<u>**Research**</u>

Bridge inspection

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Kurdistan Engineers Union no. ٣٣٩٢

Contents:

Introduction:

The objectives of bridge inspections are to assist the local authorities in its duty to carry out visual inspections of highway structures and to provide inspection reports in an agreed format.

١. Review of existing structures inspection data including drawings and inspection reports.
٢. General visual Inspection of each structure and preparation of reports and cost estimates.
٣. Identify Health and Safety or Structural Defect issues for immediate notification to the local authorities.

The structures are assumed to be accessible without requiring confined space access equipment. The main outputs of inspections are:

١. Completing Inspection Record Sheets to be submitted to the relevant authority, including cost estimates for remedial works. There are some examples on how to do bridge inspections.
٢. Immediate identification to local authorities of any major structural defects or other hazards causing risk of injury to structure users.
٣. Recommendations for remedial actions, including cost estimates.

Bridge inspections in Kurdistan

As far as I am aware there is not any bridge inspection regime to be followed in Kurdistan. Therefore, I thought it is important to shed some light on this vital process and how to create an inspection system that is well understood and standardized across the Kurdistan region. This research shows how to do bridge inspection and there are some worked examples as an annex to this research.

I went to the Dabashan bridge and I saw that this bridge surly needs some attention and I took some photos to highlight some of the problems this bridge is facing and this shows how important it is to have an inspection regime in place to deal with structural defects of road structures. There is also a need for a risk assessment to put a crash barrier where this a new route recently introduced to calm the traffic flow. It is also paramount for every single road structures to have a file held by the relevant authority, in which shows the history of the structure, construction methods and so on.

Here are some of the photos of Dabashan Bridge.

General state of the bridge looking north

Expansion joint fill is deteriorated and needs to be replaced and sealed properly to prevent further damage.

Rock face of the abutment, there are signs of spalling and cracks. Leakage can be seen running down the abutment. Damp proof memberance is required to stop the leakage.

State of the wingwall, damaged rock face and plants are growing that could further damage the wingwall.

Crash barrier over the bridge, sign of accidental damage but it was not repaired properly and still posses a risk to the bridge users.

Crash barrier, sign of accidental damage but it was not repaired

A gap between crash barriers

***Road sign is also damaged which is considered as a part of the bridge ancillary*.**

THE PURPOSE OF INSPECTIONS

The overall purpose of inspection, testing and monitoring is to check that highway structures are safe for use and fit for purpose and to provide the data required to support effective maintenance management and planning. Inspections, and where required testing and monitoring, should:

- Observe and provide information on the current condition, performance and environment of a structure, e.g. severity and extent of defects, material strength and loading. This enables the safety, functionality and durability of structures to be assessed, and provides sufficient information for actions to be planned where structures do not meet these requirements.

- Inform analyses, assessments and processes, e.g. change in condition, cause of deterioration, rate of deterioration, identification and quantification of maintenance needs, effectiveness of maintenance and structural capacity. This informs management planning and enables cost-effective plans, which deliver the required performance, to be developed.

- Compile, verify and maintain inventory information, e.g. structure type, dimensions and location, for all the highway structures the authority is responsible for.

Although the scope, procedures and work undertaken varies considerably between different inspection types (and testing and monitoring methods), these core objectives remain. As such, the inspector should be able to identify structural defects and clearly document these deficiencies; recognize structural elements that need repair in order to maintain safety and avoid the need for costly replacement; and be on guard for minor problems that could lead to the need for costly repairs. By providing this information, inspectors alert the Supervising Engineer to any defects which might impact the safety of the road user or the integrity of the structure and enable timely corrective action to be taken.

١. Overview of the Inspection Regime

- Cost-effective management of the maintenance of a structure relies on detailed, accurate and up-to-date information about its current condition and rate of deterioration. This objective can best be achieved through the development and implementation of an inspection regime tailored to meet the specific requirements of each structure.

- The inspection regime should include a combination of Safety, General, Principal and Acceptance Inspections of the whole structure; and more detailed Special Inspections or Inspections for Assessment concentrating on known or suspected areas of deterioration or inadequacy. The inspection schedule for each structure may be unique to that structure but should be designed to provide the appropriate frequency and detail of information.

- Safety Inspections are undertaken at frequencies which ensure the timely identification of safety related defects but are not specific to highway structures; they generally cover all fixed assets on the highway network. Safety inspections may also be undertaken following notification of a defect by a third party e.g. the public or the police. Safety Inspections are normally carried out from a slow moving vehicle and provide a cursory check of those parts of a highway structure that are visible from the highway; in certain instances staff may need to proceed on foot.

- General and Principal Inspections have set requirements, but differ in scope and intensity. General Inspections comprise a visual inspection (undertaken from ground level) of all parts of the structure that can be inspected without the need for special access equipment or traffic management arrangements. Principal Inspections, on the other hand, are more comprehensive than General Inspections and comprise a close examination, within a touching distance, of all inspectable parts of a structure. A Principal Inspection should utilize as necessary suitable inspection techniques, access equipment and/or traffic management works. Suitable inspection techniques that may be considered for a Principal Inspection include hammer tapping to detect loose concrete cover and paint and steel thickness measurements. All highway structures should be subjected to a General Inspection not more than two years following the previous General or Principal Inspection; and to a Principal Inspection not more than six years following the previous Principal Inspection.

- Special Inspections are undertaken for a wide variety of reasons but mainly to provide detailed information on a particular part, area or defect that is causing concern, which is beyond the requirements of the General Principal Inspection regime. They may comprise a close visual inspection, testing and/or monitoring and may involve a one-off inspection, a series of inspections or an on-going program of inspections. As such, Special Inspections are tailored to specific needs and are carried out when a need is identified or for some structures are programmed in advance.

- Acceptance inspections are undertaken when necessary for exchanging information and documentation and agreeing the current status of, and outstanding work on, a structure prior to change over of responsibility for operation, maintenance and safety

- Inspections for Assessment are undertaken when necessary to provide the information required to undertake a structural assessment

Table A.1 – Summary of Inspection Types

Inspection Type	Nominal Interval	Description
Safety Inspection (or Routine Surveillance)	At frequencies which ensure timely identification of safety defects and reflect the importance of a particular route or asset.	Cursory inspection carried out from a slow moving vehicle; in certain instances staff may need to proceed on foot.
General Inspection	2 years.	Visual inspection from the ground level. Report on the physical condition of all structural elements visible from the ground level.
Principal Inspection	6 years.	Close visual examination, within touching distance; utilising, as necessary, suitable inspection techniques. Report on the physical condition of all inspectable structural parts.
Special Inspection	Programmed or when needed.	Detailed investigation (including as required inspection, testing and/or monitoring) of particular areas of concern or following certain events.
Acceptance inspections	When needed.	A formal mechanism for exchanging information prior to changeover of responsibility.
Inspection for Assessment	When needed.	Inspection undertaken to provide information required to undertake a structural assessment.

٢. Bridges

٢.١ OVERVIEW

٢.١.١ A bridge is a structure built to provide passage over a physical obstacle, e.g. watercourse, railway, road, valley. Bridges also include subways, footbridges and underpasses. Bridges are the most common and complex type of highway structure that inspection staff are likely to encounter and for the purpose of inspection are normally defined as those having a span of ١.٥m or greater . This section:

- Introduces the general anatomy of a bridge, Section ٢.٢.
- Provides definitions for the typical elements found on a bridge, and in some cases (e.g. bearings and joints) provides common examples, Section ٢.٣.
- Summarises the typical types of highway bridges that inspection staff are likely to encounter; Section ٢.٤.

٢.٢ ANATOMY OF A BRIDGE

٢.٢.١ The success of a thorough bridge inspection lies with the ability of the inspector to identify and understand the function of the major bridge elements. As such, inspection staff should develop an understanding of the typical composition, or anatomy, of a bridge.

٢.٢.٢ In general, bridge elements can be categorised under a number of broad headings; for example: Superstructure, Substructure, Safety Elements, Durability Elements and Ancillary Elements. Definitions of these categories, and a suggested grouping of typical elements under these headings, are given in Table ٨.٢.

٢.٢.٣ Identifying *Durability, Safety* and *Ancillary* bridge elements is normally straightforward (common types are presented in Section ٢.٣), however, distinguishing between the *Superstructure* and the *Substructure,* and identifying the associated elements, can be more difficult. Figure B.l and Figure B.٢ show two typical types of bridge construction and distinguish between their Superstructure and Substructure elements; other bridge elements are also shown.

٢.٢.٤ The elements present on a bridge depend on a number of criteria, but as illustrated by Figure B.١ and Figure B.٢, it is primarily the structural form and material that dictate which elements are on the bridge

Table B.2 – Grouping of Bridge Elements		
Category	**Description**	**Typical Elements**
Superstructure	The horizontal elements of a bridge, generally above the bearings, that directly support traffic loads and transfer loads to the substructure [1].	Primary, secondary and tertiary load bearing elements (e.g. slabs, beams and arches); parapet beams and cantilevers.
Substructure	The vertical elements of a structure, generally below the bearings, that support the superstructure and transfer the loads to the supporting ground [1].	Foundations; abutments (including arch springing); piers; columns; cross-heads, bearings*.
Durability Elements	Elements that have the primary, or significant, function to protect the structure from or delay/mitigate the effects of deterioration and damage.	Drainage; waterproofing; expansion joints; surface finishes.
Safety Elements	Elements that have the primary, or significant, function to safeguard the user and/or those working on the structure.	Handrails; parapets; safety fences; walkways; access gantries.
Ancillary Elements	Other elements associated with highway bridges.	Invert; aprons; wing walls; embankments; lighting; carriageway; footway/verge.

* Bearings are normally considered as the boundary between Superstructure and Substructure. Above they are grouped with the Substructure because they help transfer the Superstructure loads to the Substructure.

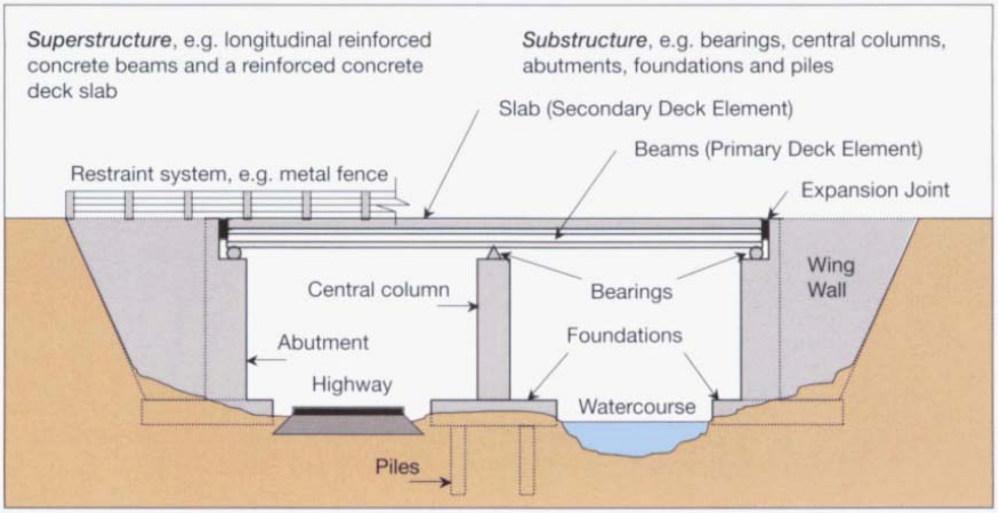


Figure B.1 – Typical modern bridge

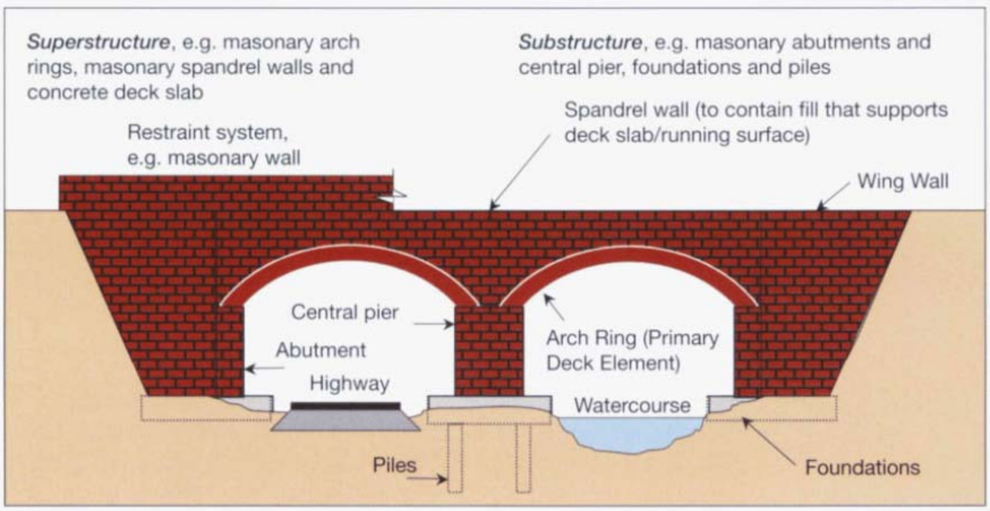


Figure B.2 – Typical older bridge

٢.٣ BRIDGE ELEMENTS

٢.٣.١ This section presents definitions of typical bridge elements, grouped under the headings of Superstructure, Substructure, Durability Elements, Safety Elements and Ancillary Elements. In some cases common examples are provided to help expand on the definition. The following definitions align with those provided in the Code of Practice.

Superstructure

٢.٣.٢ The bridge superstructure includes one or more of the following: primary, secondary and tertiary load bearing elements. The structure form and material normally dictate what are actually present on a structure, for example:

- In Figure **B.l** the primary load carrying element is likely to be some for of longitudinal beam, while the secondary load carrying element is likely to be the deck slab supported by the longitudinal beams

- In Figure ٨.٢ the primary load carrying element is the arch ring, while the secondary load carrying element may be a concrete slab, resting on the arch fill, which supports the running surface.

٢.٣.٣ As such, it is not possible to give a definitive description of the superstructure and its constituent elements, instead it is important to appreciate the different forms this can take and how these influence the form of the primary, secondary and tertiary load carrying elements. Section ٢.٤ presents a range of superstructure examples, and the following definitions relate to typical elements found in bridge superstructures.

Arch

٢.٣.٤ An arch is a curved beam or slab that functions primarily in compression and produces both vertical and horizontal reactions at its supports, a typical example of an arch bridge is shown in Figure ٦.٢.

Beam

٢.٣.٥ A beam can be defined as a linear structural member that spans from one support to another. Beams are part of the superstructure and common types include:

Primary Load Carrying Beam **-** a primary, or main, load carrying beam in a bridge that supports the bridge deck and transfers the traffic loads and superstructure weight (including their own self weight) to the substructure (via bearings on some forms of structure). Primary beams normally span parallel to the direction of traffic flow.

Girder **-** performs the same function as a beam but is normally metal and consists of two flanges with a web (could be a complete rolled section or built up from rolled plates connected together).

Parapet Beam/Cantilever **-** the main function of a parapet Beam cantilever is to support the parapet, although it may also support the carriageway and/or footway/verge. A cantilever is a structural element, normally a slab or beam, which has one unsupported (free) end and one supported (fixed or built in) end.

Transverse Beam **-** a secondary load carrying beam that transfers the traffic loads to the main beams. Transverse beams normally span between the primary beams and are perpendicular to the direction of traffic flow

Bracing

٢.٣.٦ Bracing is elements that provide longitudinal, lateral and/or torsional stiffness to the primary members and/or to the bridge deck.

Bridge Deck

٢.٣.٧ The part of a bridge superstructure that directly supports the running surface and traffic. It is normally defined as a secondary load bearing component because it transfers the traffic loads to the primary load bearing components, e.g. main beams. However, the deck may be the primary load bearing element if it is a slab bridge, i.e. the slab is the bridge deck, or even a tertiary load bearing component if there are transverse beams. A subsidiary function of the deck is to accommodate other elements which include the carriageway (surfacing), kerbs, footways, deck drainage systems, utilities, restraint systems, signs and lighting.

Truss

٢.٣.٨ A truss, when present on a bridge, is normally the primary load carrying element. A truss is built up from individual members, normally arranged and connected in a triangular/rectangular pattern, and consisting of a top chord, bottom chord and internal members.

Substructure

٢.٣.٩ The substructure elements defined in this section are abutments, bearings, piers, columns, and foundations.

Abutments

٢.٣.١٠ Abutments support the extreme ends of the superstructure and transfer the loads to the foundations or ground. Abutments generally retain or support the approach embankment and bearings and should provide adequate clearance between the superstructure and obstacle crossed. Common types of abutments include:

Bank-seat abutment **-** abutments of small vertical height that are normally situated on top *of* a natural or man-made bank (e.g. banks of watercourses, embankments) and do not provide a significant retaining function. The combination *of* the bank and the bank-seat abutment provide the clearance required.

Gravity abutment - an abutment that resists horizontal forces through its own self-weight and normally transfers vertical loads directly to the ground. Similar to a gravity retaining wall.

Cantilever abutment - an abutment wall that is rigidly fixed to the foundation and transfers traffic loads and earth pressures to the foundations principally by bending action. Similar to a cantilever retaining wall.

Embedded abutment - an embedded abutment is similar to a cantilever abutment except there is no horizontal foundation component; instead stability is achieved through the embedded depth.

Spill through abutment - this is effectively a cantilever abutment where the wall is replaced by columns in order to reduce the earth pressure acting on the abutment and the embankment spills through between the columns.

٢.٣.١ ١ Current practice is to make decks integral with the abutments, i.e. avoid the use of joints over abutments and piers.

Bearings

٢.٣.١ ٢ Bearings provide connections between the superstructure and substructure, the purpose of which includes all or some of the following:

- To transfer vertical/horizontal loads from the superstructure to the substructure.
- To allow longitudinal transverse movement of the superstructure.
- To allow rotation of beam/slab ends due to dead and live loading.

٢.٣.١ ٣ Bearings accommodate these movements by deforming (elastomeric), rotating, sliding and/or rolling, see figure B.٤ for typical examples. A large variety of bearings have evolved using various combinations of these mechanisms, including pot, rocker and spherical bearings.

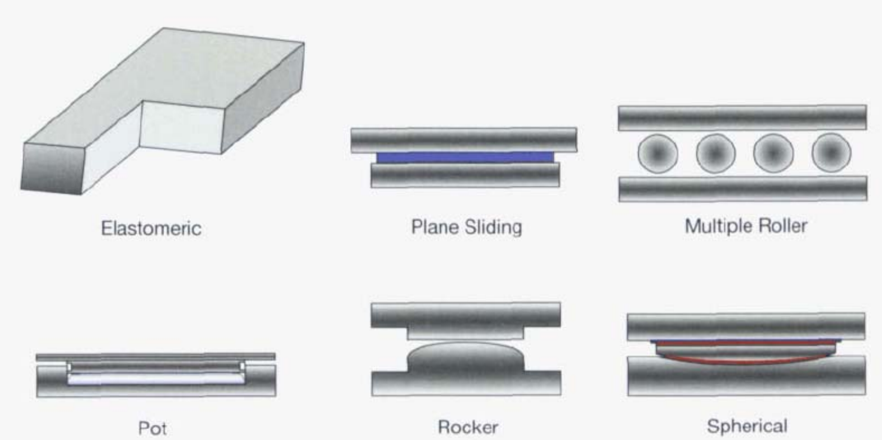


Figure B.4 – Bearings types [7]

٢.٣.١٤ The shelf/surface upon which the bearing sits either directly or via a plinth, is referred to as the bearing shelf. The bearing shelf is normally on the top of the Abutment or pier

Piers and Cross heads

٢.٣.١٥ Piers, or columns, provide support to the superstructure at intermediate points along multiple bridge spans**.** Piers transfer loads to the ground/foundation and may be of column, wall or frame construction. A pier, as with the abutment, provides adequate clearance between the superstructure and the obstacle crossed. On some bridges there is a capping beam/cross head on the top of the piers, the purpose of which is to distribute loads to the piers and to provide a base for bearings.

Foundations

٢.٣.١٦ Foundations are a construction below ground level that supports piers and/or abutments. The purpose of the foundations is to provide a solid and stable base for the bridge and to distribute loads to the ground. Foundation types depend primarily on the depth and safe bearing pressures of the bearing stratum, and also the restrictions placed on differential settlement due to the type of bridge deck. Foundations for highway structures normally fall into two categories: spread (e.g. slab, strip) or piled. Piled foundations normally have a slab or strip to distribute the abutment loads to the piles.

Durability Elements

٢.٣.١٧ The durability elements defined in this section are drainage, waterproofing, joints and surface finishes.

Drainage

٢.٣.١٨ The main function of a drainage system is to remove water away from the bridge superstructure and substructure. The superstructure drainage system collects and disposes of water from the deck and deck joints while the substructure drainage system allows the backfill material behind abutments, wing walls or other earth retaining structures to drain accumulated water .

Water proofing

٢.٣.١٩ Superstructure waterproofing is a protective coating placed between the road construction and the bridge deck in order to protect the bridge deck from the ingress of harmful agents, e.g. chloride contaminated water. Substructure Water proofing fulfils a similar function as there may be harmful agents present in the ground as well.

Joints

٢.٣.٢٠ Joints provide a running surface across the expansion gap, i.e. the area between adjacent bridge deck spans or the bridge deck and abutment **.** Joints allow movement /or are a feature of the construction form Joints may be open (allow water / debris to pass through) or closed (do not allow water / debris to pass through).

Surface Finishes

٢.٣.٢١ Surface finishes are used to protect bridge elements and/or provide the appropriate (aesthetic) finish to the element. Typical surface finishes include paint, hydrophobic pore lining impregnates, mortar rendering, concrete or advanced composite cladding and masonry facing.

Safety Elements

٢.٣.٢٢ The safety elements defined in this section are vehicle restraint systems and access gantries.

Vehicle Restraint Systems

٢.٣.٢٣ A vehicle restraint system is installed on the edge of a bridge or on a retaining wall or similar structure where there is a vertical drop and may contain additional protection and restraint for pedestrians and other road users. The vehicle restraint system is normally referred to as a parapet when it runs along the outside edges of the bridge deck parallel to the direction of traffic flow; a parapet typically takes the form of a wall, rail or fence.

Access Gantries

٢.٣.٢٤ Some bridges have permanent access gantries which provide access for bridge inspection and maintenance; these may be stationary or moveable gantries.

Ancillary Elements

٢.٣.٢٥ The ancillary bridge elements defined and discussed in this section are the approach embankment and slab, apron, highway, lighting, revetment, signs, utilities and wing walls.

Approach Embankment

٢.٣.٢٦ A bank formed above the natural ground level to create the approach to a bridge. The purpose of an approach embankment is to raise the road level so that it aligns with the bridge deck level.

Approach Slab

٢.٣.٢٧ The approach or run-on slab, is a slab positioned below the road surface on the approach to a bridge, the end of which normally rests on the back of the abutment (see Figure ٨.٣, which shows the typical location of the approach slab in relation to the bridge abutment). The purpose of the approach slab is to provide a smooth transition for traffic from the road to the bridge and vice versa. Approach slabs are normally made of reinforced concrete.

Apron

٢.٣.٢٨ A horizontal slab/mattress built into the bed of the watercourse around piers, abutments, culverts and watercourse banks, possibly in conjunction with revetments (see paragraphs ٢.٣.٣١ -٢.٣.٣٣). The purpose of an apron is to provide scour protection to the bed of the watercourse.

Highway

٢.٣.٢٩ **A** highway is a collective term used to describe facilities laid out for all types of users, including but not restricted to: carriageways, footways, footpaths and cycle ways, where these are defined as:

Carriageway - the part of the highway provided for use by motor vehicles. Surfacing is the carriageway or footway wearing course and base course materials applied upon the deck to provide a smooth riding surface and to protect the deck from the effects of traffic and weathering.

Footway – the part of the highway alongside a carriageway provided purely for use by pedestrians. Generally there are Krebs alongside footways to reduce the risk of vehicles crossing onto the footway and endangering pedestrians, see Figure B.٥.

Footpath - a highway provided purely for use by pedestrians that is not alongside a carriageway.

Cycleway - the part of a highway or a highway provided for use by cyclists. Sometimes they may also be used by pedestrians.

Bridleway - the part of a highway or a highway provided for use by equestrians, cyclists and pedestrians.

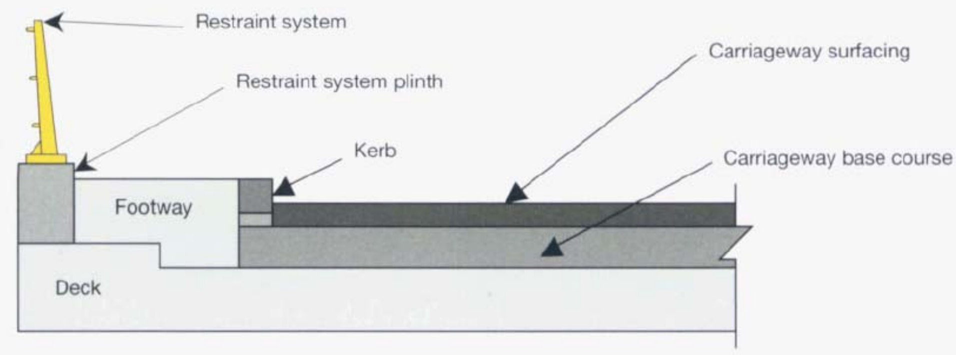


Figure B.5 – Example of concrete footway

Lighting

٢.٣.٣٠ When present, lighting on highway structures serves several purposes and consists of the following types :

Street or Highway Lighting - lighting for illuminating carriageway, footways, footpaths, cycle tracks and pedestrian subways open to public access.

Traffic Control Lights - light signals used to control traffic.

Illuminated Traffic Signs - internally or externally illuminated traffic signs, e.g., flashing school crossing warning signs, centre island beacons, and pedestrian crossing Belisha beacons.

Illuminated Traffic Bollards - bollards lit by internal or base-mounted lighting units, irrespective of whether they carry a sign or not.

Revetment

٢.٣.٣١ A revetment is cladding placed on a soil or rock surface to protect and stabilise it against erosion by water or weathering. A revetment may also be required to accommodate subsidence, surface water drainage, ground water movement, and subsoil drainage. Revetments are not normally classed as structures in their own right, but frequently form ancillary features at bridges, culverts and retaining walls. A revetment may include an apron at the toe of the slope if it is susceptible to scour.

٢.٣.٣٢ Revetments typically comprise an armour layer, to protect against erosion by weathering, water, currents or wave action, and an underlayer, to restrain subsoil movement and act as a drainage zone. The following are common types of armour layer, although the list is not exhaustive and other materials may be encountered:

- Stone rip-rap;
- Hand placed stone;
- Grouted stone or masonry;
- Gabion mesh mattresses;
- Precast concrete blocks - open jointed or interlocking
- Cable tied block mattresses;
- Concrete insitu slabs:
- Grassed geotextile mats;
- Grout filled synthetic mattresses;
- Stone asphalt.

٢.٣.٣٣ The underlayer may be a granular material, a geotextile (typically polypropylene, polyester, polythene or polyamide polymers in filament or fibre form, woven or chemically bound into textiles), or a combination of both. The layer should act as a filter, permitting the flow of water but restraining subsoil. The successful performance of a revetment is dependent on good contact being maintained between the underlayer and the adjacent armour and subsoil.

Signs

٢.٣.٣٤ Signs are provided to inform the road users about highway conditions and hazards and may include the following types: Regulatory signs, Warning signs, Direction signs, and Information signs. Examples of information that road signs may convey and are of particular importance to the bridge inspector include weight restrictions, speed limits and impaired clearances.

Utilities

٢.٣.٣٥ Utility companies/bodies use a highway to provide goods and services to the public. As a result some utilities may be attached to or carried by bridge structures in pipes or ducts located in the deck or in the fill/surfacing over the deck and may include one or more of the following: gas, electricity, water, telephone, cable TV, and sewage. There also may be private services.

Wing Walls

٢.٣.٣٦ Wing walls are essentially retaining walls immediately adjacent to the abutment. The walls may be independent or integral with the abutment wall.

٢.٤ TYPES OF BRIDGES

٢.٤.١ Depending on the required function and appearance bridges vary widely in construction form and material. The following features are normally used to describe a bridge and by combining these terms it should be possible to give a general description of most bridges:

- Span form, e.g. single, multiple, simply supported, continuous, cantilever
- Construction form, e.g. slab, beam and slab, arch, truss, cable supported
- Construction material, e.g. concrete, steel, masonry

٢.٤.٢ Typical examples of span form and construction form are provided in the following. The construction material type is frequently dependent on the construction form, where this is the case the material associated with a particular construction form is indicated.

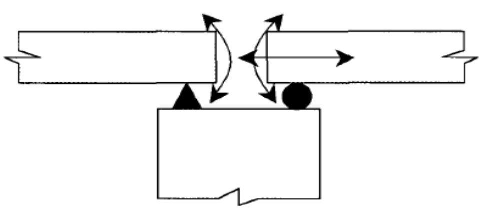
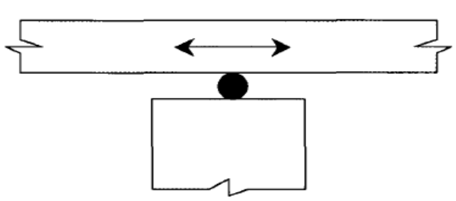
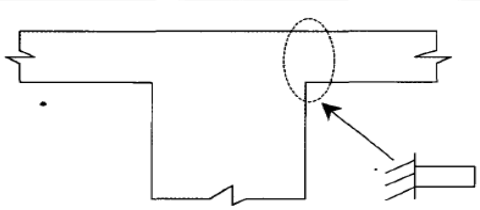
Bridge Span Forms

٢.٤.٣ The span of a bridge is the distance between its supports; the superstructure provides passage over this distance. The characteristics of the superstructure can be used to help classify some bridge types, i.e.:

- The number of spans, e.g. single span or multi-span; and
- The relationship between the spans and the supports, e.g. simply supported, continuous and integral, these arrangements are shown in Table B.٥.

٢.٤.٤ Table B.٦ shows how the number of spans and the span/support relationship can be used to help describe some common bridge types. By combining the span/support descriptions with the material type of the span (superstructure), it is possible to provide a global description for most bridge types, e.g. simply supported, reinforced concrete slab bridge, or three span continuous pretested concrete beam bridge.

Table B.5 – Span-Support Relationships

Span-Support Relationship	Description
	***Simply supported slab or beam*** – the support allows freedom of rotation of the slab/beam ends. This span-support relationship may take the form of a Pinned (or Hinged) Support which allows freedom of rotation but no movement in any other direction, or a Roller Support which allows rotation and movement in the longitudinal
	***Continuous beam/slab construction*** – the beam/slab is continuous over the support, i.e. there is no 'break' in the beam/slab. This type of arrangement is typically supported by a Roller Support, although it can be a Pinned Support.
	***Integral beam/slab and support construction*** – the beam/slab is monolithically cast with the support creating Fixed (or Rigid) Joints between the beam/slab and the support.

Joint/Support diagrammatic convention:

▲ - Pinned/Hinged Joint ● - Roller Support - Fixed Joint/Support

Table B.6 – Typical Bridge Span Forms	
Bridge Spans	**Description**
	***Simply supported single span bridge*** – the superstructure rests on the two end supports.
	***Single span integral bridge*** – the superstructure and two end supports are monolithic.
	***Simply supported multi-span bridge*** – a three span arrangement is shown, with two end supports and two intermediate supports. There is a 'break' in the superstructure over the supports.
	***Multi-span continuous bridge*** – a three span arrangement is shown, with two end supports and two intermediate supports. There is no 'break' in the superstructure over the supports.
	***Portal Frame (inclined leg) bridge*** - a three span arrangement is shown, with two end supports and two intermediate supports. There is no 'break' in the superstructure over the supports, and the superstructure is continuous with the substructure.
	***Cantilever and suspended span bridge*** - the cantilever is formed by continuing the side spans over the support to provide a seating for the central simply supported beam or slab, which is referred to as the suspended span. A series of alternating cantilever and suspended spans is sometimes used in multi-span structures

Summary of Span Ranges

٢.٤.٥ Typical span ranges for common types of beam bridges (including beam and slab, girder and box girder) are shown in Table B.٧. The span ranges are based on existing structures and values quoted by designers and manufactures, the span ranges take account of functionality and economy and must only be used as a general guide as both economics and technology are constantly changing.

Table B.7 – Typical Span Ranges for Beam and Slab Constructions			
Construction Form		**Typical Span Range**	**Longest Span**
Solid slab	Reinforced concrete	Up to 10m	-
	Prestressed concrete (not common)	Up to 15m	-
Voided slab	Reinforced concrete	Up to 25m	-
	Prestressed concrete	25 to 35m	-
Beam and slab	Reinforced concrete	10 to 25m	-
	Prestressed concrete	25 to 50m	-
	Steel beams encased in a concrete slab	5 to 15m	-
	Steel Universal Beams supporting a concrete slab	Up to 25m	-
	Steel Plate Girders* supporting a concrete slab	20 to 50m	-
Box girder	Prestressed concrete: incrementally launched	45 to 75m	301m, Stolmasundet Bridge, Austevoll Norway, 1974
	Prestressed concrete: span-by-span	45 to 60m	
	Prestressed concrete: balanced cantilever	45 to 75m	
	Steel	45 to 75m	300m, Ponte Costa e Silva Bridge, Rio de Janeiro, Brazil, 1974
Arch	Traditional masonry/iron arch	Up to 25m	-
	Modern concrete/steel arches	40 to 150m	420m, Wanxian Bridge, Wanzhou, China, 1997
Truss	Steel truss	40 to 500m	549m, Pont de Quebec Bridge, Quebec City, Canada, 1917
Cable supported	Cable stayed	150 to 500m	1018m, Stonecutters Bridge, Hong Kong, China, 2008
	Suspension	250 to >1000m	1991m, Akashi-Kaikyo Bridge, Kobe-Naruto, Japan, 1998

Note: The bridges listed in the 'Longest Span' column are special structures that have much longer spans than the typical span range.

Slab Bridges

٢.٤.٦ Slab bridges, typically used for spans of up to ٣٥m, are one of simplest forms of construction where the slab is the primary load carrying component and forms the entire superstructure. They are a descendant of the old clapper bridges (see photo) found in upland areas of the United Kingdom and constructed using large flat slabs of stone supported on stone piers and abutments or river banks.

٢.٤.٧ Modern slab bridges are normally built from either reinforced concrete or prestressed concrete and may be solid in cross section (Figure B.٦) or have voids to reduce their self weight (Figure B.٧). Above a span of ١٠m the dead weight of a solid slab bridge becomes excessive; therefore voided slab bridges are required to achieve spans of up to ٣٥m

Figure B.6 – Typical cross-section of a solid slab bridge

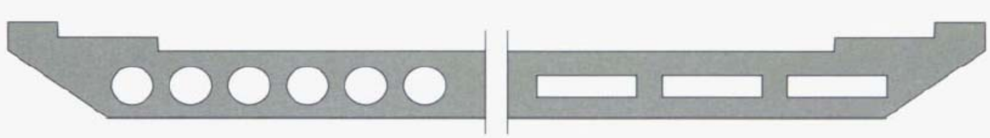


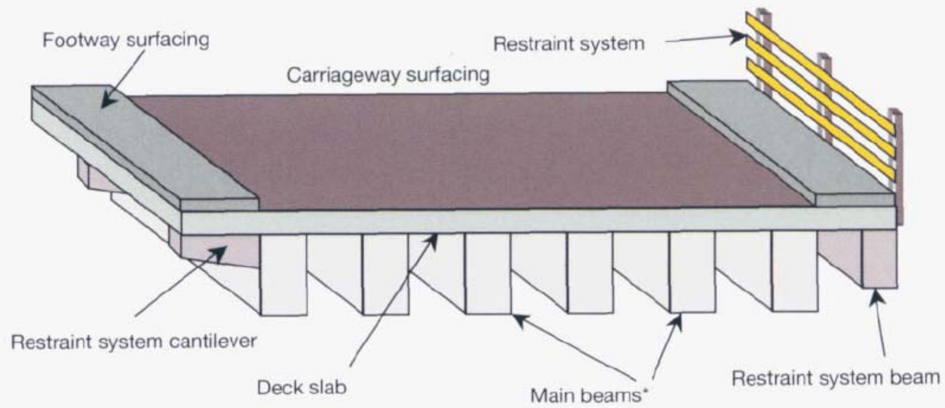
Figure B.7 – Typical cross-sections of voided slab bridges

Beam Bridges

٢.٤.٨ A typical cross section of a beam and slab construction is shown in Figure B.٨. A beam and slab arrangement may be cast as a monolithic concrete element or be cast constructed separately and structurally connected together (e.g. reinforced concrete slab supported by prestressed beams, or a reinforced concrete slab supported on steel beams). A reinforced concrete slab supported on precast concrete beams or steel beams are known as composite construct ion.

٢.٤.٩ For spans beyond the range of standard rolled steel sections, girders are built up, e.g. flanges and web rolled separately and connected together (see Figure **B.٩** for flange and web). Prior to the ١٩٤٠s the flange and web plates were joined by riveting with angles and cover plates, whereas welding has generally been used since then. In modern steel girder bridges, the most commonly used girders are I-beam girders and box-girders. In bridge construction, I-beams are normally made of steel although other materials like aluminium and timber are also used. A typical cross section of a half through girder bridge is shown in Figure B.٩

٢.٤.١٠ Box girders may be constructed of steel, reinforced concrete or prestressed concrete. They may be cast monolithically or constructed of separately fabricated components that are joined together, but in either case they are normally structurally connected with the deck slab that forms the running surface, see Figure B.١٠. The webs in a box girder add stability and increase resistance to twisting forces. Box girders are therefore more stable than I-beams and are able to span greater distances (see Table B.٧). However, the design and fabrication of box girders is more complex than that of I-beams.



* main beams come in a range of cross section shapes (e.g. T, I, Y, M, rectangular) and material types (e.g. reinforced concrete, prestressed concrete, steel).

Figure B.8 – Typical cross-section of a beam and slab bridge

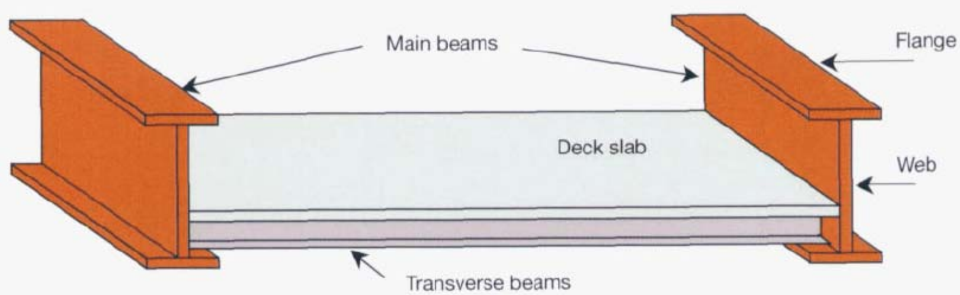


Figure B.9 – Cross-section of a half through girder bridge

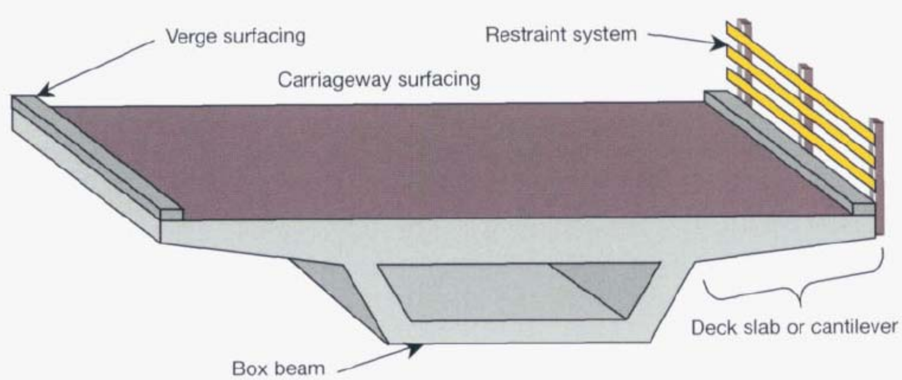


Figure B.10 – Cross-section of a box beam girder bridge

Arch Bridges

٢.٤.١١ The arch is an ancient form of construction, which has been utilised for thousands of years due to its natural strength. The first arch bridges were built of stone and brick, however modern arch bridges are constructed from materials such as reinforced concrete and steel. Arches may be solid, hollow or formed as a truss, the latter allowing arch bridges to cover longer spans.

٢.٤.١٢ Arches use a curved structure with the main carrying element being the arch itself. Both ends of an arch are fixed in the horizontal direction (i.e. no significant horizontal movement is allowed). Thus, when a load is placed on the bridge (e.g. a vehicle passes over it) horizontal forces occur in the springing points of the arch, i.e. the points at which an arch rises from its supports.

٢.٤.١٣ Arches can have open or closed/solid spandrels. The bridge deck can be either above, between or underneath the arches. Open spandrel arches are a development of the closed spandrel arch, where the earth fill is, for example, replaced by vertical columns which carry the bridge deck. Different types of arch bridges are shown in Figure B.١١a, Figure B.١١b and Figure B.١١c.

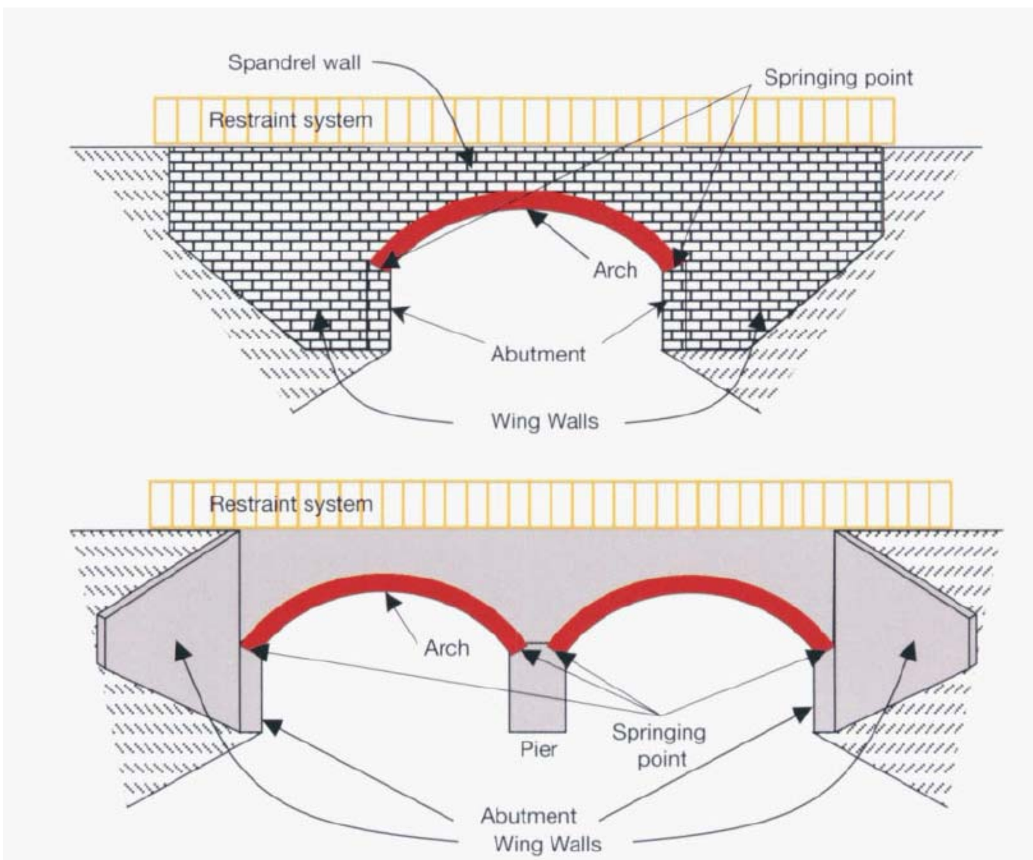
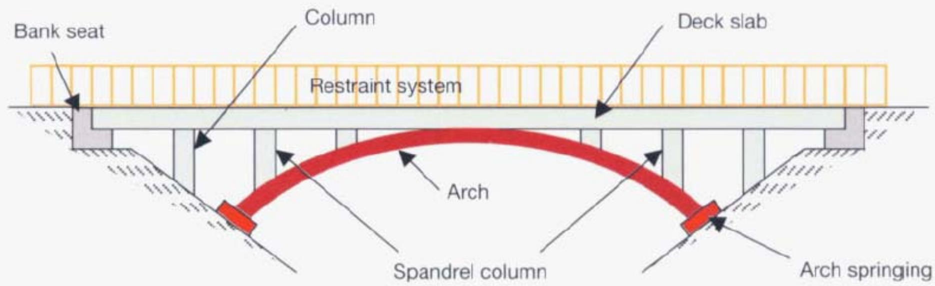


Figure B.11a – Cross-section of closed or solid spandrel arch bridges



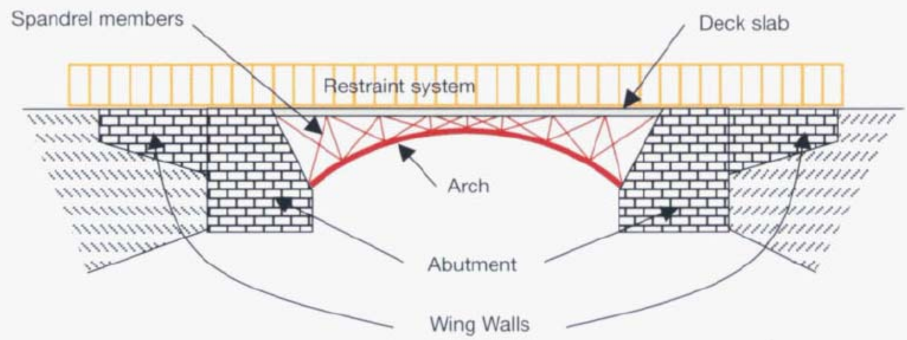


Figure B.11b – Cross-section of open spandrel arch bridges

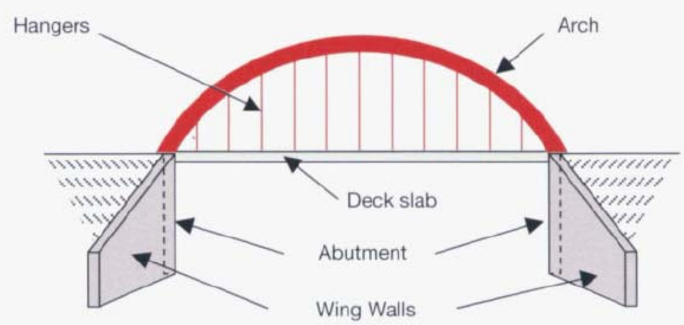


Figure B.11c – Cross-section of a tied arch (Bowstring) bridge

Truss Bridges

٢.٤.١ ٤ Trusses form the primary (main) longitudinal members in a truss bridge. The members that make up a truss are normally straight metal sections (steel in modern constructions), although timber and occasionally reinforced concrete are used.

٢.٤.١٥ The position of the bridge deck (and travelling surface) relative to the truss can be used to classify the structure, examples include:

Under slung truss-bridge -the deck is on top of longitudinal trusses, see Figure B.١٢.

***Through truss-bridge* -** the longitudinal trusses are connected by top and bottom transverse beams and bracing, that forms a 'cage' which the traffic passes through, see Figure B.١٣.

Half through truss-bridges -the longitudinal trusses are connected by bottom transverse beams and bracing but top beam/bracing is omitted because there would be insufficient headroom for traffic, see Figure B.١٤.

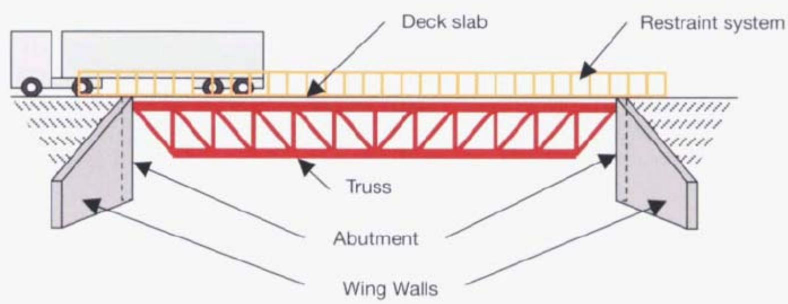


Figure B.12 – Cross-section of an underslung truss bridge

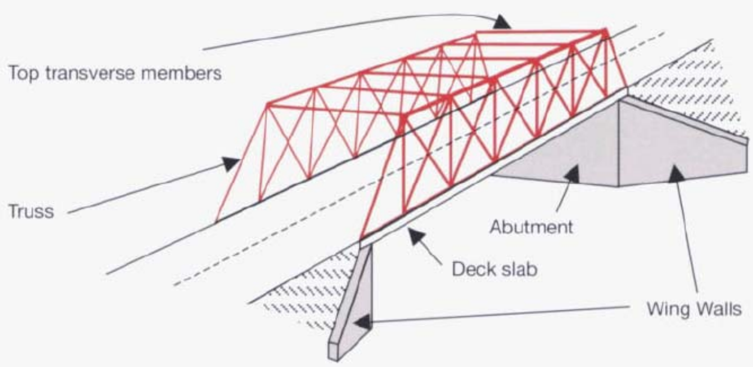


Figure B.13 – Cross-section of a through truss bridge

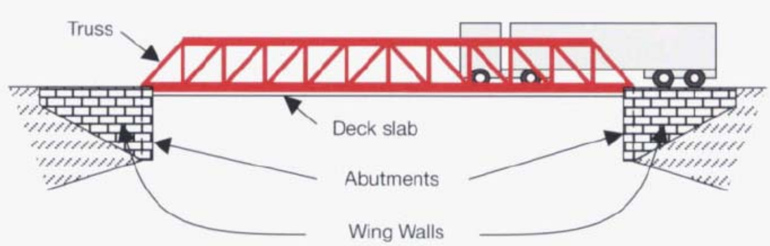


Figure B.14 – Cross-section of a half-through truss bridge

Cable Supported Bridges

٢.٤.١ ٦ A cable supported bridge is where the superstructure is directly or indirectly supported by cables, and where the cables pass over or are attached to one or more towers. There are two types of cable supported bridges: cable stayed bridges and suspension bridges.

٢.٤.١ ٧ Cable stayed bridges and suspension bridges, at first glance, may look similar, i.e. they both have towers and bridge decks that hang from cables, however, the two bridges support the load of the bridge deck in very different ways. The difference lies in how the cables are connected to the towers. In cable-stayed bridges, the cables are attached to the towers, which alone bear the load. In suspension bridges, the cables ride freely across the towers, transmitting loads to the anchorages at either end as well.

Cable Stayed Bridges

٢.٤.١ ٨ Steel cables are strong and flexible as they allow for a slender and light structure which is able to span distances of up to ١٠٠٠m, although this is continually increasing as technology progresses. The current record is ٨٩٠mTatara Bridge, in Onomichi-lmabari Japan, but this will be surpassed by Stonecutters Bridge, in Hong Kong, which will have a span of ١٠١٨m when completed in ٢٠٠٨. Cable bridges typically have a span of greater than ١٥٠m, but shorter span cable stayed bridges have become popular in community and regeneration schemes as they provide a striking landmark. Cable-stayed bridges can be classified by the number of spans, number of towers, girder type and number of cables.

٢.٤.١٩ Typically, a cable stayed bridge has a continuous deck (such as a box girder) supported by steel cables stretching down diagonally (usually to both sides) from one or more vertical towers. Types of cable-stayed bridges, differentiated by how the cables are connected to the towers, include:

Parallel attachment pattern - cables are attached at different heights along the tower, running parallel to one other, see Figure B.١٥.

Radial attachment pattern - the cables extend from a single point at the top of the tower to several points on the bridge deck, see Figure B.١٦.

Hybrid attachment pattern - the cables have a combination of features common to both the parallel and radial attachment patterns, see Figure B.١٧.

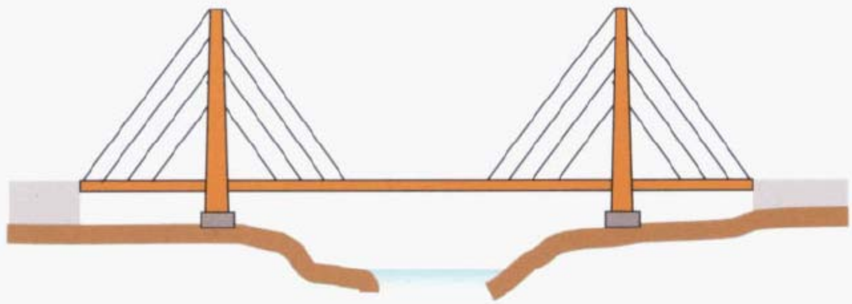


Figure B.15 – Cable stayed bridge: parallel attachment pattern

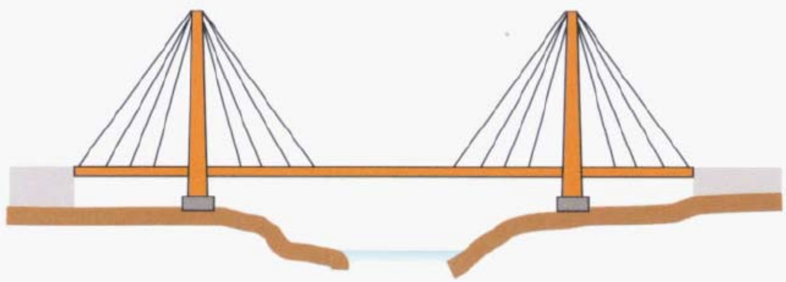


Figure B.16 – Cable stayed bridge: radial attachment pattern

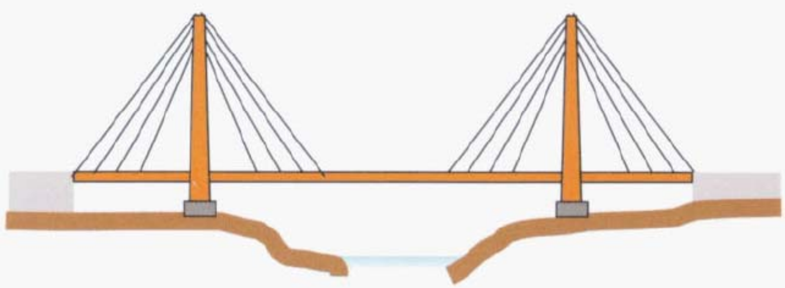


Figure B.17 – Cable stayed bridge: hybrid attachment pattern

٢.٤.٢٠ There are many variations in the number, type and arrangement of towers, typically including single, double, portal and A-shaped towers; these are shown in Figure B.١٨.

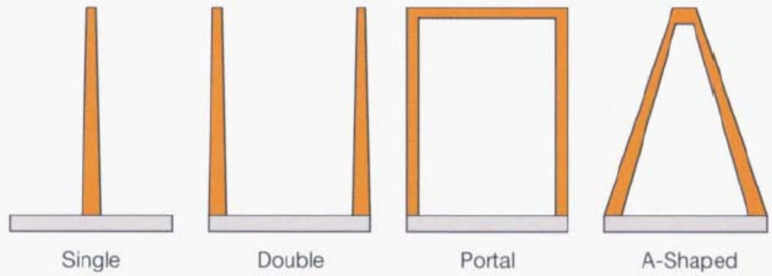


Figure B.18 – Typical towers used for cable stayed bridges

Suspension Bridges

٢.٤.٢١ In a suspension bridge, shown in Figure B.١٩, the bridge deck is held by vertical cables, also known as hanger cables, which hang from longitudinal cables. The main longitudinal cables extend from anchorages at either end of the bridge, passing over the towers to provide the required vertical height. Suspension bridges enable long spans to be achieved, i.e. currently spans in excess of ٣٠٠m are readily achievable, and there are a number of bridges where the span is well in excess of ١٠٠٠m (the current record for the longest suspension bridge is held by the Akashi Kaikyo Bridge in Japan, also known as the Pearl Bridge, which has a main span of ١,٩٩١ m).

٢.٤.٢٢ Though suspension bridges are leading long span technology today, they are in fact a very old form of bridge. In some countries, simple suspension bridges for pedestrians and livestock are still constructed, using techniques and materials similar to the ancient lnca (Latin American) rope bridges, i.e. a shallow downward arc suspended from two high locations using vines and ropes for cables.

٢.٤.٢٣ The deck of a typical suspension bridge (Figure B.١٩) is a continuous girder with one or more towers. The girder is usually a truss or box girder, though in shorter spans plate girders are not uncommon. At both ends of the bridge large anchors or counter weights are used to hold the ends of the cables. Some suspension bridges do not use anchors, but instead attach the main cables to the ends of the girder. These self-anchoring suspension bridges rely on the weight of the end spans to balance the centre span and anchor the cable. The main longitudinal cables pass over a special structure known as a saddle (Figure B.١٩). The saddle allows the cables to slide to accommodate changing loads on the bridge deck, sliding also allows smoothly transfer of the load from the cables to the towers and anchorages.

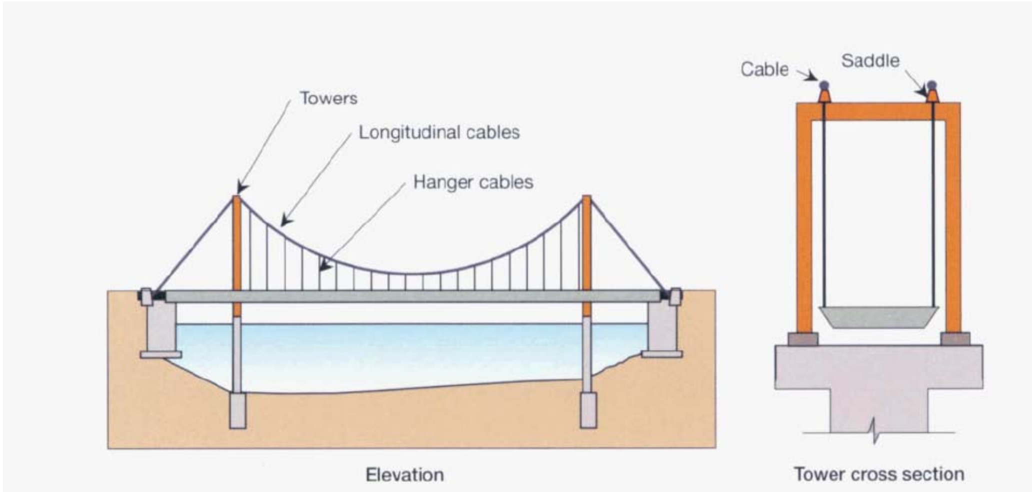


Figure B.19 – Typical suspension bridge

٢.٤.٢٤ As shown in Figure B.١٩, the length of the vertical cables changes to accommodate the downward arc of the main load-bearing cables and provide a more comfortable travelling surface. This arrangement allows the deck to be level or to arc slightly upward for additional clearance.

Movable Bridges

٢.٤.٢٥ A moveable bridge is a bridge having part of all of the superstructure capable of being raised, turned, lifted, or slid from its closed position in order to provide passage to navigable traffic. A moveable bridge is in most cases a beam or girder bridge equipped with machinery which allows the bridge to move in the desired direction.

٣. Performing Inspections

٣.١ INTRODUCTION

٣.١.١ Upon arrival on site, a careful check should be carried out to confirm the identity of the structure, i.e. to ensure it is the correct one. Mistakes can easily occur and in some instances records may be misleading. Unless the inspection team is already familiar with the structure, a quick look around is advisable to make sure that elements such as movement joints, bearings, etc. may be correctly identified, that the orientation is understood by the team and that any drawings confirm the observed layout. Where possible the co-ordinates of the structure should be checked.

٣.١.٢ Inspectors should be aware that the appearance of some structural materials may sometimes be misleading. For example, a retaining wall with a masonry face may be solid masonry or it may be masonry cladding to some other material such as mass concrete, reinforced concrete, steel sheet piling or even reinforced earth. Similarly some structures may have been subjected to repairs or alterations which are superficially similar to the rest of the structure but which may conceal a different form of construction. In the majority of cases the structure records should contain sufficient information to clarify such situations; however, inspectors should be aware that some details may have not been recorded or that the structure records are in the process of being up-dated.

٣.١.٣ Before commencing work, inspectors must ensure that any necessary traffic management measures (see paragraphs ٣.٥.٥-٣.٥.٢٠) are in place, that they have been correctly set up and that they are diverting the traffic in a safe manner. At intervals during the work, checks should be made to ensure that the traffic management is still operating correctly, for example signs may have fallen over or become obscured; cones may have been displaced; signals may have ceased to function, etc. Traffic management is put in place for the safety of the inspectors as well as that of the public and as such inspectors have a duty of care to ensure that it operates satisfactorily.

٣.١.٤ The inspection should proceed in a logical and systematic manner within the constraints imposed by any safety, traffic management and access considerations. The first stage of any inspection should be to review the overall condition of the structure paying particular attention to any evidence of structural movement, e.g. settlement. During this initial ‘overview’ of the structure, the inspector should focus on identifying the effects of structural defects and not the defects themselves.

٣.١.٥ Inspections should be thorough, i.e. conscientious and to the full requirements of the specific brief for the type of inspection being undertaken. The work should never be skimped and if problems are encountered, these should be discussed with the inspection team leader and, if necessary, referred to the Supervising Engineer. For example, a typical problem might be difficulty in obtaining access to some part or parts of the structure. Every effort should be made, without compromising safety, to obtain all the required information during the inspection. Where there are restrictions on the working hours, such as on busy motorways or during railway track possessions, it is particularly important to work efficiently so that the work may be completed within the allotted time.

٣.١.٦ In some instances, the lead inspector may be required to consider whether the value of the inspection would improve by undertaking work additional to the original brief while on site. For example, the results of early tests or the initial discovery of unforeseen movements should be used to review the scope of the work. Any proposed changes should be agreed with the Supervising Engineer prior to being implemented.

٣.١.٧ Inspectors should always be alert to anything unusual while on site and focus on any part of the structure that may cause particular concern. Possible examples include incomplete or missing secondary elements, clearances that are too small or too large, or elements which are over or under-sized. Any such observations or concerns should be brought to the attention of the Supervising Engineer.

٣.١.٨ Any damage or disturbance caused on or adjacent to a highway structure during an inspection should be made good. This frequently includes reinstating drill or core holes in concrete or masonry, painting exposed steel surfaces or refilling trial pits. The correct materials and good workmanship are essential as poor repairs may result in accelerated deterioration or affect the appearance of the structure.

٣.١.٩ On completing an inspection, the team should verify that all the information required has been captured. The site must be cleared thoroughly of all equipment, materials and rubbish. If working on a highway, before a stretch of the highway is reopened to traffic, the lead inspector, or another responsible person, should ensure that the area is safe for public use. On railways, a formal checking and reporting procedure should be followed to ensure safety at the end of a possession.

٣.١.١٠ The following sections give general advice and guidance on carrying out inspections for structures constructed of different materials and certain special structures. Detailed advice on the defects that may occur on these structures is included in Part D of the Manual. The level of activity and information acquired should be commensurate with the type of inspection being undertaken.

٣.٢ CONCRETE STRUCTURES

٣.٢.١ The main cause of deterioration of reinforced concrete structures is corrosion of the reinforcement. Inspectors should pay particular attention to the presence of reinforcement corrosion or the risk that corrosion may occur in the future. Areas particularly at risk are those subjected to leakage of de-icing salts through joints, and concrete subjected to salt spray from passing traffic or from the sea for structures in a marine environment. Vulnerable areas on bridges may include bearing shelves, half joints, piers and abutments, crossheads, ballast walls, deck ends and areas around defective or blocked drainage.

٣.٢.٢ Where cracking of concrete due to reinforcement corrosion or corrosion of prestressing tendons is suspected, in addition to visual examination it may be appropriate to carry out some simple testing during a Special Inspection such as measurement of chloride content, carbonation depth, reinforcement cover or electrode-potential (half-cell). This would enable a better assessment of the condition of the reinforced concrete to be made. The results obtained should be recorded in the Structure Records for future reference.

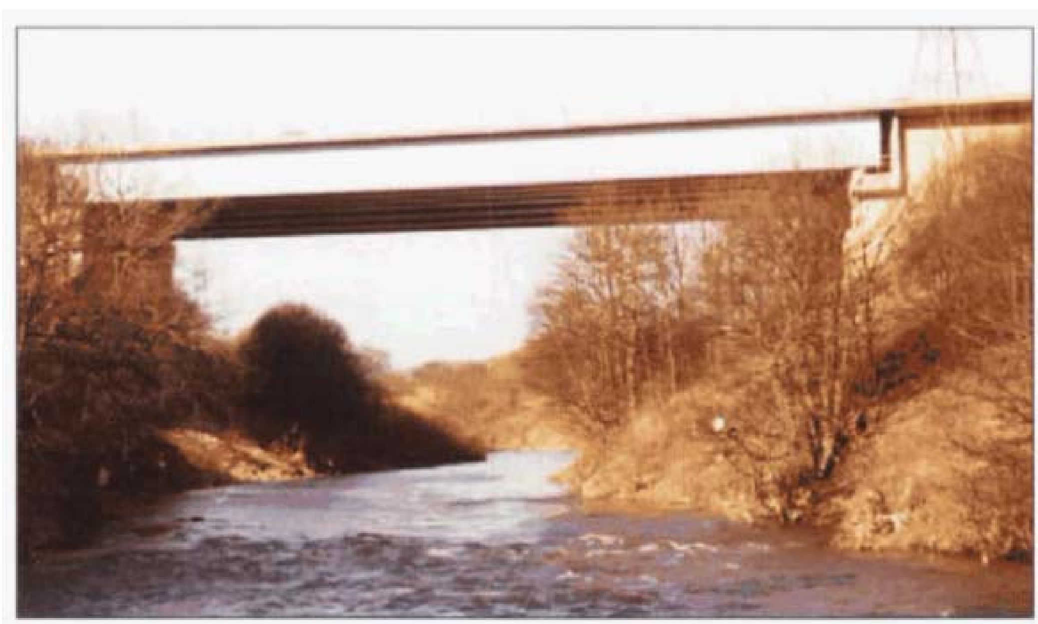
٣.٢.٣ Concrete structures suspected of suffering from alkali-silica reaction **(ASR)** or any other form of chemical degradation should have a Special Inspection to check the cause and extent of any deterioration.

٣.٢.٤ Prestressed concrete structures (pretensioned or post-tensioned) can suffer from any of the defects described above for reinforced concrete. However, particular attention should be paid to cracks in the concrete or any other indication, e.g. rust staining, that the prestressed elements may be subject to corrosion and therefore at risk of loss of prestress.

٣.٢.٥ Post-tensioned concrete bridges with grouted tendon ducts are particularly vulnerable to corrosion and severe deterioration in segmental construction and/or where internal grouting of the ducts is incomplete. The findings of the Special Inspection should be taken into account when planning and undertaking an inspection. Where such an inspection has not been undertaken previously, a Special Inspection should be carried out. The purpose is to establish whether there are voids in the grouted ducts and the extent of any tendon corrosion or other deterioration, so that the vulnerability of the bridge and its residual strength may be assessed. It is important to determine the form **of** the bridge and its load-carrying system as this can have a considerable influence on its vulnerability to tendon corrosion.

٣.٣ STEEL STRUCTURES

٣.٣.١ Steel is particularly vulnerable to corrosion when exposed to wet conditions or to aggressive ions, such as chlorides from de-icing salt, or when exposed to a marine environment. Most steelwork on highway structures is therefore protected with paint or some other protective coating. Corrosion is usually associated with the breakdown of protective systems, which is probably the most common defect associated with steel superstructures. It is important to assess the magnitude, location and form of corrosion and, if possible, identify its cause. Inspectors should assess and record any loss of structural section. Special Inspections of the protective system using specialist inspectors may be required to identify the cause of any deterioration of the paint system and to identify the need for maintenance painting. There are also circumstances when Special Inspections are required in order to identify if corrosion is taking place and to monitor it over a period of time.



٣.٣.٢ The steelwork in some structures, particularly bridges, has been enclosed to reduce the rate of corrosion and to provide access for inspection. Such enclosures should be inspected during all General and Principal Inspections of the structure. Although enclosures should have long service lives some components or seals may have shorter lives.

٣.٣.٣ Older bridges may be at risk of fatigue-induced failures, although fatigue susceptible details may also be present on more recent bridges. Deformation or distortion of members may reduce the load carrying capacity of the structure. Sighting along flanges may aid checking of members, taking measurement of the maximum deformation if necessary.

٣.٣.٤ Weathering steel is particularly vulnerable in wet/dry situations and at web flange joints, where settled rust deposits may retain water like a sponge. Weathering steel should be visually inspected for irregularities in the appearance of the patina, at critical areas and in particular at fixed joints and expansion joints. Any irregularity of appearance should be reported. Where irregularity occurs, a Special Inspection may be needed to ascertain the cause. Steel thickness measurements on weathering steel are also required generally at six year intervals at predetermined locations to check for loss of steel, normally at the time of a Principal Inspection.

٣.٣.٥ Steel/concrete composite bridges rely on interaction between the steel and the concrete provided by shear connectors. Failure may be indicated by separation between the top flange and the concrete slab. The inspector should examine this interface for evidence of separation.

٣.٣.٦ Corrugated steel buried structures (CSBS) used as culverts, deteriorate mainly through hydraulic wear in the invert and along the wet/dry line. The hydraulic action removes protective coatings and exposes the steel substrate to corrosion. Deterioration of CSBS is also caused by exposure to water laden with de-icing salts or sulphur compounds present in the backfill and surrounding soil. Deterioration of CSBS used as cattle creeps, pedestrian underpasses, etc. will also occur due to this cause. Deterioration is often localized and in extreme cases results in perforation of the steel shell, which might require strengthening works or, if in an advanced state, replacement of the structure. Inspection of corrugated steel buried structures is generally limited to exposed surfaces. Inspectors should look for signs of bulging and deformation in the shape or line of the steel arch or ring and for signs of the settlement of fill in areas above or adjacent to the arch. An overview of the immediate surrounds should be made to identify changes such as erection of structures, subsequent to the construction of the corrugated structure that may, for example, alter the loading or the level of the water table in the vicinity.

٣.٣.٧ Connections are points of weakness in steel construction, whether welded, riveted or bolted, and may have material or loading defects. Inspectors should be aware that structural movement or failure may initially propagate as movement at connections. Therefore, all connections should be checked for defects. Welds, particularly those between deck plates, and stiffeners should be inspected for cracking, which may require the use of non-destructive testing techniques. Bolts and rivets should be checked to establish that none are loose or missing.

٣.٣.٨ Older structures often have details which are susceptible to corrosion so inspectors should give particular attention to areas such as:

- Small gaps between components which are not adequately sealed.
- Where components are built into concrete or masonry.
- Water traps and areas where debris can build up.
- The insides of unsealed hollow members that are not readily accessible, e.g. look for external indications of corrosion and/or use specialist techniques during a Special Inspection.
- Areas subject to leakage of de-icing salts, e.g. members below deck joints, joints in trough or plate decking.

٣.٤ CABLE SUPPORTED STRUCTURES

٣.٤.١ Particular factors that may affect the performance of cable supported structures include excessive vibrations, corrosion, fatigue, and the general inability to reliably ascertain the condition of the cables, especially in the critical anchorage zones. Depending on the type of inspection performed, currently available methods that may be used for cable supported structures include conventional visual inspections and some non-destructive testing techniques such as magnetic, ultrasonic, x-ray, laser, acoustic, and remote or contact based vibration methods.

٣.٤.٢ During Principal Inspections of cables, the entire surface of the cable should be inspected at close range, followed by an inspection of neoprene boots and rings, visible surfaces of guide pipes, and accessible anchorage surfaces.
Visual inspections of cables typically involve the following (the relevance of the following will depend on the specific arrangement of the cables and the size of the structure):

- Identification of longitudinal or transverse cracking or excessive bulging in the sheathing, as well as damage at connections to dampers or cross cables.
- Inspection for cable alignment irregularities including waviness or excessive sag. Cable sag may be estimated or measured using optical devices or through video or photo image processing. Cable angle may be measured with an inclinometer at specific points.
- Identification of changes to bridge deck elevations.
- Examination of protective tape wrapping, e.g. tears, cracks, and delaminations.
- Examination of the sheathing, particularly any evidence of cracking in the sheathing located at high stress areas.
- Identification of damage to connections between anchorage pipes and cable sheathing.
- Inspection for damage, loosening, lack of water tightness, and deterioration of neoprene boots and band clamps.

- Inspection for damage or dislocation of neoprene rings and keeper rings, if applicable.

- Identification of gaps between the neoprene rings and the sheathing.

- Examination of sheathing surface inside the guide pipe through a boroscope or other means, looking for damage or deformation to the sheathing near the anchorage.

- Identification of cracking or damage to guide pipes or evidence of the impact of cable components on guide pipes.

- Examination of surface conditions on the visible anchorage components including ring nuts, end caps, and bearing plates.

- Examination of visible parts of saddles for damage, corrosion, and cracking.

- Review of evidence of moisture or fillers (such as grease) exiting the anchorage components. If there is an access port at the end cap (ideally at the lowest point), it can be opened and examined for moisture or moisture contaminated grease.

- Removal, in some cases, of the end caps on the sockets to allow for visual inspection of the anchorage plate and anchorage devices and to see if there is moisture or corrosion inside.

- Inspection of the cross tie cables for sagging, i.e. losing their tension force and require to be retensioned.

- Inspection of damage or cracking on components of cross tie cables. Evidence of fretting and fatigue, especially at connections, are of particular interest.

- Examination of dampers, if any, as per recommendations of manufacture .

٣.٤.٣ Due to the nature of these bridges and because no two cable supported structures are identical, it is recommended that inspection procedures for major cable supported bridges are tailored to each specific structure. Special Inspections entailing the use of non-destructive methods should be led by a specialist familiar with both the testing techniques and these particular types of structures.

۳.۵ MASONRY STRUCTURES

۳.۵.۱ Inspection of masonry structures relies on visual inspection rather than testing. The main defects found on masonry structures are: cracking, arch ring separation, bulging and deformation, loss of mortar, loss of bricks or stones, seepage of water through the structure and deterioration of the bricks or stones. Cracking arises from a variety of causes including overloading, vibration or impact from traffic, settlement, foundation failure, temperature and humidity changes i.e. cycles of freeze/thaw activity or wetting and drying. It may be necessary to initiate a Special Inspection in order to determine the cause of the cracking.

۳.۵.۲ Cracks in masonry may affect the appearance only or be indicative of a more serious defect. Recent or progressive cracks are more serious than those which may have occurred soon after the structure was constructed. Evidence that cracks are recent may include clean faces to the crack and loose fragments of masonry or mortar. Cracks formed in the mortar only may be indicative of joint deficiencies. Inspectors should map the extent of cracking in order that comparisons can be made with previous inspections.

۳.۵.۳ Inspections should generally seek to take into account the age of the structure, the type of masonry, local knowledge (many masonry structures are very old) and the exposure environment. Some types of masonry (e.g. sandstone) deteriorate more readily than others (e.g. granite) and this can be exacerbated by the severity of the environment they are in.

۳.۷ ADVANCED COMPOSITES STRUCTURES

۳.۷.۱ The surface of advanced composites should be inspected for signs of crazing, cracking or delamination and for signs of local damage such as impact or abrasion. Where there is a protective layer, it should be checked to ensure that it is intact. Bonded plates should be checked to ensure that they are not becoming detached. It is recommended that this should generally be carried out by inspectors with experience of the delamination of such materials.

٣.٨ TIMBER STRUCTURES

٣.٨.١ The main problems for timber structures/elements are decay, insect attack, splitting and separation of laminated layers. The principal forms of decay are dry rot and wet rot with the latter more likely on highway structures. Timber attacked by dry rot looks dry and brittle, developing deep cracks across the grain and breaking into brick-shaped pieces. Wet rot can only attack wood with high moisture content; it does not spread into dry wood. Affected wood becomes soft, pulpy and wet, with the structure of the wood progressively breaking down. Prolonged dampness and vegetation growing from crevices are also signs that the timber may be decaying. Areas which are particularly susceptible to decay are those which are in contact with both water and air.

٣.٨.٢ Chemical treatment to prevent decay will not penetrate to the middle of the timber so even if the outside is sound, decay may still be occurring below the surface. Signs of hidden decay include water stains on the timber or soft areas on the surface.

٣.٨.٣ Insect attack may occur anywhere and can seriously weaken a timber structure. Insect holes usually have dust in them or near them. A few small holes (less than ٥mm in diameter) are not usually serious. If there are more small holes or much larger holes, the problem is serious.

٣.٨.٤ Evidence of possible decay or insect attack can be detected using a sharp instrument to check the condition below the surface. Where deterioration has occurred, samples may be taken for examination and testing. Sampling in this way is usually only done in exceptional circumstances.

٣.٨.٥ Splitting commonly occurs in timber as it dries out, and does not necessarily seriously affect the structure. Splitting defects that should be treated more seriously include:

- Splits across the grain of the wood.
- Splits orientated so that water can accumulate in them.
- Splits around connections such as bolt holes.
- Splits that are observed to be increasing in size.

٣.٨.٦ Loose or damaged joints can seriously affect the strength of the structure, and in some cases can also cause serious accidents. Steel connection members, such as plates, bolts, pins and cables, may also be subject to corrosion, particularly in saline environments. Additionally, oak when wet gives off acids that can corrode ferrous connectors.

٣.٨.٧ In glued-laminated timber elements, separation of the laminations may occur due to degradation of the adhesive. Delamination may be seen at the edges of the timber, where the edges of laminations are exposed, or on top or bottom surfaces as blistering.

CSS Inspection Process

١. GENERAL

Guidance is provided for reporting the condition of structural elements observed during General and Principal Inspections. Detailed guidance is provided on the use of the inspection pro-forma for bridges, retaining walls and sign/signal gantries, classification of elements, defect type, severity and extent of damage.

٢. BRIDGE INSPECTION PRO-FORMA

٢.١ The layout of the two-page bridge inspection pro-forma is shown in Figure G.١
and replicated in the subsequent pages. The inspection pro-forma is divided into the following areas:

General Bridge Data (paragraph ٣) - This area of the pro-forma is for recording general information about a bridge such as bridge name, road name, O.S. grid reference, number of spans, span length, Bridge Type Code, etc.
Bridge Elements (paragraph ٤) - This area of the pro-forma lists all the bridge elements for which a condition score needs to be recorded.
Element Condition Reporting (paragraph ٥) - This information is recorded on the pro-forma for each bridge element, with separate columns for 'Severity', 'Extent' and 'Defect Type'.
The 'Work Required', 'Work Priority' and 'Cost of Work' may also be recorded against each element.
Inspection Dates.
Multiple Defects Reporting (paragraphs ٥.٦-٥.٩) - This area of the pro-forma allows the severity/extent of up to three defects on one element to be recorded.
Comments (paragraphs ٦.١ -٦.٢) - Space is provided on the proforma for the Inspector and Engineer to record their comments.
Work Required and Signing Off (paragraphs ٦.٣ and ٦.٤).
The pro-forma presented herein identifies data fields that enable the creation of a comprehensive bridge database; however, the pro-forma is not a standard form and may be altered to the needs of individual authorities. The data fields that are mandatory and must not be altered are the Bridge Type Code, the element list and the element condition. The other data fields may be altered to suit each individual authority's needs but it is recommended they form the minimum data collection requirements.

٢.٢ The pro-forma presented herein identifies data fields that enable the creation of a comprehensive bridge database; however, the pro-forma is not a standard form and may be altered to the needs of individual authorities. The data fields that are mandatory and must not be altered are the Bridge Type Code, the element list and the element condition. The other data fields may be altered to suit each individual authority's needs but it is recommended they form the minimum data collection requirements.

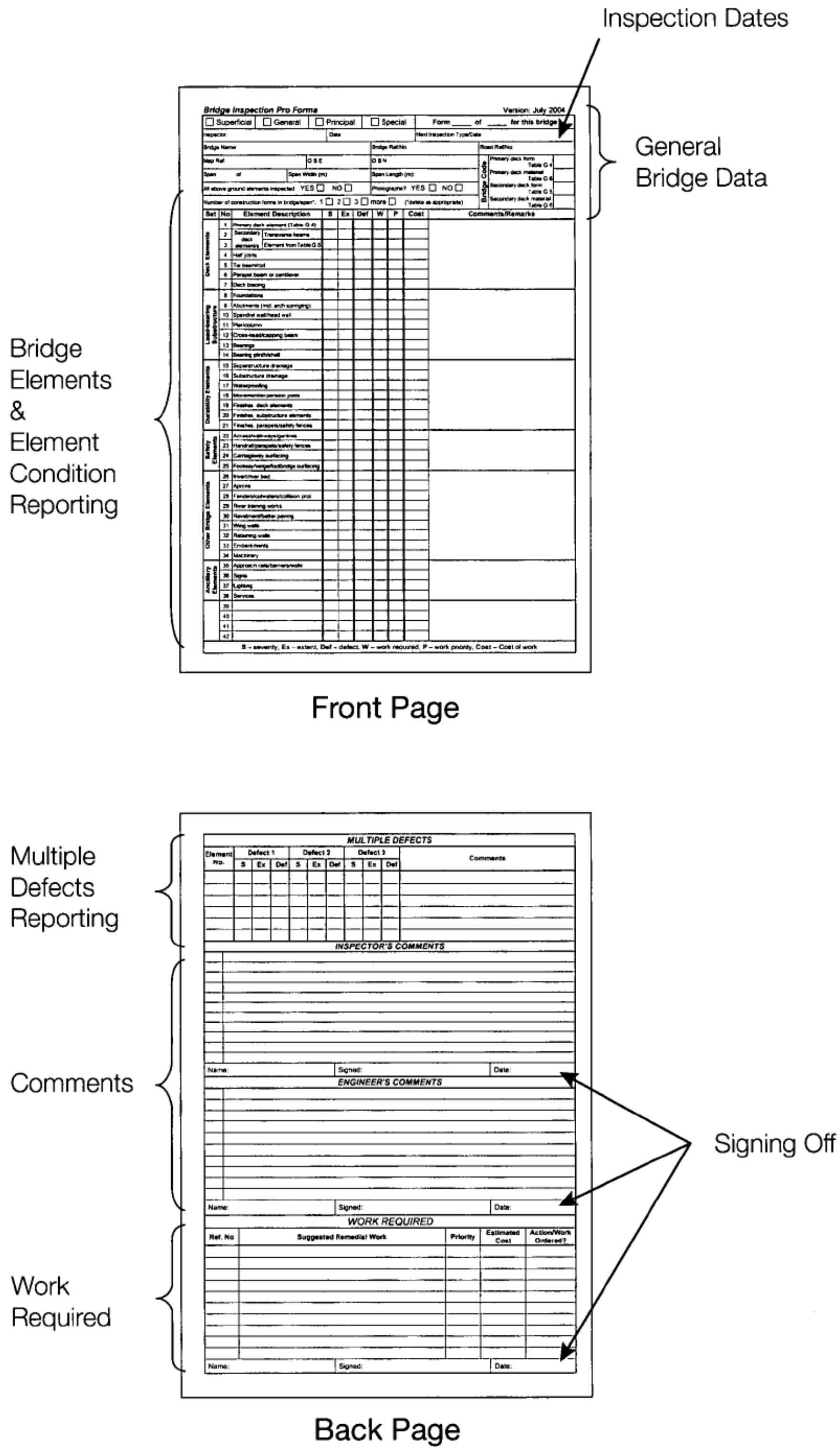


Figure G.1 – Bridge inspection pro-forma layout

Bridge Inspection Pro Forma

☐ Superficial	☐ General	☐ Principal	☐ Special	**Form _____ of _____ for this bridge**

Inspector:	Date:	Next Inspection Type/Date:
Bridge Name:	Bridge Ref/No:	Road Ref/No:

Map Ref:	O.S.E	O.S.N	**Bridge Code**	Primary deck form Table G.4
Span of	Span Width (m):	Span Length (m):		Primary deck material Table G.6
All above ground elements inspected: YES ☐ NO ☐		Photographs? YES ☐ NO ☐		Secondary deck form Table G.5
Number of construction forms in bridge/span*: 1 ☐ 2 ☐ 3 ☐ more ☐ (*delete as appropriate)				Secondary deck material Table G.6

Set	No	Element Description	S	Ex	Def	W	P	Cost	Comments/Remarks
Deck Elements	1	Primary deck element (Table G.4)							
	2	Secondary deck element/s: Transverse beams							
	3	Secondary deck element/s: Element from Table G.5							
	4	Half joints							
	5	Tie beam/rod							
	6	Parapet beam or cantilever							
	7	Deck bracing							
Load-bearing Substructure	8	Foundations							
	9	Abutments (incl. arch springing)							
	10	Spandrel wall/head wall							
	11	Pier/column							
	12	Cross-head/capping beam							
	13	Bearings							
	14	Bearing plinth/shelf							
Durability Elements	15	Superstructure drainage							
	16	Substructure drainage							
	17	Waterproofing							
	18	Movement/expansion joints							
	19	Finishes: deck elements							
	20	Finishes: substructure elements							
	21	Finishes: parapets/safety fences							
Safety Elements	22	Access/walkways/gantries							
	23	Handrail/parapets/safety fences							
	24	Carriageway surfacing							
	25	Footway/verge/footbridge surfacing							
Other Bridge Elements	26	Invert/river bed							
	27	Aprons							
	28	Fenders/cutwaters/collision prot.							
	29	River training works							
	30	Revetment/batter paving							
	31	Wing walls							
	32	Retaining walls							
	33	Embankments							
	34	Machinery							
Ancillary Elements	35	Approach rails/barriers/walls							
	36	Signs							
	37	Lighting							
	38	Services							
	39								
	40								
	41								
	42								

S – severity, **Ex** – extent, **Def** – defect, **W** – work required, **P** – work priority, **Cost** – Cost of work

MULTIPLE DEFECTS

Element No.	Defect 1			Defect 2			Defect 3			Comments
	S	Ex	Def	S	Ex	Def	S	Ex	Def	

INSPECTOR'S COMMENTS

Name:	Signed:	Date:

ENGINEER'S COMMENTS

Name:	Signed:	Date:

WORK REQUIRED

Ref. No	Suggested Remedial Work	Priority	Estimated Cost	Action/Work Ordered?

Name:	Signed:	Date:

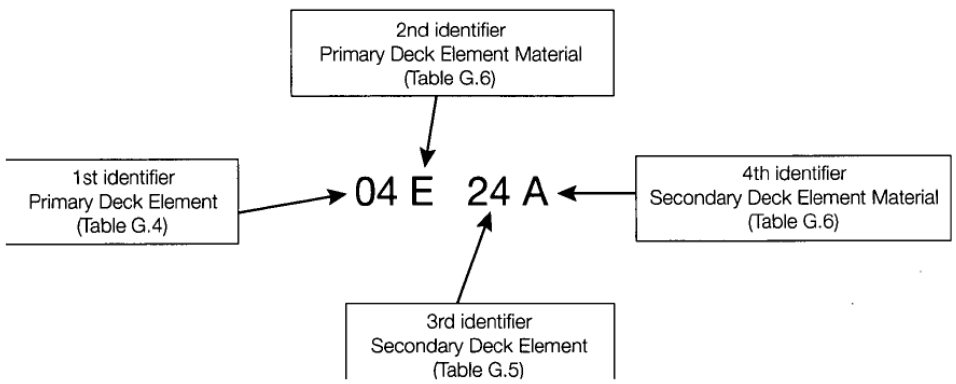
٣. GENERAL BRIDGE DATA

٣.١. The data required in this area of the pro-forma are described in Table G.١

Table G.1 – Definition of General Bridge Data Fields	
Field	**Description of Data Required**
Form *x* of *n* for this bridge	Used to keep account of the number of inspection pro-forma used for a bridge i.e. separate pro-forma may be completed for different spans and/or different construction types within a span. x refers to this pro-forma and n to the total number of pro-forma used for this bridge.
Bridge Name	The name used for the bridge in the authority's records.
Road Name	The name used for the road in the authority's records.
Bridge Ref/No	Bridge reference used in the authority's records.
Road Ref/No	Road reference used in the authority's records.
Map Ref	Reference of map that O.S. readings are taken from.
O.S. E	Ordnance Survey grid reference, Easting.
O.S. N	Ordnance Survey grid reference, Northing.
Span *x* of *n*	Only needs to be filled in when individual spans are reported on separate pro-forma. When spans are reported separately n represents the total number of spans for the bridge and x represents which span the form relates to e.g. Span 2 of 4 refers to the second span of a four span bridge.
Span Length (m)	Used to report span length when one pro-forma is used per span of a multi span bridge, otherwise may be ignored. Some authorities may wish to collect bridge span data for all their structures if this does not exist in their records.
All above ground elements inspected	Used to determine if the inspection covered all above ground bridge elements. The inspectors should tick the 'NO' box if they are unable to survey all above ground elements due to difficulty in access, obstruction by vegetation, etc. An appropriate comment must be made on the pro-forma when an element cannot be inspected and NI (Not Inspected) recorded in the Severity or Extent column.
Photographs?	Questioning if photographs were taken during the inspection. The inspector's comments must describe which elements/bridge views were photographed.
Number of construction...	Many bridges have different construction types within, or between spans. See section on Multiple Construction Types (see paragraphs G.3.4 to G.3.8)
Bridge Type Code	Describes the structural form of the bridge, see section on Bridge Type Code (see paragraphs G.3.2 and G.3.3)

Bridge Type Code

٣.٢ There are a wide variety of bridge types in the UK, the major differences typically being between deck forms. The bridge type here is defined using a ٤-key code combining the primary and secondary deck elements and their material as illustrated below (see paragraphs ٤.٥-٤.١٤ for element type and material lists).



Examples

٣.٣ Examples of Bridge Type Code are shown below:

- **٠٤E ٢٤A –** a bridge composed of a reinforced concrete deck slab supported by longitudinal steel beams.
- **O١K ٢٠P** - solid spandrel brick arch.
- **١OE ٣٢E** - full through steel truss with a flat steel plate deck and transverse beams.

Multiple Construction Types

٣.٤ Some bridges can have more than one construction type, normally due to road widening, but also due to different construction types used on different spans of a multi-span bridge or within a span. When a bridge has more than one construction type a separate inspection form should preferably be used for each type if merited by the total number of elements related to it, see paragraphs ٣.٧-٣.٨.

٣.٥ The inspector must tick the relevant box in the 'Number of Construction Forms' field to indicate how many are on the bridge. The inspector must clearly state on the pro-forma (e.g. in Bridge Name field and Comments field) which construction type, and part of the bridge/span, the pro-forma relates to e.g.

original bridge, road widening, footpath widening, etc.

٣.٦ When more than one construction type exists it is the responsibility of the inspector to decide which elements should be recorded on each pro-forma. The following recommendations are made:

- The first pro-forma for a bridge/span should be for the original construction type and include all substructure, durability, safety, etc. elements relevant to it.

- Each additional pro-forma should report on one other construction type. The inspector should also attempt to distinguish which other bridge elements belong to the modification/widening e.g. abutments, drainage, etc. and report these on the same pro-forma.

٣.٧ When the construction type of a bridge changes from one span to the next, separate pro-forma are preferable and merited because it is relatively easy to distinguish which elements correspond to which construction type. When there is more than one construction type within a span, it is generally more difficult to distinguish which elements correspond to each type.

٣.٨ When there is more than one construction type in a single span, a separate pro-forma is preferable if five or more elements can be distinguished for each type. Otherwise the inspector should record a combined element condition on one pro-forma for an element present on more than one construction type in the span. Additional guidance on recording a combined primary or secondary deck element condition, when they are present in more than one construction type, is provided in paragraphs G.٤.٦ and G.٤.١٢ respectively.

٤. BRIDGE ELEMENTS

General

٤.١ The bridge inspection pro-forma contains ٣٨ predefined bridge elements categorized into: Deck Elements, Load-bearing Sub-Structure Elements, Durability Elements, Safety Elements, Other Bridge Elements and Ancillary Elements.

٤.٢ The form of the primary and secondary deck elements are defined using codes to minimize the number of elements listed on the inspection pro-forma. These codes, along with the primary and secondary deck element material type codes, are used to define the Bridge Type Code (see paragraphs ٣.٢-٣.٣ on Bridge Type Code).

٤.٣ The primary deck elements are denoted using the codes defined in Table G.٤, while the secondary deck elements are denoted using the codes defined in Table G.٥. Material type codes are defined in Table G.٦.

٤.٤ The element list shown on the bridge inspection pro-forma does not cover all the terms or element types currently used by authorities. Table G.٢ and Table G.٣ provide a list of 'equivalent elements' that relate to other element

Types/terms than those used on the pro-forma.

Table G.2 – Equivalent Elements

No.	Element description	Equivalent elements
1	Primary deck element	Main Beams Truss members Culvert Arch Arch Ring Vousoirs/Arch face Arch Barrel/Soffit Encased Beams Subway Box beam interiors Armco/Concrete pipe Portal/Tunnel portals Prestressing Sleeper bridge Tunnel Linings
2	Transverse Beams	
3	Secondary deck element	Concrete deck slab Timber deck Steel deck plates Jack Arch Troughing Stone slab (or Primary member) Troughing Infill Buckle plates
4	Half joints	
5	Tie beam/rod	
6	Parapet beam or cantilever	Edge Beams
7	Deck bracing	Diaphragms
8	Foundations	Piles
9	Abutments (incl. Arch springing)	Arch Springing Abutment slope Bank seat Counterfort/Buttresses
10	Spandrel wall/Head wall	Stringcourse Coping

Table G.2 – Equivalent Elements (continued)		
No.	**Element description**	**Equivalent elements**
11	Pier/Column	
12	Cross-head/Capping beam	
13	Bearings	
14	Bearing plinth/shelf	
15	Superstructure drainage	
16	Substructure drainage	Subway drainage Retaining wall drainage
17	Water proofing	
18	Movement/Expansion joints	Sealants
19	Painting: deck elements	Sealants Decorative appearance
20	Painting: substructure elements	Sealants Decorative appearance
21	Painting: parapets/safety fences	Sealants Decorative appearance
22	Access/Walkways/Gantries	Steps
23	Handrail/Parapets/Safety fences	Balustrade Barrier
24	Carriageway surfacing	Ramp surface Approaches
25	Footway/Verge/Footbridge surfacing	
26	Invert/River bed	Channel bedstones
27	Aprons	
28	Fenders/Cutwaters/Collision protection	Flood Barrier
29	River training works	
30	Revetment/Batter paving	
31	Wing walls	Newel
32	Retaining walls	Counterfort/Buttresses Gabions Wall
33	Embankments	Approach embankments Side slopes
34	Machinery	

Table G.2 – Equivalent Elements (continued)		
No.	**Element description**	**Equivalent elements**
35	Approach rails/barriers/walls	Posts Remote approach walls
36	Signs	
37	Lighting	Subway lighting Primary lighting Secondary lighting
38	Services	Manholes Pipes Mast

Table G.3 – Other Element Relationships	
Other elements	**Covered by**
Pointing/Arch mortar	Severity description No. 3 (see Table G.10)
Condition of masonry/brickwork	Severity description No. 3 (see Table G.10)
Condition of masonry/brickwork	Severity description No. 3 (see Table G.10)
Masonry/Brickwork	Severity description No. 3 (see Table G.10)
Vegetation	Severity description No. 5 (see Table G.10)
Decorative appearance	Severity description No. 4 (see Table G.10)
Cleanliness	Various severity descriptions
Dry Stone Wall & other walls	Corresponds to 9, 10, 11, 23, 31, 32 or 35 on the pro-forma, depending on function and location
Scour	Severity description No. 6 & 7 (see Table G.10)
Finishings	Various severity descriptions
Corrugated metal	Material codes
Leakage	Severity descriptions No. 8, 10 and 14 (see Table G.10)
Rivets and bolts	Severity descriptions No. 1 (see Table G.10)
Welds	Severity descriptions No. 1 (see Table G.10)
Arch cracks and deformation	Severity descriptions No. 3 (see Table G.10)
Fillets and haunching	Reported with element they are part of

Primary Deck Elements (or Span Primary Structural Form)

٤.٥ The Primary Deck Element is No.١ on the bridge inspection pro-forma and is denoted using the codes defined in Table G.٤. This identifies the form of the structural elements spanning in the longitudinal direction. Volume ١ : Part B: Section ٢: Paragraph ٢.٤ contains schematic illustrations of the majority of the bridge types and primary elements listed in Table G.٤.

٤.٦ Some bridges contain more than one of the primary deck element types shown in Table G.٤ on an individual span. Paragraph ٣.٨ recommends a separate pro-forma for a construction type if five or more elements can be distinguished for it.
When there are less than five elements for a construction type, or if the authority does not wish to report construction types separately, the condition score of the different primary deck element types should be recorded separately on the same pro-forma (i.e. utilizing the blank rows, ٣٩ to ٤٢, on the pro-forma).

٤.٧ The condition of the dominant (by area, length or number, which ever is most appropriate) primary deck element should recorded in row No. ١ of the pro-forma. The blank rows, ٣٩ to ٤٢, on the pro-forma should be used to report the condition of the other primary deck elements. The inspector's comments must clearly state if an element is a primary deck element. The inspector should also record the approximate deck area (or proportion of deck area) served by each different primary deck element type (the proportion may be based on length or number as appropriate).

٤.٨ Multiple construction types may be used where there is more than one primary structural form within a bridge/span, see paragraphs ٣.٤-٣.٨ for further guidance. However, it is recommended that a separate pro-forma is used for each construction type.

Table G.4 – Primary Deck Element Codes		
Span Structural Form (Primary Deck Element)		**Code**
Arch	solid spandrel	01
	open/braced spandrel	02
	tied (including hangers)	03
Beam/Girder	at/below deck surface	04
	box beams (exterior & interior)	05
	half through	06
	filler beam	07
Truss	at/below deck surface (underslung)	08
	half through	09
	full through	10
Slab	solid	11
	voided	12
Culvert/Pipe/Subway	circular/oval	13
	box	14
	portal/U-shape	15
Troughing		16
Cable stayed/Suspension		17
Tunnel		18
Other		19
Multiple construction types		MC

Secondary Deck Element

٤.٩ Secondary Deck Elements are recorded in row No.s٢ and ٣ on the bridge inspection pro-forma. These are denoted using codes defined in Table G.٥, which identifies the form of the structural elements spanning transversely between primary elements. On some bridges secondary deck elements may not be present, e.g. arch bridges, a code of '٢٠' or '٣٠' signifies 'no secondary deck element', the code used depends on whether or not transverse beams are present. No secondary deck element code is required for retaining walls.

٤.١٠ Transverse beams are a very common type of secondary deck element and have been assigned their own row on the bridge inspection pro-forma, i.e. row No. ٢. If transverse beams are not present codes '٢٠' to '٢٦' are used in the Bridge Type Code, when transverse beams are present codes '٣٠' to '٣٦' are used in the Bridge Type Code.

٤.١١ When transverse beams are present the elements given in Table G.٥ are sometimes called 'tertiary' deck elements; if transverse beams are not present they are called 'secondary' deck elements. For simplicity, and consistency, they are called 'Secondary' deck elements throughout this document whether transverse beams are present or not.

Table G.5 – Secondary Deck Element Codes		
Secondary Deck Element	**Code**	
	No Transverse Beams	**Transverse Beams**
No secondary deck element	20	30
Buckle Plates	21	31
Flat Plate	22	32
Jack Arch	23	33
Slab	24	34
Troughing	25	35
Other	26	36

٤.١٢ Some bridges contain more than one of the secondary deck element types shown in Table G.٥ on an individual span. Paragraph ٣.٨ recommends a separate pro-forma for a construction type if five or more elements can be distinguished for it. When there are less than five elements to a construction type, or if the authority does not wish to report them separately, the condition score of the different secondary deck element types should be recorded separately on the same pro-forma (i.e. utilizing the blank rows, ٣٩ to ٤٢, on the pro-forma).

٤.١٣ The condition of the dominant (by area, length or number, which ever is most appropriate) secondary deck element should be recorded in row No. ٣ of the pro-forma. The blank rows, ٣٩ to ٤٢, on the pro-forma should be used to report the condition of the other secondary deck elements. The inspector's comments must clearly state if an element is a secondary deck element. The inspector should also record the approximate deck area (or proportion of deck area) served by each different secondary deck element type (the proportion may be based on length or number as appropriate).

Material Type

٤.١٤ The material type code of the primary and secondary deck elements is also used in defining the Bridge Type Code. The Material Type codes are given in Table G.٦.

Table G.6 – Material Type Code		
Material		**Code***
Concrete	reinforced	A
	plain/mass	B
	post-tensioned	C
	pre-tensioned	D
Metal	steel	E
	cast iron	F
	wrought iron	G
	aluminium	H
	corrugated steel	I
	corrugated aluminium	J
Masonry	brick	K
	stone	L
FRP/GRP/Composite		M
Timber		N
No secondary element, so no material		P
Other		Q

*Letter O not used, avoids confusion with zero 'element type' codes

Multiple Elements

٤.١٥ If one element description on the pro-forma covers several equivalent elements (see Table G.٢ and Table *G.* ٣) then the condition reporting should take the condition of all of these into account.

٤.١٦ The following situations are covered by one element description and one condition score on the pro-forma:

- Multiple elements of one type e.g. longitudinal beams, transverse beams, piers/columns, etc.
- Elements repeated over several spans if the whole bridge is reported on one bridge inspection pro-forma e.g. primary deck elements, abutments, invert/river bed, etc.
- Element descriptions on the bridge inspection pro-forma that cover several element types, e.g. the primary deck element description on the pro-forma covers arch barrel and voussoirs for a masonry arch bridge.
- 'Elements' that were previously treated as separate items by some authorities, e.g. pointing is now included in masonry severity description, vegetation is covered by severity descriptions, welds are covered by metalwork severity descriptions, etc. Severity descriptions are covered in paragraph ٥.

Half-joints

٤.١٧ Half-joints, although not distinct elements, receive a separate entry on the inspection bridge inspection pro-forma due to their structural criticality and inherent maintenance problems. However, given that half-joints are an integral part of the primary deck element there is the possibility that defects may be double counted during the inspection. The condition of half-joints should be reported as:

- Defects on the primary element, in the immediate vicinity of the half-joint, likely to have been caused by the presence of the half-joint, e.g. defects in a region D (beam or slab depth) either side of the joint, see Figure G.٢; and
- Defects to the half-joint e.g. dowel/bearing plate, filler, etc.

٤.١٨ Defects used to assess the condition of the half-joint should not be included in the condition assessment of the primary deck element. A typical section through a half joint is shown in Figure G.٢.

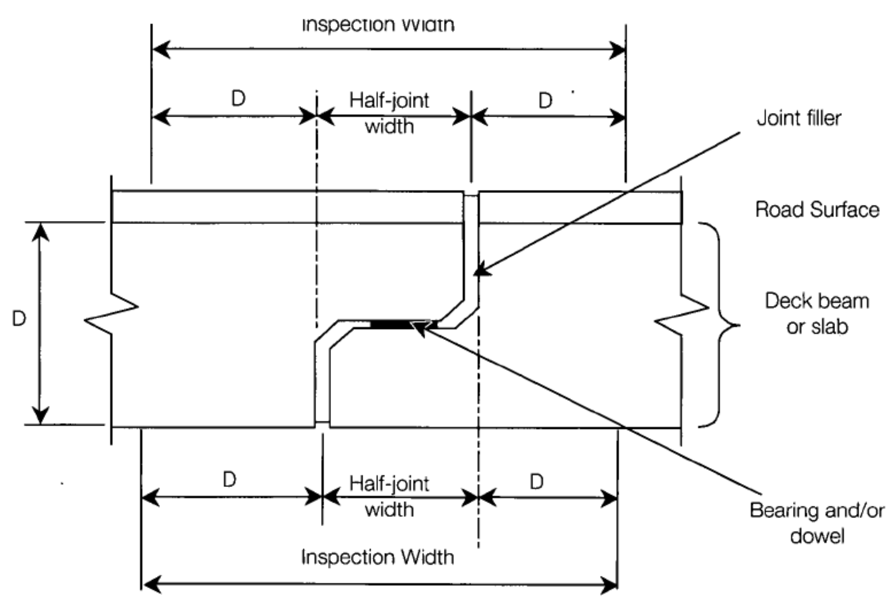


Figure G.2 – Half-joint cross-section

Blank Rows

٤.١٩ Four blank rows, ٣٩ to ٤٢, are provided on the bridge inspection pro-forma. These may be used for any elements that are not covered by the pro-forma if the inspector regards it as important to report the condition of these elements, e.g. third party elements, fire equipment, telecommunications, smoke detectors, one-off element types, decorative elements, etc. However, it is recommended that every effort is made to report the complete bridge condition using the element descriptions already provided on the pro-forma.

٥. ELEMENT CONDITION REPORTING

Extent and Severity Codes

٥.١ The condition of a bridge element should be recorded in terms of the Severity of damage/defect and the spatial Extent of the damage/defect. The following definitions may be adopted to describe the Extent and Severity parameters:

- Extent: The area, length or number (as appropriate) of the bridge element affected by the defect/damage.

- Severity: The degree to which the defect/damage affects the function of the element or other elements on the bridge.

٥.٢ Both extent and severity are parameters that are used to inform decisions about maintenance planning and management. The use of separate codes for each parameter eliminates any obscurity in the distinction between, for example, a single but severe defect and extensive but superficial deterioration. Codes that may be used to describe the Extent and Severity levels are shown in Table G.٧ and Table G.٨ respectively.

٥.٣ Permissible combinations of Severity and Extent are shown in Table G.٩. This shows that some severity/extent combinations are not permissible, such as ٢A, ٣A, ٤A and ٥A. These combinations are not permitted because it is not possible to have a Severity condition greater than ١ with an Extent description of 'no significant defect'.

Table G.7 – Extent Codes

Code	Description
A	No significant defect
B	Slight, not more than 5% of surface area/length/number
C	Moderate, 5% - 20% of surface area/length/number
D	Wide: 20% - 50% of surface area/length/number
E	Extensive, more than 50% of surface area/length/number

Table G.8 – Generic Severity Descriptions

Code	Description
1	As new condition or defect has no significant effect on the element (visually or functionally)
2	Early signs of deterioration, minor defect/damage, no reduction in functionality of element
3	Moderate defect/damage, some loss of functionality could be expected
4	Severe defect/damage, significant loss of functionality and/or element is close to failure/collapse
5	Extensive, more than 50% of surface area/length/number

Table G.9 – Permissible Combinations of Severity and Extent					
Extent	**Severity**				
	1	**2**	**3**	**4**	**5**
A	1A				
B		2B	3B	4B	5B
C		2C	3C	4C	5C
D		2D	3D	4D	5D
E		2E	3E	4E	5E

٥.٤ More detailed guidance on severity descriptions for different construction material and defect types is contained in Table G.١٠. These descriptions do not cover all element or defect types but provide general guidance on the identification of severity states. Many of the severity states in Table G.١٠, contain a number of descriptions for each item, e.g. metalwork has four possibilities in severity state ٣. The element condition only needs to satisfy one of these possibilities to be categorized as severity state ٣. Volume ٢: Part B provides photographic examples of some of the defects described in Table G.١٠.

٥.٥ Table G.٨ gives the generic severity descriptions and must be used as the primary source for defining severity. Table G.٨ should be used to assess those materials, elements and defect types not covered by Table G.١٠. It is considered that if Table G.١٠ is used in conjunction with Table G.٨ a more consistent approach to inspection reporting will be achieved by authorities.

Table G.10 – Severity Descriptions							
No	**Item**	**Severity**					
		1		**2**	**3**	**4**	**5**
1	Metalwork	.1	No signs of rusting or damage	Minor surface rusting	Moderate pitting	Deep pits and perforations (localised severe corrosion)	Disintegrated by corrosion mechanisms
		.2	No loss of section thickness	Minor section loss (penetration less than 5% of section)	Moderate section loss causing some reduction in functionality (penetration 5 to 20% of section thickness)	Major section loss causing significant reduction in functionality (penetration more than 20% of section)	Collapsed or collapsing
		.3	No signs of rusting or damage to bolts, nuts and rivets	Non structural bolts loose, minor corrosion of nuts and washers	Non structural bolts missing, moderate corrosion of rivet heads, nuts and washers	Structural bolts missing, rivets loose or missing, crack through bolt	Failure of element due to missing/failed bolts/rivets
		.4	No corrosion or damage of weld runs	Slight corrosion of weld run	Crack at toe of weld, moderate reduction in size of weld due to corrosion	Longitudin-ally cracked weld, major reduction in size of weld due to corrosion	Weld connection failure (longitudinal crack)

Continued

Table G.10 – Severity Descriptions (continued)

No	Item	Severity					
		1		2	3	4	5
2	Reinforced Concrete, Prestressed Concrete & Filler Joist	.1	No spalls	Minor localised spalls exposing shear links	Major localised spalls exposing shear links and main bars with general corrosion	Joined up deep spalls exposing shear links and main bars with general and pitting corrosion	Collapsed
		.2	Hairline cracks, difficult to detect visually	Cracks and crazing in areas of low flexural behaviour (cracks less than 0.3mm)	Cracks and crazing in areas of high flexure. Cracks approx. 1mm and easily visible	Wide/deep cracks (more than 2mm). Shear cracks	Element unable to function due to structural cracks
		.3	No signs of damage to prestressing	Substandard grouting of ducts (may not be visible)	Cracks along line of prestressing duct	Exposed prestressing cables	Failed prestressing cables
		.4	No signs of delamination	Early signs of delamination e.g. cracks with rust staining	Delamination in areas of low flexural and/or shear action	Delamination in areas of high flexural and/or shear action	Failure due to delaminated bars
		.5	No signs of thaumasite or freeze-thaw attack	Slight cracking caused by thaumasite or freeze-thaw	Moderate thaumasite or freeze-thaw attack	Major thaumasite or freeze-thaw attack	Failure due to thaumasite or freeze-thaw attack

Continued

Table G.10 – Severity Descriptions (continued)

No	Item	Severity					
		1		2	3	4	5
3	Masonry, Brickwork & Mass Concrete	.1	No evidence of deformation	Minor deformation	Moderate deformation	Major deformation	Collapsed
		.2	Pointing sound	Minor depth of pointing deteriorated	Moderate to significant depth of pointing lost, but does not appear to be rapidly disintegrating or crumbling, bricks not easily loosened	Pointing in very poor condition, severely weathered, crumbling to touch and/or significant depth loss, bricks easily loosened	Collapsed
		.3	No arch ring cracking or separation	Arch ring cracks difficult to see	Arch ring separation (gap less than 25mm)	Arch ring separation (gap greater than 25mm)	Disintegrated
		.4	No arch barrel cracks	No diagonal cracks, longitudinal cracks less than 3mm wide, lateral cracks	Diagonal cracks, longitudinal cracks greater than 3mm wide	Diagonal cracks, longitudinal cracks breaking barrel into 1m sections or less	Arch barrel failure
		.5	No cracks	Minor hairline cracks and shallow spalls	Moderate cracks (easily visible, crazing) and deep localised spalls	Major cracks and spalling	Failure due to structural cracks
		.6	No bricks/ masonry blocks missing, minor surface weathering	Few bricks/stones missing (no adjacent ones missing), major surface weathering	Moderate loss of bricks/stones	Severe loss of bricks/stones	Failure due to missing bricks/stones
		.7	No bulging, leaning or displacement	Minor bulging, leaning or displacement	Moderate bulging, leaning or displacement	Severe bulging, leaning or displacement	Collapsed or non functional

Continued

Table G.10 – Severity Descriptions (continued)							
No	**Item**	**Severity**					
		1		**2**	**3**	**4**	**5**
4	Paintwork & Protective Coatings	.1	Finishing coat sound, slight weathering	Normal weathering of finishing coat	Spots, chips and cracks of finishing coat, undercoat exposed but sound	Failure of finishing coat and spots, chips and cracks to undercoat/ substrate	All coats failed
5	Vegetation	.1	Slight to no vegetation	Minor vegetation causing no structural damage (surface mosses, small grass and weeds)	Vegetation growth on or near bridge causing minor structural damage and/or deformation e.g. roots and branches of nearby trees, small tree/plants growing on structure	Vegetation growth on or near bridge causing major structural damage and/or deformation e.g. roots and branches of nearby trees, large tree growing on structure	Failure caused by vegetation growth or a tree collapsing on the structure
		.2	Slight to no vegetation	Low depth/density of vegetation cover, easily removed, e.g. moss	Significant depth/density of vegetation, obscuring inspection, e.g. ivy	Inspection impossible due to vegetation growth but structural damage due to vegetation unlikely	Inspection of critical structural elements not possible due to density of vegetation and root systems likely to be causing structural damage

Continued

Table G.10 – Severity Descriptions (continued)							
No	**Item**	**Severity**					
		1		**2**	**3**	**4**	**5**
6	Foundations	.1	No visible settlement of structure	No visible settlement, but cracks that may be due to it	Minor settlement of structure	Major settlement of structure	Collapsed due to settlement
		.2	No visible differential movement of structure	No visible movement, but cracks that may be due to it	Minor differential movement of structure	Major differential movement of structure	Collapsed due to differential movement
		.3	No visible sliding of structure	No visible sliding, but cracks that may be due to it	Minor sliding of structure	Major sliding of structure	Collapsed due to sliding
		.4	No visible rotation of structure	No visible rotation, but cracks that may be due to it	Minor rotation of structure	Major rotation of structure	Collapsed due to rotation
		.5	No scour	Minor scour	Moderate scour	Major scour	Dangerous scour or failure
		.6	Substructure appears unaffected by foundation faults (assume no foundation faults)	Foundation faults causing minor cracks in substructure	Foundation faults causing moderate cracks in substructure	Foundation faults causing major cracks and deformation in substructure	Failure due to foundation faults
7	Invert, apron & river bed (also see 2 and 3)	.1	No scour	Minor scour	Moderate scour	Major scour	Dangerous scour or failure
		.2	No vegetation growth or silting	Vegetation growth, trapped debris and silting causing slight disruption to flow	Vegetation growth, trapped debris and silting, significant disruption to flow causing faster flow in areas of the river	Vegetation growth, trapped debris and silting, severe disruption to flow causing much faster flow in areas of the river	Failure caused by vegetation growth, trapped debris and silting

Continued

Table G.10 – Severity Descriptions (continued)							
No	**Item**	**Severity**					
		1		**2**	**3**	**4**	**5**
8	Drainage	.1	In sound condition and fully functional	Mostly functional (less than 25% of cross section blocked)	Part functional (25 to 50% of cross section blocked)	Mostly non-functional (more than 50% of cross section blocked)	Totally blocked / non-functional / broken
		.2	Causing no staining	Causing minor staining	Cleaning of staining required	Urgent cleaning required	Urgent & frequent cleaning
		.3	No structural damage	Causing minor structural damage	Causing moderate structural damage	Causing major structural damage	Causing severe damage to adjacent elements
		.4	No blockage of weep holes, outlets	Minor blockage of weep holes, outlets	Moderate blockage of weep holes, outlets	Major blockage of weep holes, outlets	Non functioning weep holes
9	Surfacing	.1	Little to no wear and weathering	Minor wear/ weathering	Moderate wear/ weathering	Major wear/ weathering	Dangerous
		.2	No crazing, tracking or fretting	Minor crazing, tracking and/or fretting	Moderate crazing, tracking and/or fretting	Major cracks, tracking and/or fretting	Complete break up
		.3	Dense	Poor texture	Open texture	Very open texture	Dangerous
		.4	Sound	Cracks in top layer	Top layer breached	Deep cracks and potholes	Top layer completely missing
		.5	Not slippery	Starting to become slippery	Definitely becoming slippery	Slippery	Dangerous
	Flagged surface	.6	No defects	Trips < 5mm	Cracked flags Trips >5mm and < 10mm	Trips >10mm and <20mm	Trips > 20mm

Continued

Table G.10 – Severity Descriptions (continued)								
No	**Item**		**Severity**					
			1		**2**	**3**	**4**	**5**
10	Expansion Joints	Asphaltic plug	.1	Sound	Minor debonding between plug and road	Moderate debonding between plug and road	Major debonding between plug and road	Dangerous
			.2	Sound	Slight loss of surface binder and aggregate	Loss of aggregate (surface penetration 20 to 50mm)	Loss of material from joint (causing holes > 50mm deep)	Missing
			.3	Sound	Minor tracking and flow of binder	Moderate tracking and flow of binder	Major tracking and flow of binder	Disintegrated
		Nosing Defects	.4	Sound	Minor cracking along nosing	Moderate cracking along nosing, some break-up	Break-up of nosing material	Disintegrated
		Elasto-meric and others	.5	Minor signs of wear	One bolt missing at cross section	Numerous bolts missing at cross section	Majority of bolts missing at a cross section	Failure due to missing bolts
			.6	Strip sealant sound	Strip sealant loose/poor, compression seal dropped and/or worn	Sealant breached, strip sealant breached	Sealant missing, strip sealant missing/out	Failure
			.7	Sound road surface adjacent to joint	Minor break up of road surface adjacent to joint	Moderate break up of road surface adjacent to joint, some debris in joint seal	Major break up of road surface adjacent to joint, significant debris in joint seal	Joint failure due to deteriorated condition of adjacent road surface
			.8	Sound fixings	Bolt sealer missing	Fixings loose	Fixings missing, plates and angles loose	Failure due to missing fixtures
			.9	Sound components	Initiation of cracking or tearing of components	Crack/tear < 20% of width of component	Crack/tear > 20% but <50% of width of component	Failure of expansion joint components

Continued

Table G.10 – Severity Descriptions (continued)

No	Item			Severity					
				1		2	3	4	5
10	Expansion Joints	Buried Joint	.10	Reasonably sound		Minor surfacing cracking	Moderate surfacing cracking	Major surfacing cracking	Failure
			.11	Sealant for induced crack is sound		Minor cracking or break up of sealant for induced crack	Moderate cracking or break up of sealant for induced crack	Major cracking or break up of sealant for induced crack	Disintegrated or missing sealant for induced crack
		Joint leakage	.12	No visible signs of leakage		Minor leakage through joint	Moderate leakage through joint	Major leakage through joint causing minor structural damage	Open joint causing major structural damage
11	Embank-ments		.1	Sound No deformation		Minor subsidence Minor deformation	Minor slip/ settlement causing slight cracking of carriageway	Major slip/ settlement causing major cracking of carriageway	Critical slip/ settlement
12	Bearings (also see **1**: Metalwork)		.1	Negligible rusting, minor weathering		Minor rusting, moderate weathering	Moderate rusting	Major rusting	Failed or seized due to rusting
			.2	Correct position		Minor offset	Moderate offset/tilt	Dislodged	Off bearing/ missing
			.3	Sliding bearing in correct position		Sliding bearing in slightly skewed (off centre) position at normal temp	Sliding bearing at end of travel in normal temperatures	Designed extent of travel at normal temperatures	Sliding bearing failed
			.4	No crazing		External crazing	External breakdown	Major breakdown (PTFE, laminations, rubber, etc.)	Complete breakdown
			.5	Sliding plate sound		Minor deformation of sliding plate	Moderate deformation of sliding plate	Major deformation of sliding plate	Bearings seized by sliding plate deformations
			.6	Bearings sound		Minor cracks	Moderate cracks or loose	Splitting and deformation	Disintegrated

Continued

Table G.10 – Severity Descriptions (continued)							
No	**Item**	**Severity**					
		1		**2**	**3**	**4**	**5**
13	Impact Damage	.1	No damage	Slight surface scoring, minor displacement of element, e.g. marking and chipping of beam faces, several bricks across arch barrel width, slight impact deformation of steelwork	Moderate displacement of element, e.g. beam slightly offset on bearings, significant number of bricks knocked out across arch barrel width, moderate impact deformation of steelwork	Severe displacement of element, e.g. beam dislodged off bearings, many bricks knocked out across arch barrel width,major impact deformation of steelwork	Knocked down,Broken, collapsing
14	Water-proofing (exclude leaks through joints)	.1	No visible sign of seepage	Minor seepage through deck/arch, etc. (slow dripping)	Moderate seepage through deck/arch, etc. (some resistance to seepage)	Major seepage (little resistance) through deck/arch, etc. causing structural damage	Non-functional Causing critical structural damage
		.2	No visible sign of seepage	Damp surface, slight water stains on soffit	Wet surface, drops of water falling and significant staining	Very wet surface and stalactites causing structural damage	Major structural damage caused by waterproofing not functioning properly
15	Stone slab bridges	.1	Sound, no defects or damage	Minor cracking	Moderate cracking but no visible displacement	Major cracking and/or displacement	Collapsed

Continued

Table G.10 – Severity Descriptions (continued)							
No	**Item**	**Severity**					
		1		**2**	**3**	**4**	**5**
16	Timber	.1	No sign of damage	Minor signs of damage	Moderate signs of damage	Major signs of damage	Disintegrated through damage
		.2	No loss of section	Minor section loss (decay less than 5% of section)	Moderate section loss causing some reduction in functionality (decay 5 to 20% of section thickness)	Major section loss causing significant reduction in functionality (decay more than 20% of section thickness)	Collapsed or collapsing
		.3	No visible signs of open joints	Joints/shakes open slightly on surface or cracked coating at joints/shakes	Open joints/shakes < 50% width of beam, in areas of low flexure or < 25% in areas of high flexure	Open joints/shakes > 50% width of beam, in areas of low flexure or > 25% in areas of high flexure	Beam separated into multiple elements
		.4	No signs of rusting or damage to fixings	Non structural bolts loose, minor corrosion of fixings	Non structural bolts missing, moderate corrosion of fixings	Structural fixings missing	Failure of element due to missed/failed fixings

The column headed 'Def' on the bridge inspection pro-forma is for the Defect Type e.g. '3.2' for masonry pointing. If there are no defects then insert '0'.

Multiple Defects on an Element

٥.٦ When an element has more than one type of defect/damage, the guidelines contained in Table G.١١ and Table G.١٢ should be used to assess its condition.

Table G.11 – Dominant Defect is Present	
Severity	When the severity of one defect is adjudged to be at least one severity category higher (see examples in Table G.13) than any other defect on the element, the Severity for the element is defined based on this dominant defect, AND Other defects do not reduce the functionality of the element beyond that caused by the dominant defect.
Extent	The extent code in this case should correspond to the area affected by the dominant defect alone.

Table G.12 – Interacting Defects, or No Dominant Defect Present	
Severity	Where the cumulative effect of several defects is adjudged to be the same as, or worse than, the effect of the dominant defect then the severity code should be reported based on the cumulative effect of all the defects on the element, OR Where no dominant defect is evident, the severity should be based on the cumulative effect of the defects the inspector feels are relevant.
Extent	The extent code in this case should correspond to the area affected by all defects considered in assessing the severity.

٥.٧ The inspector should record the worst condition for the element at all times from either dominant or interacting defects and enter the severity/extent codes on the front page of the bridge inspection pro-forma.

٥.٨ The dominant and interacting defects are described in terms of the damage to a single element. The same guidelines also apply when assessing the condition of multiple elements. For example, if one primary beam, out of a total of ١٠, has a severity of ٤ and all the others are ٢ then the severity recorded is ٤ and the extent recorded is C (i.e. ١٠% of elements), giving a condition of ٤C. However, if all the beams were in condition ٢ then the extent category would be E, giving a condition of ٢E. Some examples of interacting defects are shown in Table G.١٣.

Table G.13 – Examples of Interacting Defects					
Element		**Individual Defects**	**S/Ex**	**Interacting Effect**	**S/Ex**
1	RC Abutment	10% of concrete spalled, general corrosion of steel	3C	Extent increases; Severity does not increase, abutment is generally in compression therefore anchorage of steel not critical	3D
		15% delaminated (signifies corrosion of underlying steel)	3C		
2	RC Beam	10% of concrete spalled, general corrosion of main tensile steel.	3C	Extent increases; Severity also increases because anchorage of the tensile steel is critical to the functionality of the element	4D
		15% of main tensile steel cover delaminated	3C		
		Cracking parallel to tensile reinforcement	3B		
3	Masonry Arch	Arch ring separation (<25mm)	3E	Extent already maximum of E; Severity increases because all defects interrupt the load path and together have a significant influence on functionality	4E
		10 to 25mm of pointing lost	3E		
		Pockets of bricks missing and loose	3C		
4	Masonry Retaining Wall	Few bricks missing at base of retaining wall	3B	Extent is low due to small area of wall damaged; Severity increased because stability of bulge is directly influenced by missing bricks	4B
		Moderate bulging above missing bricks	3B		
5	Metal beam	Slight corrosion of girder weld run between web and bottom flange at mid span	2B	Extent stays the same; Severity increases because the corrosion is concentrated at the critical section of the member	3B
		Minor section loss of flange and web cross section at mid span	2B		

٥.٩ If the inspector feels that one condition entry is not sufficient for assisting maintenance management for the structure, then they can provide additional severity/extent codes, for up to three defects per element, in the multiple defects section of the bridge inspection pro-forma:

- Enter an 'M' in the Defect column (De٩ on the front page of the pro-forma to indicate that Multiple defects have been recorded for this element on reverse of the pro-forma.

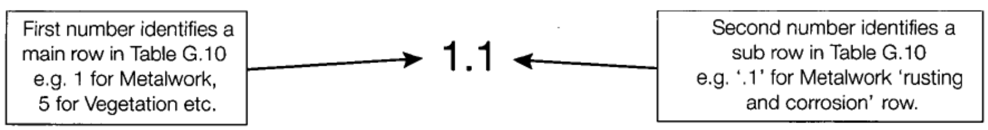
- The element number, from the front page of the pro-forma, is entered in the first column (Element No.) of the Multiple Defects section.
- The severity, extent and defect code for the most severe defect on the element are entered in the Defect ١ columns.

- The severity, extent and defect code for the defect with the next highest severity are entered in the Defect ٢ columns.
- The severity, extent and defect code for the defect with the next highest severity are entered in the Defect ٣ columns.
- Additional notes can be entered into the Comments column.

Defect Code

٥.١٠ Defect code helps in the identification of Work Required, Priority and Cost. This also provides valuable information about defect types, their frequency of occurrence and cost of repairs.

٥.١١ When the observed defect relates to a defect described in Table G.١٠ the appropriate reference should be recorded in the defect column of the pro-forma The defect code is recorded as:



٥.١٢ The severity code is not used in the defect code because it is reported for the elements in the severity column on the pro-forma. If the defect is not covered by the codes in Table G.١٠ then a description, consistent with the generic descriptions in Table G.٨, should be entered in the comments box.

٥.١٣ The inspector should record the most relevant or dominant defect. If other defects are also felt to be appropriate to work requirements (type, priority and cost) then their code/description should be entered in the comments column.

٦. OTHER ENTRY FIELDS ON THE BRIDGE INSPECTION PRO-FORMA

Comments

٦.١ Space for comments is provided on the front and back of the pro-forma. Comments should be used by the inspector to provide additional information that will be beneficial to the engineer and for the development of a computer database, e.g. clearly define if the bridge has several construction types.

٦.٢ Space is also provided for the engineer to add comments to the pro-forma. This may include an assessment of the overall condition of the bridge.

Work Required

٦.٣ Space is provided for identifying work required. The details of the information to be recorded in this area are not covered in this document and should be defined by individual authorities.

Signing Off

٦.٤ The inspector, engineer and data processing personnel must print their name, sign and date the pro-forma in the appropriate sections. The signing of the pro-forma is essential for future reference and traceability.

References

1. *Management of Highway Structures: A Code of Practice*, TSO, 2005.

2. *Highways Act 1980*, HMSO.

3. *The Roads (Northern Ireland) Order 1993* (SI 1993, No. 3160), HMSO.

4. *The Roads (Scotland) Act 1984* (SI 1990, No. 2622), HMSO.

5. *Bridge Inspection Guide*, Department of Transport et al., HMSO, London, 1984 (out of print).

6. *BD 53 Inspection and Records for Road Tunnels*, DMRB 3.1.6, TSO.

7. *The Operation and Maintenance of Bridge Access Gantries and Runways*, 2nd Edition, Institution of Structural Engineers, London, 2007.

8. *BD 63 Inspection of Highway Structures*, DMRB 3.1.4, TSO.

9. *BD 21 The Assessment of Highway Bridges and Structures*, DMRB 3.4.3, TSO.

10. *Design Manual for Roads and Bridges* (DMRB), TSO.