SHEAR FORCE DISTRIBUTION IN GROUPED AND UNGROUPED STUD ARRANGEMENTS

Utsunomiya University, Graduate Student, ○ Md. Khasro Miah
Utsunomiya University, Akinori Nakajima, Isao Saiki
Sano City Office, Masayuki Nakamura and Topy Industries Ltd, Hirokazu Ooe

1. INTRODUCTION

Prestressed concrete slab is often employed for the composite girder bridges with two steel girders. Grouped stud arrangement[1),2)] as shown in **Fig. 1** is provided in order to introduce the prestress into the concrete slab effectively. It is pointed that all the studs in the grouped arrangement transfer the almost same magnitude of the shear force[1)]. However, this fact is not always clear. Therefore, proper investigation needs to observe the exact behavior of studs in the grouped arrangement.

In this study, the authors pointed their attention towards the shear force distribution among the studs provided in push- and pull-out test specimens with grouped stud (Type-I) and ungrouped stud arrangement (Type-II). Pipe studs[3)] were used as the shear connectors to observe the strain behavior at the base of the stud shank. A series of the static tests were carried out on the specimens with grouped and ungrouped stud arrangement under the pulsating and alternating load conditions.

2. TEST SPECIMEN

The push- and pull-out test specimen with pipe studs as shown in **Fig. 2** was employed for the experimental investigation. Three pairs of pipe studs with inside diameter 17.9mm, and outside diameter 21.7mm and length 120mm were arranged on the base plate. The longitudinal spacing of studs for the Type-I and II were as 110mm and 200mm whereas transverse spacing was taken as 69.5mm for both types. The pipe studs were embedded through the opening in the base plate and welded from the outside of the pipes. To provide sufficient resistance against plate bending, another steel plate was attached to the base plate on the other side.

Ahead of applying the load, the concrete block was inserted between the steel base block and the upper steel plate and was fixed by eight screwed steel bars with the diameter of 20mm. All the screwed bars were subjected to almost equal tensile force that was checked by the torque wrench. The shape of the concrete block was selected to prevent any rotation during experiment. Three pairs of displacement transducers were installed to measure the slip between the concrete block and the base plate at the same level of the studs. One pair of strain gauges was installed at the base and another pair at the mid height of each pipe stud as shown in **Fig. 2**. The inside area of the pipe stud was filled by cement mortar to minimize the local deformation of the pipe section during the tests.

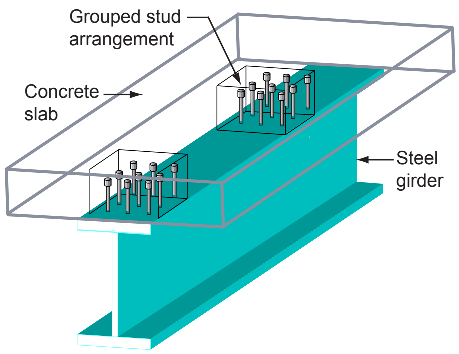

Fig. 1 Grouped stud arrangement

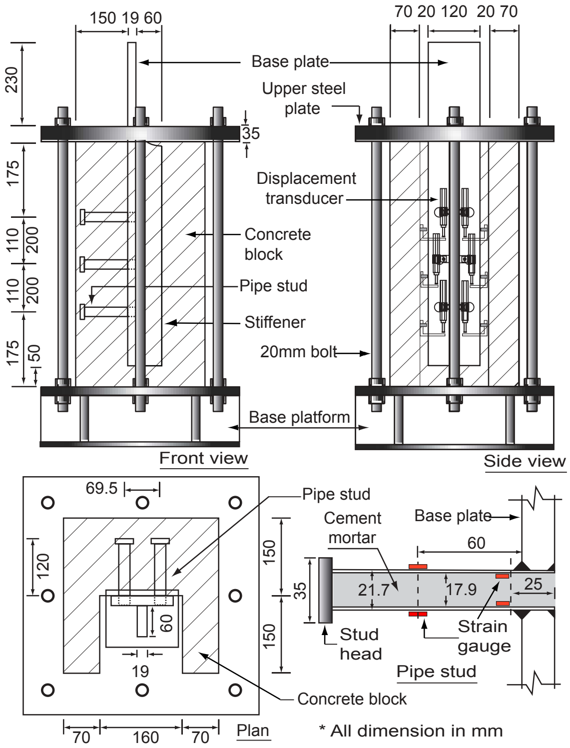

Fig. 2 Outline of test specimen

3. TEST PROCEDURE

A series of tests was carried out on the twelve push- and pull-out test specimens with grouped and un-

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321-8585 Utsunomiya University, 7-1-2 Yoto, Utsunomiya-shi. Tel. 028-689-6208 Fax. 028-689-6208

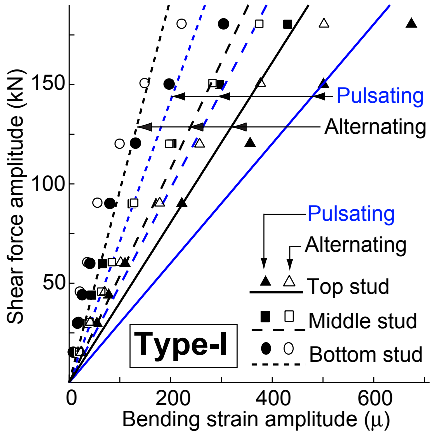

Fig. 3 Shear force-bending strain amplitude relation (Type-I)

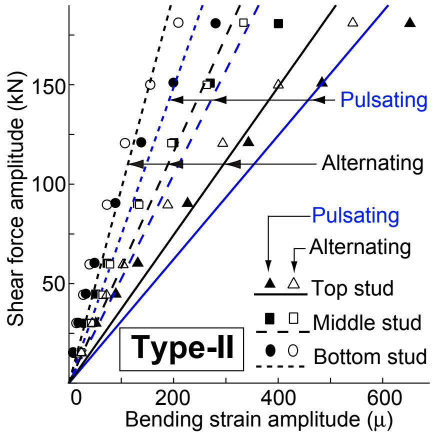

Fig. 4 Shear force-bending strain amplitude relation (Type-II)

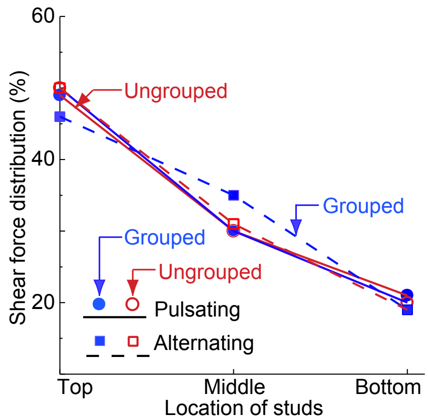

Fig. 5 Shear force distribution

grouped stud arrangement under pulsating and alternating load condition. While the one sided pulsating loading cycles were repeated with several incremental peak loads, complete reversal loading cycles were repeated under the alternating load condition up to 180kN and then the load was increased monotonically. During each test, the slip between the concrete block and the base plate and the strain behavior at the base and mid height of the stud shank were measured for each loading step.

4. EXPERIMENTAL RESULTS AND DISCUSSION

The relations between the shear force amplitude and the bending strain amplitude at the base of the stud shank are shown in **Figs.3** and **4** for the Type-I and II under the pulsating and alternating load conditions. Average of three similar tests result is considered here. The amplitude of the shear force is defined as the difference of the maximum and minimum peak values of the applied load under a particular loading cycle and the corresponding strain amplitude is taken into account. Linear regression lines are plotted to observe the behavior of the studs in lower load range. According to the **Figs.3** and **4**, it is clear that the tendency of the shear force distribution among the studs in the Type-I and II is almost similar. The bending strain amplitude is larger in the order of top, middle and bottom studs in both types of stud arrangement under the pulsating and alternating load conditions. Furthermore, for a particular shear force amplitude, the bending strain amplitude at any level of studs under pulsating load condition is larger than the one under the alternating load condition.

The bending strain amplitude relations are considered here for explaining the behavior of the studs because the bending strain amplitude relations are more appropriate for predicting the shear force transferred through the pipe stud under the pulsating and alternating load conditions[3)]. The shear force distribution among the top, middle and bottom studs at the base of Type-I and II specimens is shown in **Fig. 5** from the bending strain amplitude consideration. The shear force distribution under the pulsating load condition for the Type-I and II is almost same which indicates that the effect of stud arrangement is not so significant for shear force transferred. On the other hand, under the alternating load condition, the shear force distribution slightly differs between the Type-I and II, which is less than 5%. The variation of the shear force distribution between the pulsating and alternating load conditions for the Type-I and II is about less than or equal to 5%. However, in this distribution, it can be seen that about 50%, 30% and 20% of the total shear force are carried by top, middle and bottom studs.

5. CONCLUSIONS

The shear force resisted by the top, middle and bottom studs are not same even in the grouped stud arrangement. In this case, the top studs resist more shear force than the others in the grouped and ungrouped stud arrangement under the pulsating and alternating load conditions.

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