of hauling and compacting equipment, the lower part of the embankment may be constructed by placing successive loads in a uniformly distributed layer (bridging lift) of a thickness not greater than necessary to support hauling equipment, and the placing and compacting of subsequent layers. Such supporting layers shall not be subjected to the compaction requirements specified in the below sections. The remainder of the embankment shall be constructed in layers as specified in this specification.
- 3 Suitable embankment materials shall meet the following requirements:
 - (a) Materials classified as A-2 or better according to AASHTO Specifications; and
 - (b) In areas subject to flood and prolonged inundation of the embankment, the material used in the embankment shall be either rockfill or earth materials classified as A-1-a, A-1-b or A-2-4 according to AASHTO Specifications. The same types of material shall be used for the reinforced embankment and reinforced earth structures.
 - (c) Unsuitable rockfill materials include water-soluble rocks, or other types of rocks, which can be either easily disintegrated after their exposure to local weather conditions, or crushed during compaction.
- 4 Suitable non-compacted rockfill materials shall meet the following requirements:
 - (a) Low strength rocks: Microdeval Index (resistance to wear) with the presence of water $MDE > 40$; Los Angeles index (resistance to fragmentation) $LA > 40$;
 - (b) Medium strength rocks: Microdeval Index (resistance to wear) with the presence of water $25 < MDE \leq 40$; Los Angeles index (resistance to fragmentation) $30 < LA \leq 440$;
 - (c) High strength rocks: Microdeval Index (resistance to wear) with the presence of water $MDE \leq 25$; Los Angeles index (resistance to fragmentation) $LA \leq 30$;
 - (d) The percent passing by weight from the sieve of 22.4mm shall be less than 25% and the percent passing by weight from the sieve ISO 565 of 0.063 mm shall be less than 7%;

- (e) The maximum size of the used rock particles (D) shall not exceed 50% of the thickness of the compacted layer. No rock particles having $D>500\text{mm}$ shall be used as rockfill materials;
- (f) The granulometric curve of the rockfill materials shall meet the requirements of the following Table:

Table 6.1
Requirements for rockfill material

Particle size (Sieve opening)	Percent passing by weight (%)
D	90 – 100
D/4	45 – 60
D/16	25 – 45
D/64	15 -35

Where D is the maximum size of the rockfill particles

- 5 For reinforcing materials, in reinforced embankments, their quality certificates together with their long term tensile strength and durability shall be provided to the Engineer for SONO. An appropriate certificate shall be submitted proving that the materials are not affected by biological and chemical actions as well as UV radiation. In case of steel reinforcement, all necessary certificates assuring its long term anti-corrosion and durability performance shall be provided to the Engineer for a SONO.

6.4.2 Construction equipment

- 1 The Contractor shall provide all types, sizes and numbers of equipment which are necessary for loading, hauling, spreading, mixing, watering, compacting and finishing material to form the embankment in accordance with his plans and specifications.
- 2 Compacting operations shall include adequate blading with motor graders to insure uniformity of the layers of embankments being compacted. The number of blades and rollers in use shall be sufficient to blade and compact adequately all materials being delivered to the embankment.
- 3 When construction of rock embankment is required, the Contractor shall propose details of the plant and equipment to be used, and include these details in the method statement.
- 4 The Contractor shall propose the speed of compression rollers and number of passes etc.

6.4.3 Compaction of the base of the embankment

- 1 When the embankment height is less than 600 mm and the original sub-ground consists of suitable material, the original ground shall be scarified to a depth of 200 mm, watered or dried to obtain uniform moisture content and compacted to 95% of maximum Modified Proctor Density (or equivalent relative density values). If the top 300 mm of original ground does not meet the suitability requirements or there is excessive moisture present, the top 300 mm shall be removed and replaced with material meeting these requirements. This material shall be compacted to 95% of maximum Modified Proctor Density (or equivalent relative density values).

- 2 When the embankment height exceeds 600 mm, any unsuitable material below the embankment footprint shall be removed up to the necessary depth, until suitable material shall be found. This depth shall not exceed the final embankment height, if no ground improvement techniques are used. After removal of any unsuitable material, the foundation base shall be scarified to a depth of 200 mm, watered or dried to obtain uniform moisture content and compacted to 95% of maximum Proctor Density (or equivalent relative density values).

6.4.4 Compaction of the embankment

- 1 The Contractor's method statement for the embankment construction methodology shall include construction method, material types to be used, layer thickness, compaction equipment, compaction objectives, minimum number of roller passes, wetting methodology, compaction control procedures, type and frequency of tests to be performed as well as characteristics required for ensuring compaction sufficiency.
- 2 Prior to the commencement of any embankment construction work, a test embankment shall be constructed using the same materials as those to be used for actual embankment construction. The objective of the test embankment shall be to validate that the construction methodology proposed by the Contractor in his method statement meets the Employer's Requirements.

6.5 ROADWORKS

6.5.1 General

- 1 Only materials which achieve the requirements given in the QCS shall be used.

6.5.2 Execution

- 1 All related roadworks shall be executed in accordance to the QCS.

6.6 GROUND IMPROVEMENT

6.6.1 General

- 1 Ground improvement may be required:
- (a) In underground works in order to improve stability of the excavation faces and/or walls, reduce ground subsidence due to excavations and its potential adverse effects on surface structures and utilities, reduce the ingress of groundwater in the tunnel, improve the foundation soil of buildings and generally any other related to excavation operations for the needs of the Project;
 - (b) In surface works (embankments and elevated railways) in order to found embankments on weak soils and to alleviate the liquefaction potential; and
 - (c) Around pile foundations to improve against liquefaction and/or improve lateral capacity of pile foundations.
- 2 Based on the provisions herein, a detailed specification and method statement shall be submitted for any ground improvement Works to the Engineer for a SONO.
- 3 Ground improvement Works may include, but are not limited to:
- (a) permeation and compaction grouting;
 - (b) soil stabilization injections of all kinds (cement grout, chemicals etc.);
 - (c) jet grouting;
 - (d) compensation grouting;
 - (e) lime or cement improvement of embankment foundations; and/or
 - (f) dynamic compaction, vibro-compaction or vibro-replacement of embankment foundations or around pile foundations.

END OF PART