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NUMERICAL STUDY ON THE BEHAVIOR OF STIFFENER IN JOINT CONNECTION OF HYBRID-RIGID FRAME BRIDGE

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1. Introduction

Generally, connection between the reinforced concrete pier and steel girder of the hybrid rigid-frame structure is post-tensioned with prestressing tendons. Though this connecting method has reliable durability, the application to actual bridges is limited because of its inferior efficiency and economy. The present study describes the detailed aspects of a finite element program developed for the nonlinear analysis of two dimensional composite steel-concrete structures by using MARC [1]. The objectives of this paper are to investigate the behavior of stiffener in connection of hybrid-rigid frame bridge by using a finite elements method. There are two types of specimens; type-S and type-T, which had been tested in an experimental study [2] and will be used herein as the model for the analysis. The difference between these two types is that in type-T, there are some stud shear connectors in the stiffener in the connection, while no stud exist in type-S. The analytical results are compared with the experimental results and good agreement is obtained. The results of the analysis demonstrate that nonlinear finite element method can be used reliably to evaluate the behavior of hybrid rigid bridge, and predict its strength.

2. Constitutive Equations

In this study, concrete is modeled as shown in Figure 1, in which the behavior of concrete in compression was proposed by Saenz [3]. Cracking is monitored by checking the magnitude of σ_1 and σ_2. When the principal stress reach at the point equals or exceeds the tensile strength of concrete, cracking is assumed perpendicular to the particular direction. After initiation of cracking, concrete is also able to transfer tension between the cracks. This phenomenon is considered herein by assuming a descending branch for the concrete in tension. Concrete can still carry some tension up to a maximum tensile strain of 10 ε_{cr}, where ε_{cr} is the cracking strain.

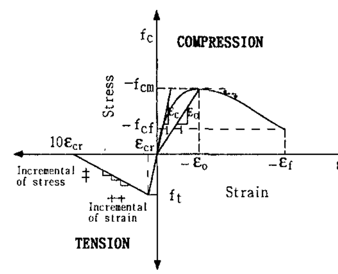

Figure 1. Constitutive Equation for Concrete

3. Numerical Analysis and Result

The specimens, which have been tested experimentally, were modeled as finite element mesh. The structures are divided into several elements. The dimension and the mesh of each element are shown in Figure 2. 8 node plane stress element was used for modeling the concrete and steel plate, and 2 node truss element is used for modeling steel reinforcement and stud shear connector. Material properties used in this study are f_c' = 3.374 kg/mm^2 and 3.412 kg/mm^2 for type S and T, respectively; f_y = 37.86 kg/mm^2, 30.72 kg/mm^2, 30.21 kg/mm^2 for reinforcing bars, web plate, and flange, respectively. E_c: 2755.27 kg/mm^2 for type-S, and 2770.74 kg/mm^2 for type-T, E_{rc} = 16300 kg/mm^2, and E_{plate} = 21000 kg/mm^2.

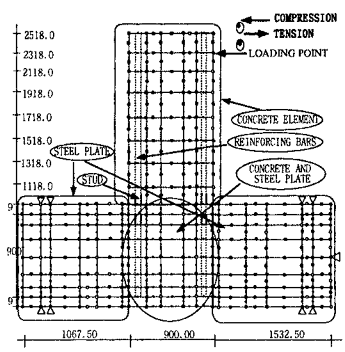

Figure 2. Dimension and mesh generation

First the load-deflection relationship for each specimen is investigated to check the accuracy of the model. The comparison of result for type-S is shown in Figure 3. From this figure we can conclude that in the elastic range, flexural rigidity of the analytical model is smaller than the experimental result. The first crack occurs at 10 tf load level during experiment, while in the analysis the first crack occurs at 11.5 tf load level. From this point up to 75 tf, flexural rigidity of the specimen is smaller than the analytical result. The maximum difference of the deflection between the analytical model and specimen was about 9 %, which occurs at load level 40 tf. At higher load level, the analytical result matched to the experimental result. In tension side, it can be observed that the two curves are closely matched, and the maximum difference was about 1 %. The same phenomenon was also observed for type-T. The first crack occurs at load level 12.4 tf. At load level between 55 to 100 tf, the flexural rigidity of numerical result is higher than the experimental one. The difference

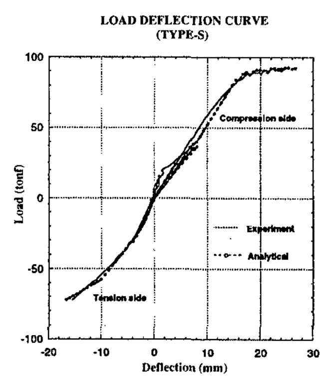

Figure 3. Load-deflection curve for type-S

between the numerical and experimental result is about 1.5 %. Even if the deformation of the connection part is large, the stiffener does not reach to the yield point. In analytical study, the specimens failed due to crushing of concrete element in the connection part. Though this phenomenon was also appeared in the experiment, the excessive opening between the steel beam and the RC column was in ultimate state, and the fatal damage would not occur in the steel beam by making plastic hinge to that section.

To investigate the behavior of the stiffener, we focused on tension and compression strengths of the stiffener. The detail of connection is shown in Figure 4. As shown in figure, a-b-c-d are the point that we used as an investigation point. From numerical analysis results, the model can predict the results closely as compared to the experimental result. All the results are shown in Figure 5 and 6. When compression load is applied to the specimen, the stiffener will carry the compression and tension strength. The maximum tension strength and compression strength can be carried by stiffener are about 34 tf. In type-T case for upper part (ab) the tension strength increases gradually, and then drops suddenly in the load level 70 tf, and the strength is larger than type-S. On the other hand, the compression strength for type-S is larger than type-T. The phenomenon mention above also appear on the behavior of the lower part of stiffener (cd) in tension and compression strength results. From the experimental study, this phenomenon can be clearly understood that the tension strength in this part will be taken care by stud shear connector. This phenomenon also occurs in the analytical study. It is clear that the force on stud shear connector is not directly proportional to the load applied to the column, but depends on the stiffness of various component on the connection part. Furthermore, residual stress in the steel element and further material non linearity in the concrete element make it more complicated problem to determine the forces in the stud shear connector. Due to the complexity of the component that affects the behavior of stud shear connector, as proven in the analytical study on stud shear connector behavior becomes very complicated. So far the analytical study concentrated in this subject is still in progress. We can conclude that the effect of studs shear connector in the stiffener on the loading capacity is some of the compression stress carried by stiffener can be transferred smoothly to studs.

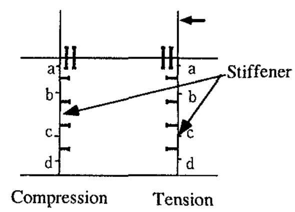

Figure 4. Detail of Connection part

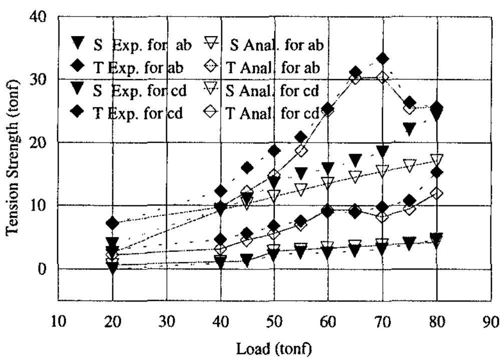

Figure 5. Load-Tension Strength relationship

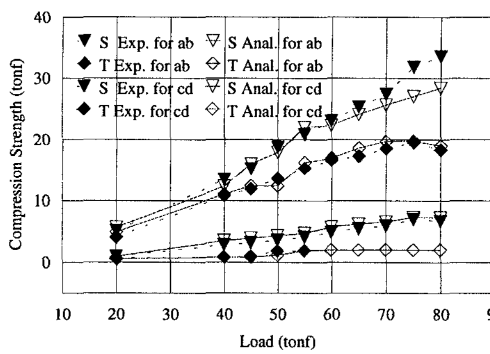

Figure 6. Load-Compression Strength relationship

4. Conclusion

The following conclusions are supported by the analytical and experimental results reported in this study:

- The analysis result demonstrate that nonlinear finite element method can be used reliably to evaluate the behavior of hybrid rigid bridge, and predict its strength.
- Residual stress in the steel element and further material non linearity in the concrete element make it more complicated problem to determine the forces in the stud shear connector.
- The effect of studs shear connector in the stiffener on the loading capacity is some of the compression stress carried by stiffener can be transferred smoothly to studs.

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3. Saenz, L.D., 'Discussion of equation for the stress-strain curve of concrete by Desayi and Khrishnan ', J.ACI. ,61(9), 1964, pp. 1229-1235.