FATIGUE PERFORMANCE OF SINGLE SPAN WOOD-CONCRETE-COMPOSITE BRIDGES

Leander Bathon[1], Oliver Bletz-Mühldorfer[2]

ABSTRACT: Wood-concrete-composite structures in residential and commercial applications are gaining market shares in recent years. The application of the wood-concrete-composite bridges however is very limited. This is mainly because there is a lack of knowledge on the fatigue behaviour of the wood-concrete-composite bridges. The authors believe there is a great potential to design these bridges using wood-concrete-composite cross sections with single span of 30 meters and more.

KEYWORDS: wood-concrete-composite, glued in shear connectors, bridges, fatigue, cyclic loading test

1 INTRODUCTION

The use of wood-concrete-composite systems for highway bridges in Germany was not possible in the past due to a lack of code approval of the shear connectors. The research work of this paper however was the base for the first code approval given in Germany for this kind of application. The authors believe that there is now a great potential for highway bridges using the wood-concrete-composite technology.

2 TESTING

The performance of a wood-concrete-composite bridge depends solemly on the performance of the shear connection. The shear connetors used in this application is a hbv-shear connector which consists of a steel mesh of S 235 (equvalent to A36). On half of the hbv-shear connector reaches 40 mm into a 3,2 mm wide channel within the timber and is secured through adhesive action. The other half (50 mm) is reaching into the concrete. In order to provide a durable bridge system it is desirable to use this stiff but ductile connection system.

2.1 SHEAR TEST

The shear tests were conducted as push-out-tests. The specimens were 600 mm long. The wooden cross section for the beam solutions was 80 by 140 mm and for the plate solution was 400 by 80 mm. The concrete cross section was 70 by 400 mm. The hbv-shear connector reaches 40 mm into the wooden and 50 mm into the concrete part of the composite system. All shear tests show steel failure within the shear connectors under ultimate load conditions (Fig. 1). Figure 1 shows a great plastic performance with almost now variation due to the steel failure of the shear connectors.

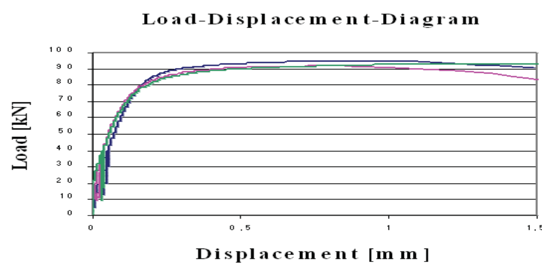

Figure 1: Shear testing on shear connector

2.2 FATIGUE TESTING

The fatigue testing was performed on the shear connector itself (tension shear) and the wood-cocnrete-composite system (compresion shear). Again all test showed steel failure within the shear connectors. Figure 2 shows the results of the fatigue tests in the hbv-shear connector. The shear connectors were tested under a sinustype tension ramp-load and a frequency of 2 to 20 Hz. The load was applied at constant strain ratios $\kappa = \sigma_u / \sigma_o$. Two test-series differing in a gap between the two clampings were conducted (Δ = 2 mm, Δ = 4 mm).

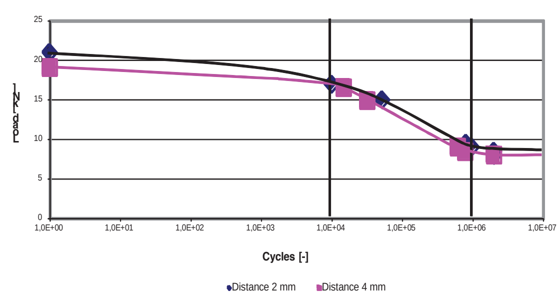

Figure 2: Fatigue testing on shear connector

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The ultimate load in the short-time tests arise in dependancy of the gap to $F_{u,2mm}$ = 20,7 kN respectively $F_{u,4mm}$ = 19,2 kN. The fatigue strength – identified for a an expected load cycles of 2 x 10^6 – shows a value of 8,47 kN at a gap of 2 mm and 7,98 kN for the gap of 4 mm.

3 ANALYSIS

3.1 TRUSS MODEL

The analysis of the wood concrete composite bridge is performed through a truss model. The model is shown in Figure 3. The truss model consists of a top and bottom member representing the concrete and wood respectively. The spring diagonals represent the shear connector based on the shear test of the steel mesh. The truss model provides both the prediction of the test performance as well as a design tool for the commercial application of the system.

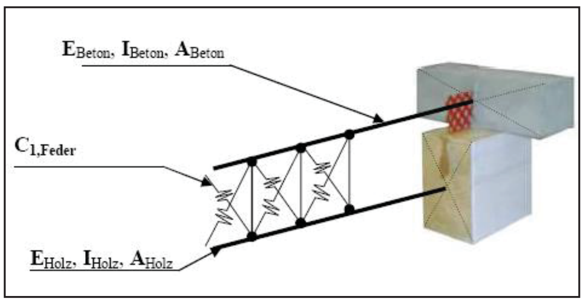

Figure 3: Truss model

The analysis showed that the wood concrete composite system produces a nearly fully composite action. The fatigue design is shown in the EC 5. In order to perform the fatigue design you need the factor **a** and **b** (Fig. 4) for the shear connector in use. The code approval of the hbv-shear connector shows **a=2,5** and **b=4**.

$$\sigma_{d,max} \le f_{fat,d} \tag{1}$$

$$f_{fat,d} = k_{fat} \frac{f_k}{\gamma_{M,fat}} \tag{2}$$

$$k_{fat} = 1 - \frac{1-R}{a(b-R)} \log(\beta N_{obs} t_L) \tag{3}$$

Figure 4: Fatigue design (Eq. 1,2,3) of EC 5

3.2 FATIGE ANALYSIS

The fatigue analysis is based on the EC 5. It uses the cumulative linear fatigue theorie of Palmgren-Miner. Figure 5 shows the comparison of the Palmgren-Miner Rule for a strain ration $\kappa = \sigma_u / \sigma_o$ of κ =0,09. Figure 5 shows that the application of the Palmgren-Miner-Rule will produce conservative design values for the fatigue design of the wood-concrete-composite bridges.

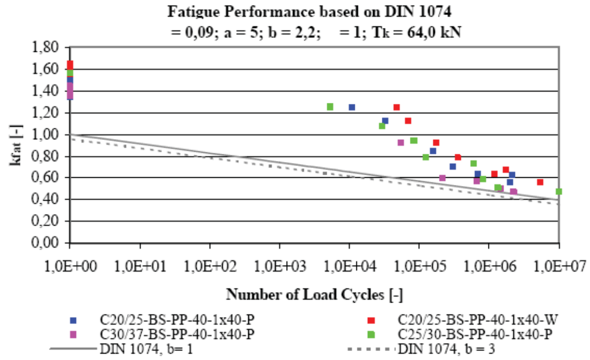

Figure 5: Fatigue analysis vs. test data

In recent years a number of wood-concrete-composite bridges have been build using the data presented (Figure 6). The authors are convinced that with the knowledge gained based on this research there will be more opportunities for the timber industry to build wood-concrete-composite bridges throughout the world.

Figure 6: WCC-bridge in Winschoten (NL)

4 CONCLUSIONS

This paper introduces a fatigue design approach for a single span wood-concrete-composite bridge. The design is based on 200 shear test as well as 60 fatigue test that have been performed at the Test Laboratories in Wiesbaden, Germany. The test data provides the information needed to design the wcc-bridges according to the code approval of the system used. The code approval paper determines the stiffness and strength of the shear connector for static loading conditions as well as the factors a/b for fatigue loadings conditions according to EC 5.

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