

Category 1 Standard

S1055 Civil Engineering – Deep Tube Tunnels and Shafts



**Please read the Written Notices
attached to this standard**

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1 Purpose

- 1.1** The purpose of this Standard is to define the whole life cycle requirements for Deep Tube Tunnel and Shaft assets. These assets are collectively defined as “Deep Tube Tunnels” in the Deep Tube Tunnels Foundation Document which is contained in LU Standard S1042 (Asset Condition Reporting).

Note: The Deep Tube Tunnel asset types are numbered and defined in the Foundation Document as follows:

101 Platform or Concourse Tunnels

102 Station Passageway Tunnels

103 Running Tunnels

104 Cross Passages between Running Tunnels

105 Step Plate Junctions

106 Crossover Tunnels

107 Depot Approach Tunnels

108 Overrun Tunnels

109 Siding Tunnels

110 Inclined Shafts (eg escalator shafts)

111 Vertical Shafts (eg ventilation, access, service, lift and substation shafts)

112 Disused Tunnels

113 Disused Shafts

114 Other Tunnels

115 Miscellaneous Structures (TTMS)

Category 115, Miscellaneous Structures was an interim classification introduced prior to complete catalogueing of the Deep Tube Tunnel assets. The category should not be required for future asset classification purposes.

Independent Structural components within a Deep Tube Tunnel e.g. escalator support steelwork, ladders, shaft landings, gratings etc. are included in LU Standard S1053 (Civil Engineering – Building and Station Structures)

Subsurface tunnels (i.e. cut and cover tunnels) and associated shafts constructed by surface methods e.g. sheet piles or diaphragm walls are included in LU Standard S1051 (Civil Engineering – Bridge Structures)

- 1.2** Tunnel Portal structures shall be designed as Earth Retaining Structures in accordance with LU Standard S1051 (Civil Engineering – Bridge Structures)
- 1.3** In defining requirements specifically applicable to Deep Tube Tunnel assets, this Standard complements LU Standard S1050 (Civil Engineering - Common Requirements) that defines mandatory requirements generally applicable to all Civil Engineering assets including the Deep Tube Tunnel assets.
- 1.4** A supporting Manual of Good Practice G-055 gives guidance and explanation on Deep Tube Tunnel assets.

2 Scope

- 2.1 This Standard applies to Deep Tube Tunnel assets owned by, or being constructed for, LU.
- 2.2 This Standard defines the requirements for Deep Tube Tunnel assets through the following lifecycle 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; and
 - h) Decommissioning.

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 shall ensure that the Deep Tube Tunnel assets will satisfy their Required Duty.

Note:	The Required Duty for Deep Tube Tunnels is given in the current Foundation Documents 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).
1.2	Support static and dynamic design loads within acceptable stress limits.
1.3	Maintain the planned design envelope and adequate clearance to permit 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; this includes externally sourced wear or damage which is greater than that currently accepted for the asset.
1.6	Sustain a Condition and state so as to maintain all interfacing non-railway services and facilities at full design capability.
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 and stations), and dynamic and static assets (e.g. not contributing to degradation of the signalling equipment).

- 2.2 Minimise the degradation of all interfacing assets which support non-railway services or facilities (e.g. as evidenced through Maintenance cycles). This includes interfaces with dynamic & static assets (e.g. roads, Outside Party buildings, etc).
- 3 **Match the LU policy in respect of realistic user perceptions.**
Ensure the asset does not cause undue degradation of interfacing assets, disruption to railway operations or unacceptable environmental nuisance, and that the asset provides acceptable appearance and general ambience. This includes visual evidence of seepage even where this is not a structural problem.
- 4 **Provide resistance against external interference and events.**
Asset minimises the likelihood and consequence of asset abuse. Asset abuse encompasses, vandalism, planned/unplanned work, damage due to external event (e.g. piling), etc. This applies primarily to new or refurbished assets.
- 5 **Present acceptable environmental impact.**
 - 5.1 Present an acceptable societal environmental impact (noise, vibrations, odours, ground borne contaminants, etc).
 - 5.2 Provide for ease of cleaning and support environmentally acceptable routes for disposal of cleaning residues.
 - 5.3 Support (intrinsically and at asset interfaces) appropriate temperature mechanisms to control temperatures within the range considered societally acceptable by LU policy.
- 6 **Minimise environmental impact throughout lifecycle.**
Minimise environmental impact and demands at all stages in the lifecycle; this includes effects now and into the future, including successive refurbishment, final decommissioning, and disposal routes.
- 7 **Function within the legal and standards framework.**
Ensure the asset functions within the framework defined by legislation (including environmental); regulatory guidance; LU, Infracore and applicable national and international standards; and LU and Infracore 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, general public, employees, and emergency services in planned & reasonably anticipated emergency scenarios. This includes the means of transfer from the asset to the principal interfacing assets and transfer mediums (e.g. walking over trackbed or interaction with tunnel during evacuation).
 - 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 to LU.**

Note: The designer should be aware of the best practice guidance on tunnelling published by the British Tunnelling Society and others referenced in Section 6.1

3.1.2 Inception

- 3.1.2.1** All proposals for new works, including Strengthening and Renewal, made by suppliers to LU shall be initiated and controlled in accordance with LU Standards S1538 (Assurance) and S1050 (Civil Engineering – Common Requirements).

3.1.3 Design process

- 3.1.3.1** The design shall proceed in a staged manner in accordance with LU Standard S1538 (Assurance).

- 3.1.3.2** Conceptual Design Statements (CDS) shall be completed for all Deep Tube Tunnel permanent and Temporary Works in accordance with LU Standard S1538 (Assurance) and the additional requirements given in Attachment 1 of this Standard.

3.1.4 Structure profile and space requirements

- 3.1.4.1** The design shall determine the minimum internal dimensions for Deep Tube Tunnels from the space requirements of:

- a)** Structure profile in accordance with LU Standard S1156 (Gauging and Clearances);
- b)** Plant and services in accordance with LU Standard 1-068 (Station Mechanical Services, Utility Provision and Energy Management);

Note: Plant and services include tunnel and shaft drainage, ventilation, internal finishes, fire safety installations and electrical installations (including power supply, emergency lighting, telecommunications and signalling).

- c)** Air flow and ventilation from LU Standard 1-067 (Tunnel and Passenger Area Ventilation);
- d)** Passenger and personnel spatial requirements in accordance with LU Standard S1371 (Station Planning);
- e)** Emergency evacuation in accordance with LU Standard S1371 (Station Planning);
- f)** Platforms, architectural finishes and furniture in accordance with LU Standards S1131 (Premises – Station Platforms) and S1135 (Premises – Finishes);
- g)** Construction equipment and operations as determined by the designer;
- h)** Maintenance equipment and operations as determined by the designer;
- j)** Construction tolerances as determined by the designer;
- k)** Deformation tolerance as determined by the designer; and
- l)** Cable requirements from LU Standard S1120 (Power Cable Route Design, Testing and Recovery Requirements).

3.1.4.2 Trackbed in running tunnels

- a)** The structural design shall provide space and make provision for the trackbed and for the variation in position of the structure due to tolerances.

Note: The diameter of the tunnel may need to be enlarged where floating slab trackform is required. Specific consideration should be given to the load imposed on the tunnel lining and infill (stage 1) concrete by the support bearings for the floating slab.

- b) The structural design shall be coordinated with the track support design, LU Standards S1157 (Track – Performance, design and configuration), S1158 (Track – Inspection and Maintenance), S1162 (Conductor rail – Performance, design and configuration) and S1163 (Conductor rail – Inspection and maintenance).
- c) Where it is necessary for cables to cross tracks the design shall make suitable provision in a manner which does not encroach on the vehicle envelope nor endangers cable function.

Note: The type of trackbed and required resilience may influence the tunnel design basis, for example dowels between the tunnel lining and trackbed may be required to restrict trackbed movement.

3.1.4.3 Drainage

- a) The structural design shall provide space for the drainage system and the variation in position of the structure due to tolerances.
- b) The structural design shall be coordinated with the drainage system design, LU Standard S1052 (Civil Engineering – Gravity Drainage Systems).

3.1.4.4 Service fixings and connections

- a) The design shall comply with the requirements for service fixings and connections in accordance with LU Standard S1050 (Civil Engineering – Common Requirements).

3.1.4.5 Contained structural components

- a) The design shall provide space for structural components contained within the asset and for the variation in position of such structural components due to tolerances.
- b) Structural design shall be coordinated with the design of Contained Structural Components as defined in LU Standard S1053 (Civil Engineering – Building and Station Structures).

Note: Requirements for fixing and connection of internal structures are given in S1050 (Civil Engineering – Common Requirements).

Contained structural components include:

- a) Cable brackets;
- b) Cable bridges;
- c) Brackets for holding equipment such as water mains, signals ducts and fans;
- d) Noise reduction screens;
- e) Emergency and maintenance walkways; and
- f) Access stairs and landings.

3.1.4.6 Finishes

- a) All finishes shall comply with LU Standard S1135 (Premises – Finishes);
- b) Where the function of the asset includes its use as a part of the ventilation system the finish shall be as required by LU Standard 1-067 (Tunnel and Passenger Area Ventilation);
- c) The structural design shall provide space for installation or application of finishing systems consistent with structure tolerances;

- d) The structural design shall be coordinated with the design of the finishing systems to ensure durability, water control and structural integrity of the asset;
- e) Finishing systems for new works shall allow inspection of the structure;
- f) Finishing systems for existing assets shall not diminish the inspectability of the structure; and
- g) Where no finishing systems are required, the structural elements shall have a surface finish compliant with Clauses 3.1.8 and 3.1.9 of this Standard.

Note: Requirements for fixing and connection of internal structures are given in S1050 (Civil Engineering – Common Requirements).

3.1.5 Alignment

- 3.1.5.1** Alignment of tunnels containing track shall be designed in accordance with the requirements of LU Standards S1157 (Track – Performance, design and configuration), S1158 (Track – Inspection and Maintenance), S1162 (Conductor rail – Performance, design and configuration) and S1163 (Conductor rail – Inspection and maintenance).

Note: The precise arrangements of tunnels, particularly around junctions, may have a significant impact on both constructability and structural efficiency. Further guidance on the layout of tunnel junctions is provided in G-055 (Civil Engineering - Deep Tube Tunnels and Shafts).

3.1.6 Ground investigation information

- 3.1.6.1** Ground Investigations and desk top studies for Ground Investigations shall be carried out in accordance with LU Standard S1050 (Civil Engineering – Common Requirements).

3.1.7 Design life

- 3.1.7.1** The Design Life for Deep Tube Tunnel assets shall be a nominal 120 years.
- 3.1.7.2** Deep Tube Tunnels assets shall be designed, where practicable, to minimise the requirement for maintenance interventions other than visual inspections. To support this requirement the designer shall provide a statement of potential degradation modes identified during design and a schedule of the expected interventions during the design life.

Note: To prepare the schedules required under clause 3.1.7.2 the designer will need to consider all components including structural elements, gaskets and sealing materials and also the ability of all materials to resist degradation by soil, ground water and the environment through the Design Life.

- 3.1.7.3** All metal structures and steel reinforcement in concrete prone to corrosion shall be earthed in accordance with LU Standard 1-106 (Earthing and Bonding).

3.1.8 Fire resistance

- 3.1.8.1** The design shall meet the requirements for fire performance in LU Standard 1-085 (Fire Safety Performance of Materials).
- 3.1.8.2** The design shall meet the requirements for passive fire resistance to support the fire safety strategy for the asset in LU Standard 1-083 (Passive Fire Protection Systems).

3.1.9 Water resistance

- 3.1.9.1** Deep Tube Tunnel assets shall be designed to be free from all leakage, seepage and damp patches. To achieve this the design shall include a continuous water barrier separating the soil from the internal environment of the tunnel.

Note: While the design intent is for a completely dry tunnel it is recognised that this may be difficult to achieve both in initial construction and throughout the operational life of a tunnel or shaft. Therefore this standard includes further requirements to control the residual risk of water ingress.

- 3.1.9.2** Where Deep Tube Tunnels have internal finishes which are distinct from the tunnel structural linings there shall be no leakage, seepage or damp patches in the space within the finishes. To remove residual risk of water ingress to these areas consideration shall be given to provision of a water management system between the structural lining and the internal finishes. The water management system should either be fully drained or, if there is evidence that the risk of water ingress is very small, evaporation based systems may be provided. Specific consideration shall also be given to maintenance of any water management system and also to protection of architectural finishes and their fixture from damage due to water ingress.
- 3.1.9.3** Where a water management system is not provided within the structural lining the design of the tunnel structure shall include design of generic repair techniques to seal any future leakage or seepage through the lining. This shall include consideration of any need to make good finishes within the structure.
- 3.1.9.4** The design shall include measures to prevent leakage at the junction between new waterproofing and existing assets.
- 3.1.9.5** Materials specified for waterproofing shall meet the requirements of Clauses 3.1.8 and 3.1.9 of this Standard and LU Technical Specification T0006 (Deep Tube Tunnels Materials and Workmanship). They shall also be on LU's Products Register (<http://www.lu-apr.co.uk>). Should a supplier or contractor wish to use a product not on the register then special approval from the LU Profession Head (Deep Tube Tunnels) shall be sought and granted before it can be incorporated in to the works. The product shall then be submitted for formal approval and entry on to the Products Register as soon as practicable thereafter.
- 3.1.9.6** The design of water resistance measures shall cater for the effects of long term ground movements and movements associated with the construction of adjacent structures, where such construction is reasonably foreseeable.
- 3.1.9.7** The design of water resistance measures shall cater for the effects of long term ground movements and movements associated with the construction of adjacent structures, where such construction is reasonably foreseeable.
- 3.1.9.8** Bolted linings shall be provided with a caulking groove and a gasket and all bolts shall be grommetted.
- 3.1.9.9** Bolted SGI and fabricated steel linings shall be machined on all joint faces and a groove shall be provided to accommodate a waterproof seal.
- 3.1.9.10** In-situ and sprayed concrete permanent linings shall be protected by an external water resistant membrane except in the cases described in clauses 3.1.9.11 and 3.1.9.12. Construction joints in the concrete lining on the inside of the membrane shall be provided with waterbars except where the membrane is fully bonded to that lining.

Note: The membrane may be applied as either a solid sheet form or as a sprayed or painted liquid. Different membrane types have different characteristics. In making a selection the designer will need to consider factors such as the potential for a bond to the structural lining, the potential creation of water paths and how the membrane may be repaired during its operational life.

3.1.9.11 Where concrete-lined headings are used locally for structures such as overbridges and openings into or between existing tunnels the available space may make it impractical to comply with the requirement to install an external water resistant membrane. In this circumstance the membrane may be omitted and waterproofing shall be by means of at least two separate systems in addition to the concrete itself. At least one of the systems shall provide the ability to repeatedly re-inject sealing material into areas where leakage may occur during the service life of the asset.

Note: A combination of waterbars, hydrophylic strips at joints and a reinjectable grout tube system has been found to be generally satisfactory in the circumstances described in clause 3.1.9.11. The use of concrete additives to enhance waterproofing is permitted but is not acceptable as one of the mandated “two separate systems in addition to the concrete itself”.

3.1.9.12 Where sprayed concrete linings are used there may be benefit to LU in using the concrete outside the membrane to carry a part of the permanent load. This solution is permitted subject to the designer providing evidence to LU that:

- a) the structure will satisfy its Required Duty (clause 3.1.1);
- b) that the structure, including permanent works outside a membrane, will be durable (clauses 3.1.7 and 3.1.8);
- c) that all possible cases for distribution of loads between different parts of the lining structures are addressed;
- d) that the structure will satisfy the water resistance requirement (clause 3.1.9); and
- e) that the structure and waterproofing system are sufficiently robust to withstand any likely movements.

Note: The requirement in clause 3.1.9.12 c) is driven by problems experienced with cracking developing in very lightly loaded secondary linings. This is believed to be due to the secondary lining gaining less load than anticipated as a result of the primary (notionally temporary) lining being capable of carrying a significant part of the long term load.

3.1.9.13 For the purpose of design of interfacing assets it shall be assumed that the performance of the tunnel waterproofing system should achieve the following levels:

- a) For tunnels containing track, above axis level shall be free from all leakage seepage and damp patches;
- b) For tunnels containing track, below axis level leakage shall be limited to damp patches minor weeping at joints with less than one litre/day/m² ingress;
- c) Shaft water ingress shall be limited to damp patches and minor weeping at joints with less than one litre/day/m²;
- d) Station, passenger and escalator tunnels shall be free from all leakage, seepage and damp patches; and
- e) Other non-track tunnels shall be assumed to have the same water-resistance requirements as tunnels containing track.

Note: The requirements for protection against flooding are given in LU Standard S1052 (Civil Engineering – Gravity Drainage Systems).

3.1.10 Structural design

3.1.10.1 All Deep Tube Tunnel assets shall have a structural lining.

3.1.10.2 Structural design for Deep Tube Tunnel linings shall be in accordance with the principles set out in BS EN 1990:2002 + A1:2005 (Eurocode – Basis of Structural Design). The designer shall establish the appropriate limit states and verify that none of these limit states is exceeded.

Note: Eurocodes do not explicitly cover the design of tunnels. The designer may apply rules derived from appropriate Eurocodes but particular care must be taken to ensure that the application is appropriate to the context. This includes identification of appropriate limit states and selection of appropriate partial factors. The Tables 1 and 2 present values of partial factors which have been found appropriate for the majority of London Underground tunnel design scenarios.

The design loads Q_A , are determined from the nominal loads Q_K according to the equation $Q_A = \gamma_{fl} Q_K$ where γ_{fl} is the minimum partial factor for each type of loading as given in Table 1.

Nominal dead and superimposed Dead Loads shall be combined with the Live Loads using the minimum partial factors in Table 1. The calculated resistance, R_A^* , determined from material strengths and measured section properties, shall be calculated from the following expression:

$$R_A^* = \text{function} (f_k / \gamma_m)$$

where f_k is the characteristic strength of the lining materials and γ_m is the partial factor of safety on material strength. Minimum values of γ_m shall be as stated in Table 2.

Load		Ultimate (ULS)	Serviceability (SLS)
Dead	Construction materials	1.4	1.0
Super-imposed dead	Soil, overburden	1.4	1.0
	hydrostatic Pressure (beneficial effect)	1.0	1.0
	hydrostatic Pressure (adverse effect)	1.1	1.0
Grouting pressure (arising from adjacent works)		1.2	1.0
Horizontal earth pressure	horizontal pressure (adverse effect)	1.1	1.0
	horizontal pressure (beneficial effect)	1.4	1.0
Imposed loads		1.6	1.0

Table 1 - Partial factors for load

Load	Ultimate (ULS)	Serviceability (SLS)
Concrete	1.5	1.0
Reinforcement	1.15	1.0
SGL	1.15	1.0
Bolts	1.15	1.0

Table 2 - Partial factors for materials

- 3.1.10.3** No part of the lining or support shall encroach within the structure profile under any conditions of loading or deflection, as stated in Clause 3.1.4.1 of this Standard.
- 3.1.10.4** Structural analysis methods shall be justified and sensitivity analyses shall be undertaken.
- 3.1.10.5** The designer shall validate computer programs used for structural analysis.
- 3.1.10.6** Openings in tunnels may be designed as arches or beams. Both shall be considered and the most efficient adopted unless there are clear benefits to LU to do otherwise.
- 3.1.10.7** Where openings are formed using steel members encased in concrete consideration shall be given to the load carrying capacity of the concrete.

Note: The construction of large steel members may pose significant buildability issues and safety risk in a tunnel and so if such members are proposed it must be rigorously demonstrated that they are necessary and that they are the optimum solution when construction issues are considered.

- 3.1.10.8** In new build tunnels openings shall be designed to use an opening set with provision for the safe removal of temporary infill panels. The formation of openings into new build tunnels by methods such as stitch drilling, cutting or breaking is not acceptable.
- 3.1.10.9** Where new openings are to be formed in existing tunnels the opening may be formed either from inside the tunnel by sequential replacement of the existing lining or from outside the lining by the use of a “bolt on the back” opening set. In the design of an opening into an existing tunnel consideration shall be given to the capacity of the existing lining to carry part, or all, of the load.

Note: In some situations it may be possible to enhance the capacity of the existing structure at an opening through measures such as the introduction of additional bolts or dowels.

- 3.1.10.10** Headwalls may be designed as either arches or beams. Both shall be considered and the most efficient adopted unless there are clear benefits to LU to do otherwise.
- 3.1.10.11** Where new works are to be formed using steelwork encased in concrete (commonly referred to as “squarework”) consideration shall be given to the load carrying capacity of the concrete.

3.1.11 Loading

- 3.1.11.1** The structure shall be designed to carry and transfer design loads and load effects for the Design Life.
- 3.1.11.2** The designer shall define loads and load effects for each element of design.
- 3.1.11.3** Evaluation of ground and water pressures shall take account of the construction method, the relative rigidity of the lining and the interaction of the lining with the ground.
- 3.1.11.4** A minimum surface surcharge of 75.0kN/m² shall be used for the permanent load cases unless it is known that a greater loading will be applied.

Note: The maximum surface surcharge may not give rise to the most onerous load case.

- 3.1.11.5** The design shall include load from grouting carried out for construction, Maintenance or repair including loads that may arise from the execution of ground improvement measures, or measures to control settlement.
- 3.1.11.6** The design shall take account of the following:
- a) changes in long-term Groundwater level as defined by LU; and

b) seasonal variation in Groundwater level

3.1.11.7 Deep Tube Tunnel assets shall have a design capacity to carry and transfer a radial pressure equal to the unfactored overburden pressure together with bending stresses produced by a change in diameter of 1.15%.

Note: This ensures that the lining is capable of withstanding some post construction deformation and/or poor geometrical control.

3.1.11.8 In Deep Tube Tunnel assets containing track all structures, cladding, cladding support frames and fixings of the same shall be designed to resist both pressures and suctions of 0.2kN/m^2 using a load factor γ_f or γ_{fl} as appropriate of 1.0.

Note: Combination of loads depends on structural form and construction sequence and may include:

- a) Superimposed loads based on traffic loading, loads due to existing buildings and foundations over and adjacent to the tunnel and any specified future loads;
- b) Short and long term soil and hydrostatic loads;
- c) The structural requirements for resisting buckling;
- d) Loads produced by long and short term ground yield or squeeze;
- e) Load from grouting operations planned as part of construction;
- f) Loads from adjacent tunnelling operations and excavations;
- g) Loads from openings and extensions to the linings;
- h) Long and short term loads induced by the construction procedure;
- i) Temperature and shrinkage;
- k) Long term variation in Groundwater levels;
- l) Handling, erection and TBM rams where applicable;
- m) Accidental (collision) load;
- n) Seismic;
- o) Compressed air;
- p) Mitigation of ground movement;
- q) Flotation;
- r) Internal loads; and
- s) Load effects created by construction tolerances, such as steps, lips, roll and broken joints for segmental linings.

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

3.1.11.9 Collision loading: any structure or support that is at risk of destruction or disproportionate damage from impact by a rail vehicle shall be designed for collision load.

3.1.11.10 The design shall specify measures to validate the design concept during construction.

Note: This requirement arises because soil structure interaction in tunnels is difficult to model reliably in design. Validation may be by means of monitoring to demonstrate that loading and deflections are in accordance with the designer's expectations.

3.1.12 Impact on operational railway and adjacent structures

Note: The requirements for assessing impact and mitigation are given in LU Standard SS1050 (Civil Engineering – Common Requirements).

3.1.12.1 The designer shall determine the potential ground movement associated with the construction method for the following purposes:

- a) to demonstrate that the environmental effects of the tunnelling-induced ground movement have been considered and taken account of in design;
- b) to draw attention to those zones where the implementation of the design is likely to cause ground movement;
- c) to assess the risks of damage associated with the design, to investigate alternatives, and modify the design as necessary;
- d) or, if avoidance is not possible, to design protective measures against the likely damage, which measures could include settlement mitigation such as compensation grouting that could themselves have effects requiring assessment; and
- e) to indicate where the purchase of property is required for demolition or structural modification.

3.1.12.2 The ground movement expected to arise from tunnelling activities shall be estimated by empirically calibrated methods.

Note: In most cases relatively simple forms of analysis are appropriate and preferred for reasons of simplicity and ease of validation. The use of complex numerical analyses may be appropriate for complex problems such as junctions but such tools should first be validated by comparison with other methods or case history data.

Case history evidence of particular value for current tunnel construction methods in London includes that from the King's Cross station upgrade (for sprayed concrete and timber supported headings) and the Channel Tunnel Rail Link (for tunnel boring machines). Further information on these projects is available in London Underground's Core Asset Information System (CAI).

The requirements for assessing impact and mitigation are given in LU Standard S1050 (Civil Engineering – Common Requirements). Reference may be made to CIRIA Special Publication 200, 2001: Volume 1 (of 2) Projects and Methods: Building Response to Tunnelling, Case Studies from Construction of the Jubilee Line Extension, London. Editors J B Burland, J R Standing, F M Jardine

3.1.13 Provision for maintenance

3.1.13.1 The design shall incorporate provisions to facilitate the inspection and Maintenance operations necessary for the achievement of the Required Duty for the Design Life.

3.1.13.2 As part of the design, the designer shall produce a plan for inspection, Maintenance and, if appropriate, instrumentation and monitoring of the asset to ensure serviceability throughout the Design Life.

3.1.13.3 The design shall demonstrate the asset can be cleaned:

- a) to reduce the risk of vermin infestation and fire;
- b) to reduce the environmental risk to system users and staff;
- c) to promote a positive customer perception of the underground environment;
- d) to remove obscuration of structural elements and so facilitate inspection; and

- e) to fulfill the requirements of LU Standard 1-160 (Cleaning of the track environment).

3.1.14 Temporary works

3.1.14.1 Temporary works shall comply with S1062 (Temporary Works).

3.1.14.2 Temporary Works required for the construction of the permanent works shall be fully compatible with the continuing safe and reliable operation of the adjacent facilities.

Note: Also refer to LU Standard S1354 (Customer Facing Aspects of Temporary Works at Stations) and for spatial constraints refer to LU Standard S1371 (Station Planning).

3.1.14.3 Any loads which Temporary Works impose on new assets shall be allowed for in the design.

3.1.14.4 Existing assets which will be required to sustain loads imposed by the Temporary Works associated with the construction of new assets shall be checked for their ability to do so and if necessary, additional support shall be designed.

3.1.15 Design documents

3.1.15.1 A design report shall be prepared in accordance with LU Standard S1050 (Civil Engineering - Common Requirements).

3.1.15.2 The design report shall describe any requirements for instrumentation and monitoring including full details of purpose, installation requirements, and frequency of readings.

Note: Further requirements for design documents and checking are given in LU Standard S1538 (Assurance).

3.1.16 Construction documents

3.1.16.1 Construction documents shall be prepared in accordance with LU Standard S1050 (Civil Engineering - Common Requirements).

3.2 Construction, installation, testing and commissioning

3.2.1 General

3.2.1.1 LU Standard S1552 (Contract QUENSH Conditions) shall be complied with during all construction, installation, testing and commissioning work.

3.2.1.2 Construction installation, testing and commissioning work, including Strengthening and Renewal, 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 design for that work has been approved in accordance with LU Standards S1538 (Assurance) and S1050 (Civil Engineering – Common Requirements).

3.2.1.4 A system to control and manage the construction process shall be maintained. This system shall comply with The Joint Code of Practice for Risk Management of Tunnel Works in the UK.

Note: This system is required to enable LU:

- a) to discharge their responsibilities to the 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