INVESTIGATION OF TIMBER-STEEL HYBRID BRIDGE STRUCTURE

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1. INTRODUCTION

Timber bridges are competitive options for short and medium span roadway bridges if adequate structural design is available. This paper presents a summary of an experimental and analytical study concerning a glulam beam-steel deck hybrid bridge, proposed by the authors. The bridge prototype was designed for a truck load of 250 kN. Test results of a one-third scale hybrid bridge model, having a span of 5.0 m and a width of 2.1 m, subjected to bending and failure test showed that the composite beam theory could closely predict the pre-failure behavior of the tested structure. In addition to this approach, a non-linear three-dimensional finite element structural analysis is being performed in order to be able to describe more accurately the performance of this hybrid structure as well as the interaction between structural members.

2. EXPERIMENTAL INVESTIGATION

The timber-steel system discussed in this paper comprises an orthotropic steel deck (the deck plate being stiffened by eight U-ribs and seven double glulam floor beams), two double glulam main beams with one upper and two lower, vertically inserted glued-in steel ribs[1]. The glulam material is Japanese cedar of strength grade E75-F240, while steel is SS400. In order to investigate experimentally this structure, an orthotropic steel deck-glulam beam hybrid bridge model was constructed, instrumented and tested to bending and failure at the structural testing laboratory of the Institute of Wood Technology, Akita Prefectural University. The main beam height-span ratio was 1/17, being comparable to ratios of bridges using other structural materials. A load-controlled testing machine loaded the simply supported model. The failure test was performed under an applied truck wheel load positioned as shown below. A total number of one hundred strain gauges were installed at four different cross sections along the bridge model. Failure occurred in a ductile manner, which is an improvement over the brittle failure observed in earlier tests, when only one lower rib per single glulam main beam was used. Local deformation of the deck plate near loading caused non-uniform strain distributions in some of the investigated cross-sections. Eight distinct failure positions (Fig. 1) were observed during the ductile failure, flexural failure starting from a knot situated at the tension side of the outer main beam under the applied load.

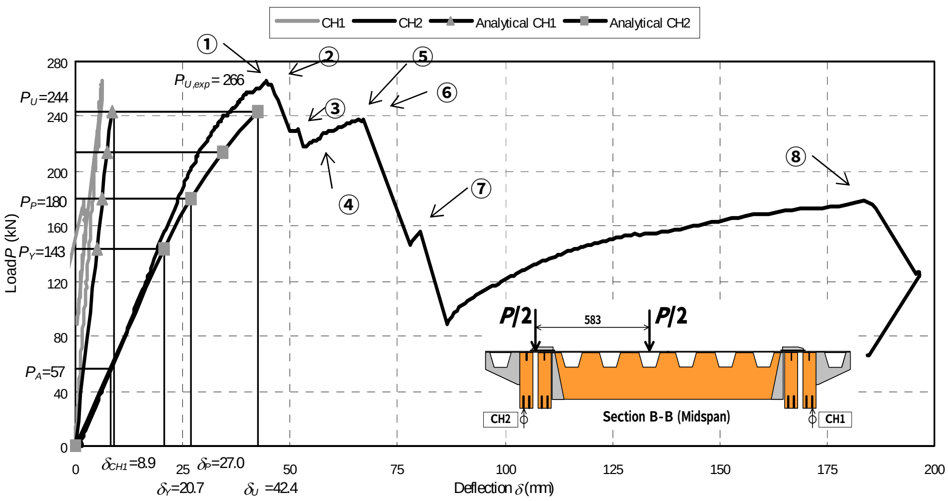

Fig. 1. Load-deflection curves at midspan (failure test)

Keywords: hybrid structure, glulam, orthotropic steel deck, failure test, composite beam theory, finite element

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3. ANALYTICAL INVESTIGATION

The discussed hybrid bridge model was investigated analytically by the plastic composite beam theory. Using this approach, all steel areas were converted to equivalent timber areas[2], resulting in a transformed cross section. In order to obtain this modified section, the ratio of moduli of elasticity of steel and timber were needed. This theory assumes that failure of the composite beam occurs when the tensile stress in the outer fibers of the double glulam main beam reaches the modulus of rupture of timber. Analytical results could closely predict the experimental data[1].

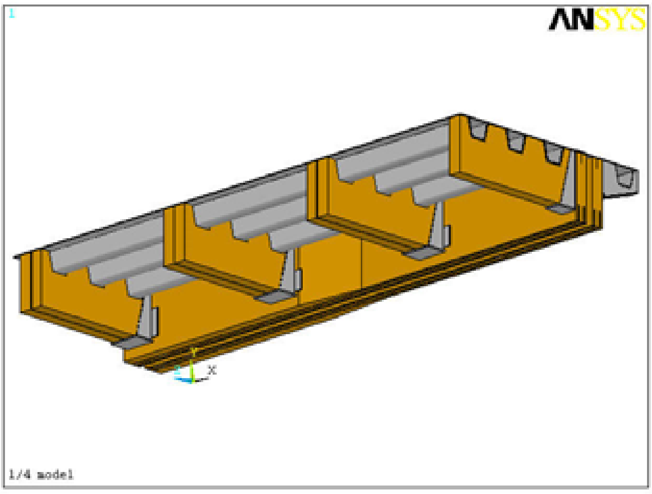

Fig. 2. Bridge model (1/4 of tested structure)

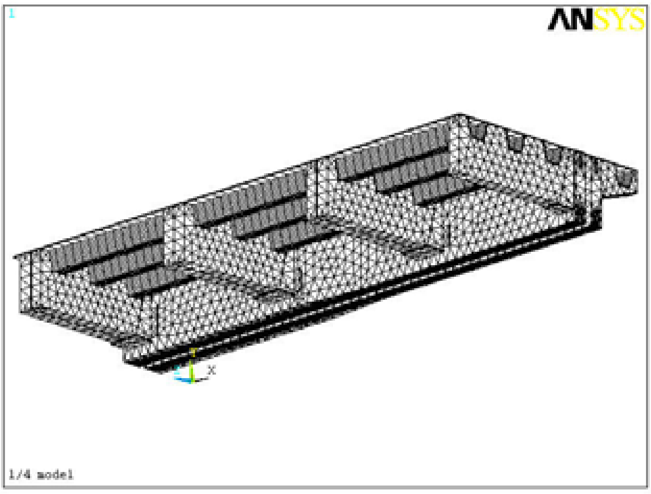

Fig. 3. Finite element bridge model

However, performing a finite element analysis became desirable in order to understand more profoundly the interaction between structural members[3]. A three-dimensional finite element model is being developed at the moment using the general-purpose nonlinear finite element program ANSYS. Due to the large size and because of double symmetry, only a quarter of the tested hybrid structure is being modeled (Fig. 2). All structural members are simulated by solid elements. The mesh consists of tetrahedral and hexahedral finite elements (Fig. 3), the number of elements[4] being approximately 150,000. Results of this analysis will be presented in a future paper.

4. CONCLUSIONS

A reduced scale bridge model was subjected to failure test in order to investigate the structural behavior of a timber-steel hybrid bridge and to validate the applied composite beam theory. The failure load predicted analytically by the plastic composite theory was only 9% less than the experimental one (Fig. 1), thus proving the ability of the applied theory to effectively describe the behavior of this kind of structure; however for further analytical investigation, a finite element analysis is now in progress. The analytical failure load as well as the behavior of the structure predicted by the FEA will be added to the load-deflection curves from Fig. 1 in a future paper. In addition to tests of a reduced scale model, full-scale bending tests and a 3D finite element analysis of double glulam floor beam-orthotropic steel deck hybrid structure[5] is also being performed.

5. REFERENCES

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