Results and Experiences from European Research Projects on Railway Bridges

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Abstract

Starting in 2003 the European Union has funded three consecutive research projects dealing with maintenance, life length, capacity and repair/strengthening of railway bridges. The main results are that many bridges are capable of carrying increased loads and can have an increased service life if up to date technologies are used for assessment, monitoring, maintenance and strengthening.

In order to obtain good value for the money spent in the projects, it is important to plan, coordinate and manage the projects in an efficient way. Long range projects of four years seem to be more effective than shorter projects of two and three years.

Keywords: Railway bridges, Assessment, Evaluation, Modelling, Monitoring, Full scale tests to failure, Maintenance, Strengthening, Life Cycle Costs (LCC), Life Cycle Assessment (LCA).

1 Introduction

1.1 Background

Growth in demand for rail transportation across Europe is predicted to continue with roughly a doubling of passenger and freight demand by 2050 [1]-[4]. Much of this growth will have to be accommodated on existing lines that contain old infrastructure. As an example the development of maximal axle load is illustrated in Figure 1. This growth in demand will increase both the rate of deterioration of these elderly assets and the need for shorter line closures for maintenance or renewal interventions. The impact of these interventions must be minimized and will also need to take into account the need for lower economic and environmental effects. New interventions will need to be developed along with additional tools to inform decision makers about the economic and environmental consequences of different intervention options being considered.

Figure 1. Development of maximal axle load in the world (triangles), Europe (full yellow line) and for the Iron Ore line in northern Sweden (brown squares) from 1890 with indicated trend to 2050 (dashed line). From C4R [5], [6] based on KTH Railway Group (Fröidh-Nelldal).

With this background the European Commission has funded three research projects dealing with railway bridges. In the paper some main results, conclusions and experiences from the three projects will be presented.

1.2 Important Actors

An important player is the European Committee for Standardization, CEN. They have recently started to work on a Eurocode for assessment of existing structures [7] and input to their work has been given by the European research project outputs discussed here.

Other important actors in the railway sector are the International Union of Railways (UIC) and its Panel of Structural Experts (PoSE), which has an active interest in the management of bridges. The PoSE is mainly working on the following items:

- The engineering of existing bridges, tunnels and earthworks
- Maintaining the current knowledge of railway specific sciences and upgrading UIC leaflets
- Support of CEN activities in the field of civil engineering structures for railways, especially
 - regarding dynamic and aerodynamic influences
 - regarding the exceeding of rolling stock masses of existing load models
- Preparing basic research projects to understand and develop the basics of future railway requirements

The European Rail Research Advisory Council, ERRAC, also gives input to rail research and has published Strategic Rail Research and Innovation Agendas [2] - [4].

Now much of the interest is focused on the new European Joint Undertaking Shift 2 Rail [8]. Shift2Rail will seek focused research and innovation (R&I) and market-driven solutions by accelerating the integration of new and advanced technologies into innovative rail product solutions. Through the R&I carried out within this Horizon 2020 initiative, the necessary technology will be created to establish a Single European Railway Area (SERA) [9]

The experience from the earlier projects reported in this paper can be useful in this undertaking.

2 Sustainable Bridges

The first project, Sustainable Bridges, was an integrated research project within FP6 carried out over 4 years between 2003 – 2007, with 32 partners from 12 countries and with a budget of more than 10 million Euros [10]. It developed some 35 background documents and four comprehensive guidelines containing many practical examples of useful methods:

- *Inspection and Condition Assessment*, 259 pp, [11]
- *Load and Resistance Assessment*, 428 pp. [12]
- *Monitoring*, 92 pp. [13]
- *Repair and Strengthening Methods*, 134 pp. [14]

As an example a flow chart for a step-wise assessment of a bridge is shown in Figure 2 based on the guideline [12]. In an initial phase simple

technical and economical evaluations are made including a site visit and studies of existing documents and rough cost estimations for a new bridge. In the intermediate phase a more thorough evaluation is made with checking material properties, making simple models and maybe some site testing together with more thorough economical examinations. In the third enhanced phase, still more advanced evaluations are made. If sufficient capacity can be shown, then the bridge may be kept in use, whilst, if the capacity is not good enough, the bridge may be strengthened/repared, or, in the worst case, exchanged (if a Life Cycle Cost Analysis shows that the costs of maintaining the bridge are too high when compared to the costs of a new bridge). Similar well-structured charts are also given in [7] and in ISO 13822:2010 [15]. Improvements to the chart to include provision for Finite Element Modelling have been proposed by Plos et al [16].

Figure 2. Flow chart for an assessment procedure of a bridge in three steps. Based on Sustainable Bridges [12].

The project also undertook full scale tests of real bridges in Finland, France, Poland, and Sweden. The results from one of them showed that the actual capacity of a trough bridge was about eight times the load it was designed for, see Figure 3.

Figure 3. Test to failure of a concrete trough bridge in northern Sweden showed that it could carry 8 times the load it once was designed for, [17]- [19]

So there is a hidden capacity in many bridges but bridge owners lack good Life Cycle Cost Analysis Tools to show the benefit of using such an approach. To remedy this obstacle was one of the main objectives of the next project, MAINLINE.

3 MAINLINE

The second project, MAINLINE, was carried out as part of FP7 during the 3 years between 2011 – 2014, with 20 partners from 12 countries and with a budget of 4,4 million Euros. Of this, about one third was devoted to bridges whilst the remainder was used for tunnels, track and other infrastructure [20].

It can be seen that not many Infrastructure Managers currently use Life Cycle Costing (i.e. financial) and/or Life Cycle Assessment (i.e. environmental) in the planning of maintenance and repair of their rail infrastructure. There is a lack of data and methods and here the MAINLINE project has given some guidance. There is also often a lack of economic resources for maintenance which may lead to a shorter service life and less sustainability than would otherwise

be the case; results from the MAINLINE Project are also intended to give advice that may help to improve this situation [20].

Guidelines were published for

- *New technologies to extend life*, 146 pp. [21]
- *Degradation indicators*, 200 pp. [22]
- *Replacement of infrastructure*, 121 pp. [23]
- *Life Cycle Assessment Tool*, 125 pp. [24].

Not replacing bridges unnecessarily may save some 180 M€ per year in Europe [25]. Data on Life Cycle Assessment of bridges can also be found in [26].

A steel truss bridge was tested to failure to check if fatigue was a major problem as was indicated by a traditional assessment, see Figure 4. However, no fatigue cracks appeared and the bridge failed due to buckling of the top boom of one of the main truss girders at a load about twice as high as was predicted based on the design parameters [27], [28].

Figure 4. Preparation for the test of a steel truss bridge on the northern Swedish main line at Åby River.

4 Capacity for Rail, C4R

The third project, Capacity for Rail, is a 4 year project that started in 2014 with 46 partners from 13 countries and a budget of 15 million Euros, out of which about ten percent is devoted to bridges while the main part is used for other infrastructure, for freight operation, monitoring and migration [5].

In C4R a deliverable concerning upgrading of lines has been produced [6]. The reason is that very few recently built railway lines are constructed specifically for freight traffic. The trend today is that new lines are constructed for high-speed passenger operations, meaning that the capacity freed up on the bypassed lines can be used to accommodate more freight and regional traffic. These existing lines were however built for the traffic demands at the time of construction. This means that lines need to be upgraded in order to meet the new demands from increased freight operations that also often have different characteristics to the freight traffic that existed before the transition. Consequently upgrading of existing lines is, and will continue to be, an important activity to meet future demands from industry and society.

At the same time freight operators often propose enhanced operations (e.g. longer trains, increased axle loads, higher speeds, more frequent operations). However, these are commonly not

realised due to infrastructure limitations. The experience from countries where upgrading has been undertaken to permit enhanced operations is that there are limitations to what can be done, but that it is possible to overcome and/or circumvent these limitations. Therefore, it is important that upgrading is carried out in a systematic manner and that state-of-the-art knowledge is employed.

Several Research & Development projects have increased the knowledge and understanding, and introduced tools to handle upgrading. This has enabled demands from freight operators to be met in an environmentally friendly and more cost efficient manner. Therefore several EU-projects carried out during the last 10 years together with findings from C4R provided input to enhance methods of upgrading freight lines.

The impact of different traffic situations on different types of structures is illustrated in Table 1

Table 1. Impact of different traffic situations on different types of structures according to C4R, [6]

Type of structure/ Traffic situation	Bridges	Tunnels	Culverts	Retaining walls
Longer trains	Some impact	No impact	Some impact	No impact
Increased trail weight	Some impact	No impact	Some impact	No impact
Increased axle loads and meter loads	Great impact	No impact	Great impact	Some impact
Higher speeds on freight trains	Little impact	No impact	Little impact	Little impact
Increased loading gauges	No impact	Great impact	No impact	No impact

5 Other Research Projects

Other European Research Projects dealing with bridges have been Bridge Management In Europe, BRIME, 1998-99, [29], Pantura, [30] and Smart Rail, [32]. Ongoing projects study the load-carrying

capacity of a prestressed bridge [32], proactive maintenance of bridges [33] and a US-European cooperation 2015-2017, Infravation [34].

6 Discussion

In order to facilitate the increased transportation demands from society and industry in an environmentally friendly and cost efficient way a better understanding of possibilities and limitations was necessary. This has been done in the following ways;

- Better understanding of real structural behaviour of bridges by full scale tests to failure. This has been performed on a couple of bridges. They all showed that the bridges had excellent load-carrying capacities.
- Codes for new built bridges used to assess existing bridges gave very conservative estimates of the load carrying capacity. Findings from the tests undertaken enabled the calibration of advanced finite element models which could describe the behaviour of the bridges much more accurately.
- One steel bridge was according to the code calculations deemed to be past its service life. However, the test showed that no fatigue cracks were critical and the actual failure of the bridge was buckling of the top boom of one of the two main truss beams.
- Corrosion of prestressing beams may be a problem. However, on two 50 year old bridges in northern Sweden no severe corrosion was observed, [17], [31].
- Life Cycle Assessment methods have been developed. Their use could save money and reduce environmental impact for infrastructure managers.

A general remark is that consultants and contractors often are most interested in testing methods they have already developed and want to use in railways. Such processes often have a high Technology Readiness Level (TRL). They are often not quite as keen to engage in long range basic research with a lower Technology Readiness Level.

Another remark is that projects with a life of say 4 years tend to produce more new results than

shorter projects of 2-3 years. This is probably due to the fact that it takes quite some time to get a project rolling and when everything finally works, it is soon time to finish up.

It is important to run the project in an efficient way and to monitor progress of work closely at least every third month. Relocating of funds to where they are best needed must often be undertaken although this might not be a popular action. The active participation of infrastructure owners/managers is important in keeping researchers focussed on project aims rather than following interesting research diversions.

The results should be included in the new Euro code on assessment [7] in order to give a uniform backbone for keeping infrastructure in service for longer time in a safe and cost efficient way.

7 Conclusions

The main results of the projects discussed are that many bridges can carry increased loads and can have an increased service life if up to date technologies are used for assessment, monitoring, maintenance and strengthening. In order to obtain good value for the money spent in the projects, it is important to plan, coordinate and manage the projects in an efficient way.

8 Acknowledgements

The Sustainable Bridges partners were by country: *Czech Republic*: Cervenka Consulting; *Denmark*: COWI A/S (Jens Sandager Jensen, WP 4 Leader); *Finland*: Finnish Road Administration, Finnish Rail Administration, University of Oulu, WSP Consulting – Kortessalo (Risto Kivilouma, WP 8 Leader); *France*: Société Nationale des Chemins des Fer Français, SNCF, Laboratoire Central des Ponts et Chaussées, LCPC (Christian Cremona, WP 7 Leader); *Germany*: Deutsche Bahn AG, Bundesanstalt für Materialforschung und prüfung, BAM (Ernst Niederleithinger, WP 3 Leader), Universität Stuttgart, Rheinisch-Westfälische Technische Hochschule; *Norway*: NORUT Technology A/S; *Poland*: PKP Polish Railway Lines, Wroclaw University of Technology (Jan Bien, WP 9

Leader); *Portugal*: Universidade do Minho; *Spain*: Universitat Politècnica de Catalunya, UPC; *Sweden*: Skanska Sverige AB (Jan Olofsson, Coordinator, and Hans Hedlund, Ass. Coordinator), Banverket - Swedish Rail Administration (Björn Paulsson, WP 2 Leader), Vägverket - Swedish Road Administration, LTU (Lennart Elfgrén, Scientific Leader; Björn Täljsten WP 6 Leader), Chalmers University of Technology, Royal Institute of Technology, Lund University of Technology, Swedish Geotechnical Institute, Sto Scandinavia AB, Designtech AB; *Switzerland*: Eidgenössische Materialprüfungsanstalt, EMPA (Glauco Feltrin, WP 5 Leader), Ecole Polytechnique Fédérale de Lausanne, EPFL; *United Kingdom*: Network Rail (Brian Bell, WP 1 Leader), City University, and University of Salford.

The MAINLINE project partners were by country: *Austria*: Graz University of Technology; *Czech Republic*: Skanska a.s.; *Denmark*: COWI; *France*: ARTTIC, Cerema/SETRA and UIC (Björn Paulsson, project coordinator); *Germany*: Deutsche Bahn Netz AG; *Hungary*: MÁV Magyar Államvasutak Zrt; *Portugal*: University of Minho; *Spain*: COMSA EMTE and Universitat Politècnica de Catalunya; *Sweden*: Damill AB, Luleå University of Technology (LTU, Technical Coordinator), and Trafikverket; *Turkey*: TCDD; *United Kingdom*: Network Rail Infrastructure Limited, Jacobs/Sinclair Knight Merz (SKM), TWI, and University of Surrey,

In C4R the bridge related work is carried out by Trafikverket and LTU, Sweden.

The authors gratefully acknowledge financial support from the European Union, Trafikverket, Network Rail, LKAB/HLRC, SBUF and LTU. They also thank colleagues and collaborators who have worked in the projects and especially Joan R Casas at the Universitat Politècnica de Catalunya, Barcelona, Spain, and the Swedish Universities of the Built Environment (Oskar Larsson and Sven Thelandersson, LTH; Kent Gylltoft, Karin Lundgren and Mario Plos, Chalmers; and Raid Karoumi, Mikael Hallgren and Håkan Sundquist, KTH) for fruitful cooperation.

The experimental work and monitoring campaigns in Sweden were carried out in cooperation with staff of Complab at LTU.

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