Guidelines for strengthening of railway bridges

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ABSTRACT: In the international project "Sustainable Bridges", one of the deliverables is a design guide for strengthening of bridges. This paper gives the reader a first look into this guideline which can be found at the projects website: www.sustainablebridges.net

1 INTRODUCTION

The Integrated Research Project "Sustainable Bridges - Assessment for Future Traffic Demands and Longer Lives" was funded by the European Commission within 6th Framework Program and has been carried out between the years 2004 and 2007. The Project aimed to help European railways to meet increasing transportation demands, which can only be accommodated on the existing railway network by allowing the passage of heavier freight trains and faster passenger trains. This requires that the existing bridges within the network have to be upgraded without causing unnecessary disruption to the carriage of goods and passengers, and without compromising the safety and economy of the railways.

A consortium, consisting of 32 partners drawn from railway bridge owners, consultants, contractors, research institutes and universities, has carried out the Project, which has a gross budget of more than 10 million Euros. The European Commission has provided substantial funding, with the balancing funding has been coming from the Project partners. Skanska Sverige AB has provided the overall co-ordination of the Project, whilst Luleå University of Technology has undertaken the scientific leadership.

The Project has developed improved procedures and methods for inspection, testing, monitoring and condition assessment, of railway bridges. Furthermore, it has developed advanced methodologies for assessing the safe carrying capacity of bridges and better engineering solutions for repair and strengthening of bridges that are found to be in need of attention.

2 GUIDELINES FOR REPAIR AND STRENGTHENING OF RAILWAY BRIDGES

The purpose with the developed guideline is to assist the railway owners when deciding necessary strengthening measures for railway bridges of concrete, steel or masonry. In addition also possible strengthening measures for the subsoil are discussed. When a structure is strengthened, this is usually done in the ultimate limit state (ULS). However, many of the strengthening methods that are described in this document will also be applicable when measures are needed in the serviceability limit state (SLS), for example decreased crack sizes for concrete structures or increased stiffness for structural components. A new idea denoted a "Graphical Index (GI)" is used. The GI takes the standpoint in a structure or a structural member. The reason for strengthening is highlighted in a figure and Method Descriptions for each method to solve the problem are referred to. In addition to this, Case Studies are connected to the method when possible. It needs to be stressed that a purpose has been to create a live document that should be easy to upgrade and that it also should be possible to add new components to the guideline.

The guideline is divided into Graphical Index document, Method Description documents and Case Study documents. Method descriptions give detailed description of the strengthening method referred to, equipment used, benefits and drawbacks and a cost estimate of the method. In the case studies different field applications of the method descriptions are presented.

How the graphical index should be used is also demonstrated. The method description and the case studies follow a template and it would be easy to add new methods or case studies to the guideline following these templates. However, when adding new strengthening methods it is suggested that an expert within that area is consulted.

2.1 *Repair and strengthening of structures*

To repair or strengthen existing structures is a complicated task. Mainly due to the fact that the conditions are already set and that there often can be complicated to decide the underlying reason for the strengthening need. In addition to this strengthening is mostly carried out for improved load carrying capacity in the ultimate limit state but a structure is almost only loaded in the service limit state, which here also includes fatigue and durability limit states. This means that the strengthening needs and design must be based on theoretical assumptions that might be difficult to verify. Despite this, there is a quite good understanding how structures behave with different strengthening measures. In this section a general discussion regarding repair and strengthening philosophy is made, discussion the connection to safety.

To consider the original design is always important, in particular for older structures that used other guidelines and codes than today. The original design forms the base in the strengthening need and here also all existing documentation and history for the structure should be considered when applicable. The next step is to consider the material in the structure and the material that are added after strengthening. Is the old and new material compatible or not? For example must composite action be obtained to transfer the forces from the structure to the strengthening? Preferably we should be able to choose between different repair and strengthening methods and hence choose the most suitable one for the structure or component studied. Important is also to consider environmental issues, are we using the most possible environmental friendly products? Furthermore, the aesthetics and life cycle aspects must also be considered. Do we obtain a better appearance after strengthening and most important do we prolong the life and performance of the structure. Wrong choice of method might decrease the life.

For all methods the cost must be considered and the cost should take in consideration the desired function and the remaining expected life of the structure.

In complicated cases tests may be needed and systems to follow up the strengthening structure over time introduced. Often these programs can be a combination of measurements and physical inspections, where the physical inspections are carried out more often the first years after completion.

Most complicated is always to decide the condition of the existing structure. However, for complicated cases it is very important that a proper assessment is carried out. This assessment should be a combination of testing, site investigations and theoretical calculations.

As earlier mentioned, all structure need a minimum level of performance to function as intended. However, all structures deteriorate over time. The deterioration process can in its simplest way be explained by the curve in Figure 1. When the structure is built it has its original performance or safety. After some time we have reach the actual performance at level A, the deterioration process continues and at B we have reach the lowest acceptable performance or safety level. If no measures are taken at this point the structure or component has reached its end of life and need replacement.

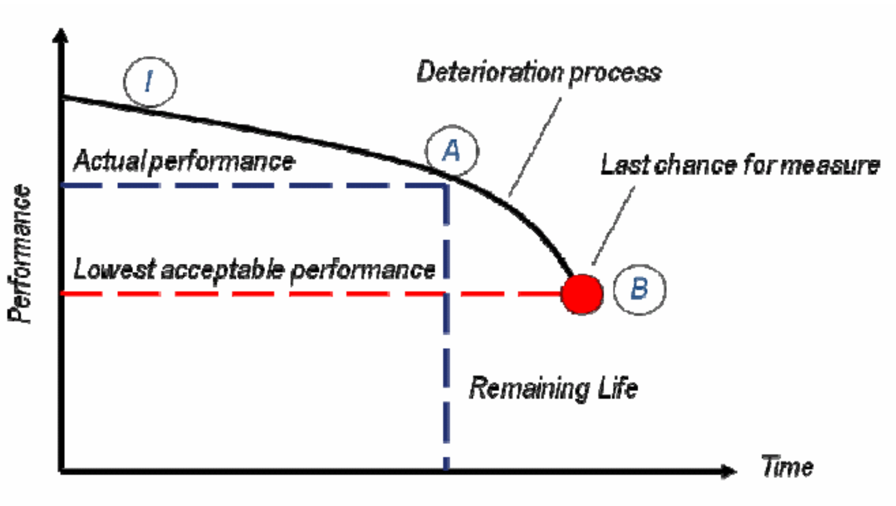

Figure 1. Philosophy regarding deterioration of structures

However, if we instead upgrade the structure at time B we reach a new performance or safety level, see Figure 2. The deterioration process will continue and new upgrading are often needed. Also upgraded structures will eventually reach their end of life and need replacement, this is illustrated by the point D in Figure 2. Thus, it is important to choose the most suitable method when a structure or component is going to be upgraded.

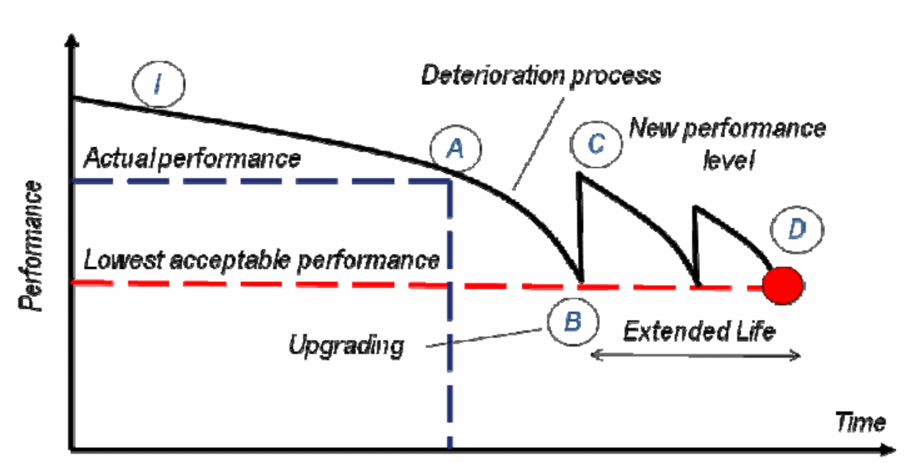

Figure 2. Upgrading of performance or/and safety

Which method that is most suitable will vary from object to object. If upgrading in general is discussed and in particular for concrete structures the principles for upgrading is shown in Figure 3.

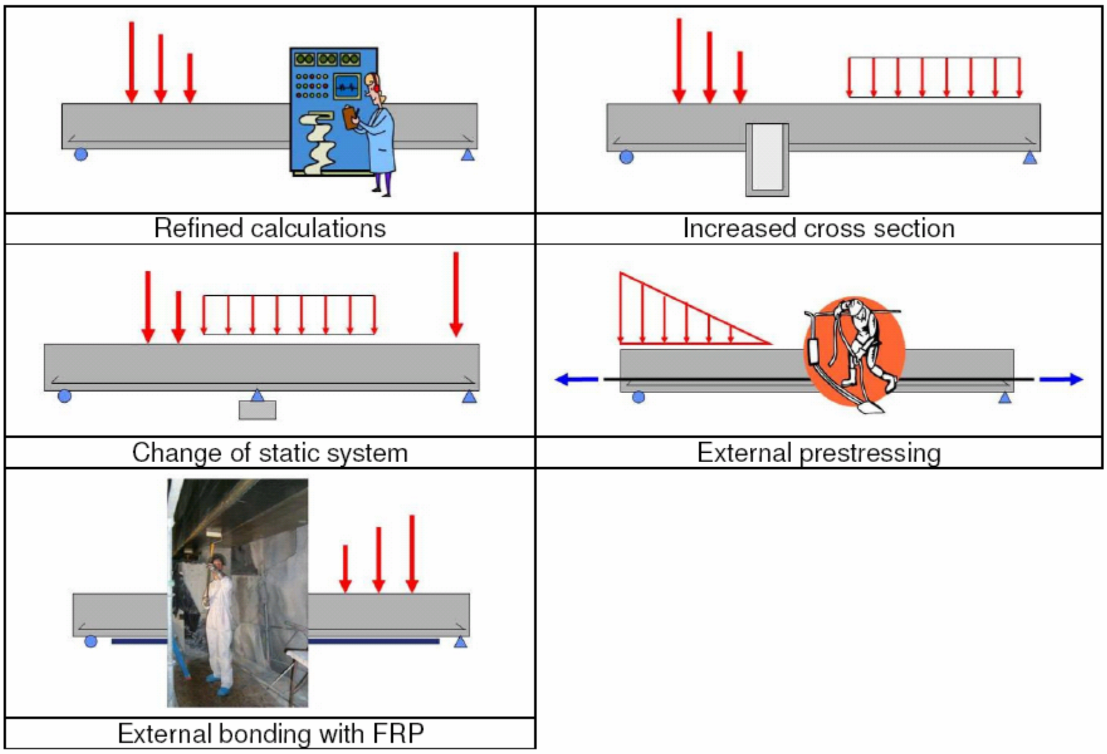

Figure 3. General upgrading methods

Often most economical is to carry out what can be denoted a refined calculation where more detailed calculation tools are used, for example FE-analysis and considerations to real material data and structural dimensions are taken. However, other methods to upgrade a structure might be increased cross section, which is a common method for concrete structures bt can also be used for steel structures by welding additional steel parts to the structural member. Sometimes it might be possible to change the static system for the structure, transfer the loads into other parts that then can take up the new loading. For concrete structure, but also for metallic structure, external prestressing can be a suitable method to increase the load carrying capacity. Here a axial, positive or negative, load is introduced to the structure by prestressing. Building components can also be upgraded by external bonding of composite materials. Concrete as well as metallic, masonry and timber have been strengthening by this method. The method is considered relatively new in the building industry even though it has been used during the last decade quite frequently.

Primarily since it was found that the knowledge and experience about traditional methods are high, but also due to the reason that the knowledge and experience regarding FRP strengthening of railway bridges is small. Nevertheless, to be able to choose the most suitable strengthening method for a railway bridge a clear structure should be followed. It was found that a structured approach for strengthening applications was missing. Therefore, a large amount of work was placed on developing a structured methodology for strengthening of existing railway bridges. This structure has been denoted “Graphical Index”. To the graphical index, Method Descriptions and Cases Studies are connected.

3 METHOD DESCRIPTIONS

3.1 *General*

The strengthening methods studied within the project are presented in the guidelines in a table format with one table for each method. Each method is named MD followed by a number #. The date when the method description was made is stated. Each table comprises a number of sections.

3.2 *Objectives*

Each method described can be used for different reasons. In the guideline it is stated for what purposes the strengthening method can be used. A structure can be repaired up to its original performance level or be in need of upgrading. Normally, repair or strengthening measures are applied in the ultimate limit state. A structure can also be taken care of due to serviceability or comfort, e.g. mean deflections or vibrations. Structural safety is included in structural repair and upgrading. In the section for objectives, Safety is related to redundancy or improvement of ductility.

3.3 *Method Descriptions available in the design guide*

Concrete Bridges:
- MD001 Adhesively Bonded CFRP Plates to Concrete Structures
- MD002 Adhesively Bonded CFRP Sheets to Concrete Structures
- MD003 Strengthening of Concrete Structures with Mineral Based Composites
- MD004 Near Surface Mounted Reinforcement (NSMR) to Concrete Structures
- MD005 External Prestressing of Concrete Structures

Metallic Bridges
- MD101 Adhesively Bonded CFRP Plates to Metallic Structures
- MD102 Adhesively Bonded CFRP Sheets to Metallic Structures
- MD103 External Prestressing of Metallic Structures
- MD104 External Prestressed CFRP Plate

Masonry Bridges
- MD201 Adhesively Bonded FRP Plates to Masonry Structures
- MD202 Adhesively Bonded FRP Sheets to Concrete Structures
- MD203 Strengthening of Concrete Structures with Mineral Based Composites
- MD204 Near Surface Mounted Reinforcement (NSMR) to Masonry Structures

Subsoil and Foundation
- MD301 Deep Mixing
- MD302 Jet Grouting - Subsoil
- MD303 Sheet Pile Walls/Stabilising Berms
- MD304 Compacting Grouting
- MD305 Embankment Piles
- MD306 Jet Grouting - Foundation
- MD307 Compaction Grouting
- MD308 Shaft Grouting and Base Grouting

REFERENCES

Carolin, A. & Täljsten, B. 2007, Repair and strengthening of railway bridges - Guideline, Deliverable SB6,1. (www.sustainablebridges.net)