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Improvement of fatigue properties of orthotropic decks

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ABSTRACT

Orthotropic decks are progressive structural elements which often occur in civil, mechanical, ship, air and space engineering. Besides the advantages like low weight, great stiffness, and low structural height, they suffer from dynamic forces causing fatigue cracks. Therefore, it was tried to improve their fatigue properties and, thus, to prolong their life. The proof of gluing the carbon fibre reinforcement composites (CFRC) in the critical details of the deck seems to be encouraging. The new types of the CFRC and glue give an other chance in the future.

1. Introduction

Steel structures with orthotropic decks are spatial elements where the deck is supported by cross girders and longitudinal ribs (stiffeners). Therefore, they provide different static properties in two orthogonal directions (orthotropic equals orthogonally anisotropic). The orthotropic deck serves for the distribution of loads on various structures, such as bridges, etc.

Steel structures with orthotropic decks have been built in several countries since the Second World War. Their number is very high, e.g. it was estimated more than 1000 on European Railway Bridges, [1], and even more on civil, machine, air and space structures.

Being fully welded the orthotropic decks often show specific problems regarding the fatigue strength under dynamic loads. The most sensitive (critical) point on this type of structures appears in the neighborhood of the area where the bridge deck joins the cross girder and longitudinal rib. The stress concentrations – a possible source of fatigue cracks – appear particularly in the web of the cross girder and/or near the cutouts [2].

Nevertheless, the orthotropic decks enjoy great popularity due to their low weight, great stiffness and low structural height.

Research of fatigue properties has been conducted in every advanced country. For example, the International Union of Railways (UIC) and its European Rail Research Institute (ERRI) executed the research of orthotoropic decks on railway bridges in the years 1990–1996, [3–6] and, now, the European Union has consecrated on this problem again in the research project BRIFAG (Bridge Fatigue Guidance)—Research Fund for Coal and Steel of the European Commission granted under the contract Nr. RFSR_CT-2008-00033) [7]. It has reflected the importance and usefulness of the aforementioned structural element.

2. Static and dynamic tests

The dimensions and forces of the specimens in the series ***A*** of the experimental program mentioned above can be seen in Fig. 1. They have to correspond to the form and dimensions of real bridges (especially railway) as well as to the dimensions and force possibilities of the laboratory. The specimen in the Fig. 1 shows a part (slice) of the deck, cross beam, and longitudinal rib. On the railway bridges, the flat ribs are preferred for the closed ones because they not suffer by corrosion.

Beside, a type ***B*** (lower height) was suggested and tested but it presented similar results.

A survey of tested specimens is shown in the Table 1 together with the most important results. The static maximum values are added for comparison.

Up to now 12 specimens in the series A have been tested. The test machine GTM with the frequency 2 Hz has been applied for testing, see Fig. 2. Fatigue cracks can be seen on Fig. 3.

All the other specimens were loaded in the machine MTS with frequency 2 Hz. The number of absorbed cycles N can be seen in Table 1. The loading process provides a sinusoidal form with a minimum force F_{min} and maximum force F_{max}, respectively, and frequency 2 Hz. The minimum force was held constant $F_{min} = 10$ or 20 kN, while the maximum force F_{max} was changed from case to case to receive the Wöhler line.

3. Carbon fibre reinforcement composites (CFRC)

Afterwards, an intention of gluing the CFRC on steel specimens was realized, see Fig. 4.

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