Static and Dynamic Analysis of the Railway Bridge on the Line Devínska Nová Ves - Štúrovo (The Red Bridge) at km 51.368

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Summary

Toward the end of 2011 a static and dynamic analysis of the railway bridge situated at km 51.368 of the line Devínska Nová Ves – Štúrovo have been carried out. It is a six-span bridge made of a pair of continuous structures of three spans each, the spans being 32.60 m long. Its structures feature a polygonal cranking in the place of their bearings each, shadowing the lining of the track. The steel structures are plate frames, riveted, with an embedded bridge deck. Calculations were performed to assess the bridge carrying capacity with regard to the load imposed to it by rail traffic and to analyse the effects of various burden types on its stress state, particularly on its rail deck and its main beams. The dynamic analysis investigated the effects of service load at various speeds to determine critical points of the structure. The evaluated stress range spectra resulting from a train passage have served to determine the residual life of the Red Bridge structure.

Keywords: Steel Bridge, Load Carrying Capacity, Dynamic Effects/Vibrations, Assessment

1. Structural Analysis

1.1 Model Characteristics

For computations, the Midas Civil 2011 (v2.1) software was used. The computation model of the load-bearing structure is made by a combination of plate elements and strut elements. The model maintains the bearing structure geometry as initially designed. The losses of material established by measurements during the inspection have been reflected in the calculation model.

1.2 Load-Bearing Capacity LM 71 and D4

The first condition to be examined by the bearing structure analysis was investigating the magnitude of burden under standard load imposed by test model LM 71 [1]. The main beam, outer cross beam, middle cross beam and intermediate cross beam are the elements which comply with the magnitude of burden by standard load from test model LM 71. The elements failing to comply with the given load are the outer and inner longitudinal girder. According to these results, the existing bearing structure of the Red Bridge fails to comply with the standard load by test model LM 71. Then, the structure was investigated under service load represented by load model D4. The elements incompliant with the given load include the outer and inner longitudinal girder whose carrying capacity reaches only 87 % of the magnitude of burden on the given element. These results indicate that the bearing structure of the Red Bridge, taking into account its existing condition, fails to comply with the magnitude of burden imposed by D4.

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2. Dynamic Analysis

Dynamic analysis was performed in particular to study the following parameters:

- Natural frequency and modes of vibration
- The effect of service load from the beginning of operation up till now, in order to determine the applicable ranges of stress in the most exposed elements and then, determine the residual life of the bridge structure
- Monitoring the behaviour of the structure when under class D4 load by rail traffic at various travelling speeds over the load-bearing structure.

2.1 Operation of the Railway Bridge during 1948 – 2010

The documents available allowed determining time intervals and their corresponding traffic intensity covering the period 1948 – 2010 [4]. Trains typically used in freight and passenger transport were assigned to those time intervals. In order to design trains, specific locomotives were used, which were operated at a given period, along with their exact axle diagrams the carriages used. At the same time, the time periods and trains were assigned speeds which are used for computation.
This part of the computation was primarily intended to define the course of stress ranges while under the load from rail traffic, in order to establish the residual fatigue life the bearing structure of the Red Bridge. Combined with the structural analysis (load-bearing capacity of steel structure elements), elements proving the worst results were then selected. Those were further investigated in detail with regard to fatigue stress. The established stress amplitudes of the bridge deck caused by typical sets of rail service load were mostly within the interval of 25 – 35 MPa.
In addition to the course of stress and deformation during the train passage over the steel structure elements, attention is as well paid to the vertical acceleration development of the structure. The value of maximum vertical acceleration on the left main girder in span 3 is 3.91 m/s^2 and it is exceeded at 100 km/h of a passenger train.

3. Residual Fatigue Life of the Load-Bearing Structure

Establishing the residual fatigue life of existing steel riveted railway bridges is not regulated by any recent standard. The principle of investigation used for the Red Bridge is based on [2]. These calculations follow up the dynamic analysis of the bridge operation over 1948 – 2010. The magnitudes of stress amplitudes to which frequencies were assigned for various load periods were deducted from the combined capacity stacked chart. The stress amplitudes applied in the described way and their respective frequencies were taken over to the stress spectrum chart covering the time period from commissioning until now. With regard to residual fatigue life, element 5118 representing the left longitudinal girder of the bridge deck has its fatigue life exhausted. Other longitudinal girders in outer spans of the continuous structure prove similar stress amplitudes as element 5118. With the same number of loading cycles, the conclusions may as well be applied to other longitudinal girders: their residual fatigue life may be until 2011 – 2014.

References

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