Effect of location of shear connectors on behavior of composite beam

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Influence de l'emplacement des joints sur le comportement de poutres mixtes

Einfluss der Schubdübelanordnung auf das Verhalten von Verbundträgern

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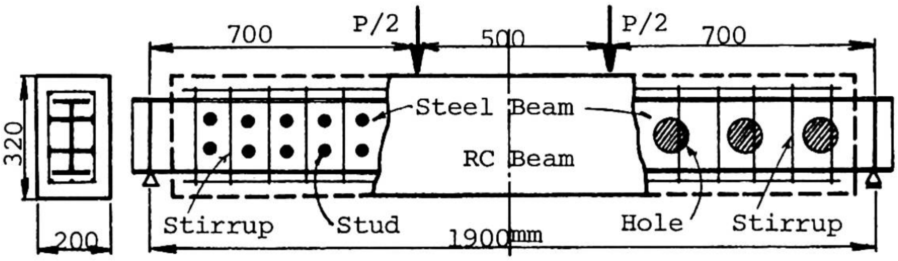
The composite beams, where steel beams are embedded in reinforced concrete, are usually applied in practice to the case where the depth of a concrete bridge is severely restricted. A sufficient number of shear connectors are necessary on the embedded steel beams, so that they may act monolithically together with the reinforced concrete. It is, however,undesirable from a view-point of the restriction of the depth of a bridge to plant shear connectors on the flanges of the steel beams.

The authors conducted a series of experiment on about twenty specimens, in which mainly the number of shear connectors, their location and the amount of stirrup were varied. The outline of two specimens is illustrated as examples in Fig.1. As a result, it was revealed that the location of shear connectors, i.e., the upper flange, the web or the lower flange had a minor influence on the behavior of the composite beam, if they were provided in a sufficient number. Thus, it was confirmed that a beam where studs were planted on the web of a steel beam embedded in reinforced concrete could be used as a perfectly composite beam. It was also found that if there was no shear connector on the steel beam, the concrete may fracture by the shearing force as shown in Fig.2 (a) and, consequently, a considerable amount of stirrup was necessary in the concrete to prevent the shearing fracture. On the contrary, a composite beam with studs on a steel beam or with sufficient stirrups failed in such a manner as shown in Fig. 1(b), and if shear connectors were planted on a steel beam, the stirrups in the concrete could be reduced as much.

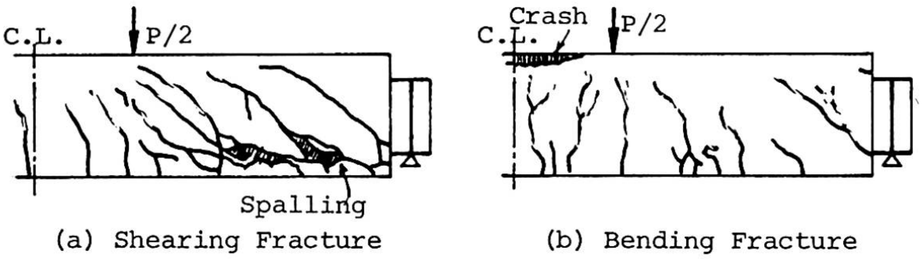
The influence of number and location of the shear connectors on the behavior of compo-



(a) Spec. with Studs (b) Spec. with Holes

Fig.1 Examples of Specimens Used for Experiment

Fig. 2 Examples of Fracture Mode



(a) Shearing Fracture (b) Bending Fracture site beams was also analytically investigated. There both the reinforced concrete beam and the steel beam in composition were devided into many bar-elements and they were connected with each other by elasto-plastic springs both in the axial and transverse directions, as shown in Fig.3. The shear connectors between the reinforced concrete beam and the steel beam were also represented by elast-plastic springs. The analytical results concerning stiffness, stresses and strength for each type of the composiste beams presented a considerably good agreement with those experimental results.

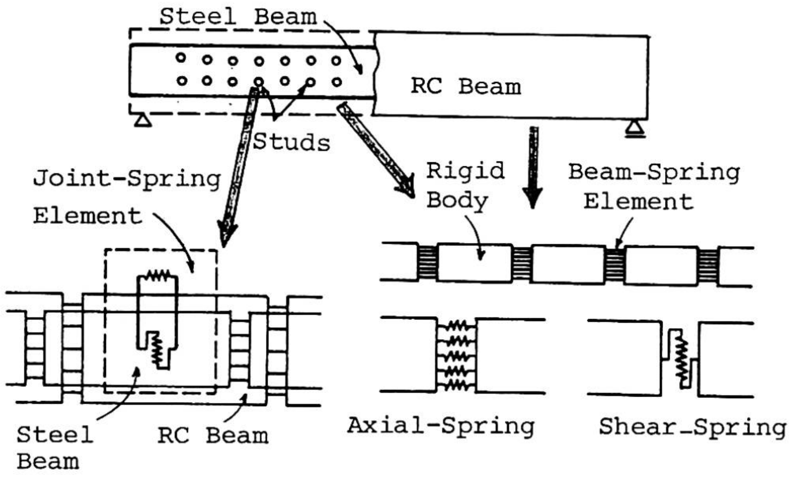


Fig.3 Rigid Body-Spring Element Model

The experiment showed also that in some cases only the perforation in the web of the steel beam made as shown in Fig.1 was as effective to accomplish the composite action. The holes in the steel beams are also useful to facilitate the transverse reinforcing bars through them in order to connect the steel beams arranged in parallel in concrete. It should, however, be noted that the resistance of the steel beam to shearing force may be reduced due to the perforation of a large diameter.

According to the results of the present experiment, even the specimen with four studs developed almost the same ultimate bending strength as the one with 56 studs, that was greater than the value obtained from the super-imposed strength method, which has been currently used in Japan. According to the analytical calculation, the specimens with more than 16 studs have the full ultimate bending strength (see Fig. 4). But the end slippage between the upper flange of the steel beam and the concrete is far larger in the former specimen than in the latter one as shown in Fig. 5. Fig. 4 also indicates that the studs of the specimen with four studs reach the yielding stress and about ten studs will be required under a repeated loading, assuming the two million cycle fatigue allowable strength as about 80 N/mm^2 (820 kgf/cm^2).

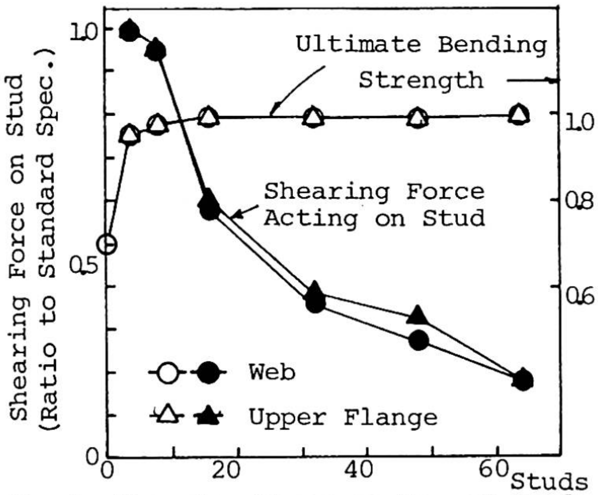


Fig.4 Shearing Force vs. No. of Stud (By Calculation)

Based on the investigaton presented here, it can be concluded that the studs on the web of the steel beam encased in concrete are as effective as those on the upper flange and the number of studs may be determined according to the calculation method the authors have developed, which will be more simplified in the future. Thus, composite bridges which are structurally more efficient and easier in construction than the conventional ones can be expected to be developed in practice.

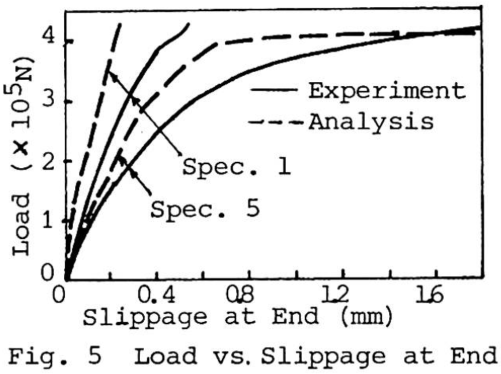


Fig. 5 Load vs. Slippage at End