令和元年度土木学会全国大会第74回年次学術講演会

Numerical Study on Mechanical Behavior of Intact Composite Twin I-Girder Bridges

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1. Introduction

The conventional way of constructing highway bridges uses the multi-girder system as the superstructure. To reduce the heavyweight and prevent the buckling of the main girders, thin plates with several stiffening members was the most common solution. To further reduce the bridge construction cost, reducing the number of main girders to twin girder bridge has become more commonly used in highway bridge. To investigate the mechanical behavior of twin I-girder bridges, a small scale of intact composite twin I-girder bridge specimen was tested under one-point load in the middle of one main girder. By using the experimental data, a numerical model of the bridge specimen was created, and nonlinear analysis was performed to investigate the performance of twin I-girder bridges.

2. Test Specimen and Numerical Analysis

Fig. 1 shows the exterior of the twin I-girder test specimen. The specimen has a total length of 4.4m, a width of 1.2m and a height of 0.42m, including 0.3m of I-shape steel girder and 0.12m of the reinforced concrete slab. The interval between two main girders was 0.8m, the span length was set to 4m in this experiment. The detailed dimensions are shown in Fig. 2. Girder-1 implies the main girder under one-point load and the other is girder-2. Referring to details of the test specimen, an analysis model was created using Finite Element Analysis (FEA) software – DIANA 10.1. By applying the nonlinear material properties for each element, the nonlinear analysis was performed.

3. Material and Physical Properties

In this experiment, the steel type of SM490 was used for the main girders, cross beams and transverse stiffeners, and the steel type of SD345 were used for all the reinforcement bar with the diameter of 10mm, SS400 was used for studs. Detailed material properties were shown in Table. 1. Compressive strength tests was done to three cylinder concrete specimens on the test day, and the average compressive strength was 33.7 N/mm^2. The stress-strain curves of steel and concrete used for the finite element model were calculated according to the JSCE specification[1)].

Fig. 1 Overview of test specimen

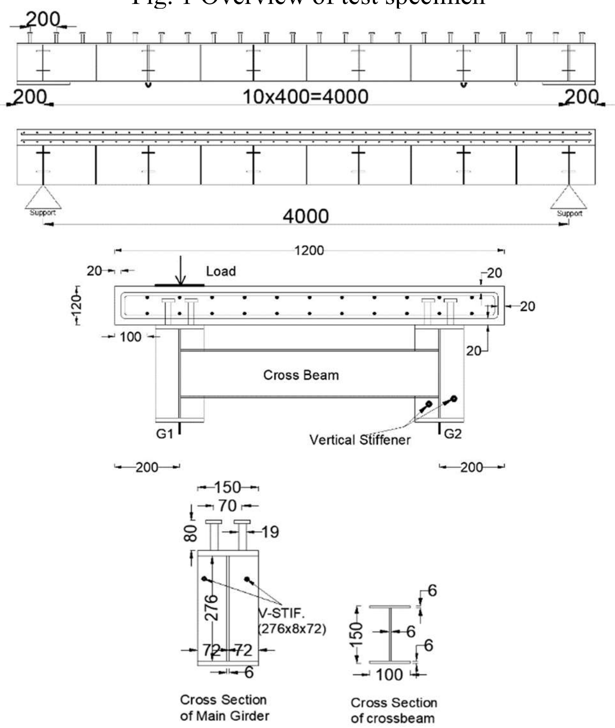

Fig.2 Details of the test specimen

Table. 1 Material properties of steel structure

Steel	Type	Young's modulus (GPa)	Yield Strength (MPa)	Ultimate strength (MPa)
Steel plate (6mm)	SM490	200	450	577
(8mm)	SM490	200	427	556
(12mm)	SM490	200	389	548
Rebar (D10)	SD345	200	406	544
Stud	SS400	200	235	400

Keywords: Numerical study; Twin I-girder; Composite bridges; One-point load test; Finite Element Analysis.
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4. Results and Discussion

4.1 Load-displacement curve

The load-displacement curves obtained under the concrete slab in the middle section of girder-1 were shown in Fig. 3. Analysis result agree well with the experiment data, from which the accuracy of numerical model is verified. During the experiment, when the applied load increased to 446kN, the yield point was reached. For the analysis result, the yield point was reached at 449kN.

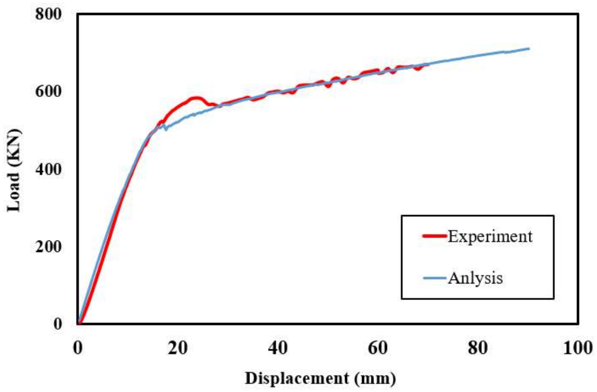
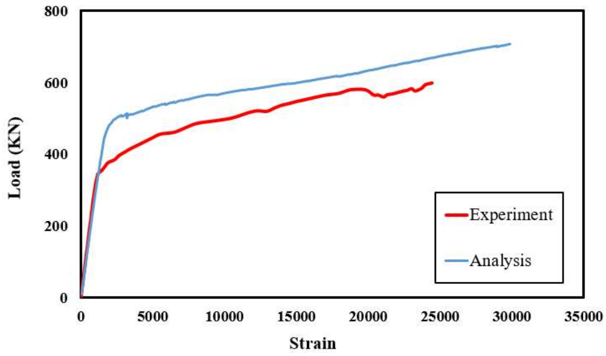


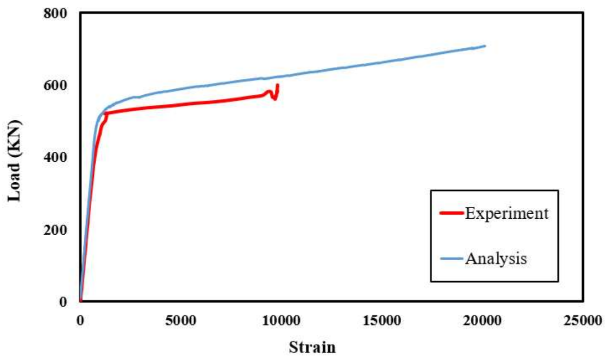
Fig. 3 Load-displacement curves at middle section

4.2 Load-strain curve in web of steel girder

Two load-strain curves obtained at the web of girder-1 were shown in Fig. 4. The position was shown in Fig. 5. For both strain gauge 143 and 142, the analysis result and experiment data fit well in elastic region. In the post-elastic region, the analysis result tends to be higher than the experiment data, and compared with the result of strain gauge 142/143 shows more difference. Residual stress due to welding when the girder was made might be one of the major reasons resulted in difference between experimental and numerical results.



(a) Strain gauge 143



(b) Strain gauge 142

Fig. 4 Load-strain curves in web of steel girder: (a)Strain gauge 143, (b)Strain gauge 142

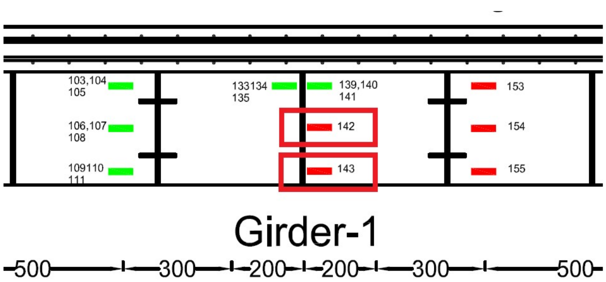


Fig. 5 Position of the selected strain gauges

5. Conclusion

The proposed finite element model incorporates experimental stress-strain relationship of steel-concrete and concrete failure mechanism after cracks happened to simulate the possible influence to deflection and strain during the experiment. The accuracy of the model was verified by comparing the nonlinear analysis results and experiment data of the test specimen.

Results of load-displacement curves at middle section agree well with the experiment data at strain-hardening region, showing that current concrete failure model corresponds closely to the actual situation. In addition, the difference between measured strain and predicted strain are presumably due to the residual stress near the welded section.

References

1) JSCE (Japan Society of Civil Engineers). (2007). Standard specification for steel and composite structures, Tokyo.
2) Lam, H., Lin, W., & Yoda, T. (2017). Performance of Composite Twin I-Girder Bridges with Fatigue-Induced Cracks. Journal of Bridge Engineering, 22(9), 04017056. doi: 10.1061/(asce)be.1943-5592.0001094

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