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Study on Stress Transfer Mechanism of Hybrid Rigid-Frame Bridge

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Summary

This paper explains about the research on stress transfer mechanism of hybrid rigid frame bridge. The behavior of stress transfer mechanism was clarified through experiments and analysis. In experimental work, two specimens of hybrid rigid frame bridge in which the super structure is rigidly connected to reinforced concrete piers were tested. Two dimensional finite element method was used to analyze the structure to clarified the result analytically. From this study it was found that the studs on the stiffener, effectively transfer the loads to the stiffener. Since the strains of inner and outer surface of the flange in the connection are within reasonable range, it is recommended that this type of connection method can be used if stud shear connectors are properly provided on the stiffeners.

1. Introduction

Hybrid rigid frame bridge structure is a structure in which the super structure is rigidly connected to reinforced concrete piers of the bridge. This type of structure now becomes famous in Japan due to some advantages. The main advantage of this type of structure is the structure can carry the seismic response more safety than the ordinary structure. On the other hand, as an economical effect, due to the reduction of bearing to handle the structure, this type of structure also cheaper than ordinary structure due to the reduction of weight of super structure. Also some damage originated from local damage in shoes and expansion joints in super structures can be eliminated[1].

Though such merits do exist, still few studies have been carried out to clarify the behavior of each component of the structures. So far the research only specified to strength and ductility of full structures [2], or studied on the properties of the corner section of the structures [3]. The objectives of this research are to study the stress transfer mechanism in developed steel-concrete hybrid rigid frame bridge and to study the mechanical behaviors including the load carrying capacity of individual elements in the structure. The experimental and analytical works were explained, and the results for each component of structures are observed analytically as well as experimentally.

It was found that the studs on the stiffener, effectively transfer loads to the stiffener. Since the strains of inner and outer surface of the flange in the connection are within reasonable range, it is recommended that this type of connection method can be used if stud shear connectors are properly provided on the stiffeners.

2. Experimental Work

2.1. Specimens

The specimens consist of steel girder, reinforced concrete column, stiffeners, main reinforcements, and stud shear connectors. Stiffeners are fixed in steel girder, and main reinforcements are continuous from the reinforced concrete column to the steel girder through the holes in the bottom flange. The reinforcements were anchored to the concrete within the space enclosed by top and bottom of flange, web plate, and stiffeners. As such, the steel girder and reinforced concrete column becomes a single structure. This type of mix hybrid structure is considered in this study using a T-shape specimen. The load transferred from RC column to steel girder can be considered as bending moment.

Figure 1 shows the detail of connection for each specimen. In S- type specimen, studs exist only in the flange of the intersection of the connection part of RC column and steel girder. On the other hand, in T-type specimen, studs exist not only in the steel flange but also in the stiffeners of the connection part. The objective of T-type specimen is to determine the effect of stud shear connectors in the stiffener which have ability to transfer some additional loads through the connection. Detailed explanation concerning about experimental work can be referred to previous paper [4].

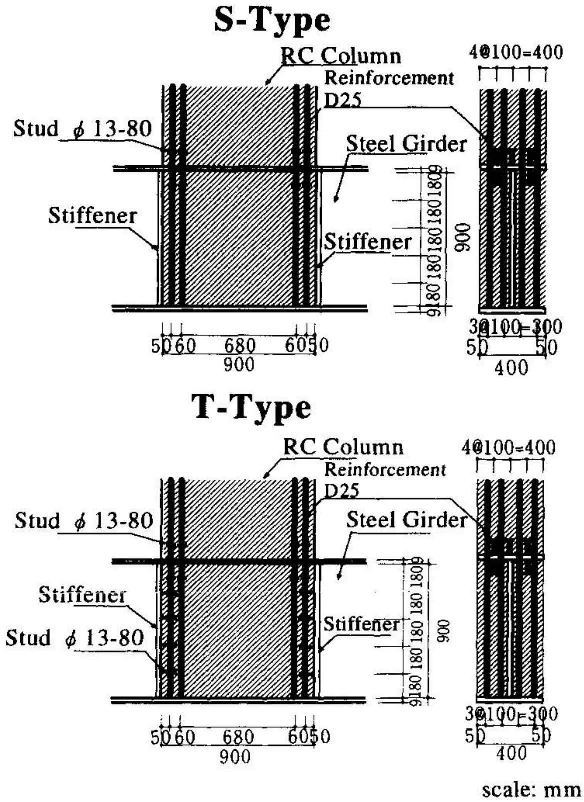

Fig. 1. Detail Specimens

2.2. Testing program

The specimens were tested in inverted position compared to the ordinary structures. The load was applied at the top of reinforced concrete column. The data was measured from the strain gauges and displacement transducers attached to the specimen. The applied loading was cyclic and as for sign convention, the direction towards of actuator head is considered to be positive for tension load, and negative for compression load. At peak displacement of each cycle, the occurrence of crack was checked and the stresses in the reinforcement bars were observed for yielding condition.

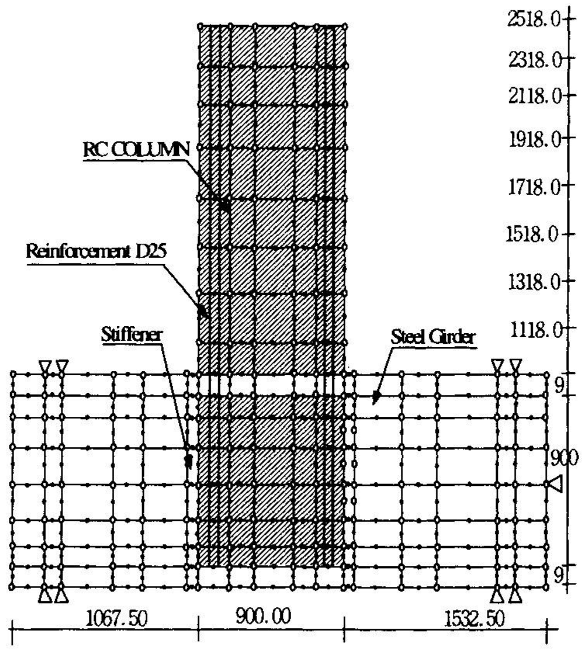

Fig. 2. Mesh generation of FEM

3. Analytical Work

The structures are analyzed by using finite element program MARC[5]. The structures are divided into several elements, and the dimensions and the mesh generation of each element are shown in Figure 2. Plane stress element with 8 node element was used for modeling the concrete and steel plate, and truss element was used for modeling steel reinforcement and stud shear connectors. Detailed constitutive equation for concrete and steel can be referred to previous paper [6].

4. Result and Discussion

4.1. Behavior of the flanges

Behavior of the flanges monitored by strain distribution on inner and outer surface of the flange. Figure 3 shows the comparison result for strain distribution on inner surface of flange both for S-type and T-type. It can be recognized from the figure that the measured strain distributions agree well with the values obtained from analysis except the point in compression flange for S-type. The strain in the point located in compression flange of north side was 4211 micron. At the same point, the analytical result was about 1500 micron. Compare to another point in compression flange, the strain in north side has large value. Figure 4 also shows the same phenomena, where the largest strain distribution was also in the compression flange of north side. These phenomena might be due to the large moment in the connection part, so the strains in that part become large. Figure 5 shows the strain distribution on tension flange for each type. The figure shows that the largest stain value was in the south side. It means that the result is in contrast to the result for the compression flange. This behavior can be easily understood that when the load is applied to the RC Column, the compression load will be transferred to the steel girder through bonding between reinforcement and concrete. Also the load transferred from the stiffener to the tension flange of the girder in south side. On the other hand, in north side the load transferred through the bonding between steel and concrete to the compression flange of the girder. It can be understood from figure 3 to 5 that the analytical result shows good agreement with the experimental result. It can be seen also that the strain in inner and outer surface of the flange in T-type is not so large. It means that even if we reduce the thickness of the flange in the connection part of T-type specimen, the structures are still all right. Since the strains of inner and outer side of the flange in the connection are within reasonable range, it is recommended that this type of connection method can be used if stud shear connectors are properly provided on the stiffeners.

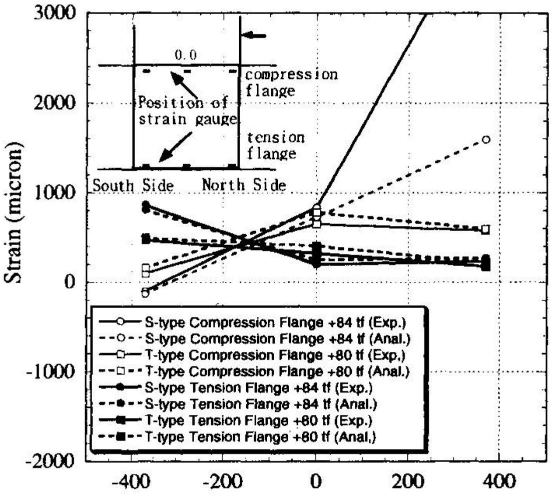

Fig. 3. Strain Distribution of Inner Surface of the Connection

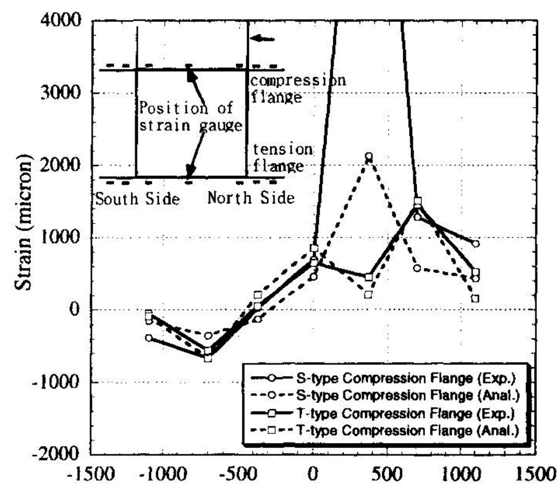

Fig. 4. Strain Distribution on Compression Flange for Each Type

4.2. Effect of the thickness of the flange in connection part on strain distribution

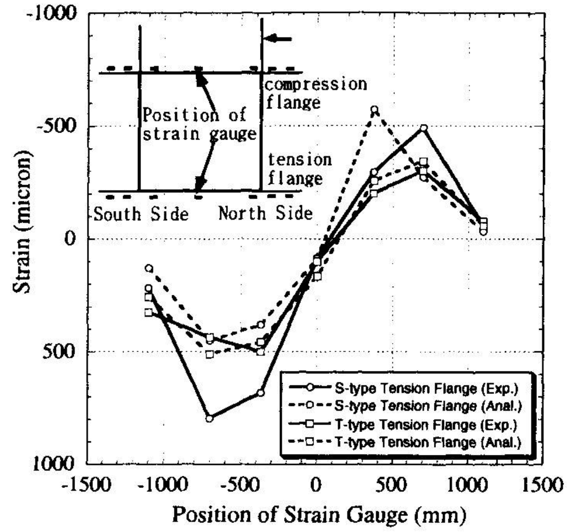

Fig.5. Strain Distribution on Tension Flange for Each Type

As mention in section 4.1 that the strain in inner and outer surface of the flange for specimen T-type was not so large. So it is possible to reduce the thickness of the flange in connection part. In analytical study, there are two cases have been studied to investigate the effect of the thickness of the flange in the connection part. In case A, the thickness in compression and tension flange of connection part reduce to 6 mm, and the thickness of stiffener is 9 mm. Case B, the thickness in compression and tension flange of connection part , and the thickness of stiffener are 6 mm. The result for inner surface of the compression and tension flange show in Figure 6 and 7, respectively. The results plotted in the figures are experimental result, analytical result for the original structure, and analytical result for case A and B. It can be investigated from the result that even if we reduce the thickness of flange in the connection part, the result still in the reasonable range. Figure 6 shows that in case-A, the strain in south and north side almost same with the result of the original structure, but the strain in the middle of connection part (in point 0.0) is larger than the original structure. This result shows a clear understanding about the effect of the thickness of the flange. Due to the reduction of the thickness, the flange will carry more strain. On the other hand in south and north side of the specimen, the value almost same due to the thickness of the stiffener same with the original structure. In case B, the strain in south and north side are larger than original structure, also the strain in the middle of connection part is larger compared to the original structure and case A. It can be understood from this study that in case A the strain in south and north side of the connection are smaller than case B, because some strain will be carried by the stiffener in the connection part. It can be concluded from these phenomena that the thickness of the flange in the compression flange and the stiffener in the connection has significant role in stress transfer.

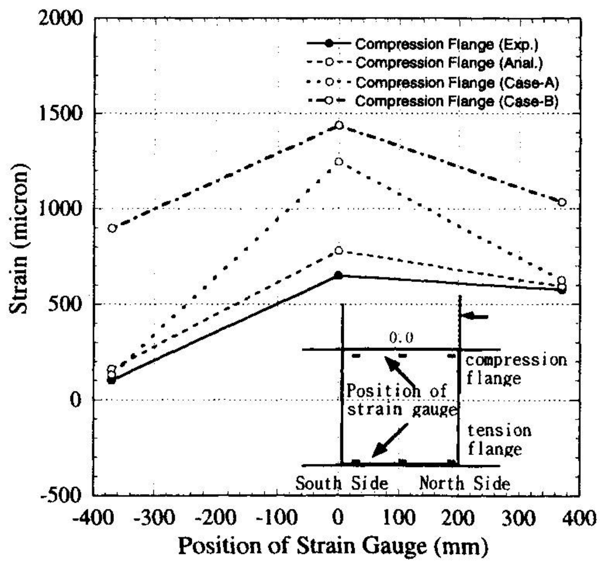

Fig. 6. Strain Distribution on inner surface of Compression Flange in the connection

Figure 7 shows strain distribution on inner surface of tension flange in the connection. This figure shows the comparison result between experimental result, analytical result for original structure, and analytical for case A and B. The figure shows that the results for case A and B in every point get larger result compare to the original structure. In case A, even if the thickness of the stiffener is same as original structure, but the results in south and north side are larger than the original structure. It can be rationalized that when the load applied to the specimen, the tension flange will carry the load which is transferred through bonding between reinforcement and concrete. In case B, compare to the original structure and case A, the stain increase in south, north, as well as in the middle of the connection part (point 0.0). Analytical result shows that the result in all of the point almost same. This phenomena also as an effect of the reduction of the thickness of the flange and stiffener in the connection part. As a result from figure 6 and 7, the effect of the thickness of the flange in the connection part shows that the thickness in compression and tension flange has significant role on stress transfer. However, that effect in the compression flange is more significant compared to the tension flange.

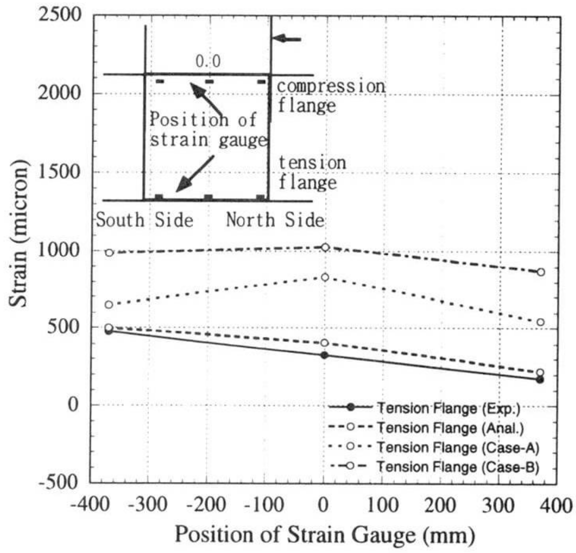

Fig. 7. Strain Distribution of Inner Surface of Tension Flange in The Connection

4.3. Behavior of the stiffener

Behavior of the stiffener monitored by checking the compression and tension force that carried by the stiffener. In experiment and analytical investigation, point a-b-c-d are used as investigation points. Point a-b located in the upper part of stiffener, and point c-d located in the lower part of stiffener. Load compression force relationship for stiffener and stud located in the investigation point a-b and c-d is shown in Figure 8 and 9. The purposes of these figures are to show the different phenomenon between S-type and T-type, to show phenomenon in the upper part and lower part of the stiffener, moreover to show good agreement between analytical and experimental result. From the figures we can see that S-type specimen carry more compression force than T-type. It can be investigated from the experimental work that when the load applied to the specimen S-type, in south side, the load directly transferred to the stiffener. Then in case of specimen T-type, the load will transferred to the stiffener and then transferred to stud shear connector. For investigation point a-b, the compression force from stiffener will transfer to stud i,

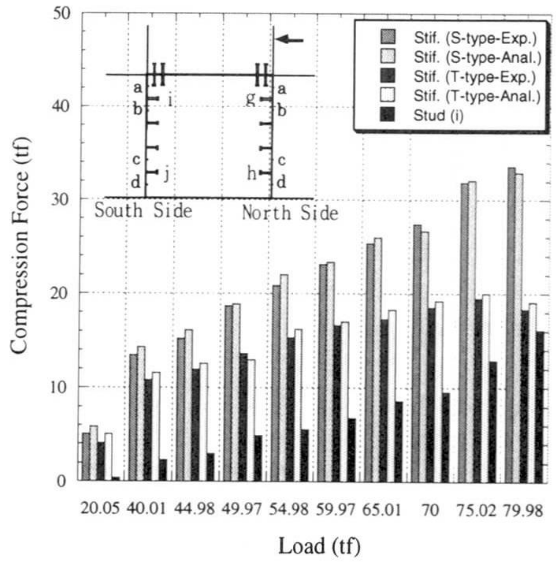

Fig. 8. Load-Compression Force Relationship in Point a-b and Stud i

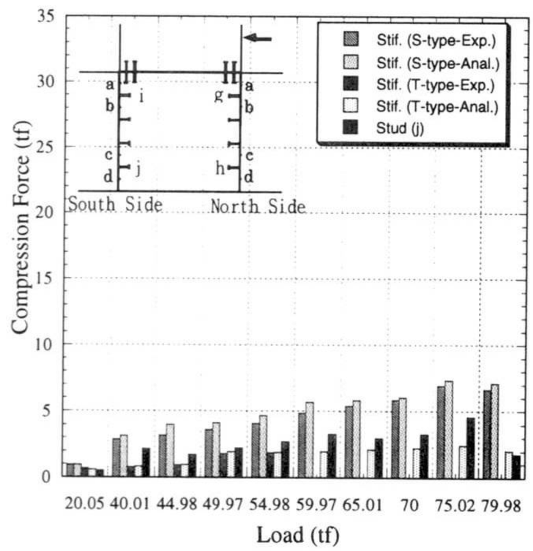

Fig.9. Load-Compression Force Relationship in Point c-d and Stud j

as shown in Figure 8. The result for investigation point c-d and stud j shows in Figure 9. This figure shows the same phenomenon with the previous figure, but the different is only in the total compression force can be carried is very small compare to the previous result. It can be concluded from these figures that the stud shear connector located in the upper part of stiffeners work effectively in transferring the stress in the connection part of hybrid rigid frame bridge. Considering the explanation from figure 8 and 9, the load transfer mechanism was drawn in Figure 10.

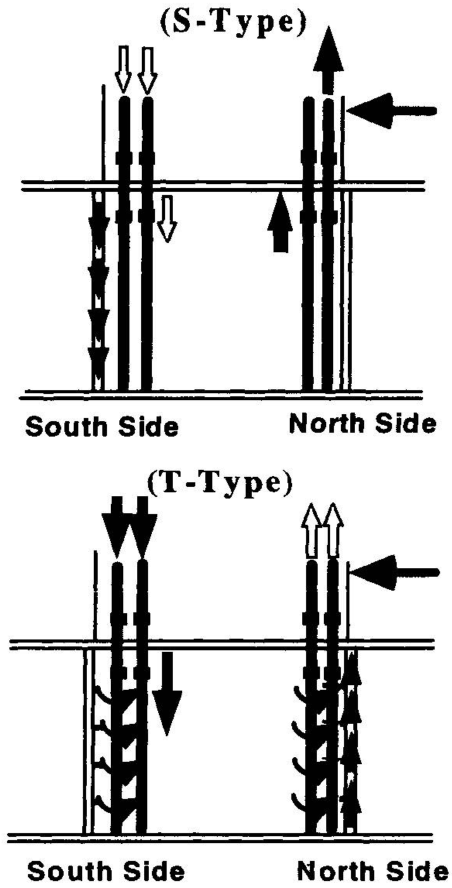

Fig. 10. Load Transfer Mechanism of Each Type

5. CONCLUSION

On the basis of the results in this study, the following conclusions may be drawn.

1. The strain in inner and outer surface of the flange in the connection of T-type is small. So it is possible to reduce the thickness of the flange for T-type specimen. Since the strains of inside and outside the flange in the connection are within reasonable range, it is recommended that this type of structure can be used if stud shear connectors are properly provided on the stiffeners.
2. Analytical results concerning the effect of the thickness of the flange in the connection part shows that the thickness in compression and tension flange has significant role on stress transfer. However, that effect in the compression flange is more significant compared to the tension flange.
3. The stud shear connectors in the upper part of the stiffener work effectively in transferring the stress in the connection part of hybrid rigid frame bridge.

REFERENCES:

1. Jiro Tajima, Yoshiniro Ito, and A. Machida, (1987)," Joints in Hybrid Bridge of Steel Girder and Concrete Pier", IABSE proceeding, pp. 425-430.
2. Shigeyuki MATSUI, Yasukuki YUKAWA, et.al., (1997)."Strength and Ductility of Beam-to-Column Connections in Hybrid Bridge", International Conference, Composite Structures, IABSE Proceeding, pp.469-474.
3. Nobuhito Okubo, Yoshifumi Maeda, et.al., (1998)."An Experimental Study on Structural Properties of a Steel-Concrete Hybrid Frame Bridge", The Sixth East Asia-Pacific Conference on Structural Engineering & Construction, EASEC-6 Proceeding, pp.513-519.
4. Mochammad Afifuddin, Takao Sugiyama, et.al., (1998)."A study on Connection mechanism of T-Joint in Steel-Concrete Hybrid Rigid Frame", Transaction of JCI Vol.20, 1998, (under published).
5. Marc Analysis Research Corporation., (1994). *Marc Manual, Vol: A - E*, California, USA.
6. Mochammad Afifuddin, Atsuhiko Machida, et.al., (1998)."Study on Behavior of Connection Mechanism on Hybrid-Rigid Frame Bridge Structure", Journal of Structural Engineering, Vol.44A, 1998, (under published).