Study on improving the slip strength of long high-strength bolted friction joints with bearing-type bolts.

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1. INTRODUCTION

In recent years, due to the increase in load and the need for rationalization of steel components, there has been a tendency for high-strength bolt (HSB) frictional joints, to become larger and longer. In contrast, as the length of the joint increases, the actual force that can be withstood is less than the design strength because the distribution of bolts within the joint becomes uneven. On the other hand, due to the presence of the secondary member in steel structure, there are many cases where the bolted joint splice plates are too long and cannot be installed.

We propose a method to improve the slip strength of a long friction-bolted joint by combining it with a bearing-type joint (hereafter referred to as the hybrid joint). For hybrid joints, previous studies[1,2] have shown the possibility of combining friction-type bolts and bearing rivets. However, the generally low and uncontrollable slip coefficients that can be provided by the contact surfaces of riveted joints make it difficult to effectively design hybrid joints with friction-type bolts and rivets. The present study focused on the slip strength of the hybrid joint, and a finite element (FE) analysis was performed to clarify the slip strength and the possibility of miniaturization of the hybrid joint.

2. FE analysis

A general-purpose structural analysis software, Abaqus / Standard 2020, was used to perform three-dimensional elasto-plastic finite displacement analysis.

2.1. Introduction of the model

The analytical model is based on a 12-row bolted friction joint, as shown in Figure 2. The thickness of the main plate was 75 mm, that of the splice plates was 38 mm, the load was applied by forced displacement from the edge, and the analysis was set up as a one-half model with the center of the joint in the longitudinal direction as the axis of symmetry.

2.2. FE case

The analysis cases are listed in Table 2. The parameters were the placement of the bearing-type bolt and friction-type bolt, and number of row in the hybrid joint. B1#1 represents the bearing-type bolt installed in bolt #1. In B2, the outer #1 and inner #12 are placed on the bearing-type bolt.

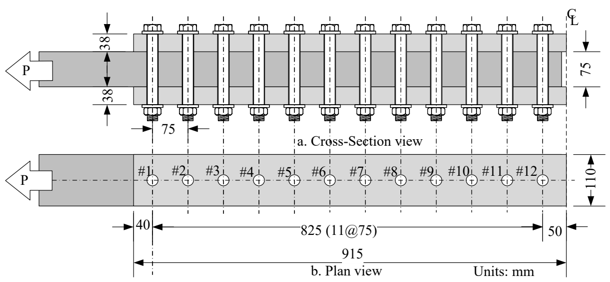

Figure 1: Dimensional drawing of the original case

Table 1: Summary of material properties $[kN]$

Member	Material	Yield strength σ_y	Ultimate strength σ_u
Plate	SM490Y	365	491
HSB	F10T	900	1091

Table 2: FEmodel case

	Fastener number (#)											
	1	2	3	4	5	6	7	8	9	10	11	12
Original	○	○	○	○	○	○	○	○	○	○	○	○
B1#1	⚙	○	○	○	○	○	○	○	○	○	○	○
B1#6	○	○	○	○	○	⚙	○	○	○	○	○	○
B1#12	○	○	○	○	○	○	○	○	○	○	○	⚙
B2	⚙	○	○	○	○	○	○	○	○	○	○	⚙
B4	⚙	⚙	○	○	○	○	○	○	○	○	⚙	⚙
B12	⚙	⚙	⚙	⚙	⚙	⚙	⚙	⚙	⚙	⚙	⚙	⚙
R10B2	⚙	○	○	○	○	○	○	○	○	⚙	-	-
R10B4	⚙	⚙	○	○	○	○	○	○	⚙	⚙	-	-

○: Friction bolt, ⚙: Bering bolt

3. Results

The relationship between the total displacement of the joint and the load is shown in Figure 2(a), where the total displacement was determined from the front end of the main plate. From Figure 2(a), it can be seen that all cases have almost the same overall initial stiffness. However, the gradient change points of the curves differed from each other. The first case to experience a nonlinear change was the initial case, followed by the B1 case with one bearing-type bolt. The gradient change point is the same in the B4 case with four bearing-type bolts and the B12 case with 12 bearing-type bolts, due to the cross-sectional yielding of the joint. Since the joints end up with cross-sectional failure, the stiffness converges to the same value after slip occurs. We also found that the clamping force fasting of the bearing-type bolts slightly increase the slip load but has little effect on the overall load sharing.

The relationship between the relative displacement of the joint and load is shown in Figure 2(b). Due to the unbalanced load share, the original case experienced load loss (1858 kN) before it reached the designed slip strength (1968 kN) The original slip load was 1594 kN when the relative displacement was 0.2mm. The slip load was reduced by about 19% compared to the designed slip strength. However, for the B2 case that was installed with bearing-type bolts, the joint did not experience load depression, and the nonlinear change in the curve occurred at approximately 2387kN, which can be judged as a change in gradient because of the yielding of the cross-section.

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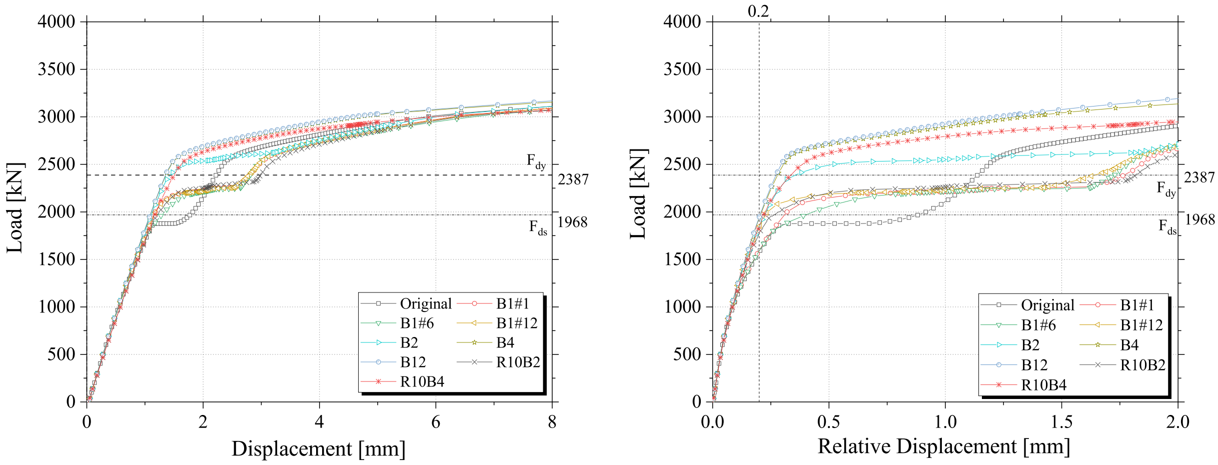

(a) Total displacement

(b) Relative displacement

Figure 2: Relationship between load and displacement

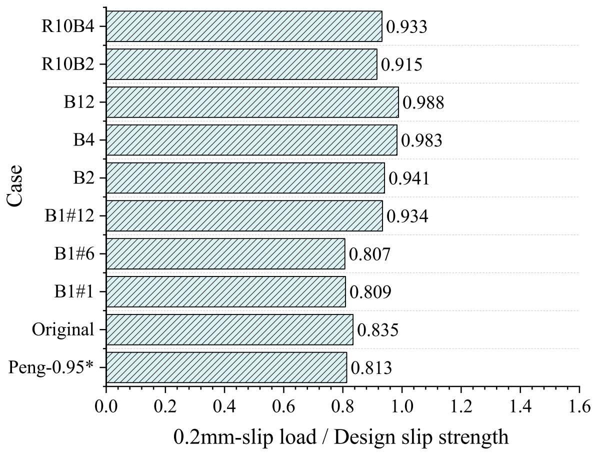

Figure 3: Dimensional drawing of the original case

4. Conclusions

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References

[1] Y. Chen, R. Sakura, T. Yamaguchi, G. Hayashi, M. Yamauchi, and K. Ueno, "Load transferring mechanism of long riveted joint partially replaced by high-strength bolts," *IABSE Symposium Prague 2022*, 2022.

[2] Y. Chen, T. Yamaguchi, M. Yamauchi, K. Ueno, and G. Hayashi, "Study on the mechanism of load transferring of riveted joints with high strengh bolts as frictional joints," *Journal of Steel Construction engineering (in Japanese)*, vol. 29, pp. 1–14, 3 2022.