Numerical Study on the Mechanical Behavior of the Steel-Concrete Composite Beam

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1. Objectives

The steel-concrete composite beam is commonly used in highway bridge design due to its low-cost comparing to other types of structure. In Japan, despite shifting to partial factor design method, the load carrying capacity is still evaluated within the elastic limit while other design specifications like AASHTO and Eurocode allow the use of plastic moment in the design of this type of bridges. Although load carrying capacity equation similar to those of Eurocode and AASHTO have been proposed[1)], no specific guideline has been implemented in Japanese design specifications. Since the bridge inventory in Japan is entering the aging stage, evaluation method that accounts for the plastic moment can reduce the cost required for maintenance or replacement of the bridge. In this context, the mechanical behavior of the steel-concrete composite beam is investigated under the project "Development of Partial Factor Plastic Design Method for Steel Girder" supported by the research contract with the National Institute for Land and Infrastructure Management. Numerical modeling method is proposed to evaluate the load carrying capacity of the steel-concrete composite beam based on the results of the experimental program.

2. Numerical Modelling of Test Specimens

As shown in Fig.1, the 4-point bending test was applied on three test specimens of the simply supported composite beam. The dimension of test specimens is shown in Table 1 and the details of the cross-section are shown in Fig.2. In the numerical model, Finite Element Method with the aid of TNO Diana 10.1 software was employed for modeling and analyzing the bridge model, as shown in Fig.3. The concrete slab is modeled by using the 8-node solid elements with 24 degrees of freedom. The reinforcement bar is modeled by using embedded bar elements. The steel girders and stiffeners are modeled by 4-node curve shell elements. Beam elements were used for modeling the shear studs and interface elements were used for simulating the interface friction between the concrete slab and main girders top flanges. For the material properties, the stress-strain relationship of the structural steel, rebars, and shear studs is shown in Fig. 4. The stress-strain relationship of the concrete is shown in Fig.5 and the bond stress-slip relationship of the interface is shown in Fig. 6.

3. Numerical Results

The load-deflection curves of MY1, MY3, and MY4 from numerical analyses and experimental results are shown in Fig. 7, Fig. 8, and Fig. 9, respectively. Consistent results between experimental models and numerical models can be confirmed. For all specimens, the ultimate failure mode is determined by the crush of the concrete slab in the experimental program. For the numerical analyses, the ultimate failure load is determined when the principal strain of the concrete slab reach 3500μ. As shown in Table 2, the ultimate loads obtained from numerical analyses are very close to those obtained from the. The numerical modeling methods used in this study are proved to be accurate to predict the performance of the steel-concrete composite beam.

4. Conclusions

This study is part of the preliminary study in the evaluation of the load carrying capacity of the steel-concrete composite beam. The validation of the numerical model is confirmed in this study. Parametric studies are performed in the future study with the aims of introducing the plastic design method of composite beam in the bridge application in Japan.

Reference

1) Gupta V.K., Okui Y., Inaba N., and Nagai M. : Effect of concrete crushing on flexural strength of steel-concrete composite girders, Doboku Gakkai Ronbunshuu A, Vol. 63, Issue 3, 2007.

Keyword: composite beam, bending test, Finite Element Method, nonlinear analyses

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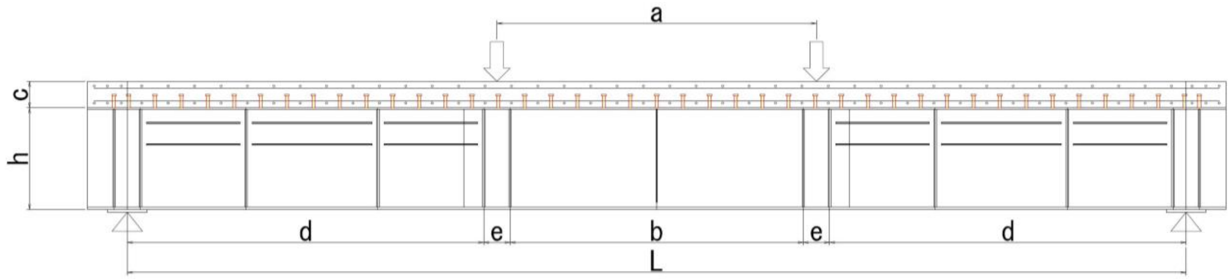

Fig.1 Longitudinal profile of test specimens

Table 1: Dimensions of test specimens (unit: mm)

Test Specimen	Span length L	Test panel b	Side panel e	Support panel d	Loading distance a	Girder height h	Slab Thickness c
MY1	8020	2220	200	2700	2420	772	200
MY3	8380	2580	200	2700	2780	892	200
MY4	8020	2220	200	2700	2420	772	200

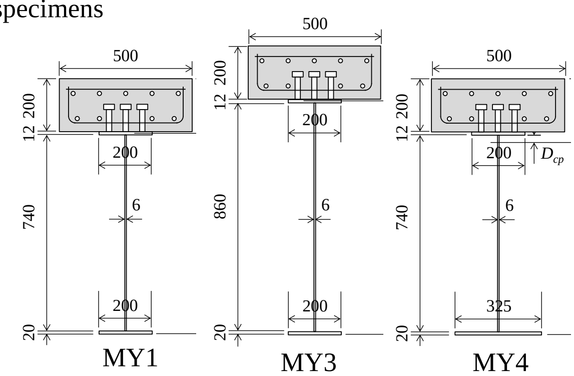

Fig. 2 Details of cross sections (mm)

Table 2: Ultimate load of each test specimens

Test specimen	MY1	MY3	MY4
Experiment (kN)	1667.04	2028.00	2185.14
Analyses (kN)	1678.00	2060.00	2240.00
Ratio	99.35%	98.45%	97.55%

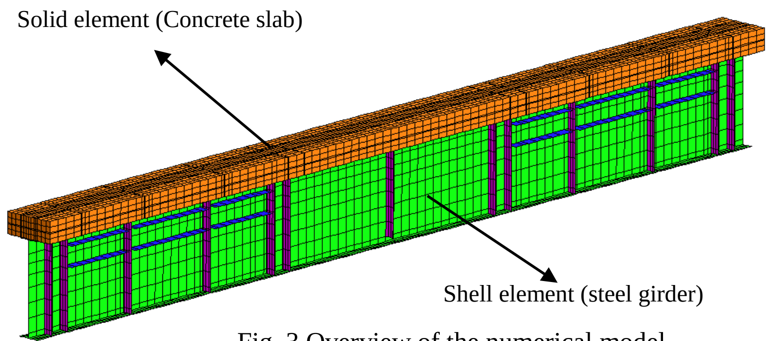

Fig. 3 Overview of the numerical model

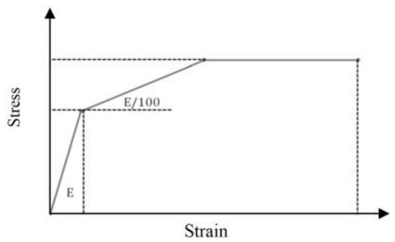

Fig. 4 Stress-strain relationship of structural steel, rebars, and stud

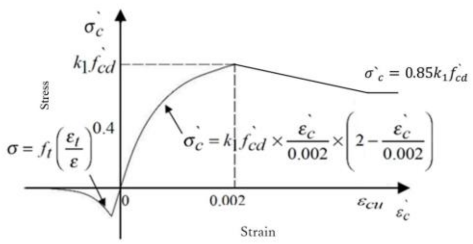

Fig. 5 Stress-strain relationship of Concrete

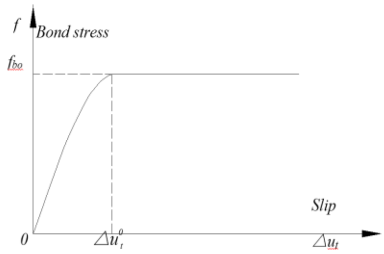

Fig. 6 Bond stress-slip relationship of interface

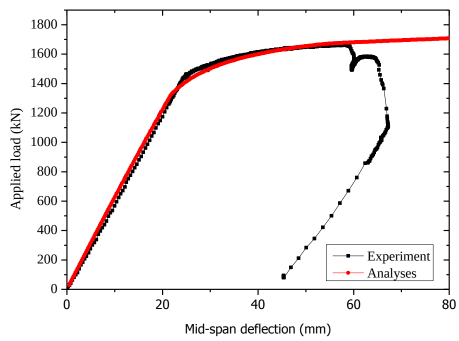

Fig. 7 Load-deflection curves of MY1

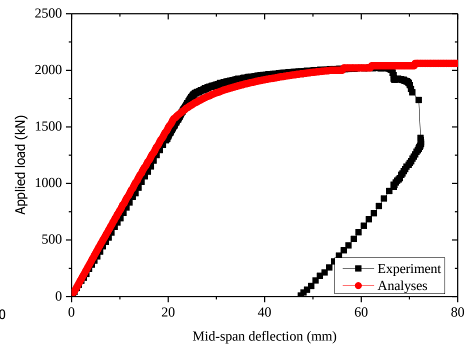

Fig. 8 Load-deflection curves of MY3

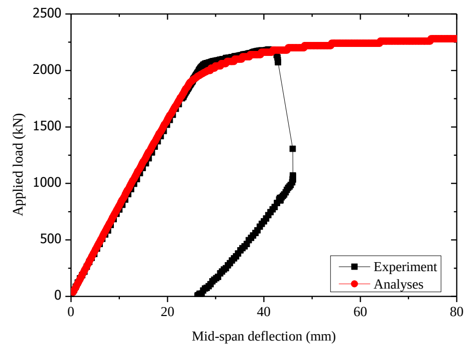

Fig. 9 Load-deflection curves of MY4