Monitoring fatigue effects in an orthotropic steel bridge deck

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Summary

The effect of fatigue is particularly relevant in steel bridges since the influence of traffic load cycles on serviceability limit stress values is very high if compared to relatively low dead weights.
Orthotropic steel decks, directly subjected to traffic loads, are very sensitive to fatigue: in most cases, fatigue defects appear as cracks in the top plates, longitudinal ribs and the bracing of the deck. In this paper the case study of a 20 years old box girder bridge affected by fatigue problems is presented: the bridge has an orthotropic steel deck with three spans whose total length is 152m. The bridge is located in one of the busiest Italian highways, the "Milan-Venice" A4 highway, characterized by high volumes of heavy truck loads. After the cracks appeared on the longitudinal welding of the ribs, a dynamic identification campaign was carried out using piezoelectric accelerometers, and a monitoring system was then installed by positioning 54 strain-gauges along one of the steel decks of the bridge.
The results of the monitoring campaign are here presented, underlining the deficiencies of the original design, and retrofit intervention are proposed for the bridge deck.

Keywords: fatigue; steel bridges; orthotropic steel decks; dynamic identification; retrofit.

1. Introduction

Due to the demand for freight volume on rail and road, traffic has increased significantly in the past years leading to increasing number of heavy vehicles in the traffic flows and greater exploitation of their loading capacities. There is also a tendency to further enhance the admissible loads in the design of new heavy vehicles. This all may affect the safety, serviceability and durability of existing bridges. During the 90's, several researches focused on the assessment of existing steel structures, mainly those dominantly exposed by fatigue loading such as bridges or crane supporting structures. Fatigue is a particular deterioration case of great importance in the assessment of existing steel bridges, in particular referring to orthotropic steel decks [1-6]. In this work the assessment of an existing A4 highway

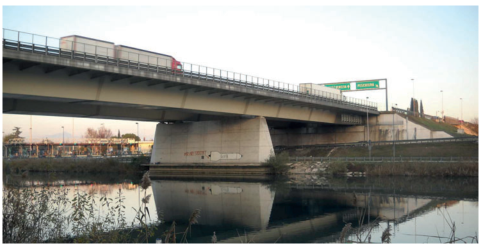

Fig. 1: The steel bridge over the Mincio River

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steel bridge crossing the Mincio River in Italy, affected by fatigue problems, is presented (Fig.1).

2. Inspection and monitoring programme

The work has been planned in two steps: in the first part an acquisition campaign has been carried out to evaluate the degradation scenario and the main deficiencies; then, in the second part, retrofit interventions have been proposed to eliminate the detected fatigue phenomena and improve the seismic behavior of the existing bridge.

The inspections performed in the past months have highlighted visible damages to the structure associated with fatigue phenomena (Fig.2). After the identification and the evaluation of the spatial distribution of the damage, a series of destructive tests have been performed on samples of structural elements taken from the bridge in order to characterize the main materials properties and the verification of the welds. In particular X-ray, metallographic, scanning electron microscopic and Vickers hardness tests have been conducted. After having evaluated the presence of a general damage state related to fatigue phenomena, it was considered appropriate, in agreement with the owners of the infrastructure, to install a monitoring system. This solution has been adopted in order to evaluate the time evolution of the degradation, and proceed with appropriate structural retrofit interventions. Operational Modal Analysis has been performed with piezoelectric acceleration sensors disposed with only three setups inside the box girder. Despite the Frequency Domain Decomposition and the Stochastic Subspace Identification, also the Polyreference Least Square Complex Frequency Identification (PLSCF) method has been used in order to validate it with this kind of structures.

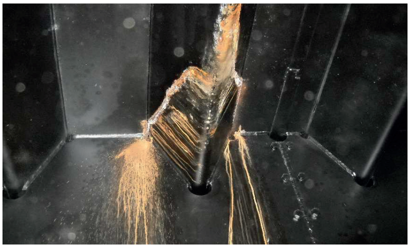

Fig. 2: Cracks in the internal "V" ribs

3. Results

The experimental results provided by the strain gauges of the installed monitoring system have been compared with the numerical results obtained from the updated FE model. The comparisons have been performed in terms of stress variations $\Delta\sigma$ induced by the application of the loads provided for the fatigue verifications in the critical points of the deck section: the bottom of the transverse beam flange, two characteristic "V" ribs (one external and the other internal to the deck box) and the top flange between two "V" ribs.

All the findings confirm the need of providing a definitive operation on the structures such as to ensure an effective and lasting result, especially regarding to the fatigue phenomena. Two alternative strengthening solutions have been proposed: the reconstruction of the orthotropic plate or the reinforcement of the deck slab with a new reinforced concrete slab interacting with the existing steel structures.

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