FINITE ELEMENT MODELING OF TIMBER-STEEL HYBRID BRIDGE

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1. INTRODUCTION

Japanese cedar usage is a major issue in Japan, which is why several researches concerning civil engineering utilization of this material, e.g. guardrails, timber bridges, are under way. The authors aim to develop a highly durable timber bridge by using a Japanese cedar-steel hybrid structure. In this paper, the authors continue to further investigate the behavior of a proposed glulam beam-steel deck hybrid bridge structure for short and medium span bridges, introduced in their previous works. One purpose of this comprehensive, ongoing study is to check the agreement between test results and calculated results from two analytical methods. Partial results are presented from an analytical approach using plastic composite beam theory and from a finite element analysis, and compared to measured results from a failure test.

2. FINITE ELEMENT ANALYSIS

This paper represents the next step[1)] in understanding the behavior of a glulam beam-steel deck hybrid bridge structure. In addition to an experimental and analytical study[2)], finite element calculations were performed by ANSYS University Intermediate v10.0, which is a general purpose FEM package. Among other mechanical problems, the ANSYS package can be utilized for static non-linear structural analysis. A three-dimensional model was created for load case LC2, in which a failure test was performed (Fig.1). Considering the loading scheme during the test and taking advantage of the geometric symmetry, only half of the tested structure was modeled (Fig.2). Symmetry boundary conditions were applied at midspan and the structure was simply supported.

In order to obtain reliable results in FEM, accurate modeling of material properties is important. Japanese cedar glulam was of strength grade E75-F240, while steel was SS400. Glulam was modeled as a linear elastic, orthotropic material, with the following values of modulus of elasticity, shear modulus and Poisson's ratio: E_Z = 9 GPa, $E_X = E_Y$ = 300 MPa, $G_{YZ} = G_{XZ}$ = 601 MPa, G_{XY} = 60 MPa, $\nu_{YZ} = \nu_{XZ}$ = 0.01, ν_{XY} = 0.2, where Z-axis is parallel to grain. Steel was modeled as a perfect elasto-plastic isotropic material, with E_S = 206 GPa, ν_S = 0.3, together with yield strength $\sigma_{y,S}$ = 297 MPa. The applied truck wheel load was modeled as a pair of concentrated loads. The geometric model was used to create a mesh of 8-node solid elements with different sizes, comprising 21,266 elements and 21,170 nodes in total[3), 4)].

Fig.1 Bridge model in load case LC2

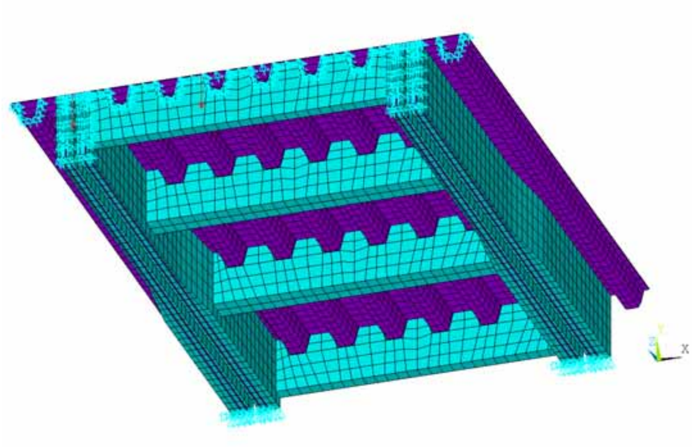

Fig.2 Half-structure finite element model in LC2

Keywords: finite element, hybrid structure, Japanese cedar, glulam beam, orthotropic steel deck, failure test

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3. RESULTS AND DISCUSSION

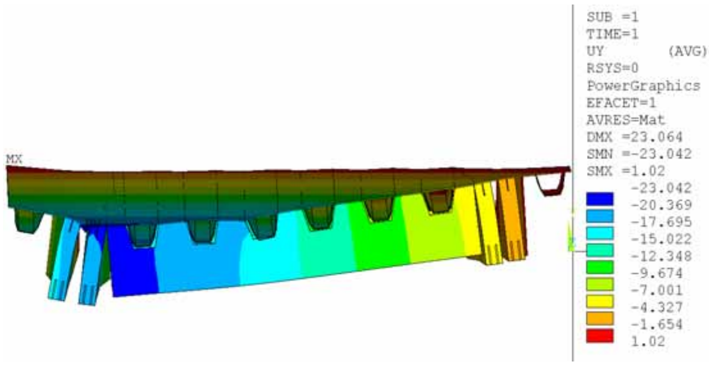

Fig.3 Deformed shape at P_Y = 143 kN

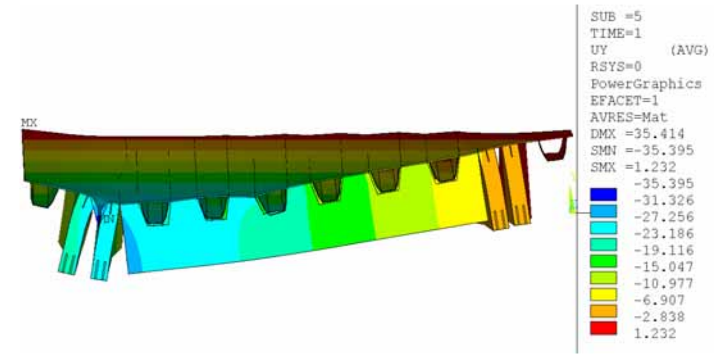

Fig.4 Deformed shape at P_P = 180 kN

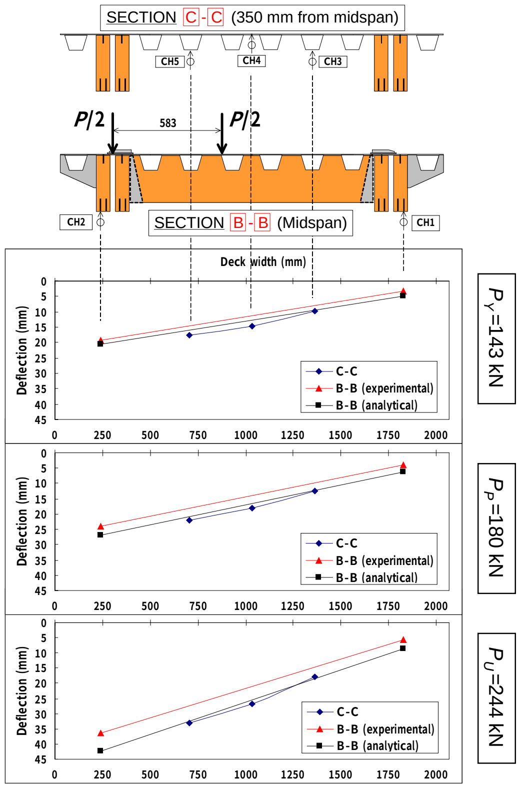

Fig.5 Deflection distribution

Fig.3 and Fig.4 show the deflection values and deformed shape at midspan of the hybrid structure from the FEM analysis at yield load P_Y and plastic load P_P, calculated by the plastic composite beam theory[2)]. Comparing these to the analytical deflection values determined by the plastic composite beam theory and to experimental deflection values from the failure test (Fig.5), a good agreement can be observed between the three of them. Note that deflections from the FEM analysis are magnified 10 times to provide better visibility.

4. CONCLUSIONS

Test results of a one-third-scale hybrid bridge model showed that the plastic composite beam theory could closely predict the pre-failure behavior of the tested bridge model. In addition to this approach, a non-linear three-dimensional FEM analysis was performed to describe more accurately the performance of the structure. However, the materials need to be modeled more accurately, especially their plasticity. After this phase, analysis at ultimate load P_U will also be performed. In the failure test, glue line represented a major cause of premature failure: while glue was not modeled this time, it also needs to be modeled in the future, since glue stiffness, thickness, etc. seems critical for this hybrid structure.
The authors intend to model the entire tested structure, so the other load cases[2)] can also be analyzed. Due to the limited node and element number capabilities of the ANSYS University Intermediate package, this model can only be achieved by converting the double glulam floor beams to equivalent single steel floor beams, modeling them as 4-node elastic shell elements. The rest of the structure will be modeled by 8-node solid elements. The authors wish to present the results of these analyses in a future paper.

5. REFERENCES

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