Experimental Study of Stud Shear Connector for Steel-Concrete Composite Beam

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1. INTRODUCTION

Recently, the application of composite structures has become increasingly popular. The composite structure has been greatly developed to fulfill complicated structural requirement. The composite member has proved its high load carrying capacity and high ductility in bending and shear. However, capacity of composite member, such as punching shear capacity, con not be predicted with reasonable accuracy because the load carrying mechanism has not been clarified yet. One of the key issue for the clarification is constitutive relation for shear connector. The shear connectors are required for transfer of shear force between concrete and steel element in order to develop the composite action. The shear connectors are also provided for stiffening the structural steel plate which also acts as formwork. It is important to understand the behavior and capacity of the shear connector as a basic knowledge for the design of composite structure. While shear transfer capacity of shear connector has been studied and well understood, researches on shear connector were conducted merely by direct pull-out tests. In actual structures, the shear connector is not only subjected to the transferred shear force but also compressive force and the local bending deformation of steel plate. The behavior and load carrying capacity of shear connector may be different from those obtained by the direct pull-out test. Considering this point the present study was conducted with a series of tastes on simply supported beam with one-point load.

Shaped steel and headed stud have been often used as shear connectors. One of the most important item regarding the composite members is how to evaluate the strength and behavior of the shear connector. In the analysis of steel-concrete composite structure, the composite action between steel plate and concrete block should be considered by using a transferred shear force-relative displacement relationship of the shear connector. There were some studied related to shear transfer capacity of shear connector but so far no study on the relation between transferred shear force and relative displacement of shear connector except for studies by Taufiq,(in those studied shaped steel shear connector was used).

The study attempted to predict experimentally the relationship between transferred shear force and relative displacement of stud shear connector in steel-concrete composite beam.

2. EXPERIMENT

2.1 Description and preparation of specimens

The experiment work was carried out for the steel-concrete beams shown in Fig.1. Stud shear connectors were provided at the interface between the concrete and the steel plate. The shear connectors were welded perpendicularly to the steel plate. Tests were carried out for 5 specimens. The specimens were designed to fail in one side of the beam. Therefore, one of the two sides has been strengthened than the other. The side which has not been strengthened is the investigated side as shown in Fig.1. The specimens S-1, S-2 and S-3 were studied to investigate the effect of the stud height on the shear transferred force-relative displacement relationship, while S-4 was tested to know the effect of changing the spacing between stud in transverse direction.

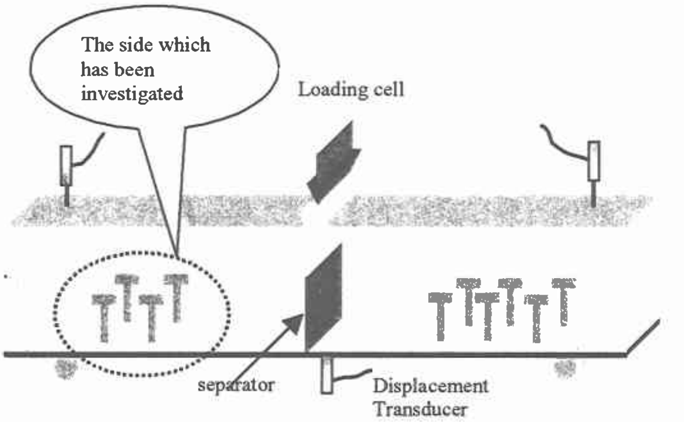
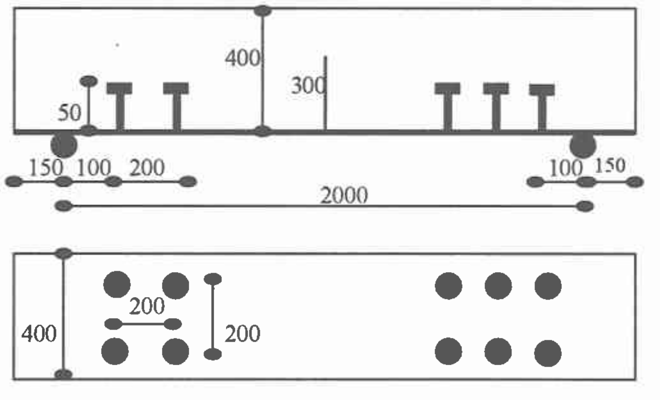


Fig.1 Test Set-up

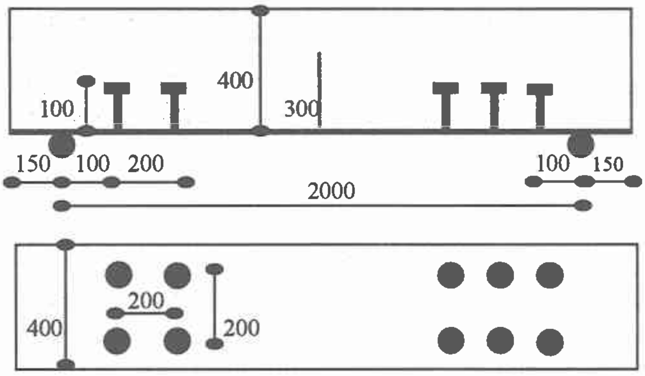
Specimen	f_c' MPa	h_s mm	h mm	b mm	s mm	b' mm	t_s mm
S－1	32	50	400	400	200	200	9
S－2	32	100	400	400	200	200	9
S－3	32	150	400	400	200	200	9
S－4	20	100	400	300	200	150	9

Table 1 Detail of specimen

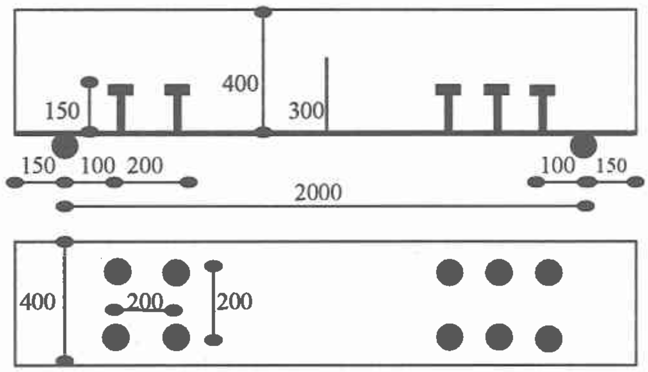
f_c' : compressive strength of concrete　　h_s : height of stud
h : height of beam　　b : width of beam
s : spacing between stud in load direction
b' : spacing between stud in transverse direction



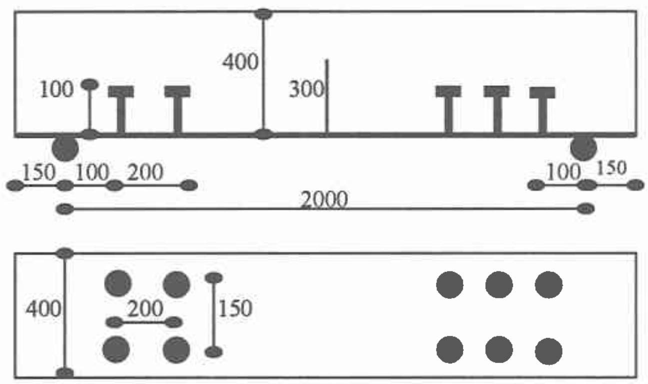
(a) Specimen S－1



(b) Specimen S - 2



(c) Specimen S - 3



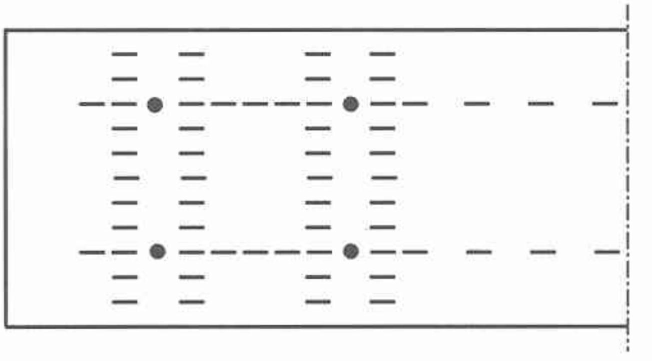
(c) Specimen S - 4

unit : mm

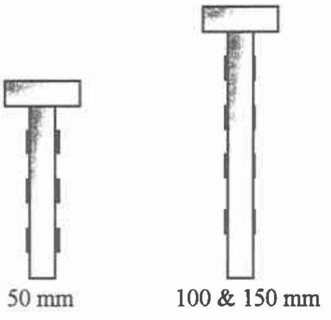
Fig. 2 Details of specimens

2.2 Instrumentation and test procedure

The experiment work of this study was performed by simply supported composite beams with one-point loading system. The load was applied by a hydraulic jack and its magnitude was measured by an electrical load cell. The deflection of the specimen was measured by using three displacement transducer. Displacement transducer was located at the center of the specimen and supported point as shown in Fig. 1. In order to calculate the transferred shear force between concrete and steel plate through the shear connector electrical strain gauges were mounted on both sides of the steel plate near the shear connector. Also to calculate the relative displacement of each shear connector electrical strain gauges were mounted on both sides of the steel plate. Detailed arrangement of electrical strain gauges is shown in Fig. 3. During the test, the deflection of the specimens and the strain of the steel plate and the shear connectors were measured at every load step.



(a) Arrangement of strain gauges in the steel plate



(b) Arrangement of strain gauges in stud

Fig. 3 Arrangement of strain gauges

Due to using a plain concrete without reinforcement we will have a crack in the mid span of the specimen and this crack will affect the result data of the experiment. Therefore we used a separator in the mid-span as an artificial crack as shown in Fig. 4.

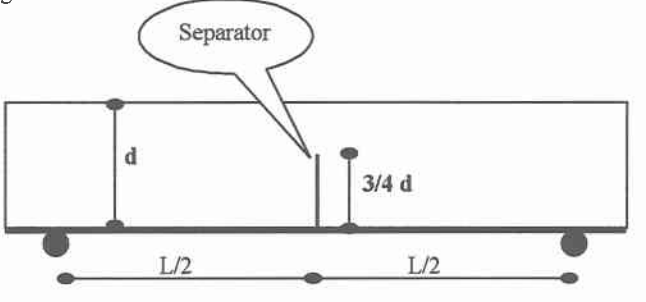
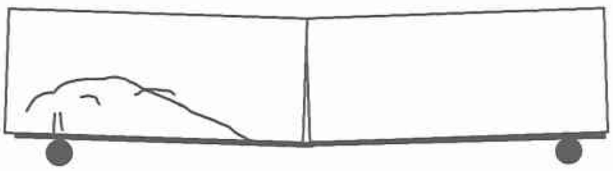


Fig. 4 Separator

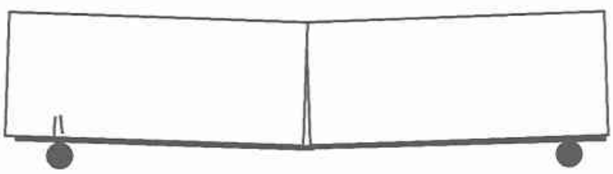
3. TEST RESULTS AND DISCUSION

3.1 Failure Characteristic

The crack patterns of the tested specimens are schematically shown in fig. 5.



(a) Crack pattern for Specimens S – 1, S – 2 & S- 4



(b) Crack pattern for Specimen S – 3

Fig. 5 Crack patterns of the Specimens

In specimens S – 1, S – 2& S – 4 we observed a crash in the concrete block in the investigated side of the beam. Otherwise, in specimen S – 3 no cracks have been observed.

Table 2

	S - 1	S - 2	S - 3	S - 4
Concrete crash	happened	happened	did not	happened
Stud sheared off	did not	did not	happened	happened

3.2 load- deflection curve

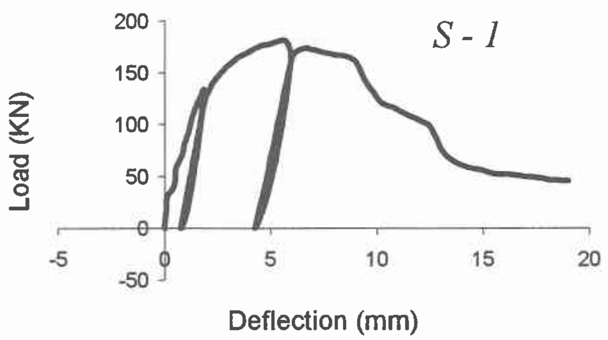


Fig.6(a) Load-Deflection curve for S- 1

Fig. 6(a) shows the Load-Deflection curve for S – 1, the peak load is 180.4 KN.

The stiffness of the re-load part is almost similar to the load part. The behavior of the beam after the peak point is near to the softening.

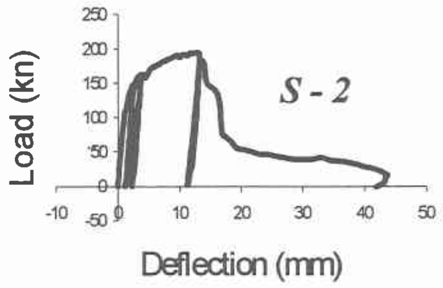


Fig.6(b) Load-Deflection curve for S - 2

Fig. 6(b) shows the load deflection curve for S –2, the peak load is 194.5 KN.

The beam behaved in a stiffening behavior.

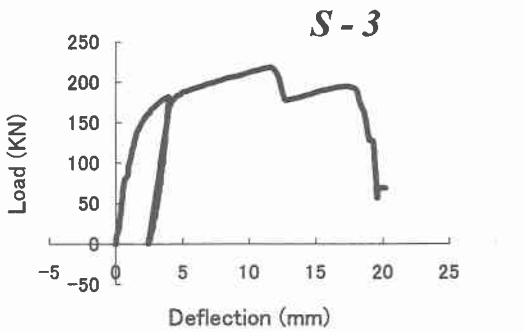


Fig.6(c) Load-deflection curve for S – 3

Fig. 6(c) shows the load deflection curve for S –3, the peak load is 218.3 KN.

The beam behavior was near to the stiffening than the softening.

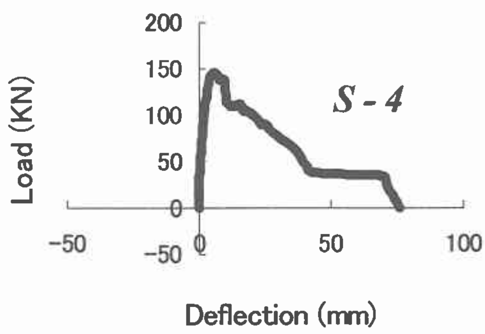


Fig.6(d) load-deflection curve for S - 4

Fig. 6(d) shows the Load-deflection curve for S – 4,and simply we can say this specimen has a high stiffness.

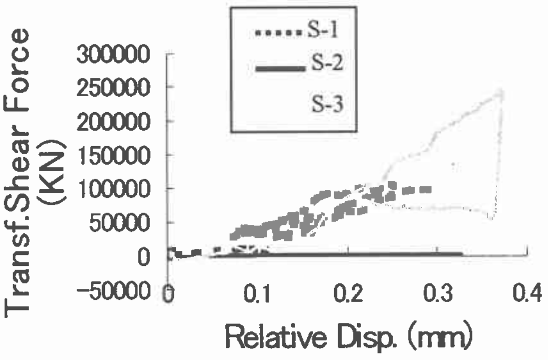


Fig. 7(a) Stud 1

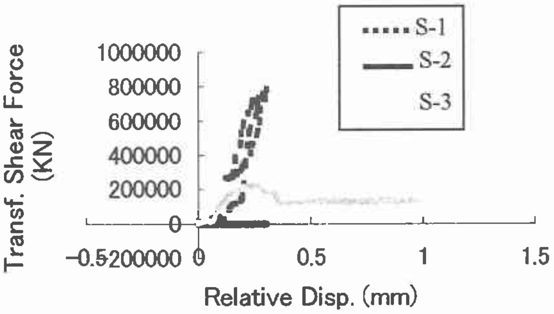


Fig. 7(b) Stud 2

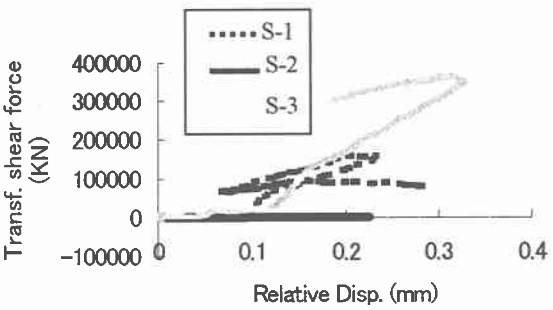


Fig. 7(c) Stud 3

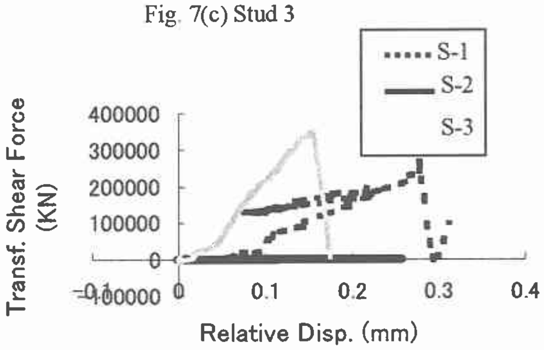


Fig. 7(d) Stud 4

Fig. 7 TSF-RD relation ship for specimen S-1, S-2& S-3

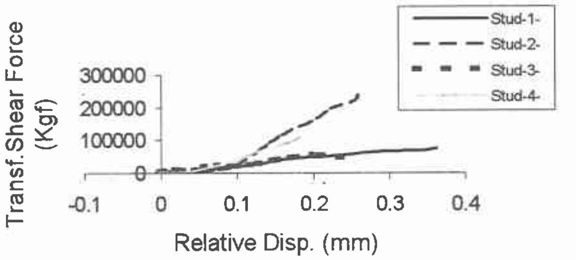


Fig. 8 TSF-RD for specimen S-4

3.3 Transferred Shear Force – Relative Displacement relationship

Fig. 7 shows the calculated Transferred Shear force – Relative Displacement relationship and as we see the TSF is very small in specimen S-2 comparing with S-1 & S-3.

From the test result we can notice that, for S-1 the stud was still connected to the steel plate but pulled out from the concrete block, for S-2 the stud was still connected to the steel plate as well the concrete block, for S-3 the stud had been sheared off from the steel plate and remain inside the concrete block as illustrated in Table 2. Therefore, 150 mm stud height is making the bond between the concrete and the stud too high that is why the stud had been sheared off, so the stud height between 100 – 150 mm is not so good in transferring shear force. Otherwise, in the 50 mm stud height the shear force has been transferred until the stud has been pulled out from the concrete block.

Fig. 8 shows TSF-RD relationship for specimen S-4, in this specimen the space between the studs in transverse direction is smaller than the other specimens and the transferred shear force decreased comparing with the other specimens.

4. CONCLUSION

This study investigates the relationship between the transferred shear force and the relative displacement of the shear connector in steel-concrete composite beam. For the studs which have been located far from the support point the relationship is rather linear until sudden failure of the studs, on the other hand, the relation for the studs which have been located near to the support point is not unique for all specimens.

The shear connector continues to transfer shear force even after the crashing in the concrete block has taken place until it sheared off from the steel plate.

For the design purpose, stud height between 50 – 100 mm is sufficient to transfer the shear force, furthermore increase the spacing between studs is better for transferring the shear force.

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2. Ollgaard, J., G., Slutter, R., G. and Fisher, J., W.: Shear Strength of Stud Connectors in Lightweight and Normal-Weight Concrete, AISC Engineering Journal, pp.55-64, April 1971