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Translation

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Defects in railway bridges and procedures for maintenance

Méthodes de maintenance et pathologie des ponts ferroviaires

Instandhaltungsmethoden für Eisenbahnbrücken einschließlich Schadensbeschreibung



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Summary

The present leaflet provides guidelines and recommendations covering procedures for the maintenance and strengthening of railway bridges. It includes inspection arrangements and methods, descriptions of defects, monitoring and assessment methods and maintenance, repair, strengthening and renewal procedures.

The purpose is to update the 1989 edition of *UIC Leaflet 778-4* and implement results from a European Integrated Research Project (2003-2008) on "Sustainable Bridges - Assessment for Future Traffic Demands and Longer Lives" (TIP3-CT-2003-001653) which had formed part of the 6th Framework Programme.

1 - Inspection of railway bridges and detection of defects

1.1 - General

Regular inspection is a way of constantly monitoring the day-to-day condition of structures, by noting defects as they occur and identifying the cause of any damage discovered. The structure's actual condition must be compared with the applicable benchmark.

If only minor defects have been identified during an inspection, these observations can serve as a basis for specifying and organising the necessary maintenance work.

However, in case of more extensive damage the structure must be repaired and restored to a satisfactory condition, and the cause of the damage should be investigated into and put to rights (see Fig. 1 - page 3, 2 - page 3 and 3 - page 4).

The structure must always be in a suitable condition to meet the operational requirements of rail traffic and the safety requirements applicable to the line category.

If operational parameters for the line are changed (for example heavier axle loads or higher speeds), any decision as to whether the structure needs to be strengthened or completely renewed rests upon its actual condition at the time.

Engineers must adopt the engineering solution which will cause the least disturbance to rail traffic, while making sure the overall economic feasibility of engineering work is not overlooked.

Those responsible for the project and bridge designers should give preference to structures which allow easy inspection, maintenance, repair and renewal throughout their service life.

The present leaflet shall refer to reports drafted as part of the EU project "Sustainable Bridges - Assessment for Future Traffic Demands and Longer Lives". The reports are available at the following address: <http://www.sustainablebridges.net>.

For masonry arch bridges, additional information is given in *UIC Leaflet 778-3* (see Bibliography - page 35) "Recommendations for the inspection, assessment and maintenance of masonry arch bridges".

EN 13306 (2001) (see Bibliography - page 35) is a standard which provides maintenance terminology.

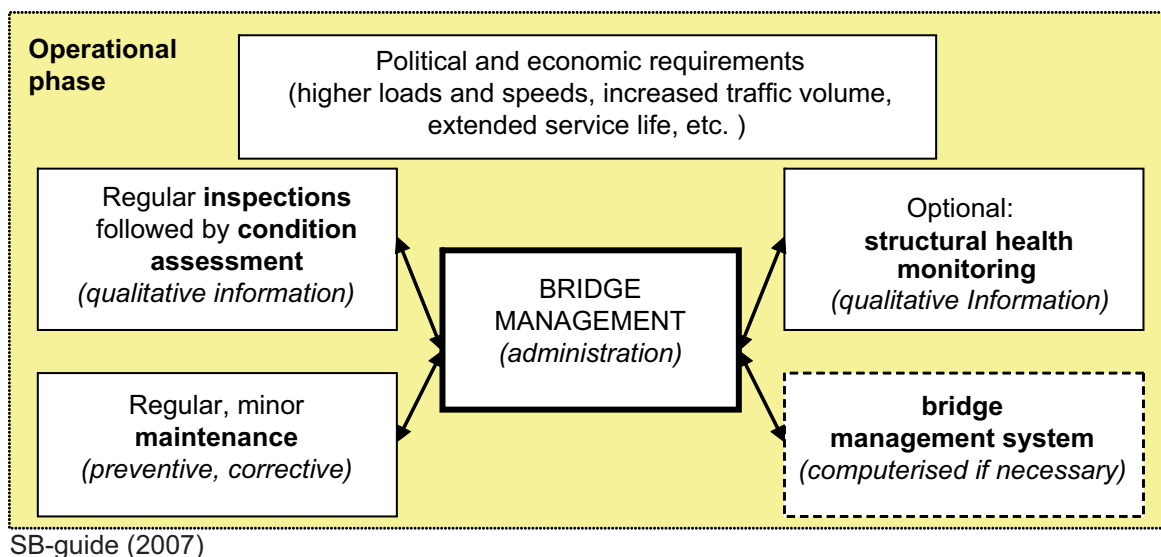


Fig. 1 - Regular operation and maintenance of bridges

If any doubts arise as to the safety, serviceability or durability of the bridge, action can be taken according to Fig. 2 and 3 - page 4.

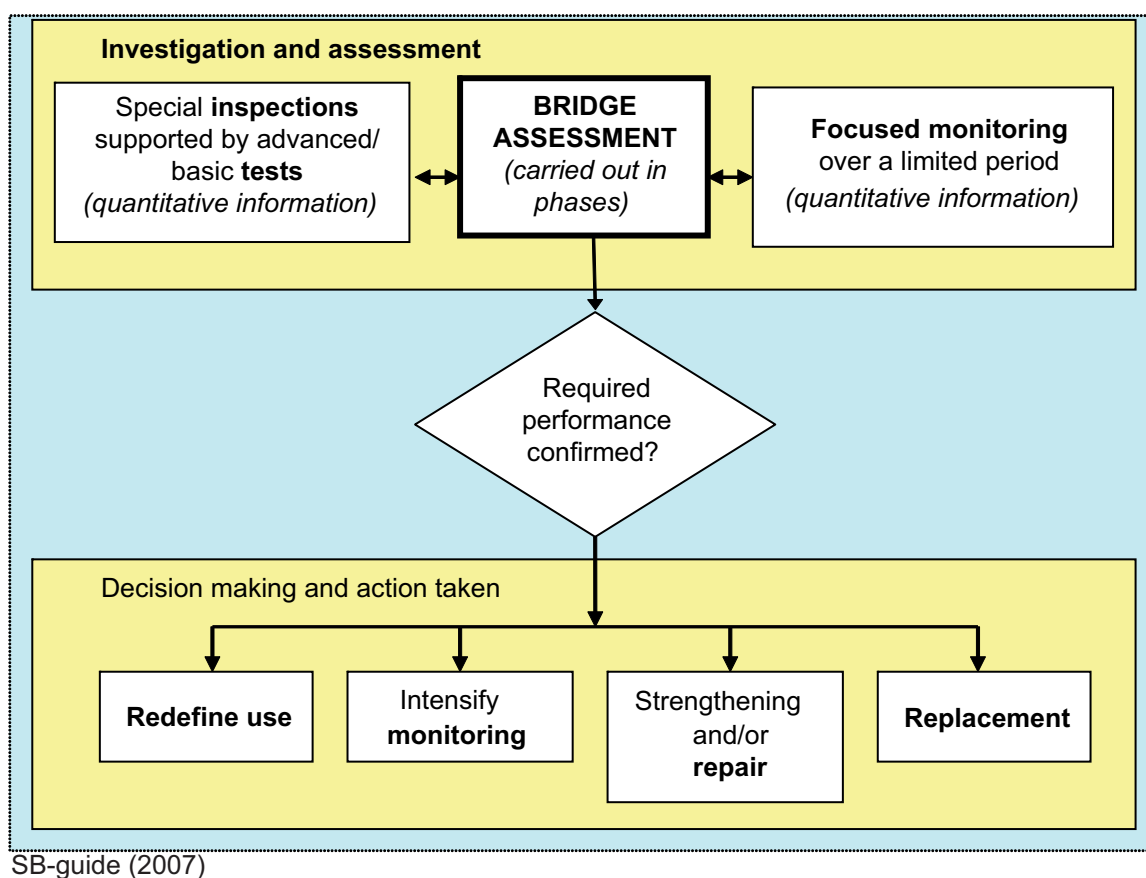


Fig. 2 - Special stage of operation and maintenance of bridges when there is a particular cause for concern regarding safety, serviceability or durability

Once decisions and action have been taken (last line in the figure), the bridge returns to regular operations and maintenance according to Fig. 1 - page 3. Fig. 3 - page 4 provides a more detailed illustration of the assessment procedure.

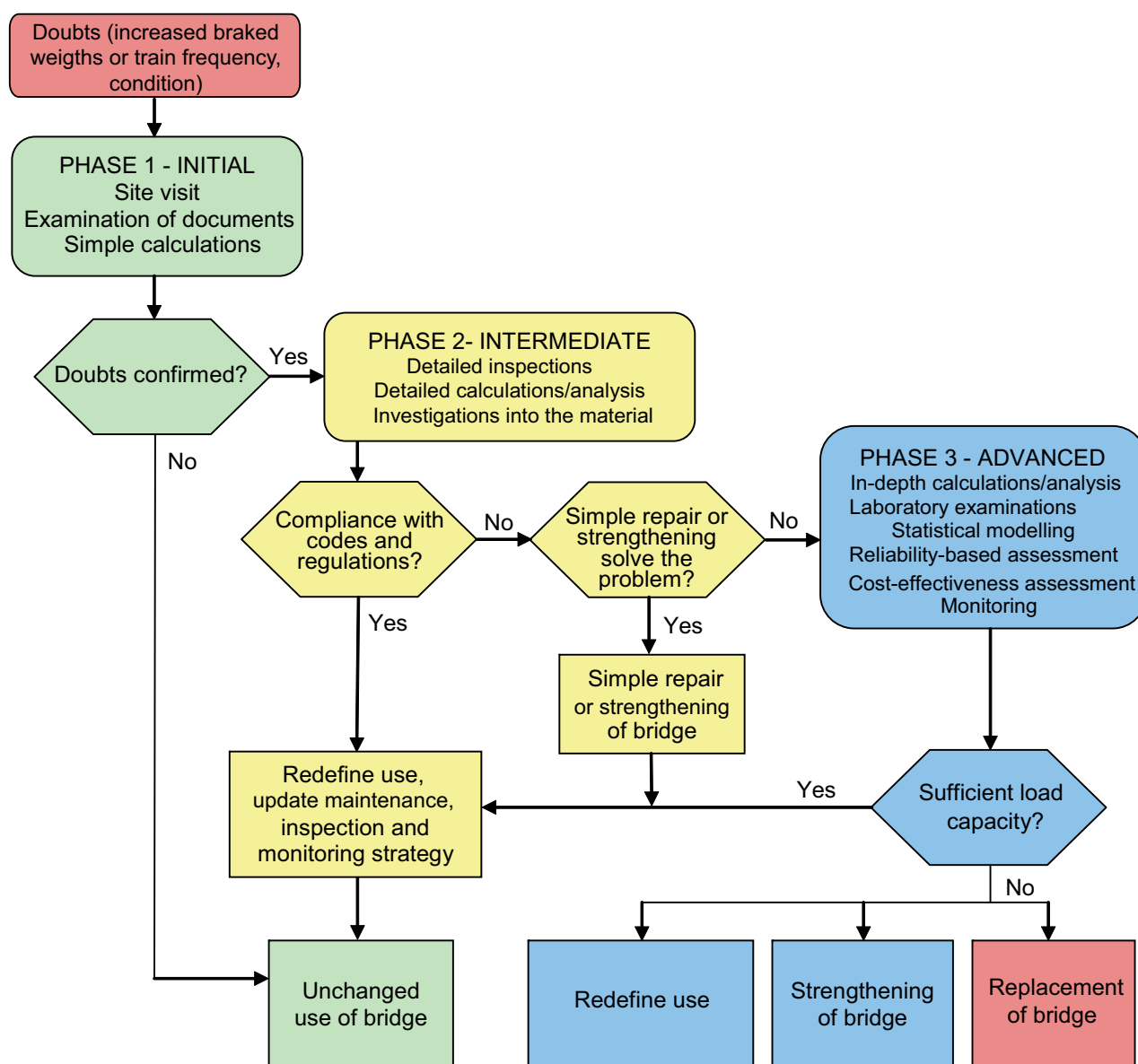


Fig. 3 - Flow chart for the bridge assessments as part of the process set out in Fig. 2, including the special stage of operation and maintenance.

There are three phases: initial (level 1), intermediate (level 2) and advanced (level 3), depending on the complexity of the issues and the extent of work required.

1.2 - Arrangements for inspection

1.2.1 - Precision and frequency

Inspections are to be carried out with varying degrees of precision and at varying frequency, depending on the type of inspection and the nature and prior condition of the structure. Apart from ordinary and ongoing monitoring of the bridge by train and track staff, a distinction is drawn between three levels of inspection:

- **Routine inspection:** Annual inspection from ground level by trained examiner.
- **Principal inspection:** In-depth visual inspection focusing on safety every (2 or) 3 years. The principal inspection may bring to light a need for further in-depth inspections, not necessarily covering the entire structure, but rather focusing on a particular component or problem area.
- **General inspection:** The most detailed inspection covering all parts of the bridge within touching distance (using a hammer to tap on concrete surfaces) takes place every 4 to 6 years. The frequency of inspections should reflect the nature of the bridge and the defects observed. In practice this means that inspection frequency varies according to bridge type and condition. The general inspection should result in a full and detailed report on the condition of the structure.

The inspection for definitive approval before the bridge enters into service or before a transfer of ownership (or following major repair work) serves as a benchmark indicating the required condition of the bridge.

Special equipment and facilities are generally required for these inspections as assistance to visual examination in locating more precisely any defects through special inspection methods.

1.2.2 - Routine inspections

The inspector must be trained and have a basic understanding of bridges.

The standard equipment includes basic tools such as hammers, cameras and lighting devices.

Foundations should be inspected at low water. See below.

1.2.3 - Principal inspections

The inspector should be aware of the methods given in point [2.2 - page 8](#).

A principal inspection consists of a visual examination of all parts of the bridge which can be accessed without the use of special equipment. All defects which are visible with the naked eye from the ground must be recorded and the condition of the structure must be classified in a particular category.

Continuous monitoring may be carried out to keep a check on particular developments or a new situation arising between two periodic inspections. Defects which are potentially hazardous to railway operations can thus be monitored between two inspections and their progression can be kept track of.

The assistance of external specialists may be necessary for such inspections.

Continuous monitoring methods are presented in greater detail in SB-MON (2007) and for masonry arch bridges in *UIC Leaflet 778-3* ([see Bibliography - page 35](#)).

1.2.4 - General inspections

General inspections should be carried out by bridge experts / engineers. They may be assisted by external specialists from the field of construction inspection with experience in bridge inspections. They should be capable not only of identifying defects but also ensuring that their development can be monitored through suitable methods to determine movement, displacement, cross-sectional reductions due to stress-induced corrosion, etc.

A basic assessment of the load capacity of the bridge may be carried out in conjunction with the inspection. The most frequent causes of damage should be recorded. The inspection report should also indicate whether repair work, further inspection or monitoring and traffic restrictions are required.

Suitable means of access to the various parts of the structure, ranging from ladders to special scaffolding, should be arranged. Depending on the topography, the features of the structure to be inspected (length, height, etc.) and the specific requirements of the railway concerned, these devices may be divided into the following categories:

- *For very long viaducts* spanning inaccessible terrain, it may be more cost-effective at construction stage to equip the structure with an inspection platform; in case of an inspection device only brought on site temporarily for an inspection, the structure should have rails on which the device can run.
- *Rail-mounted / lowering platforms.* This equipment is mounted on a rail vehicle and has an inspection platform at its outer end, with a system of hydraulically-operated articulated arms that can be controlled and operated either from the platform or from the vehicle.
- These units can be used for full inspections using only one line of a double track section. They are accompanied by an inspection vehicle.
- *Lifting platforms mounted on rail, road or road/rail vehicles.* These platforms are mounted on a rail vehicle, road vehicle or road/rail vehicle are usually equipped with telescopic arms. Controls are located either in the inspection platform itself or in the driver's cab of the rail, road or road/rail vehicle.

Examples of methods are provided in point **2.2 - page 8**, in *SB-MON (2007)*, chapter 7 "Monitoring tool-box" and, for masonry bridges, in *UIC Leaflet 778-3*.

Special investigations, such as the analysis of dynamic behaviour, mineralogical and microscopic analyses to diagnose material conditions, ultrasonic testing or radiography for cables, are to be carried out with the assistance of experts.

Preparations should be made beforehand to facilitate inspection, for example:

- cleaning of areas supporting the bearings;
- installation of scaffolding;
- removal of certain elements to facilitate inspection of main structural components;
- for piers and foundations it may be necessary to use divers.

1.2.5 - Documents

Documents such as design drawings, geotechnical surveys, calculations, construction documents and the transfer/approval documentation of the structure provide basic input for inspections. The documents should be available for the inspections in paper or digital form (e.g. on a laptop computer).

The reports of subsequent inspections should be based on previous reports and prior surveys of the actual condition of the structure, and take into account damaged or weak areas in parts of the structure and the development of damage since its initial detection.

Details should also be given of the maintenance work required in the short and long term, together with any operations carried out since the last inspection.

2 - Defects in existing bridges

2.1 - Definitions

Appendix A - page 28 provides a list of definitions and notations.

2.2 - Detection and measurements of defects

2.2.1 - Overview of methods and equipment

- Visual inspection.
- Detection and monitoring of cracks of all kinds by means of crack width gauges, indicators fixed onto the structure, ultrasonic equipment, extensometers, etc.
- Measurement of deformation under static and dynamic loads, measurement of progressive deformation, measurement of bearing reactions and twisting.
- Levelling.
- Analysis of dynamic behaviour (seismograph or vibration sensor).

The following examples of available methods are provided in *SB-ICA (2007)*, Table 5.2 (see [Bibliography - page 35](#)) also contains a toolbox for non-destructive testing (NDT) methods with a one-page summary of each method explaining its merits and drawbacks. The context in which the tool box was developed is described in Helmerich et al. (2007, 2008a, b). Methods for masonry arch bridges are provided in *UIC Leaflet 778-3*.

Table 1 : Overview of methods and equipment

Visual and simple methods	
External visual inspection	External visual inspection, usually performed systematically as part of monitoring, limited by human factors.
Internal visual inspection (endoscope)	Internal visual inspection with devices (endoscopes) through holes in hidden or covered parts of steel or concrete structures, experience required, inspection limited by the length of the cable.
Void volume measurement	Evaluation of the size of hollows by injecting air into bore holes.
Air (torrent) permeability	Fluid or air permeability of concrete surfaces as measurement of durability.
Concrete cover measurement	Depth of reinforcement in concrete structure, thickness of concrete cover, reliable equipment available on the market.
Roughness depth test	Investigation of concrete surface roughness.
Liquid penetrant test	Surface cracks in welds of steel structures.
Sclerometric test	Hardness of young concrete. From Greek <i>skleroo</i> , harden.
Hardness	Hardness of steel.

Thermographic procedure	
Transient (active) thermography	Debonding of tiles, plaster, mortar, carbonfibre reinforced polymers (CFRP), determination of humidity/ moisture content.
Pulse-phase thermography	Debonding, near surface voids with optimised contrast.

Acoustic, electric and electromagnetic methods	
Acoustic emission (AE)	Detection of growing active cracks.
Modified acoustic emission	Monitoring of active cracks in laboratory, for search of active cracks through modified AE.
Pile integrity testing	Pile length, integrity.
Parallel seismic method	Pile / sheet depth.
Seismic bore hole method	Soil probing method: scouring, excavation, parameters, consolidation beneath embankments.
Ultrasound method	Material quality in foundations.
Impulse-radar echo	Localisation of rebars and tendon ducts, hollows, areas with different dielectricity constants, thickness of concrete.
Radar tomography (concrete)	Thickness of concrete elements, localisation of rebars and tendon ducts, access generally required from both sides.
Radar interference	Micro radar for contact-free deformation and displacement measurement, incl. through interference caused by traffic.
Electrical conductivity (SIP)	Localisation of humidity, examination of rebars and tendon ducts.
Electromagnetic induction (residual magnetism)	Cracks in tendon wires (slightly destructive).
Impulse-radar echo (masonry)	Cracks from loads, surface cracks due to lack of bond in arches with several layers, spandrel wall separation, spalling or mortar loss.
Radar tomography (masonry)	Filtering, inner cracks due to traffic, freeze-thaw-cycling, hollows, moisture (at development stage).
Ground penetrating radar	Evaluation of layers and voids in embankments and subsoil.
Radar scouring	Scouring around stream piles.
Electrical conductivity (SIP, masonry)	Moisture content, backfill type and quality (at development stage).
Electrical conductivity (SIP, ground)	Moisture, soil type.
Galvanostatic pulse	Corrosion state of reinforcement, properties of cover concrete (moisture, deteriorations).
Linear polarisation	Corrosion state of reinforcement, concrete cover thickness (moisture, deterioration).

Acoustic, electric and electromagnetic methods

Sliding collar	Inspection of the integrity of steel cables on cable-stayed bridges.
Ultrasonic-echo (US-echo) Dry coupling using US-array	Thickness measurement, localisation of reinforcement or tendon ducts, delamination, hollows, inhomogeneities in RC.
Ultrasonic transmission tomography	Localisation of reinforcement or tendon ducts, inhomogeneities in the concrete (access required from both sides).
Impact echo (concrete)	Thickness measurement, localisation of reinforcement or tendon ducts, delamination, hollows, inhomogeneities.
Impact echo (concrete)	Investigation of crack depth (special use of IE).
Ultrasonic-echo	Residual thickness of mild and modern steel plates (not for wrought iron), weld defects, parallel to the surface, surface, crack depth, inhomogeneities.
Ultrasonic-phased array	Weld defects, inhomogeneities, corrosion mapping (established by industry).
Ultrasonic transmission	Inclusions and segregations in mild and modern steel plates (not for wrought iron).
Eddy current inspection	Cracks in the basic material of riveted structures (only in very thin steel plates), cracks in rivet holes (only after removal of the rivets).
Magnetic particle test	Detection of short cracks in magnetic steel on or near the surface.
Combined ultrasonic inspection	Ultrasonic velocity (transit time tomography), residual stress in rivets, integrity of rivets.
Ultrasonic-echo (masonry)	Detection of deterioration.

Radiographic methods

Radiography with gamma rays Iridium (steel)	Detection of cracks in hidden elements and inhomogeneities in steel elements or connections (welds), access from both sides required.
Radiography with gamma rays Cobalt (concrete)	Detection of voids in RC, localisation of reinforcement and tendon ducts.

Spectral-chemical and potential methods

Electrical potential field measurement	Corrosion state of reinforcement.
Laser-induced breakdown spectroscopy	Analysis of chemical elements of concrete on and near the surface.
Sparkle emission spectroscopy	Spectroscopic analysis of chemical elements of steel.
Sulphur print (slightly destructive)	Chemical analysis to determine steel / cast iron characteristics.