Engineering Structures 33 (2011) 635–646

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Strengthening of a steel railway bridge and its impact on the dynamic response to passing trains

Joakim Wallin *, John Leander, Raid Karoumi

Division of Structural Design and Bridges, Royal Institute of Technology (KTH), 100 44 Stockholm, Sweden

A R T I C L E   I N F O

Article history:
Received 28 June 2010
Received in revised form
13 October 2010
Accepted 2 November 2010
Available online 4 December 2010

Keywords:
Steel bridge
Strengthening
Finite element analysis
Monitoring
High speed train
Fatigue

A B S T R A C T

Two different strengthening methods for a through-girder steel railway bridge are investigated. The studied structure is the Söderström Bridge, located in the city of Stockholm, Sweden. Due to fatigue problems, it is in need of assessment and strengthening. In one of the methods, arches are added under the bridge modifying the structural system and lowering the stress ranges for all structural members. The other method consists of prestressing the floor beams. This increases their stiffness and transforms the mean stress in the lower flanges from tension to compression. A 3D finite element model is created and verified with measurements. The different strengthening methods are tested in the model by dynamic analysis with moving train loads. The strengthening methods show some positive effect concerning the fatigue life. Changes in vertical bridge deck acceleration for high speed traffic are also presented. A comparison between the European code and the Swedish code regarding vertical bridge deck acceleration levels for high speed traffic shows large differences for the bridge.

1. Introduction

Resent studies [1] show that more than 60% of the railway bridge stock in Europe is over 50 years old and more than 30% is over 100 years old. These bridges are subjected to higher loads and speeds than those for which they were designed. To cope with present and future demands, several bridges are in need of strengthening or replacement. For economical and environmental reasons it is greatly beneficial to increase the bearing capacity and service life of a bridge by strengthening instead of demolition and reconstruction.

The development of high speed trains has put higher demands on the existing railway network in Europe and the rest of the world. It has been shown that higher speeds increase the stress on the bridge, especially if the load frequency is close to a resonance frequency of the structure [2]. To adapt the existing European railway network to high speed trains all bridges have to be reassessed to ensure that they meet the requirements stated in the Eurocode [3]. For cases where theoretical calculations are not enough to ensure the safety of a bridge, measurements can be performed to see if the real behavior of the bridge is somewhat more favorable than theoretical calculations indicate. If this is not enough, some kind of strengthening measure or replacement is needed.

For steel railway bridges, one of the dominant problems is fatigue. The increase in load, traffic volume and speed yields higher stress ranges and a larger number of stress cycles resulting in a shorter fatigue life. A number of strengthening methods to increase the fatigue life and to repair already damaged structures have been tested and presented in the literature e.g. [4–6]. Some methods require that the bridge is closed for traffic during construction. For most traffic intensive railway networks in Europe this poses a big problem since it is very costly to have long interruptions in traffic. It is also costly if the work can only be performed during the night when there usually is less or no traffic. The best method would be one where all the work could be performed without disturbing the traffic at all.

One of the most important railway bridges in Sweden is the Söderström Bridge (Fig. 1). It is a through-girder steel railway bridge which carries the only two tracks for commuter trains, regular passenger trains and freight trains, passing through Stockholm. Theoretical studies [7] have shown that some elements of the bridge have already exceeded their fatigue life. A monitoring program was executed in 2008 to enable an evaluation of the real behavior of the bridge. The data from the monitoring system has been used for several investigations including an enhanced fatigue evaluation [8] which confirmed the theoretical calculations and concluded that the theoretical service life of the bridge, which has been in service for more than 50 years, has passed. The most critical elements are the continuous stringer beams and the transversal floor beams. Part of the presented study aims at extending the theoretical service life of the bridge considering fatigue.

* Corresponding author. Tel.: +46 8 58 00 91 76; fax: +46 8 755 95 33.
E-mail addresses: joakim.wallin@elu.se, kjw33@tele2.se (J. Wallin).

0141-0296/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2010.11.022