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1 Purpose

1.1 The purpose of this Standard is to define the whole life cycle requirements for Earth Structure assets. The Earth Structures comprise:

- a) Embankments of soil with slopes more than 1m high;
- b) Cutting slopes of soil and rock (chalk) more than 1m high.

Note: This standard does not deal with the requirements for slopes less than 1m high.

1.2 Requirements applying to the use of reinforcement in Earth Structures by placing structural elements or materials (including Geosynthetics) within the soil so that slopes stand at angles steeper than the earth would eventually adopt if no structural elements or materials were present are included in this Standard.

1.3 The Global Stability of composite slopes, where differences in grade beside the railway are created by combining Retaining Structures and Earth Structures, is a geotechnical issue and shall meet the stability requirements for Earth Structures as defined in this Standard.

Note: Retaining Structures (including gabion walls) in composite slopes are included in LU Standard S1051.

1.4 In defining requirements specifically applicable to Earth Structures, this Standard complements LU Standard S1050 that defines mandatory requirements generally applicable to all Civil Engineering assets including the Earth Structures.

1.5 Supporting LU Guidance Documents G0054A and G0054B give guidance and explanation on Earth Structure assets.

2 Scope

2.1 This Standard applies to Earth Structures owned by LU.

2.2 This Standard defines the requirements for Earth Structures through the following life cycle stages:

- a) Inception and design;
- b) Construction, installation, testing and commissioning;
- c) Inspection;
- d) Analytical assessment;
- e) Condition assessment and certification;
- f) Maintenance;
- g) Strengthening and renewal;
- h) Decommissioning;
- j) Evidence of compliance

3 Requirements

3.1 Inception and design

3.1.1 General

- 3.1.1.1 The inception and design of new works including works of Strengthening and Renewal to existing assets shall ensure that the Earth Structure assets will satisfy their Required Duty.

Note:	The Required Duty for Earth Structures is as follows:
1	Meet railway operating requirements (within the performance specification at system installation or at the most recent system upgrade).
1.1	Maintain inherent structural integrity (support itself so as not to suffer complete or partial collapse), i.e. meet or exceed factors of safety currently specified in LU standards.
1.2	Maintain the ability to carry without restriction any permitted applied static and dynamic design loads.
1.3	Allow adequate clearance to ensure the safe passage of rail vehicles.
1.4	Provide appropriate access and egress for all planned uses (including maintenance), and for reasonably anticipated emergency uses.
1.5	Sustain a condition and state so as not to cause unplanned interruption to, or restriction of, any aspect of the operating railway.
1.6	Sustain a condition and state so as to maintain all interfacing non-railway services and facilities at full design capability.
1.7	Meet or exceed the serviceability requirements currently specified in LU standards (e.g. deformation).
2	Ensure support at asset interfaces without undue wear and tear.
2.1	Minimise the degradation of all interfacing assets (e.g. as evidenced through maintenance cycles). This includes interfaces with the railway and adjacent infrastructure (e.g. track, structures, stations and premises).
2.2	Minimise the degradation of all interfacing assets which support non-railway services or facilities (e.g. as evidenced through maintenance cycles). Includes interfaces with dynamic & static assets (e.g. roads, buildings, walkways, etc).
3	Match LU policy in respect of realistic user perceptions.
3.1	Ensure the asset does not cause undue degradation of interfacing assets, disruption to railway operations or unacceptable environmental nuisance.
4	Provide resistance against external interference and events.
4.1	Asset minimises the likelihood and consequence of asset abuse. Asset abuse encompasses, vandalism, planned/unplanned work, damage due to external event, etc.
5	Present acceptable environmental impact.
5.1	Present an acceptable societal environmental impact (noise, vibrations, vegetation cover, adverse weather management, etc).
5.2	Provide resilience against the effects of climate change.

6	Minimise environmental impact throughout lifecycle.
6.1	Minimise environmental impact and demands at all stages in the lifecycle; this includes effects now and into the future, including successive maintenance and renewal, final decommissioning, and disposal routes.
7	Function within the legal and standards framework.
7.1	Ensure the asset functions within the framework defined by legislation (including environmental); regulatory guidance and applicable national and international standards; and LU policies.
8	Ensure safe operation as defined by LU.
8.1	Ensure safe operation and condition as specified by LU requirements; this includes passengers, employees and members of the general public.
8.2	Ensure safe ingress/egress by passengers, employees, and emergency services in planned & reasonably anticipated emergency scenarios.
8.3	Safeguard the health and safety of passengers, employees and members of the general public.
9	Provide above within reliability and availability targets.
	Provide all aspects of the Required Duty within the defined LU requirements.
10	Ensure Required Duty is performed without incurring excessive or prohibitive costs.

3.1.1.2 Earth Structure assets shall be designed to the principles of whole life asset management planning.

3.1.1.3 Design of the track-bed and formation shall be carried out in accordance with LU Standard S1157.

3.1.2 Inception

3.1.2.1 All proposals for new works, including Strengthening and Renewal shall be initiated and controlled in accordance with LU Standards S1538 and S1050.

3.1.3 Design process

3.1.3.1 The design shall proceed in a staged manner in accordance with LU Standard S1538.

3.1.3.2 The design shall be in accordance with the requirements of Eurocode and other standards listed in Section 3.1.9.

Note: In accordance with BS EN1997-1 section 2.1, the design requirements of a slope within the LU environment generally meets the classification of a Geotechnical Category 2 Structure.

3.1.3.2 The design process for Earth Structure assets shall be managed by a Geotechnical Specialist.

3.1.3.3 The design check certificate for Earth Structure assets shall be signed by a Geotechnical Specialist.

3.1.4 Structure gauge

- 3.1.4.1 No part of any Earth Structure shall encroach upon the structure gauge as defined in LU Standard S1156 under any conditions of loading or deformation.

3.1.5 Geotechnical information and site investigation

- 3.1.5.1 The Conceptual Design Statement (CDS) for design shall include proposed soil parameters and Groundwater conditions for the design derived from a desk study of the existing site investigation information and other available data, provided sufficient existing information to establish design criteria is available.
- 3.1.5.2 The design CDS shall consider the potential for contamination at the site.
- 3.1.5.3 In the absence of sufficient existing information to establish the criteria for design, the design CDS shall include proposals for additional ground investigation and monitoring to obtain the required level of information in the form of an investigation Conceptual Design Statement/Conceptual Work Statement (CDS/CWS).
- 3.1.5.4 Ground Investigations shall be carried out in accordance with BS EN 1997-2, BS 5930:1990+A2:2010 and LU Standard S1050 which includes the investigation CDS/CWS.
- 3.1.5.5 The CDS/CWS for Ground Investigation at existing Earth Structures shall include the considerations defined in Section 3.4.3 of this Standard.

Note: The design parameters for the Strengthening and Renewal of an asset will normally be the parameters previously established for use in the Analytical Assessment of the asset, and for which a desk study and site investigation will already have been carried out as provided in Section 3.4 of this Standard. In that case no further investigation should be required.

- 3.1.5.6 Interpretation of the Site Investigation results shall include the factors listed in Section 3.4.3.6 of this Standard.
- 3.1.5.7 The design shall not be finalised until all the required geotechnical information is available and incorporated as appropriate to determine ground model and geotechnical design parameters.

Note: This requirement does not preclude rigorous application of the Earth Structure Observational Method to design and construction, in which a hierarchy of appropriate contingency procedures are fully established ahead of the works for the possible range of conditions and circumstances that could be encountered.

3.1.6 Soil parameters

- 3.1.6.1 The characteristic soil parameter values for use in the design of new works shall generally be determined in accordance with BS EN 1997-2.
- 3.1.6.2 The characteristic soil parameter values for use in the design of Strengthening and Renewal works to existing assets shall generally be determined in accordance with Section 3.4.4 of this Standard.

3.1.7 Groundwater and drainage

- 3.1.7.1 The groundwater conditions applicable for use in the design shall be the most unfavourable anticipated conditions during the Design Life of the asset.
- 3.1.7.2 The groundwater conditions for the design of Strengthening and Renewal to existing assets shall be determined in accordance with sections 3.4.5 of this standard.
- 3.1.7.3 The design shall take account of the following:

- a) changes in long-term groundwater levels;
- b) seasonal variations in groundwater levels.

3.1.7.4 Earth Structure design shall, as far as reasonably practical, avoid modification to groundwater tables outside the asset area during both construction and operation, and shall include a risk assessment of the consequences of anticipated groundwater level changes when avoidance is considered impractical.

Note: CIRIA Report C515 provides guidance on the design and operation of Groundwater control systems involving pumping from wells.

3.1.7.5 Where the assumed groundwater regime is dependent on the performance of existing track or land drainage, the condition of the existing drainage shall be confirmed as fulfilling its required function up to the point of secure discharge by Inspection in accordance with LU Standard S1052.

3.1.7.6 Cleaning or replacement of existing drainage shall be included in the design if the existing drainage does not fulfil its required function in the new works, including Strengthening and Renewal.

3.1.7.7 Inspection, improvement and design of drainage shall be carried out in accordance with LU Standard S1052.

3.1.7.8 Existing counterfort drains on the slope of cuttings shall not be relied upon as providing a drainage function in the long term during the design life of the earth structure, unless it can be demonstrated that they are fully functional or can be improved to be fully functional through maintenance. Checks shall also be made to determine if the counterfort drains are positively discharged into an outfall through a collector pipe located at the toe of the cutting. Further guidance on the effects of existing counterfort drains is provided in the LU Guidance Document G0054B.

3.1.7.9 The design shall consider the topography of the area adjacent to the toe of embankments and ensure that ponding at the toe or flooding of the adjacent properties is avoided. Where necessary, toe drainage shall be incorporated in the design in order to mitigate the risk.

3.1.7.10 The design shall consider the topography of the area adjacent to the crest of cuttings and ensure that flooding of the cutting and the railway from the adjacent property is avoided. Where necessary, a crest drain or ditch shall be incorporated in order to mitigate the risk.

3.1.7.11 All new drainage shall be designed to have a suitable outfall or discharge location.

3.1.7.12 The review of the need to install new drainage shall include considerations of the effects of climate change over the life of the structure and recommendations of LU Earth Structures Inclement Weather Report.

3.1.8 Design methodology

3.1.8.1 The slope stability analysis for the design including Strengthening and Renewal to existing earth structures shall be carried out in accordance with Section 3.4.7 of this standard.

3.1.8.2 Earth Structures shall be designed to have adequate stability against shear failure and to ensure that deformation is within acceptable limits.

3.1.8.3 Except as described in Section 3.1.8.4 of this standard, adoption of BS EN1997-1 for design, coupled with a sound, well-drained trackbed formation and a crest width of embankments meeting the requirements of Section 3.1.15 and 3.1.16, shall be considered sufficient to limit deformation to below that of the Serviceability Limit State (SLS).

- 3.1.8.4 In cases where the investigation and assessment of an existing Earth Structure has indicated that it is undergoing deformation that may be detrimental to track performance, including but not limited to ravelling of ash embankments or seasonal track deformation by high water demand trees on high plasticity clay fill, the design of Strengthening and Renewal works shall specifically address limiting future track deformations to within the maintenance target level of LU Standard S1159.

Note: High water demand trees are defined in National House Building Council, Building Near Trees, 2003 and LU Guidance Document G0058 Civil Engineering – Technical Advice Notes.

3.1.9 Design standards

- 3.1.9.1 Design of Earth Structure assets, including Strengthening and Renewal to existing assets shall be carried out in accordance with the latest revision of the codes of practice in Section 6 of this standard.
- 3.1.9.2 The stability assessment of existing Earth Structures shall use the assessment procedure defined in Section 3.4 of this standard to determine the critical Factor of Safety for the proposed sections.

3.1.10 Retaining structures

- 3.1.10.1 The geotechnical design of retaining structures used to strengthen or renew Earth Structures assets shall be in accordance with BS EN 1997-1 and the National Annex to BS EN 1997-1.
- 3.1.10.2 Retaining structures and any supports they rely upon must be designed against structural failure in accordance with LU standard S1051, BS EN 1992 (concrete), BS EN 1993 (Steel) and BS EN 1996 (Masonry).

Note: BS EN 1997-1 does not explicitly cover the detailed design of soil nails or reinforced earth soil structures. The design of reinforced soil structures should be carried out in accordance with the National Standards i.e. BS 8006-1 and CIRIA C637

3.1.11 Actions (Loading)

- 3.1.11.1 Actions (variable and permanent loadings) to be used in the design of Earth Structure assets shall be as given in Section 3.4.6 of this Standard.

3.1.12 Design life

- 3.1.12.1 The Design Life for Earth Structure assets shall be 120 years.
- 3.1.12.2 The design shall state any monitoring and maintenance liability required to achieve the Design Life and this shall be identified in the design report.
- 3.1.12.3 The Design Life shall apply to the Earth Structure asset as a whole and all elements within the Earth Structure contributing to its performance of the Required Duty other than drainage elements covered by LU Standard S1052.

3.1.13 Fire resistance

- 3.1.13.1 Earth Structure design within areas covered by the Fire Precautions (Sub-surface Railway Stations) Regulations, 2009 shall meet the requirements for fire performance in LU Standard 1-085.
- 3.1.13.2 Earth Structure design for assets requiring a fire safety strategy shall be designed to the requirements for passive fire resistance in LU Standard 1-083 in support of the fire safety strategy.

3.1.14 Constructability and Temporary Works

- 3.1.14.1 The overall stability of slopes for temporary cuttings and open excavations during construction should be determined in accordance with the principles of BS EN 1997-1.

NOTE The Design Life of Temporary Works to support construction activities, in most cases, is of sufficient duration to adopt effective stress analysis. Adoption of total stress (undrained) analysis should be limited to short term Temporary Works where the designer is satisfied that insufficient time is available for porewater pressure to dissipate and drained conditions to develop. This decision must be carefully considered as the transition from undrained to partially drained conditions occurs relatively quickly in most fine grained soils on the LU system.

- 3.1.14.2 The design shall evaluate Temporary Works and intended construction methods required for the construction of the permanent works in accordance with LU Standard S1062.

- 3.1.14.3 Monitoring of temporary works, the track, the earth structure and other associated structures (e.g., culverts, bridges, abutments, wingwalls, etc.) shall be carried out as appropriate in order to ensure stability of the works and the operation of the railway during construction.

3.1.15 Impact on operational railway and adjacent structures

- 3.1.15.1 The design shall take account of LU Standard S1050.
- 3.1.15.2 The design shall take account of the top level railway safety principles in the “Railway Safety Principles and Guidance” (RSPG).
- 3.1.15.3 The design shall provide for supporting other infrastructure elements of the railway, such as track bed, cable posts, signals, signage and lighting.
- 3.1.15.4 The design shall provide for adequate access and working space to any cable run.
- 3.1.15.5 The design shall provide adequate space including access and working space for the installation of a new cable run if none is currently provided wherever practicable.

Note: LU Standard S1156 requires that “The minimum distance from running edge to the face of a cable post shall be 2.44m. This dimension shall be increased to allow for cant effect and vehicle throw on curves as shown on the appropriate structure gauge diagram.” A further distance is required from the cable post to the edge of an embankment to provide stability of the cable posts as determined by analysis.

3.1.16 Provision for Inspection and Maintenance.

- 3.1.16.1 The design shall incorporate provisions to facilitate the Inspection and Maintenance operations necessary for the achievement of the Required Duty over the Design Life of the Earth Structure asset.
- 3.1.16.2 The design shall provide for an unobstructed cess with a minimum width of 700mm at a distance not less than 430mm from the swept envelope at both sides of the line along which persons can walk and may stand in safety during the passage of trains to be maintained at all times during Maintenance work of Earth Structures.
- 3.1.16.3 The design shall provide for an unobstructed walkway with a minimum width of 1000mm between the outermost part of the cable run and the edge of an embankment in order to provide access for inspection and maintenance of the cable run and embankment.
- 3.1.16.4 The design shall consider the need for provision of cable stiles to facilitate access to walkway from track. The design of cable stiles shall be in accordance with LU Standard S1057. A drawing of an acceptable cable stile design is attached as

attachment 10 of S1057. This design is deemed to satisfy standard and may be fabricated and installed without any further design approval. Any proposal for alternative designs shall be submitted for approval.

- 3.1.16.5 The design shall provide for an unobstructed walkway with a minimum width of 1000mm between the boundary fence and the toe of an embankment or crest of a cutting in order to provide access for inspection and maintenance of the earth structure and the boundary fence. In areas where space is limited the width of the walkway may be locally reduced to 700mm. Approval for this reduction in width will be required before the design can be finalised.

3.1.17 Operational boundary fence

- 3.1.17.1 Where the existing boundary fence at the toe of an embankment or crest of a cutting is sub-standard or is affected by the remedial works it shall be replaced with a new boundary fence.
- 3.1.17.2 The specification, design and installation of the boundary fence shall be in accordance with LU Standard S1167.

3.1.18 Steps

- 3.1.18.1 The design shall consider whether steps are required to facilitate access from the toe to the crest of an earth structure. Where steps are required the design shall be carried out in accordance with the LU Standard S1133 and LU Guidance Document G0054A.
- 3.1.18.2 A handrail shall be provided on one side of the steps as a minimum. The design of the handrail shall be in accordance with LU Standard S1133.

3.1.19 Noise barriers

- 3.1.19.1 Where a noise barrier is required to be installed to mitigate the noise disturbance from the railway to the local residents, the noise barrier shall be designed and installed in accordance with HA 65/94 and HA 66/95 the relevant LU, national and international standards.

3.1.20 Services

- 3.1.20.1 The design shall investigate the location of all services affected by the works in accordance with PAS 128:2014 "Specification for underground utility detection, verification and location" and clearly identify these on the design drawings by hazard triangles.
- 3.1.20.2 The design shall avoid the location of services where possible. Otherwise the design shall arrange for diversion or protection of the services, as appropriate. The design intent shall be clearly shown on the design drawings and included in the designer's risk assessment.

3.1.21 Buried structures

- 3.1.21.1 The design shall identify the location of any buried structures affected by the works and shall take appropriate measures to comply with the relevant LU and other applicable standards regarding exclusion zones and loading requirements.
- 3.1.21.2 Where it is considered not possible to comply with the requirements of relevant LU and other relevant and applicable standards a concession to the requirements will be required before the design can be finalised.

3.1.22 Ground improvement techniques

- 3.1.22.1 Ground improvement techniques included in the design shall be assessed over the whole Design Life of the new works including quantification of all anticipated Maintenance and Monitoring work.

3.1.23 Geosynthetics

- 3.1.23.1 The design for Earth Structures that incorporate geosynthetic materials at appropriate locations to enhance the natural behaviour of soil and rock (chalk) shall demonstrate that the specified materials have been assessed for the railway environment, including assessment of risks due to fire, vandalism, and the short and long-term exposure to chemical, biological and ultra-violet degradation.

Note: Potential uses of geosynthetics in Earth Structures include:

- a) separation - the geosynthetic forms a boundary between different soil materials, thus segregating two or more particle sizes;
- b) reinforcement - the geosynthetic imparts tensile strength to a reinforced soil system;
- c) filtration - the geosynthetic effectively retains particles while allowing water to flow through with little or no increase in pore pressure;
- d) drainage - the geosynthetic effectively allows water to flow in the plane of the fabric, thus allowing drainage of water away from a structure or system.

A given geosynthetic material may fulfil several of these uses. In erosion control the primary function of a geosynthetic is filtration with the separation function playing a secondary role.

- 3.1.23.2 The design shall determine the minimum Design Life required for geosynthetic materials incorporated in the works in relation to their design function, and relate these to the properties of proposed materials as established by Agrément Certificates or other verified testing.
- 3.1.23.3 For permanent works the geosynthetic shall retain the properties required to fulfil the in service design function throughout the Design Life of the Earth Structure asset.
- 3.1.23.4 Where a geosynthetic material is proposed to be incorporated into works, both its beneficial and detrimental effects on the performance of the structure shall be taken into account in the design of the works. This shall include the long-term effects of geosynthetics included for a temporary purpose.
- 3.1.23.5 Testing shall be carried out to confirm properties of geosynthetics affecting Earth Structures design except where the required information is available from Agrément Certificates and other such quality assured sources, which may include appropriate guidance documents and recommendations of the manufacturer and validated performance records.
- 3.1.23.6 The need for and extent of testing shall be assessed from the safety implications of the work and the performance record of the proposed material in equivalent applications to that under consideration.
- 3.1.23.7 Justification of the design parameters used for geosynthetics shall be included in the design records, including tensile, shear, burst strength, creep, frictional, filtration and hydraulic characteristics as applicable to the usage.

3.1.24 Instrumentation and monitoring

- 3.1.24.1 The design shall state the requirements for instrumentation and monitoring to assist construction, to evaluate performance including ongoing deformation in relation to the requirements of Section 3.1.8.4 over an annual cycle, and to improve understanding for the long-term management and maintenance of the asset.

3.1.25 Landscaping and planting

- 3.1.25.1 The design shall consider the implementation of a landscaping and planting scheme to environmentally enhance the appearance of the Earth Structure in accordance with LU Standard S1165.
- 3.1.25.2 As part of any new works at an Earth Structure, the design shall ensure that the resulting slope vegetation is consistent with the requirements of LU Standard S1165. Where necessary this shall include provision of measures to prevent the erosion of topsoil before the vegetation is established.
- 3.1.25.3 The species and associations of grass, trees, shrubs and other plants for landscaping shall be selected on the basis of their growth characteristics and site conditions and compliance with LU Standard S1165, except that only low water demand trees, as defined by National House Building Council 2003 Building Near Trees, shall be planted on Earth Structure slopes to ensure an even water demand during the Design Life.
- 3.1.25.4 The landscaping design shall minimise future maintenance and risk of tree and leaf fall to the operation of the railway.
- 3.1.25.5 For slopes steeper than 30° where topsoil is unlikely to remain stable in the long term, consideration shall be given to the use of erosion mats, hydroseeding or ground covering planting.

3.1.26 Design documents

- 3.1.26.1 A design report shall be prepared in addition to the requirements of LU Standard S1050.
- 3.1.26.2 The design report shall describe any requirements for instrumentation and monitoring including full details of purpose, installation requirements, and frequency of readings.
- 3.1.26.3 The Designer shall have a process for checking and verifying design calculations.

3.2 Construction, installation, testing and commissioning

3.2.1 General

- 3.2.1.1 LU Standard S1552 shall be complied with during all construction, installation, testing and commissioning work.
- 3.2.1.2 Construction installation, testing and commissioning shall put into effect the design requirements as defined in Section 3.1 of this standard.
- 3.2.1.3 No new or Strengthening and Renewal construction work shall start until the permanent works and temporary works designs for that work has been approved in accordance with LU Standards S1538 and S1050.
- 3.2.1.4 A system to control and manage the construction process shall be maintained.

Note:	This system is required to enable LU:
a)	to discharge their responsibilities to Office of Rail Regulation (ORR);
b)	to discharge their responsibilities to maintain safe structures and operating railway systems during construction works;
c)	to satisfy itself that the construction is in accordance with the design; and
d)	to satisfy itself in respect of the adequacy of the system for the recording of construction data and information that may be relevant to the subsequent Maintenance, Strengthening and Renewal and eventual decommissioning of the Earth Structure assets.

- 3.2.1.5 Procedures shall be in place for controlling any changes to the design during the construction, installation, testing and commissioning phases including staged and temporary construction work. Such procedures shall ensure that:
- a) proposed design changes are not implemented until they have been duly considered and approved by a person competent to appreciate their impact on construction methodology and their implications for the safety of the operational railway; and
 - b) records are made of the design changes and their approval.
- 3.2.1.6 Adjacent buildings, structures, utilities and facilities, and the track shall be protected from the effects of construction work in accordance with LU Standard S1050.
- 3.2.1.7 Sufficient testing of systems, sub-systems, materials and components shall be carried out to give assurance that they are in accordance with those specified in the approved design.
- 3.2.1.8 All necessary attendance during site visits shall be afforded to LU to enable LU to discharge its responsibilities in respect of its duties including verification.
- 3.2.1.9 Where appropriate to the scope of work, a design capability shall be made available throughout construction to ensure and certify implementation of the design intent.

Note: Ensuring implementation of the design intent includes interpretation of Monitoring data and modification of the design if necessary.

3.2.2 Work sites and access

- 3.2.2.1 The location and size of the working sites required for the efficient and safe servicing of construction activity shall be selected.
- 3.2.2.2 Arrangements necessary to obtain permission to use sites for the intended purpose for the duration of construction activity shall be made.
- 3.2.2.3 The provision of an unobstructed cess with a width of at least 700mm at a distance not less than 430mm from the swept envelope at both sides of the line along which staff can walk and may stand in safety during the passage of trains shall be maintained at all times during Earth Structures construction activity alongside an operational railway.

3.2.3 Construction methods

- 3.2.3.1 The construction method(s) shall meet the requirements defined in the documentation for implementation within the specified tolerances and of the specified dimensions and quality.
- 3.2.3.2 Before any modifications are made to a construction method the design shall be checked and if necessary modified.

3.2.4 Materials

- 3.2.4.1 All construction materials supplied to the works shall comply with the requirements of LU Standard S1050.

3.2.5 Instrumentation and monitoring

- 3.2.5.1 Where appropriate to the scope of work, the following shall be carried out:
- a) Verify the predictive ground movement and the effects which such ground movement will have on LU and adjacent assets by measurement.
 - b) Determine the impact on Outside Party assets in accordance with LU Standard S1023.

- c) Establish Monitoring base readings of the construction activity sufficiently in advance to ensure underlying and seasonal environmental trends are understood.
- d) Implement contingency plans if the results of Monitoring so indicates.

3.2.6 Pumping

- 3.2.6.1 Pumping of water shall wherever practical be performed within the boundary of the excavation.
- 3.2.6.2 Where pumping is to be undertaken, provision shall be made to prevent the removal of fines from the soil, such that adjacent buildings, structures utilities or facilities are not affected by the pumping operations.
- 3.2.6.3 Pumping shall be undertaken in the manner foreseen by the design determinations of the effect of modifying groundwater level.

3.2.7 Construction documents

- 3.2.7.1 Construction documents shall be prepared in accordance with LU Standard S1050.
- 3.2.7.2 At the end of construction the drawings shall record the works as built.
- 3.2.7.3 A record of all as-built drawings shall be provided in an electronic format.
- 3.2.7.4 The as-built drawings shall record the location of all temporary works.
- 3.2.7.5 All temporary works left in place shall be clearly shown on the as-built drawings.

3.3 Inspection

3.3.1 General

3.3.1.1 Inspections shall be undertaken to achieve the following objectives:

- a) to provide information necessary for the managed maintenance of Earth Structure assets;
- b) to confirm that Earth Structures are safe for railway operations and for public and third party use;
- c) to provide the information necessary to assess the condition of the Earth Structure assets in a consistent and accurate manner;
- d) to provide information enabling the Engineering Asset Register (LU Standard S1041, Engineering Asset Information) to be maintained as an accurate record of the physical nature of the Earth Structure assets;
- e) to provide the information required for Stage 1 of the Asset Condition Assessment and Certification (ACAC) process as defined in Section 3.5 of this Standard;
- f) to maintain quantitative records of the on-going changes of condition of the Earth Structure assets for long-term asset management planning;
- g) to identify defects, the causes and effects of deterioration and high risk Earth Structures.

Note: Inspection is the core procedure by which LU are able to maintain awareness of the condition of the Earth Structure assets for which they are responsible, detecting incipient defects at an early stage and identifying the need and urgency for corrective action.

In addition, the Inspection records provide the knowledge basis needed for the long-term management of LU's Earth Structure assets.

3.3.1.2 Any usage of Earth Structure assets or development of defects which might place at risk the operational railway, interfacing assets, passengers, staff, or the public shall be identified, made safe, recorded and brought to the immediate attention of LU.

3.3.1.3 Where defects are observed, a decision shall be made whether a more detailed appraisal is necessary to ensure that appropriate information is available to meet the requirements of the Condition Assessment and Maintenance obligations.

3.3.1.4 Following completion of each Inspection the Engineering Asset Register for each Earth Structure shall be reviewed and the records updated as part of the reporting process.

3.3.1.5 All inspections shall be preceded by a sufficient review of recent maintenance history, previous inspections and any known changes of circumstances to establish as far as possible the background information about the asset and likely hazards.

3.3.1.6 The role of Inspection in the ACAC/ACR process shall be as shown in Attachment 7.3.

3.3.2 Types of inspection

3.3.2.1 Earth Structure assets shall be subject to the following types of Inspection:

- a) Principal;
- b) Special;
- c) Defect Advice;
- d) General.

3.3.2.2 Obtaining and recording of information by Principal Inspections shall be the primary means of achieving the objectives for Inspection of Earth Structure assets set out in Section 3.3.1.1 of this Standard.

3.3.3 Principal Inspections

- 3.3.3.1 Principal Inspections shall provide all the information required to make a visual evaluation of the condition of the asset and its ability to perform the Required Duty and to complete Stage 1 of the Asset Condition Assessment and Certification (ACAC) process.
- 3.3.3.2 Principal Inspections shall be carried out in accordance with the procedure set out in Attachment 7.1 to this Standard except as provided in Section 3.3.4 below.
- 3.3.3.3 The information to be recorded in a Principal Inspection shall as a minimum be sufficient to complete a full entry of the Inspection into the LU Earth Structures Database and use of the accompanying condition rating tool (see Section 3.3.10 below) except where a reduced scope of Inspection has been justified in accordance with Section 3.3.4. The information to be recorded to meet the entry requirements for the database is tabulated on the sheets in Attachment 7.2.
- 3.3.3.4 The information to be recorded in a Principal Inspection shall include a description of the visible elements of all Strengthening and Renewal works or other support works in place, and an appraisal of their condition.

3.3.4 Reduced scope of Principal Inspection

- 3.3.4.1 A reduced scope of Principal Inspection may be undertaken where there is a negligible risk to rail traffic, passengers, staff and the public, e.g. along branch lines where trains are no longer running, provided no change in condition from the most recent full Principal Inspection is anticipated. Justification of the reduction in scope of the Inspection shall be recorded. This inspection shall be recorded as a General Inspection.

3.3.5 Special Inspections

- 3.3.5.1 Special Inspections shall be instigated under the following circumstances and at the following intervals in order that awareness of the condition of particular areas or defects causing concern is maintained.
 - a) Earth Structures that have failed to meet the minimum condition to operate without restriction in accordance with section 3.5.8 (3 monthly maximum interval). Less frequent intervals can be adopted subject to approval by the Head of Earth Structures;
 - b) Earth Structures supporting track that have a current speed restriction in force as a result of a previous Assessment of Earth Structure condition to the requirements of Section 3.4 of this standard (3 monthly maximum interval);
 - c) Earth Structures of concern after previous routine inspections e.g. classified as 'poor' condition and continued Monitoring recommended following a Principal Inspection (interval as recommendation).
- 3.3.5.2 The scope of Special Inspections and reporting shall be determined based on the extent of the concerns identified, but will typically involve the recording of defects with a comparison of those defects from one inspection to the next, for the purpose of identifying deterioration of the asset. This comparison may be achieved using measurements, photographs or such other means as may be appropriate.

3.3.6 Defect Advice Inspections

- 3.3.6.1 Defect Advice Inspections shall be carried out following defect notification from any source, or in response to a report of an Incident that causes damage to an Earth Structure asset or has the potential to affect adversely the ability of the asset to perform its Required Duty.

Note: Typically Defect Advice inspections at Earth Structures are required by reports of sub-standard track, slope bulges and cracks, etc, or by events such as cloud bursts and local flooding, blocked drains, etc.

- 3.3.6.2 Defect Advice Inspections shall bring to notice obvious deteriorations in condition, unusual conditions and any short term development of defects which might place at risk the traffic, passengers, staff, the public or the Earth Structure asset as a whole.
- 3.3.6.3 The Inspector shall inspect the Earth Structure asset from all readily accessible locations and levels as necessary to evaluate the cause for concern.
- 3.3.6.4 The Inspector shall certify in his report that the structure appears to be in a satisfactory condition, and shall note any exceptions where action may be required before the next scheduled Inspection and the associated degree of urgency, or shall call for immediate action if the situation so demands.
- 3.3.6.5 Where defects are observed which, in the opinion of the Inspector, require closer Inspection, the Inspection report shall include recommendations for further investigation.
- 3.3.6.6 The information to be recorded in the Inspection report shall include details of the defect notification or Incidents that triggered the Inspection and shall make use of photographic records as appropriate, including photographs of all observed defects.
- 3.3.6.7 Sufficient information shall be collected to enable the full reporting of any notifiable Incident to the ORR.

3.3.7 General Inspections

- 3.3.7.1 These inspections are intended to provide a more frequent but less onerous means of monitoring the condition of an asset.
- 3.3.7.2 General Inspections may be carried out between principal inspections for assets where there is an inclement weather risk or serviceability concern identified that justifies an increased inspection frequency but which does not require more frequent principal inspections.
- 3.3.7.3 General inspections are carried out for the entire earth structure, but do not require recording of transects as in a Principal Inspection.
- 3.3.7.4 The purpose of the inspection is to highlight any defects or areas of deterioration in the condition of the asset and to record any unusual conditions on the asset which may compromise the stability of the asset and its ability to perform its required duty.

3.3.8 Preparation for inspections

- 3.3.8.1 Inspectors undertaking Earth Structure Inspections shall be trained to ensure that a consistent level of reliable Inspections is maintained.
- 3.3.8.2 All new Inspectors shall demonstrate by the Inspection of a typical Embankment and Cutting under supervision, at locations where historic assessments have been undertaken, that they have been trained to provide Principal Inspection results consistent with experienced inspectors.
- 3.3.8.3 Training shall cover the preparatory steps needed to achieve a safe and comprehensive Inspection of the target site, such as assessing access requirements and special safety considerations, and the examination and understanding of previous Inspection and Maintenance history, available construction records, etc.
- 3.3.8.4 The records shall be maintained to permit the auditing of Inspector training.

3.3.8.5 The Inspector shall establish the known issues associated with an Earth Structure before undertaking its Inspection commensurate with the scope of the Inspection in accordance with Section 3.3.1.5.

3.3.8.6 In the case of a Principal Inspection the known issues shall include the design and function of any existing Strengthening and Renewal works or other slope support works recorded at the asset.

3.3.9 Maximum inspection intervals

3.3.9.1 The maximum interval between inspections shall be such that:

- a) Sufficient information is gathered for the timely identification of defects and deterioration for action within the asset management plan such that the risk to railway safety from events and changes of condition is ALARP.
- b) Information is obtained to meet the requirements of the ACAC/ACR process for Earth Structures.

3.3.9.2 The maximum interval between Principal Inspections shall not exceed that given in Table 1 for the appropriate condition rating category of the asset, as qualified by any recommendation for geotechnical investigation. The condition rating category shall be as determined from Table 3 (see Section 3.3.10.5) following the most recent Inspection or Assessment.

Condition rating category	Maximum interval between Principal Inspections (years)
Earth Structures categorised as in 'Poor' condition and where further geotechnical investigation is recommended or assessed to present a higher risk based on factor of safety and/or physical condition	1
Earth Structures categorised as in 'Poor' condition	2
Earth Structures categorised as in 'Marginal' condition	5
Earth Structures categorised as 'Serviceable' or 'Good'	10

Table 1 - Maximum interval between Principal Inspections of Earth Structures

3.3.9.3 As a minimum Defect Advice Inspections shall be carried out following any report or event that may indicate an abnormal change of condition may have occurred at an Earth Structure asset.

3.3.9.4 The maximum interval between Special Inspections shall be in accordance with Section 3.3.5.1.

3.3.9.5 The maximum interval between General Inspections shall not exceed that given in Table 2. These inspections shall be in addition to the Principal Inspections.

Condition rating category	Maximum interval between General Inspections (years)
Earth Structures categorised as being at 'High' risk of flow failure, frost shattering or scour erosion.	1
Earth Structures categorised as having 'Poor' (D_S) serviceability concern. Earth Structures categorised as being at 'Medium' risk of flow failure, frost shattering or scour.	2
Earth Structures categorised as having 'Moderate' (C_S or B_S) serviceability concern. Earth Structures categorised as being at 'Low' risk of flow failure, frost shattering or scour.	5

Table 2 - Maximum interval between General Inspections of Earth Structures

3.3.10 Information from inspections

- 3.3.10.1 The information from inspections shall be held in databases having the equivalent record structure to the "LU Earth Structures Database" or in a format compatible with future entry into such a database. The system adopted shall include input data checks to prevent clear errors in observation or of data handling from entering the database record and adversely affecting the calculation of condition ratings.

Note: The "LU Earth Structures Database" refers to a database set up by LU to hold Inspection information for all transects along the LU railway system that cross Earth Structures. Information at inspected sections not covered by the transect records is also held. The database structure is set up to hold all the information collected in a full Principal Inspection, which encompasses the data that might be collected by other classes of Inspection. The original database is no longer maintained but the record structure remains and is to be retained as part of the long-term asset management of Earth Structure assets. Populating databases having this common record structure with the results of inspections over an extended period will enable the long-term changes to the Earth Structures to be quantified and better understood across the network.

- 3.3.10.2 The information held shall maintain a consistent and repeatable standard that shall ensure compatibility in condition rating for inspected Earth Structure assets across the railway network and through time.
- 3.3.10.3 A response shall be provided to any condition revealed by the collection or processing of Inspection information that calls for immediate action ahead of completion of the Inspection report in order to achieve compliance with Section 3.3.1.2 and Section 3.5.8 of this Standard.

3.3.11 Determination of condition rating

- 3.3.11.1 The information from Principal Inspections shall be used to determine a condition rating for the slope at each inspected Transect and Feature as a measure of the state of the slope compared with a slope in a notional perfect condition, i.e. 100% represents a slope in perfect condition and 0% represents a slope in very poor condition.
- 3.3.11.2 The calculation of condition ratings shall be based on the standardised condition rating algorithm used by the LU Earth Structures Database Condition Rating Tool (CRT). The logic of that algorithm may be incorporated into the working module provided any such module has been independently checked and audited to show that it gives the same results as the standard LU Earth Structures Condition Rating Tool. Copies of

the check and audit of the condition rating procedure shall be maintained. Refer to LU Guidance Document G0054A for further details on CRT and the algorithm.

Note: The LU Earth Structures Condition Rating Tool (CRT) is a module that accompanies the LU Earth Structures Access Database. It is available in an Excel spreadsheet format. The tool is used to determine a provisional condition rating from inspection for each completed record in the Principal Inspection data. The calculated condition ratings from the condition rating tool ranges from 5% to 90%. Reference should be made to the LU Guidance Document G0054A for guidance on CRT.

3.3.11.3 For recently remediated assets, some of the defects may be residual defects relating to movement prior to remediation (eg leaning cable posts), and that if this is established, the effect of these defects need not be taken into account in the determination of the condition rating. However, the presence and magnitude of such defects should always be recorded accurately, to allow monitoring of future changes.

3.3.11.4 The Earth Structure shall be assigned a condition rating category from the overall condition rating as given in Table 3:

Condition rating category	Overall condition rating %
Poor	0 to ≤40
Marginal	>40 to ≤65
Serviceable	>65 to ≤85
Good	>85 to 100

Table 3 - Earth Structure condition rating categories

3.3.11.5 If the Inspector considers that there are concerns in the performance or condition of Strengthening and Renewal or other support works that are beyond the scope of an Inspection to reasonably evaluate then he shall recommend further Analytical Assessment to determine the condition and performance of those works.

3.3.12 Inspection reports

3.3.12.1 Inspection reports shall be prepared by the Inspector as part of the Inspection process that record the data collected and the conclusions and recommendations of the Inspectors appropriate to the type of Inspection carried out as indicated in Sections 3.3.4 to 3.3.6 of this Standard.

3.3.12.2 All Inspection reports shall include a full copy of the recorded data and photographic records of any defects noted. In addition the reports of Principal Inspections shall include at least one general photograph of each Transect or Feature inspected.

Note: Photographs shall be presented in the inspection report with the LCS reference and location clearly stated

3.3.12.3 The Inspection report shall classify the extent and severity of any defects observed together with the recommendations of any necessary action and associated urgency in accordance with the system shown in Table 4.

Extent	A -	No 'significant' defect
	B -	'Slight', not more than 5% affected (of area, length, etc)
	C -	'Moderate', 5% to 20% affected
	D -	'Extensive', over 20% affected
Severity	1 -	No 'Significant' defect
	2 -	'Minor' defects of a non-urgent nature
	3 -	'Heavy' defects of an unacceptable nature
	4 -	'Severe' defects where action is needed. These shall be reported immediately to the supervisor.
Recommended action	R -	Repair
	M -	Monitor
	I -	Special Inspection regime
	D -	Design remedial works
	C -	Replace
	G -	Ground investigation
	T -	Topographic survey
	A -	Slope stability assessment
	S -	Speed restriction
Priority	I -	Immediate (within 4 weeks)
	H -	High (within 12 months)
	M -	Medium (within 2 years)
	L -	Low (before next Principal Inspection)
	R -	Review (at next Principal Inspection)

Table 4 - Earth Structure defect classification system

3.3.12.4 The Inspection report shall recommend the date for the next principal or special Inspection where appropriate. The maximum interval between Principal Inspections is given in Table 1, for General Inspections in Table 2, and for Special Inspections in Section 3.3.5.1.

3.3.12.5 The inspection report of a Principal Inspection shall contain the provisional condition ratings derived from the procedures in Section 3.3.11. Justification for changing the provisional condition ratings shall be recorded in the report and shall be auditable.

Note: Condition ratings calculated using the LU Earth Structures Condition Rating Tool algorithm as described in Section 3.3.10 of this Standard are in significant part derived from a parametric estimate of inherent slope stability for a range of standard soil profiles and slope heights which are matched to the observed and measured data on the basis of reported geology, slope height and geometry. The Assessor should use professional engineering judgement in assessing the impact of this approach, in particular whether soil conditions have been reasonably represented in the data used by the algorithm to select the dominant material controlling slope stability. If the soil conditions are not well represented by the basic data input procedure then the Assessor can obtain more realistic results by suitably adjusting the data input for geology and recalculating the condition rating values. Reference shall be made to LU Guidance Document G0054A for CRT and the algorithm.

3.3.12.6 All Principal Inspection Reports shall be reviewed and approved by an accredited Inspection Review Engineer (IRE) before being finalised. Any revisions to the condition ratings for the asset by the IRE shall be recorded in the report.

- 3.3.12.7 Any proposed change in the Asset Condition Classification and/or inspection frequency shall be submitted for approval by the Head of Earth Structures or his accredited representative.
- 3.3.12.7 The recommendations of the finalised Inspection report shall be included in the asset management programme as soon as reasonably practical after completion of the report.
- 3.3.12.8 The finalised Inspection report with the Inspection records securely attached shall be retained for the life of the asset.

3.4 Analytical Assessment

3.4.1 General

- 3.4.1.1 The Analytical Assessments of existing Earth Structure assets shall be carried out in order to achieve the following objectives:
- a) determination as to whether the asset remains fit to safely fulfil its Required Duty in the current environment and condition and if not of the degree to which it fails to reach that requirement;
 - b) determination of the Factor of Safety against slope failure of the asset for all foreseen modes of failure;
 - c) evaluation of the asset Assessment Condition Rating which places the asset in a condition category; and
 - d) fulfilment of the requirements of Stage 3 of the Asset Condition Assessment and Classification (ACAC) process as defined in Section 3.5 of this Standard.
- 3.4.1.2 The Assessment of an Earth Structure asset shall include:
- a) examination of information on the physical conditions in the vicinity of the asset, including the topography and layout of the site;
 - b) consideration of the nature of the ground, Groundwater and surface water conditions and seasonal variations;
 - c) examination of details of adjacent foundations and services, and other adjacent and interfacing assets, including track, cess and walkways;
 - d) characterisation of the type and location of vegetation on the slope, particularly the presence of bare or grass covered slopes or the presence of high water demand trees;
 - e) determination of the Factor of Safety against failure of the slopes under the applicable loadings;
 - f) determination of the deformation behaviour, where this is a separate consideration in the performance of the Required Duty;
 - g) evaluation of the performance of installed works that contribute to the support of the slope including Strengthening and Renewal works.
 - h) determination of the asset Assessment Condition Rating
 - i) recommendations for future management of the asset
 - j) undertaking of appropriate risk assessment depending on the derived Assessment Condition Rating

Note: This list is not exhaustive and other items may be required on a case-by-case basis.

- 3.4.1.3 The information required to perform the Assessment shall be obtained from a thorough desk study and walk-over survey and from Site Investigation.

Note: The desk study and walk-over survey constitute stage 2 of the Asset Condition Assessment and Classification (ACAC) process as defined in Section 3.5 of this Standard.

3.4.1.4 The results of the Analytical Assessment shall be presented in an Assessment report as described in Section 3.4.14.

3.4.1.5 The processes of Analytical Assessment for Earth Structure assets shall be managed and assessed by Geotechnical Specialists.

3.4.2 Desk study

3.4.2.1 Before undertaking the Analytical Assessment of an Earth Structure or as otherwise required by the ACAC/ACR process all the information available for the asset, and for adjacent foundations and services, and other adjacent and interfacing assets as appropriate, shall be collected and reviewed in a thorough desk study.

3.4.2.2 The desk study shall identify all the issues to be resolved by an Analytical Assessment.

3.4.2.3 The desk study shall determine the information required for an Assessment, which as a minimum shall cover the factors listed in Section 3.4.1.2 of this Standard, and shall consider the sufficiency of existing information at cross-sections for stability analysis, including the zoning of materials and their properties, Groundwater levels, and factors determining the influence of vegetation on the slope.

3.4.2.4 A list of potential sources of information to be reviewed in the desk study is given in Table 5. This list should not be considered as exhaustive.

Information Source	Typical information available or to be obtained
Inspection reports	All current and previous inspection reports for the same asset; All current and previous inspection reports for interfacing assets; and Inspection reports of assets with similar material properties and geometry to the asset undergoing assessment.
Walkover survey reports	All current and previous walkover reports for the same asset; All current and previous walkover reports for interfacing assets; and Walkover reports of assets with similar material properties and geometry to the asset undergoing assessment.
Analytical Assessments	All current and previous Analytical Assessments; All current and previous Analytical Assessments for interfacing assets; and Analytical Assessments of assets with similar material properties and geometry to the asset undergoing assessment.
As built data	Date of construction; Method of construction; Material properties used in the design; and Design calculations.
Monitoring data	All monitoring reports.
Operational information	Operational history of the asset; Operational history of adjacent assets; and Operational history of interfacing assets.
Incident reports	For the asset under assessment ; For adjacent assets; and For interfacing assets.
Literature review	Asset type behaviour; and Material properties.

Table 5 - Information sources to be reviewed by a desk top study