

## Category 1 Standard

# S1051 Civil Engineering - Bridge Structures



**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 Bridge Structure assets. These assets comprise:
- a) **Rail bridges** - This category of structure covers structures owned by LU carrying LU tracks, including:
    - I) Underbridge;
    - II) Overbridge;
    - III) Viaduct;
    - IV) Girdering;
    - V) Way beam.
  - b) **Highway bridges** - This category of structure covers structures owned by LU carrying public or private road traffic, including:
    - I) Overbridge;
    - II) Viaduct.
  - c) **Footbridges;**
  - d) **Underground structures** - This category of structure covers:
    - I) Covered Ways;
    - II) Subsurface tunnels (i.e. cut and cover brick arch tunnel);
    - II) Subways;
    - IV) Culverts.
  - e) **Earth retaining walls, including gabions;**
  - f) **Ancillary structures and components** - This category of structure covers:
    - I) Cable bridges;
    - II) Pipe bridges;
    - III) Pipe crossings over / under track;
    - IV) Signal gantries, these are metal framed structures carrying a signal or signals. Signal posts and signal access ladders and hoops do not form part of the civil asset responsibility;
    - V) Gantries over railway;
    - VI) Crash barriers;
    - VII) Longitudinal Timbers.
- 1.2 In defining requirements specifically applicable to assets, this Standard complements LU Standard S1050 that defines mandatory requirements generally applicable to all Civil Engineering assets including the Bridge Structure assets.
- 1.3 A supporting Manual of Good Practice G0051 gives guidance and explanation on Bridge Structure assets.

**Note:** Structural elements of stations within tunnels are included in LU Standard S1055

Drainage to Bridge Structures is included within LU Standards S1052 and S1056

Station Planning requirements including spatial requirements are included in LU Standard S1371

Station platform finishes, tolerances tactile warning strips and safety markings are included in LU Standard 1-131.

Stairways and ramp requirements are included in LU cat 1 Standard 1-133.



Ladders and Step Iron requirements for drainage installations are included within LU Standard S1052.

Guidance on the requirements for barriers is given within LU standard S1132.

## 2 Scope

- 2.1 This Standard applies to Bridge Structure assets owned by LU.
- 2.2 This Standard defines the requirements for 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
  - h) Decommissioning
  - i) 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, shall ensure that Bridge Structure assets will satisfy their Required Duty.

**Note:** The Required Duty for Bridge Structure assets as defined in S1042 Asset Condition Reporting (ACR) 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).
  - 1.2 Maintain the ability to carry without restriction any permitted applied static and dynamic design loads.
  - 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.



|           |                                                                                                                                                                                                                                                                                                                  |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>2</b>  | <b>Ensure support at asset interfaces without undue wear and tear.</b>                                                                                                                                                                                                                                           |
| 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). This includes interfaces with dynamic & static assets (e.g. roads, buildings, walkways, etc).                                                                |
| <b>3</b>  | <b>Match LU policy in respect of realistic user perceptions.</b>                                                                                                                                                                                                                                                 |
|           | Ensure the asset does not cause undue degradation of interfacing assets, disruption to railway operations or unacceptable environmental nuisance.                                                                                                                                                                |
| <b>4</b>  | <b>Provide resistance against external interference and events.</b>                                                                                                                                                                                                                                              |
| 4.1       | Asset minimises the likelihood and consequence of asset abuse. Asset abuse encompasses, vandalism, planned/unplanned work, damage due to external event, etc.                                                                                                                                                    |
| 4.2       | Asset minimises the likelihood of occurrence of, and enhances the ability to respond to, personal attack on passengers or staff.                                                                                                                                                                                 |
| <b>5</b>  | <b>Present acceptable environmental impact.</b>                                                                                                                                                                                                                                                                  |
|           | Present an acceptable societal environmental impact (noise, vibrations, vegetation cover, adverse weather management, etc).                                                                                                                                                                                      |
| <b>6</b>  | <b>Minimise environmental impact throughout lifecycle.</b>                                                                                                                                                                                                                                                       |
|           | 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.                                                                                                         |
| <b>7</b>  | <b>Function within the legal and standards framework.</b>                                                                                                                                                                                                                                                        |
|           | Ensure the asset functions within the framework defined by legislation (including environmental); regulatory guidance; LU, Infraco and applicable national and international standards; and LU and Infraco policies.                                                                                             |
| <b>8</b>  | <b>Ensure safe operation as defined by LU.</b>                                                                                                                                                                                                                                                                   |
| 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 bridges and structures asset to the principal interfacing assets and transfer mediums (e.g. public footpaths). |
| 8.3       | Safeguard the health and safety of passengers, employees and members of the general public.                                                                                                                                                                                                                      |
| <b>9</b>  | <b>Provide above within reliability and availability targets.</b>                                                                                                                                                                                                                                                |
|           | Provide all aspects of the Required Duty within the defined LU requirements.                                                                                                                                                                                                                                     |
| <b>10</b> | <b>Ensure Required Duty is performed without incurring excessive or prohibitive costs.</b>                                                                                                                                                                                                                       |

- 3.1.1.2 Bridge Structure assets shall be designed to the principles of asset management planning.



### **3.1.2 Inception**

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 and 1-050.

### **3.1.3 Design process**

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

### **3.1.4 Structure gauge and clearance**

3.1.4.1 Assets shall conform to LU Standard S1156, under any loading combination.

3.1.4.2 The maximum practicable lateral clearances shall be provided from structural supports to the railway track.

3.1.4.3 Unless the physical constraints of the location make it impractical, a clearance of 4.5 m shall be provided from structural supports to the nearest running rail.

3.1.4.4 Where a support is provided at a distance less than 4.5m from the nearest running rail, the following shall apply:

- a) piers shall be of continuous construction rather than composed of individual columns, or a solid plinth shall be provided up to a height of not less than 915 mm above the rail level;
- b) the ends of the pier or plinth shall have suitably shaped ends to deflect derailed vehicles away from the support;

3.1.4.5 Places of safety shall be provided in accordance with LU Standard S1156.

### **3.1.5 Ground investigation information**

Ground Investigations and desk top studies for Ground Investigations shall be carried out in accordance with LU Standard 1-050.

### **3.1.6 Groundwater**

The design shall take account of the following:

- a) Changes in long-term Groundwater levels as defined by LU
- b) Seasonal variations in Groundwater levels.

### **3.1.7 Design life**

3.1.7.1 The Design Life for Bridge Structure assets shall be 120 years.

3.1.7.2 The Design Life of Way Beams shall be twice the estimated time of service of the Way Beam.

### **3.1.8 Fire resistance**

3.1.8.1 The design shall meet the requirements for fire performance in LU Standard 1-085.

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.

3.1.8.3 Main structural elements in sub-surface locations shall have a fire resistance of at least 60 minutes.

3.1.8.4 Structural elements supporting buildings or which are part of evacuation routes shall have a fire resistance as given in LU Standard S1053.



### 3.1.9 Constructability

The structural effects of the intended methods of construction shall be taken into account in the design.

### 3.1.10 Impact on operational railway and adjacent structures

The design shall comply with the requirements of LU Standard 1-050.

### 3.1.11 Co-ordination with Outside Parties

3.1.11.1 Where assets are required to carry or cross highways, other railways, waterways, or Outside Party property the Supplier shall identify and comply with the requirements of the relevant authorities.

3.1.11.2 Any conflicts between LU requirements and those requirements of the other authorities shall be referred to LU. See also clause 3.6.2.4.

### 3.1.12 Services

3.1.12.1 Provisions shall be made for:

- a) The relocation of existing services within the asset;
- b) Accommodating services within service voids in the asset;
- c) Draining service voids; and
- d) Allowing for the movement of the structure without detrimental effect on the services or utilities.

3.1.12.2 Cable locations and fixings requirements shall comply with LU Standard S1120.

### 3.1.13 Drainage

Assets shall be designed to shed water and avoid the accumulation of water.

- a) Arrangements to direct water to a specified outlet shall be incorporated for the collection and discharge of water clear of the asset.
- b) Maintainable drainage features shall be incorporated into abutments and Earth Retaining Walls to ensure that ground water is controlled in accordance with the design intent.

### 3.1.14 Parapets and handrails

#### 3.1.14.1 Rail bridges

Pedestrian handrails on Rail Bridges shall comply with the requirements given in Attachment 7.1.

#### 3.1.14.2 Highway Bridges

Parapets to LU owned Highway Bridges shall be designed to the requirements of BS EN 1317-2; Very High Containment level (H4b). (BS EN 1371-12 specifies the vehicle weights, speeds and angles of impact, but does not specify the Equivalent Static Nominal Loads (ESNL) which are published in BS6779. At present BS6779 only publishes ESNL for low and high containment parapets. The high containment ESNL encompasses H4a loading, but not H4b loading. When testing has been undertaken for H4b parapets, ESNLS will be published for H4b. Until ESNLS for H4b are published, parapets for LU owned overbridges will be designed for Very High Containment Level H4a). They shall be 1850mm high, with no footholds on the footway face and with steep copings.

#### 3.1.14.3 Footbridges

Pedestrian handrails on Footbridges shall comply with the loading requirements given in Attachment 7.1. Where footbridges cross a railway with existing or proposed overhead lines they must be a minimum of 1.5m above the surface of the bridge deck with no footholds or projections on the inside face. Where the railway is electrified by



means other than overhead lines, the parapet must be a minimum of 1.25m above the surface of the bridge deck with no footholds or projections on the inside face. Where handrails are provided on the inside face, either the parapet must be raised 1.5m or 1.25m above the parapet as appropriate or the footbridge must be completely caged. The parapet must be solid up to the height of the handrail.

#### **3.1.14.4 Underground Structures, earth retaining walls and ancillary structures**

Where the structure forms a vertical or near vertical face 1.5m or more in height and it would be possible for a person to gain access to the upper edge of the structure, a pedestrian restraint system such as a protective fence or guardrail shall be installed close to, or on top of the structure. Where protective fences or guardrails are required they shall comply with the loading requirements given in Attachment 7.1.

### **3.1.15 Structural design**

#### **3.1.15.1 General**

- a) Structural design shall be to Limit State principles in accordance with the relevant British Standard or European Standard.
- b) The validation status of computer programs used for structural analysis shall be confirmed in the design process.
- c) For bridges owned by others the Supplier shall refer to the relevant authority for details of design standards to be adopted.

#### **3.1.15.2 Concrete, steel and composite structures**

- a) The design of LU Rail Bridges shall be in accordance with:
  - BS EN 1991,
  - BS EN 1992,
  - BS EN 1993,
  - BS EN 1994,except as supplemented or amended by this Standard.
- b) The design of LU owned Highway Bridges shall be in accordance with the requirements of the relevant highway authority.
- c) The design of Footbridges shall be in accordance with:
  - BS EN 1991,
  - BS EN 1992,
  - BS EN 1993,
  - BS EN 1994,except as supplemented or amended by this Standard.

#### **3.1.15.3 Underground structures and earth retaining walls**

- a) Underground structures and Earth Retaining Walls shall comply with the following:
  - BS EN 1997-1
- b) Underground structures and Earth Retaining Walls shall, in addition to a), comply with the requirements of:



- BS EN 1991,
  - BS EN 1992,
  - BS EN 1993,
  - BS EN 1994,
  - as appropriate.
- c) The design process shall demonstrate that full consideration has been given to forming new foundations structurally independent of existing foundations and Earth Retaining Walls.
- d) Existing Earth Retaining Walls and other structures that are to remain shall be checked for stability and deformation in all Conditions during the phases of demolition, construction and loading.
- e) Deformation of the structure under the design loading shall not cause loss of serviceability in structures, track or services sited on or near the retaining structure.
- f) Design earth pressures shall take account of the mode and deformation or strain that is acceptable at the Limit State under consideration.
- g) The design shall consider the Limit States of the structure and of adjacent structures under long term equilibrium conditions associated with construction of the structure.
- h) The design shall consider the effects of the most adverse water pressures that are considered to be reasonably possible and where the structure is subject to tidal action, the most adverse drawdown condition shall be assumed.
- i) If the safety and serviceability of the design depends on the successful performance of drainage, the consequences of failure of the drainage system shall be considered in the design.
- j) Underground structure assets shall be designed to achieve a level of water resistance as set down in S1064 Civil Engineering - Waterproofing
- l) Earth Retaining Walls constructed predominantly below ground e.g. in sub-surface railways, shall be provided with waterproofing to attain a performance level of Grade B as defined by CIRIA Report 81 'leakage to be restricted to minor patches with no visible flow of water with the exception of purposely constructed weep holes'.
- m) Drainage systems to control water pressure behind or beneath a retaining structure shall be designed for ease of Maintenance.
- n) Gabion Walls
- I) The design for gabion walls shall demonstrate that the specified materials for the gabion retaining boxes, infill stone and backfill have been assessed for the railway environment, including considerations of construction access, fire, vandalism, and short and long-term exposure to chemical, biological and ultra-violet degradation.
  - II) The design shall include criteria for the acceptance of materials for the gabion baskets to ensure these meet the Design Life requirements defined in Clause 3.1.7 above by reference to Agreement certificates or other verified testing.

- Note 1:** Gabion retaining walls possess several technical and practical advantages over other retaining wall systems. In particular, gabions are relatively simple to construct, even on sites with difficult access. The permeability and flexibility of gabions make them suitable where the retained material is likely to be saturated and where the bearing capacity of the soil is poor. Fire and vandalism considerations preclude the use of plastics and similar non-metallic materials for the gabion boxes.
- Note 2:** The Manual of Good Practice G-054 provides guidance on the use of gabion walls, including design references and considerations of their use in the railway environment.
- Note 3:** The Manual of Good Practice G-051 provides guidance on the specification clauses relating to gabions.

#### 3.1.15.4 Longitudinal Timbers

Longitudinal timbers shall be designed in accordance with the requirements of LU Standard T0416.

#### 3.1.15.5 Ancillary structures and components

Ancillary Structures shall be designed in accordance with relevant British and European Standards

#### 3.1.15.6 Foundations

- a) The design process shall demonstrate that full consideration has been given to forming new foundations structurally independent of existing foundations and Earth Retaining Walls.
- b) The design and proposed methods of construction shall minimise effects of construction-related ground movements on adjacent buildings, structures and utilities.
- c) Settlement and damage predictions shall be undertaken in accordance with LU Standard 1-050.
- d) The design and proposed methods of construction shall control construction-related ground movements to ensure that damage to adjacent buildings, structures, and utilities does not exceed Category of Damage 2 (Slight) as defined by Burland et al (1977).

**Note:** Burland et al defined 'Slight' as "Cracks easily filled. Redecorating probably required. Several slight fractures showing inside of building. Cracks are visible externally and some repainting may be required externally to ensure weather tightness. Doors and windows may stick slightly."

The approximate crack width (in masonry construction) was suggested at 5mm. The limiting tensile strain 0.075% to 0.15%.

- e) The owners of adjacent buildings, structures and utilities shall be consulted on the assessment of the effects of settlement on movement and serviceability.
- f) Suitable provision shall be made to allow for movement of foundations without detrimental effect to services and utilities.
- g) The foundation system shall be designed such that the net downward load is always positive, in the construction, operation and accident conditions,
- h) Existing foundations and other structures that are to remain shall be checked for stability and deformation in all conditions during the phases of demolition, construction and loading.



- i) The design of temporary or permanent Underground Structures and of dewatering systems shall, as far as is practical, avoid lowering of the external water table and shall minimise the reduction of piezometric head in the adjacent soils.

### 3.1.15.7 Bearings and expansion joints

- a) Designs for bearing and expansion joints for assets shall be in accordance with the requirements of BS EN 1337 parts 2-8.
- b) Whenever an underbridge is constructed or re-constructed a “slip” membrane consisting of a 2 layers of 2000 gauge polythene overlaid with a ballast protection mat consisting of a polymeric alloy at least 4.5mm thick shall be placed immediately above the waterproofing protection.

### 3.1.16 Loading

#### 3.1.16.1 General

- a) Loadings to be adopted in the design of assets shall be determined and applied in accordance with the principles of Limit State design described in BS EN 1990 and the relevant European Standard except where an alternative approach is described within this Standard.
- b) Notwithstanding the loading conditions defined in this Standard, the Supplier shall ensure that all loadings that may reasonably be identified as potentially acting on the asset during its Design Life are addressed during the design process so as to ensure that the Required Duty is achieved.

#### 3.1.16.2 Permanent loading

- a) Permanent loading, comprising structural Dead Loads and Superimposed Dead Loads shall be calculated in accordance with BS EN 1991-1-1, or from the actual known weights of the materials.
- b) Cable loading requirements shall comply with LU Standard S1120.

#### 3.1.16.3 Live loading

##### a) Rail bridges

- I) Assets supporting LU railway tracks shall be designed for RL loading, as defined in Attachment 7.5, except where a Train Operating Company (TOC) has rights to operate. The accidental design situations in BS EN 1991-2 clause 6.7.1 are not applicable to RL loading.
- II) Assets supporting LU railway tracks, where a TOC has rights to operate, shall be designed for the BS EN 1991-2 Load Model 71 with an  $\alpha$  factor of 1.00.
- III) Any support or other element of the structure types listed below that risks either destruction or loss of carrying capacity when struck by an errant rail vehicle shall be designed for collision loads and shall be capable of surviving the incident without partial collapse or significant permanent damage or distortion.
  - i) railway Overbridges (crossing over the LU railway);
  - ii) road Overbridges (crossing over the LU railway);
  - iii) station footbridges (crossing over the LU railway);
  - iv) any major structure spanning two or more LU railway tracks, but not cable bridges or Ancillary Structures.
- IV) Structural supports described in the previous sub-clause shall be designed at the Ultimate Limit State (ULS) for the collision loads defined in Attachment 7.2, using a partial load factor ( $\gamma_{fl}$ ) of 1.0.



- V) Collision loads shall be considered in conjunction with the associated loads from the supported structure factored for the ULS.

**b) Highway bridges**

- I) Highway Live Loadings shall be determined and applied in accordance with BS EN 1991-2 load model LM1 with an  $\alpha$  factor of 1. The design shall also be verified against load models LM2, LM3 and LM4.
- II) The choice of the particular vehicle for STGO or SO for the verification of LM3 shall be agreed with the highway authority.
- III) Any support or other element of a structure which risks either destruction or loss of carrying capacity when struck by a highway vehicle shall be designed in accordance with BS EN 1991-1-7 Clause 4.3.

**c) Footbridge loading**

- I) Pedestrian Live Loading shall be in accordance with Attachment 7.1.

|                                                                                                                                               |
|-----------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Note:</b> Where pedestrian loading could arise from stadium routes the Supplier should make due allowance for abnormal Footbridge loading. |
|-----------------------------------------------------------------------------------------------------------------------------------------------|

- II) User comfort standards shall be in accordance with the requirements of Appendix B of BD 37/01.

**d) Underground structures and earth retaining walls**

Underground structures and Earth Retaining Wall Live Loading shall comply with the requirements of:

- i) 1-054 Civil Engineering – Earth Structures for structures subject to dynamic loading, highway and pedestrian traffic..
- ii) BS EN 1992 and BS EN 1993 as appropriate, for structures not subject to dynamic loading.

**e) Ballast retainers**

Ballast retainers shall be considered to be king-pile retaining walls and designed for the loads specified in the relevant sub clauses above.

**f) Ancillary structures and components**

Floors and horizontal surfaces of Ancillary Structures shall be designed for an imposed loading in accordance with Attachment 7.1.

**g) Collision Protection Beams**

Collision Protection Beams for railway bridges crossing over public and private roads shall be designed in accordance with DfT standard BD65/97 Design Criteria for Collision Protection Beams. No criteria or deflection criteria other than those specified in BD65/97 shall be introduced.

**3.1.16.4 Pressure effects of railway traffic**

- a) Assets shall be designed to take account of the effects of dynamic pressure and suction from railway traffic outside tunnels.
- b) Loading due to dynamic pressure and suction from railway traffic shall be determined in accordance with the requirements of BS EN 1991-2.