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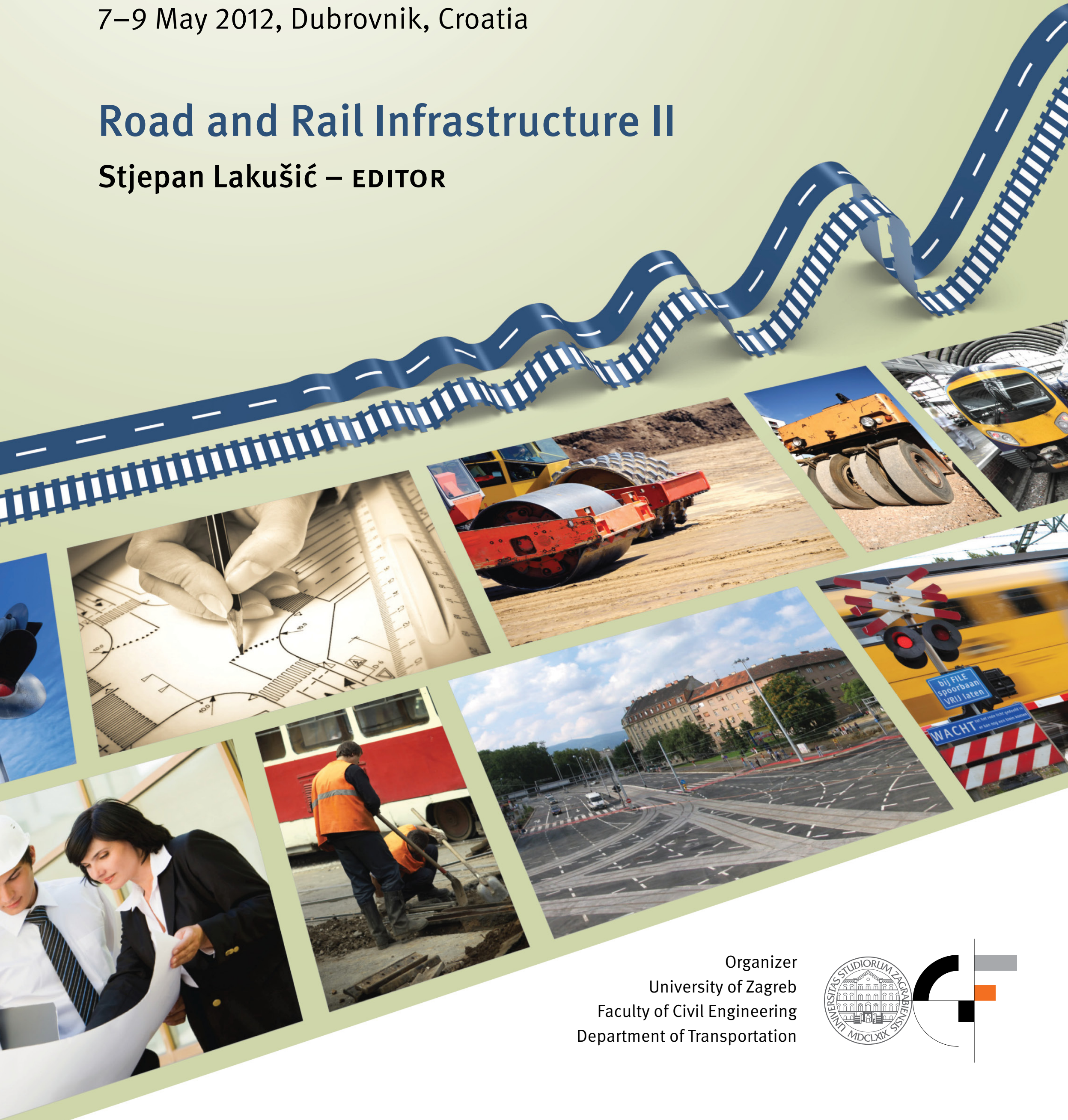
2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



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ÖBB RAILWAY BRIDGE CONSTRUCTION – CHALLENGES IN USING THE EUROCODES

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Abstract

The so called Steyrthal Bridge is situated in the Phyrn area of Upperaustria. It is a steel bridge with three single spans of approximately 30 m, 80 m and again 30 m. In addition it has two arches build as natural stone masonry both at the beginning and at the end of the structure. The so called Brunngraben Bridge, a single span steel bridge, is situated in the middle Ennsvalley in Upperstyria.

Both bridges are railway bridges and are part of the Austrian railway network, to be more precise of the railway line Linz – Selzthal. Due to problems with the load bearing capacity when the track classification of the named railway line is raised to class E in both cases a new building is obligatory.

Since the erection of both constructions must take place with active railway operation, quite special boundary conditions must be considered. For example these can be the adherence to the clearance beneath the superstructure or also the available period of stopped active railway operation.

For Steyrthal Bridge an additional special problem must be considered. The planned overall length of the Steyrthal Bridge will be approximately 185 m. The superstructure should be a continuous beam steel–concrete composite bridge with three gaps. In spite of the big total length of the superstructure no rail expansion joints should be used.

All these points were a quite special challenge for the planning. How this was solved with an extremely innovative construction for the Brunngraben Bridge and which lessons we have learnt with adoption of the Eurocode for the combined response of railway track and superstructure will be part of this paper.

Keywords: bridge, Eurocode, combined response of structure and track, maintenance, execution class

1 Introduction

The single track railway line Linz – Selzthal between Linz, the capital of Upperaustria, and the northern region of Styria was established in the very early of the twentieth century. Until 2016 this railway line shall be toughened up in such a way that the permanent execution of heavy load traffic will be possible.

Situated in km 65,622 there is a large viaduct running across the river Steyr, which is retained in this area. Situated in km 100,144 there is a small bridge across an agriculture way and a very small stream. In both cases within the planning process the Eurocode set some special challenges due to boundary conditions defined for their renewing.

2 Steyrthal Bridge

2.1 General

The existing railway bridge Steyrthal was erected with three single span steel superstructures in the year 1905 and is so now more than 100 years old. The middle field has an effective span of about 80 m and bypass the storage lake of the river Steyr. One of the main posts is founded in the storage lake. The two neighbouring fields of the middle field have an effective span of about 30 m. They are stretched towards the embankment on both sides of the river Steyr. Due to very bad maintenance condition the existing structure shall be replaced by a new one.

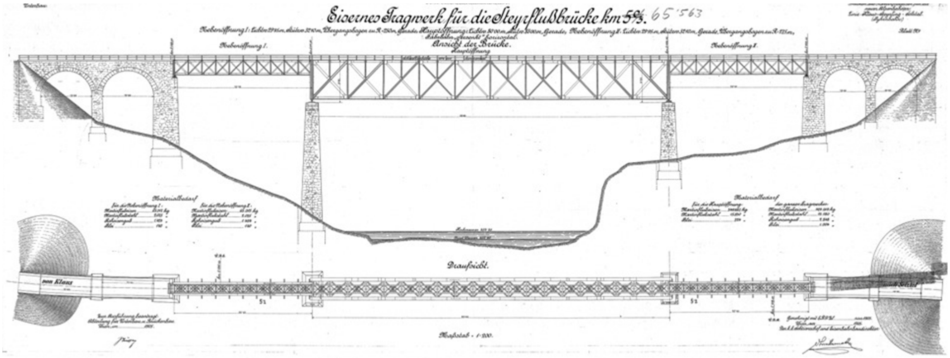

Figure 1 Longitudinal cut of existing Steyrthal Bridge over river Steyr.

Since the erection of the structure must take place with active railway operation, the solution is to erect a structure beside the existing one. So afterwards also the existing line shall be replaced in optimized quality.

One of the challenges is to find a design of the structure with avoiding rail expansion joints, which not only lead to very high maintenance costs but also to problems in railway operation. Therefore you have to fulfil permissible additional rail stresses due to the combined response of structure and track to variable actions, given in EN 1991 'actions on structures', part 2 'traffic loads on bridges' [2].

3 Basic principles for combined response of structure and track

When starting the calculation there are parameters to specify affecting the combined response of structure and track like configuration of the structure, configuration of the track, properties of the structure and properties of the track.

This means also to fix the longitudinal load–displacement behaviour of the track or the rail supports, the kind of used rail with values for the tensile strength and the minimum value of track radius. In the case of Steyrthal Bridge there are all parameter values beyond the range of values given not only in the Eurocode but also in the National Annex. Where it was necessary the boundary conditions where co–ordinated with the experts of the Austrian Railways. In the end the Austrian Railways as relevant authority gave the agreement.

3.1 Conceptual design

With beginning of the design the first attempt was to replace the existing steel framework bridge with a similar construction. It should be a modern designed steel–framework composite bridge with concrete deck outlined as a three field continuous beam. But this design did not fulfil the requirements for the combined response of structure and track. Some more designs were investigated but with no one it was possible to avoid the rail expansion joints. In the end it was clear a very high horizontal stiffness is required and so finally the design process ended up with a concrete arch.

3.2 Calculation of combined response of structure and track

The actions which shall be taken into account are traction and braking forces, thermal effects according to EN 1991–1-5 in the combined structure and track system, classified vertical traffic loads and other actions such as creep and shrinkage according to EN 1992-1-1 [2].

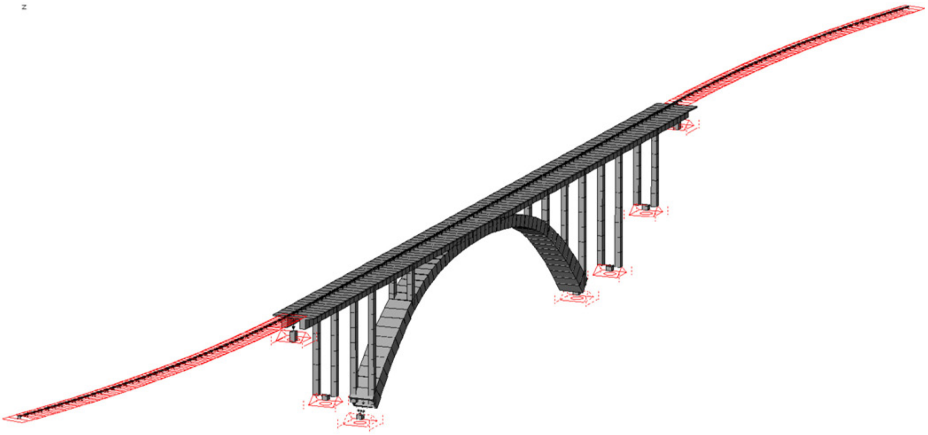

Figure 2 Three–dimensional model of concrete arch structure with rails.

In context with the combined response of structure and track for creep and shrinkage the time of space closure of the rail is of highly importance because only beginning with this moment there are forces brought forward to the rail. In the calculations it was decided to fix an age of the concrete of 6 month or 180 days when closing the space between the rails.
Together with the rails the structure was modelled as three–dimensional problem. Corresponding to designations in literature the rail was considered in the static model in an area up to 90 m in front of the superstructure and also after the superstructure [3]. The in longitudinal direction existing load–deformation behaviour of the rail track and also of the rail fastening system was put into effect with nonlinear springs. There was a differentiation between loaded and unloaded rail track. The foundation of the structure with abutments and piers was integrated into the static model with vertical, horizontal and torsion springs corresponding to the designations of the soil expert. Again for the spring stiffnesses there was a differentiation between static and dynamic loading.
With consideration of all the given points and with a series of investigated variations for the arch bridge the proof of combined response of structure and track according to Eurocode was finally fulfilled in a positive way. There was no more any need for rail expansion joints.
Substantial was the possibility in modelling the soil properties with nonlinear stiffness's near to the reality including differentiated specifications for varied actions. Results of the calculations are additional rail stresses due to combined response of structure and track to variable actions after superposition of the single rail stresses [4].

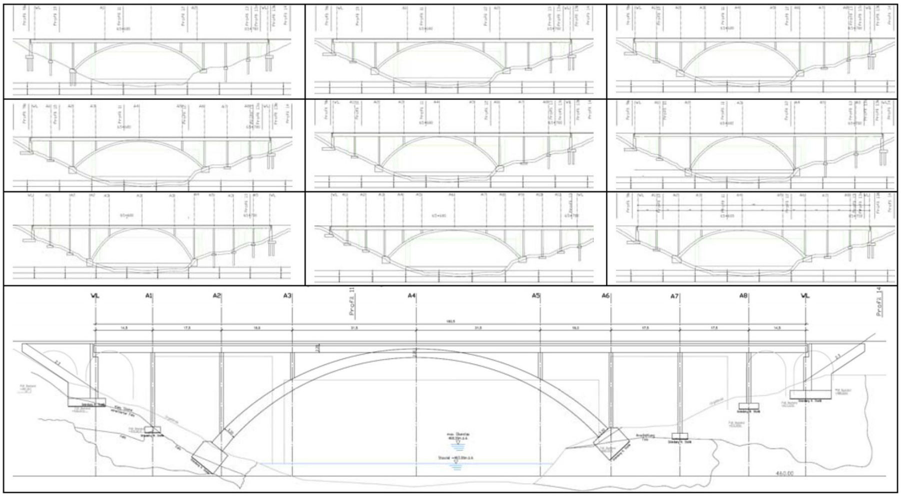

Figure 3 Investigated variations for the arch bridge with final structure.

4 Brunngraben Bridge

4.1 General

The so called Brunngraben Bridge, a single span steel bridge, was to be replaced with a new building due to problems with the load bearing capacity when the track classification of the railway line Linz – Selzthal is raised to class E.
Since the erection of the construction must have taken place with active railway operation, quite special boundary conditions must have been considered like adherence to the clearance beneath the superstructure and the retention of the existing elevation of the rail track, but also the substitution of the open rail track with a ballast substructure and stopped active railway operation of only 6 days.

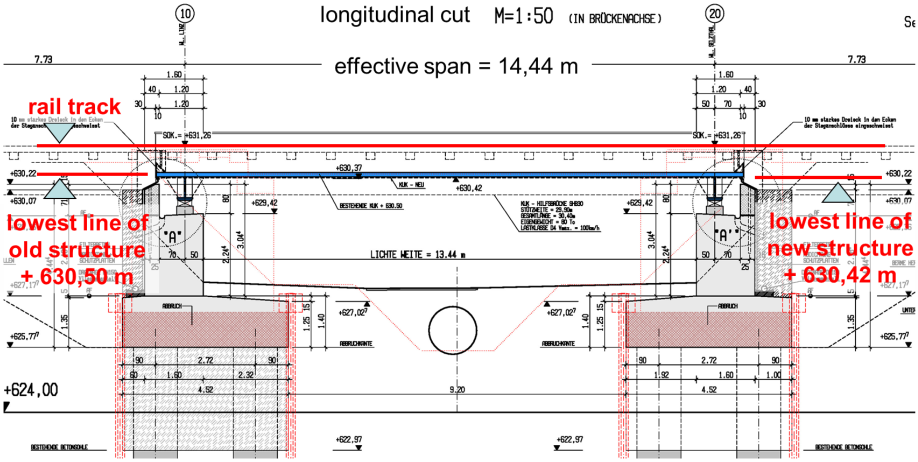

Figure 4 Longitudinal cut of new Brunngraben Bridge with given boundary conditions.

4.2 Design, statics, non–deformability and secondary moments

Before the conceptual design process started some initial data were indicated. One was that the design shall be a single–way track trough bridge with minimized overall size considering the structure clearance given in the technical guideline for railway bridges.
Overall seven cross sections had been investigated in a study concerning ultimate, serviceability and fatigue limit states as defined in the latest European Standards. Particular attention was laid on the design of the bottom plate as deck plate with 120 mm width and on the stability of the two main beams. Result of the study was a cross section, which is extremely convenient for a structure type with initial data as given before.

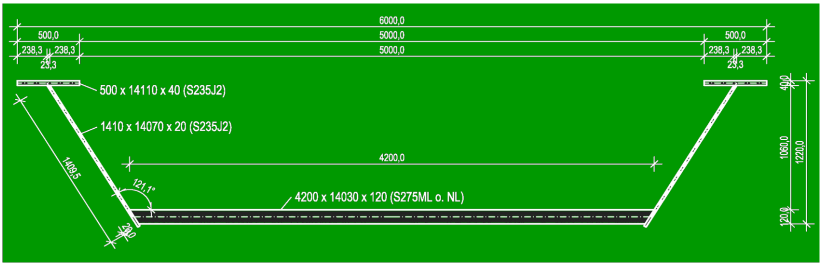

Figure 5 Principle cross section of new Brunngraben Bridge [5].

Following, this cross section was investigated by an own master statics, considering the ultimate, serviceability and fatigue limit state properties. The internal forces were calculated with warping torsion in the tenth points of the span under consideration of the load cases for railway bridges given in EN 1991-2 [1].
For creating the load groups 11 to 17 defined in the EN 1991-2 the dynamic factor f2 and the classification factor a have been considered. The different combinations for the ultimate, serviceability and fatigue limit states were defined according to EN 1990. To get the fatigue loads, the adaptation factor l was used. The effects of shear lag of wide flanges, especially of the deck plate, were considered by effective widths.
Based on the internal forces calculated with the named load combinations and section properties, the stresses were computed. The normal stresses resulting from the normal force and the bending moments as well as the shear stresses resulting from the shear forces and the primary torsional moment had to be considered.
Concerning the calculation of the internal forces due to warping torsion, there also had to be considered normal stresses resulting of the bimoment of warping torsion and, obviously, shear stresses due to the secondary torsional moment. Finally the equivalent stress according to Mises' yield hypothesis had to be compared with the limiting stress values in certain points of the cross section.
Concerning the serviceability limit states, the resonance frequencies, the vertical deflection for the verification of the driving comfort and the deflection of the simple beam, the maximum twisting of the structure on a length of 3 m and furthermore the horizontal deflection and resonance frequency were confronted with the permitted values.
Two special investigations for the trough bridge type were necessary. The first one was an investigation on the contour accuracy of the cross section because of the lack of stiffeners between the two transversal girders at the end supports. The second one was an investigation on the cause and effects of the 'secondary moments'. The deck plate with a width of 120 mm is elastic end–restrained to the web of both main girders. With regard to the loading of the plate a small elastic restraint is of negligible magnitude, since the activated very low hogging moments have no real effect on the sagging moment of the plate. However, this is not valid for the loading of the web in the region of the connection plate to web.

4.3 EN 1090–2 and execution classes

Since 15th September of 2009 in Austria the global family of standards for steel constructions is basically complete with the issue of EN 1090-1. Now one has on one side the Eurocodes, on the other side the material standards and in the middle as a principal item EN 1090 as execution standard.

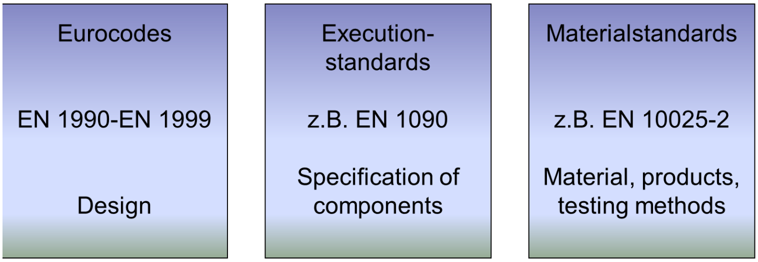

Figure 6 Global family of standards for steel constructions.

Here new territory began. Suddenly there must be specified additional information that is required for execution of the work to be in accordance with EN 1090-2 [6]. Furthermore every component must be classified in execution classes with range from EXC1 to EXC4.
The determining of an execution class is a multistage process. First step is a classification in consequences classes. The range runs from CC1 to CC3 and is deposited with description and examples. The consequences classes also are coupled directly with the reliability classes RC1 to RC3.
And here it is extremely important to note: A design using EN 1990 with the partial factors given in annex A and EN 1991 to EN 1999 is considered generally to lead to a structure with a reliability index value equal or greater then 3,8 for a 50 year reference period. This corresponds to a RC2 requirement. That means not more but that a classification in a higher consequences class has no immediate effects on the results, for example, of a static calculation.
The choice of the consequences classes should be made only based on this knowledge. In reality as values for decision only a few parameters remain such as for example the time to restore the availability of a railway line in accordance with its importance or the accessibility of locations, which are of absolute importance for the structural safety of a structure.
Thus, the Brunngraben Bridge would have to be classified in consequences class CC2. However, the longitudinal fillet welds for connecting the bottom plate to the two main girders are no longer accessible for expert opinion due to the existing ballast substructure. Therefore, here inspection level IL3 was chosen by the ÖBB concerning the inspection during execution. By linking with the associated reliability class RC3 the result was a classification in consequences class CC3.
Until now you have moved in the content of Annex B of EN 1990. Now you jump over in Annex B of EN 1090-2 and determine in a second step the service categories and the production categories. With first the type of actions is considered, with the second steel grade products and assembling.
The Brunngraben Bridge is designed for fatigue actions according to EC3, so the service category is SC2. Due to components manufactured from steel grade products below S355 and that they are assembled by welding exclusively in the metal working plant the production category is PC1. Thus, for the Brunngraben Bridge the determination of the execution class would be finally possible: CC3 with SC2 and PC1 result in EXC3. However, but this was not the case. The tendering for the structure must have been done with EXC4. Reason were the technical contract conditions for steel structures RVS 08.08.01, which automatically demand EXC4 for railway bridges independent of the way to determine the execution class introduced before.

5 Conclusions

For the Steyrthal Bridge there were three controlling points in fixing the design of the construction. The first one is the abandonment rail expansion joints. This problem specification was in fact the determining factor for the design of the construction and led in the end to a concrete arch bridge. The choice of the design of the arch was not only based on the thrust line but was also carried out under consideration of optimizing the tensile stresses in the rail due to cleverly elected horizontal stiffness and deformability behaviour. The third one was to have a bridge structure which is harmonically integrated in the characteristic landscape of the Phyrn area in Upperaustria.

For the Brunngraben Bridge in the end the main point was the application of EN 1090. Here not only the Execution Classes are regularly subject of protracted discussions. Generally there is a lack of will to deal with the requirements of EN 1090. In part various requirements are quite simply ignored deliberately. And no one insists on the implementation, possibly due to lack of knowledge.

The ÖBB had already very early consisted in application of existing Eurocodes in the design of steel structures. The gains in experience with a view to the results are to be valued as throughout positive.

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