Statics and dynamics of carbon fibre reinforcement composites on steel orthotropic decks

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Abstract

Carbon fibre reinforced composites (CFRC) have become an increasingly applicable material in civil engineering over the last decades. The advantages of CFRC usage are its high stiffness and strength. The steel and composite interaction was tested on simple beams, which could forestall the development of fatigue cracks. It is projected that the application of this material be applied to real steel bridge construction, especially to repair damages of orthotropic decks. The paper examines the influence of material characteristics with and without CFRC.

Orthotropic deck details have been investigated under static and dynamic loads and several theoretical and experimental methods have been applied. The experiments of orthotropic deck details are turned to the crack propagation, stress concentrations and fatigue life. The most vulnerable detail appears in the spatial crossing of the deck with cross girder and longitudinal rib, where the stress concentration appears. The static tests were realised on a real size part of the orthotropic deck. The specimens are loaded by many times the repeated load.
Keywords: carbon fibre reinforced composite, orthotropic deck, fatigue life, dynamic load, crack propagation.

1 Introduction

Steel bridges with orthotropic decks are spatial structures where the bridge deck is supported by cross-girders and longitudinal stiffeners. Therefore, they provide

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different static properties in two orthogonal directions (orthotropic equals orthogonally anisotropic). The orthotropic deck serves for the distribution of loads on bridges.

The steel bridges with orthotropic decks have been built since the Second World War in several countries. Now, their number in service reaches many thousands in the world. Their advantage is a low constructional height, appreciated especially in towns. However, being fully welded, the orthotropic decks raises specific problems regarding fatigue under dynamic loads. The most vulnerable point on this type of structure is the spatial crossing of the bridge deck, cross-girder and longitudinal rib. The stress concentrations appear at that places and form a possible source of fatigue cracks [1, 2].

Therefore, a lot of calculations and tests of orthotropic decks have been conducted, e.g. [3]. Today's, plastic materials have been applied in many cases and that is why an idea crossed our mind to apply the carbon fibre reinforcement, glued on the steel plates, to reduce the formation and propagation of fatigue cracks in orthotropic decks.

2 CFRC composites

Our idea is a test of Carbon Fibre Reinforcement Composites (CFRC), which glued on the specimen, could forestall the development of fatigue cracks. After a search of materials offered by the market, we choose the carbon fibre composite (Fig. 1, type Carbonpree 300 Biaxial) and the glue Sikadur 30.

Figure 1: Carbon fibre reinforcement composites (CFRC).

Before application of the glue, the surface of steel specimens must be carefully brushed.

The CFRC was tested separately (Fig. 2) as well as glued on a steel bar. The stress-strain diagrams are represented on Figs. 3 and 4.

The form of the Czech standard specimen for tensile tests is shown in Fig. 5.

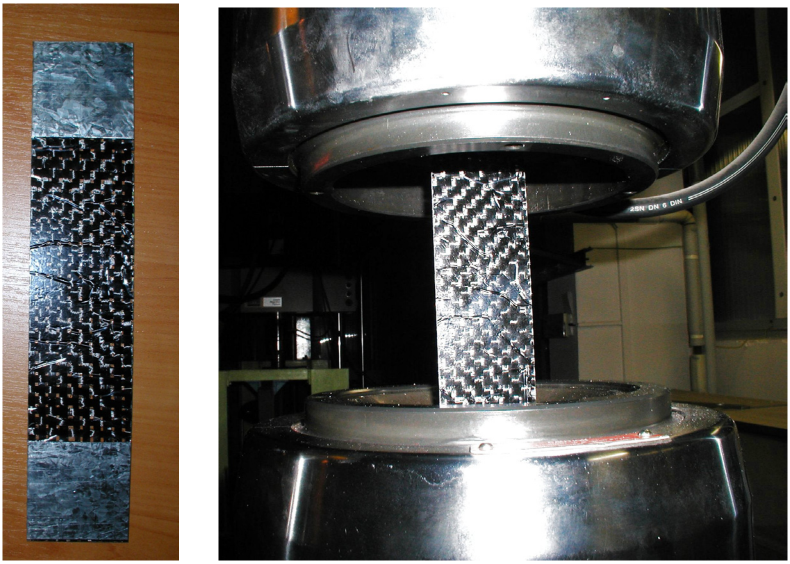

Figure 2: Tensile test of CFRC.

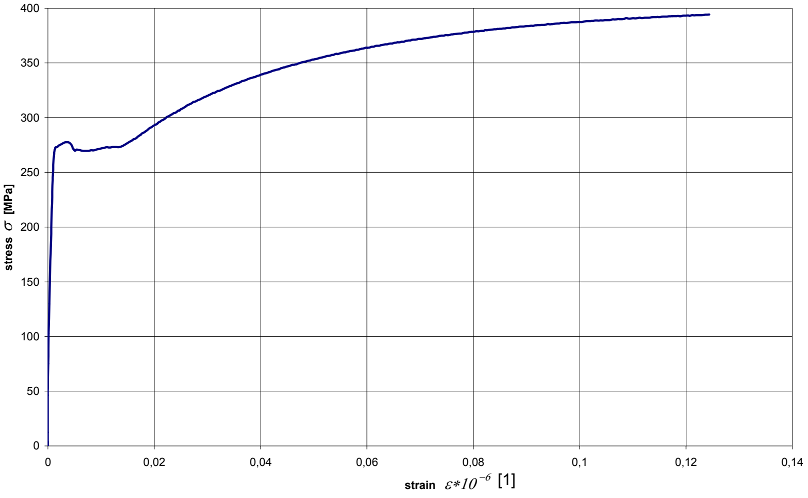

Figure 3: The stress-strain diagram of the steel bar.

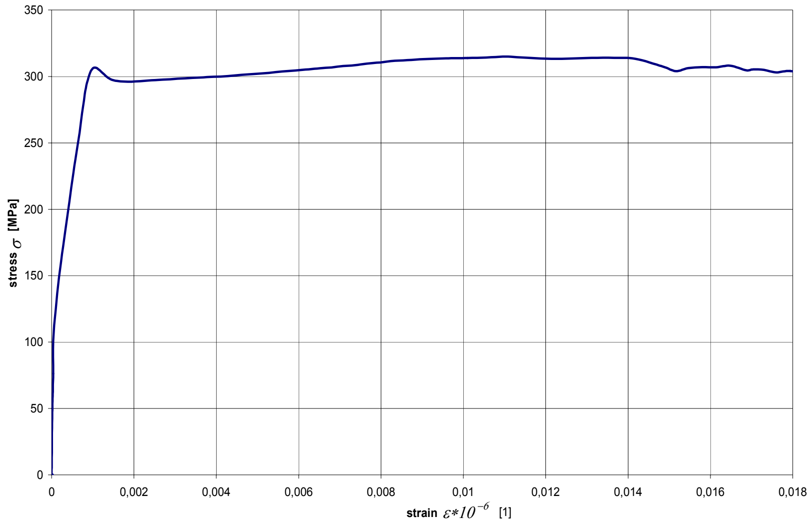

Figure 4: The stress-strain diagram of a steel bar with glued CFRC.

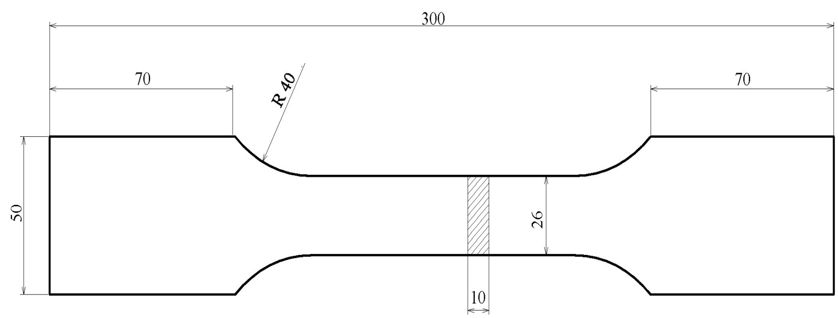

Figure 5: Standard specimen for tensile tests.

3 Orthotropic decks

The experiments of orthotropic deck details are turned to the crack propagation, stress concentrations and fatigue life. The most vulnerable detail appears in the spatial crossing of the deck with cross girder and longitudinal rib where the stress concentration appears. Therefore, the specimen of type A (see Fig. 6) was designed and tested. The first specimen A1 was subjected to static forces from 0 to 477 kN with steps of 20 kN, loading machine GTM 500 kN.

After completing these tests, we intend to glue the CFRC on some specimens of type A, subject them to alternating forces and compare with the results of steel specimens.

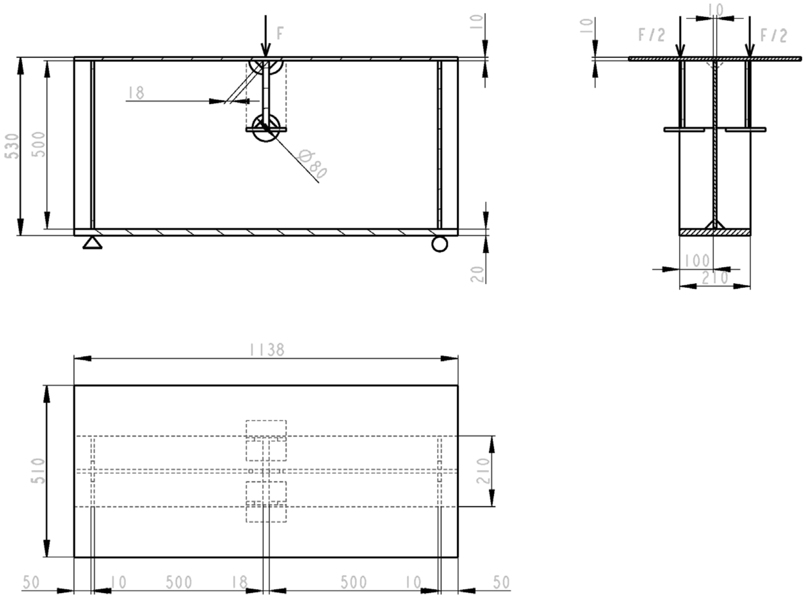

Figure 6: The specimen of type A.

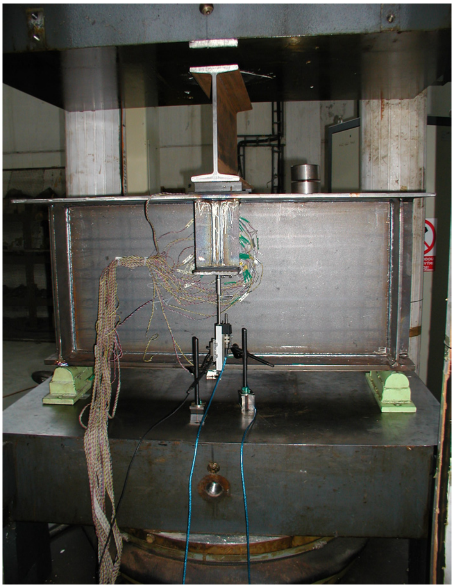

Figure 7: Static test of the specimen A1, supported on two bearings.

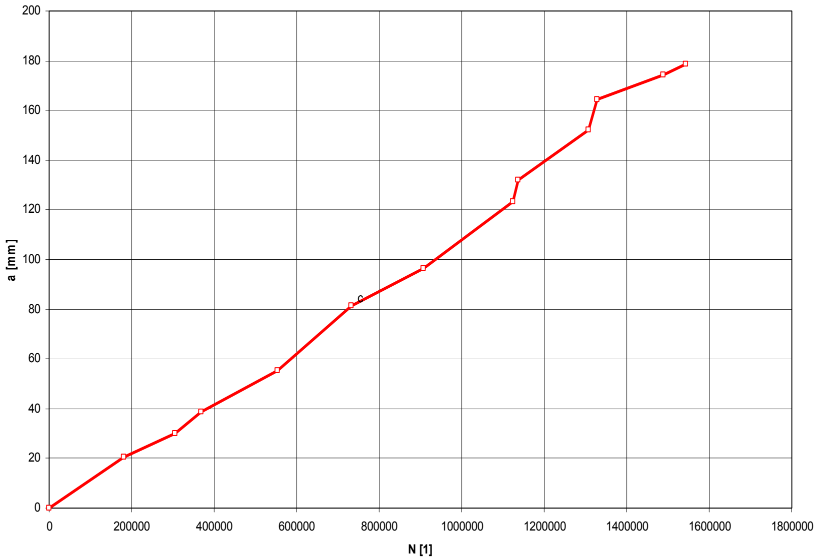

Figure 8: Fatigue crack length a as a function of the number N of stress cycles (specimen A2).

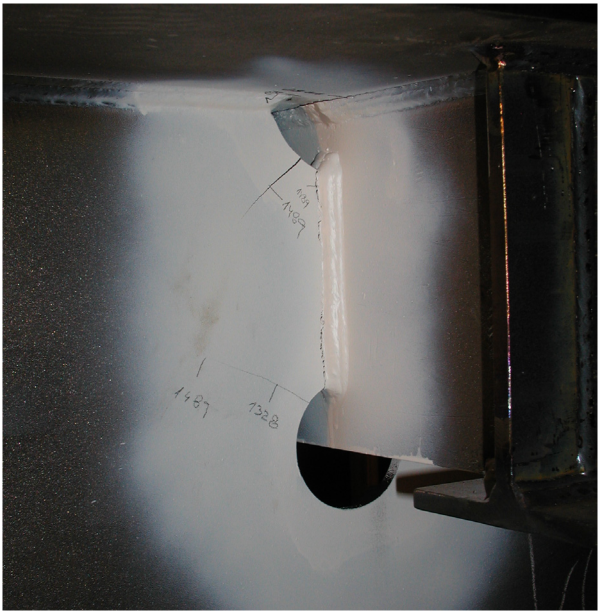

Figure 9: Fatigue crack on the specimen A2.

4 Fatigue cracks in the steel orthotropic decks

The first step of our investigations contained the study of fatigue cracks propagation.

The specimen A2 was cycled with the force 10 kN to 210 kN, test machine MTS 250 kN, frequency 3 Hz, N = 5 527 812 cycles without any crack.

After that, the specimen A2 was cycled with the force 10 kN to 410 kN, test machine GTM 500 kN, frequency 2 Hz. The relation between fatigue crack length *a* and the number N of stress cycles can be shown in Fig. 8. The end of the test was at N = 1 543 930 cycles when the specimen lost rigidity in general.

Propagation of a fatigue crack shown in Fig. 8; it can be seen in Fig. 9.

5 Conclusions

The future of our research contains the steel and composite interaction on selected details of orthotropic decks. We focus our investigation on the adhesive gluing.

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