THE LOAD SHARING OF RIVET AND HTB COMBINED JOINT

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1. Introduction

Before high-strength bolts and welding techniques were widely used in the world, rivets were commonly used to fasten steel components and were used for cross-sectional connections of steel bridges. To date, many riveted bridges are still in service [1]. Some of the rivets might be corroded and loosen due to aging deterioration. From previous studies, the influence of rivet corrosion on bearing strength is few, but the reduction of the volume of a rivets head is severely affected fatigue life and the bending deformation of the splice plate may also lead to the corroded bolt fall off. For structural performance recovery, replacing the corroded rivets with high-strength bolt (HTB) as a frictional joint is a desirable approach to repairing the corroded riveted joint [2]. However, the load transfer mechanism of the combined joint with rivet and HTB is still uncertified, and the load capacity of the combined joint has not been sufficiently discussed. This study using FEA to examine the load transfer mechanism of the combined joint.

2. Finite Element Analysis (FEA)

The general-purpose structural analysis code Abaqus-2018 was employed for the FEA, and a three-dimensional elastic-plastic finite displacement analysis performed. The analysis model is shown in Fig. 1. The analysis cases are shown in Table 1. The analysis model sets to 1/2 of the joint along the plate width direction in consideration of symmetry. The slip and bearing strength calculate from Equations (1) and (2), respectively. The slip coefficient is 0.21 that obtained from the slip test of the D bridge s riveted joint part.

$$F_{slip} = \mu m(n_b N_b + n_r N_r) \qquad (1)$$

$$F_{bea} = \mu m n_b N_b + 1.5 n_r d_r t \sigma_y \qquad (2)$$

Where μ is slip coefficient, m is 2 (double shear), n_b is the number of bolts, n_r is the number of rivets, N_b and N_r is the clamping force of bolt and rivet respectively, d_r is rivet hole s diameter, t is main plate s thickness, σ_y is the yield strength of the main plate.

The mechanical properties of materials calculate by material tests on 90-year-old D rivet bridge, as shown in Table 2. The stress-strain relationship of each material was modeled by the bilinear type. In the analysis, the clamping force was introduced into the rivet and the HTB in step 1, and applied the forced displacement to the end of the main plate in step 2. The rivets clamping force was set concerning the previous studies [3], when shank length is 33mm, the clamping force is 45kN(φ23.5mm), when shank length is 75mm, the clamping force is 78kN.

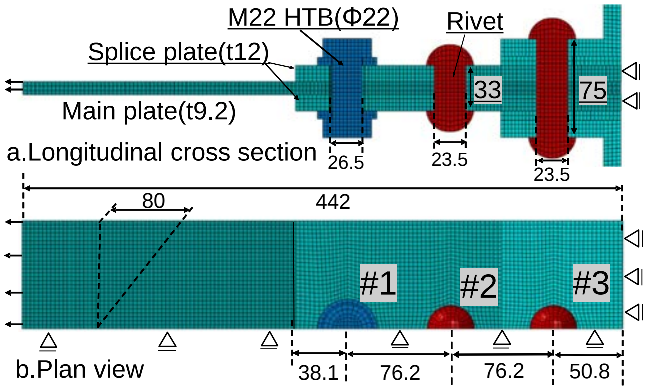

Fig. 1 FE Model (e.g.RP1, Unit: mm)

Table 1. Analysis case

Case	Slip Strength F_{slip} [kN]	Bearing Strength F_{bea} [kN]	Fastener Arrangement #1	#2	#3
RP0	70.8	268.3	○	○	○
RP1	138.0		●	○	○
RP2	138.0	265.0	○	●	○
RP3	123.9		○	○	●
RPA	258.3	-	●	●	●

○: *Rivet*, ●: *HTB*

Table 2. Mechanical properties of materials

	Material	Yield strength [N/mm²]	Ultimate strength [N/mm²]
Plate	St39	275.8	454
Rivet	Sv34	295	389
HTB	F10T	900	1000

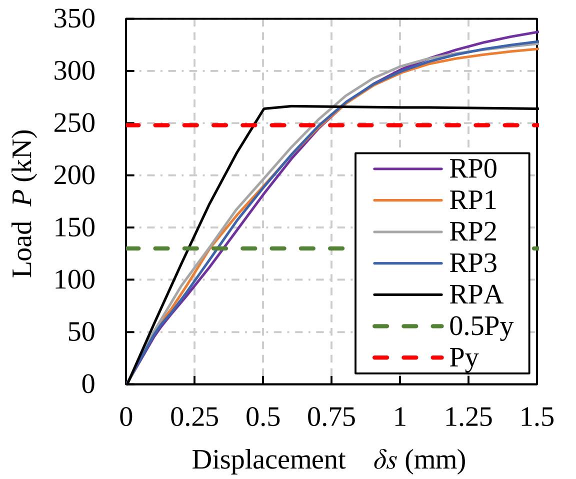

Fig. 2 The relationship between load and displacement

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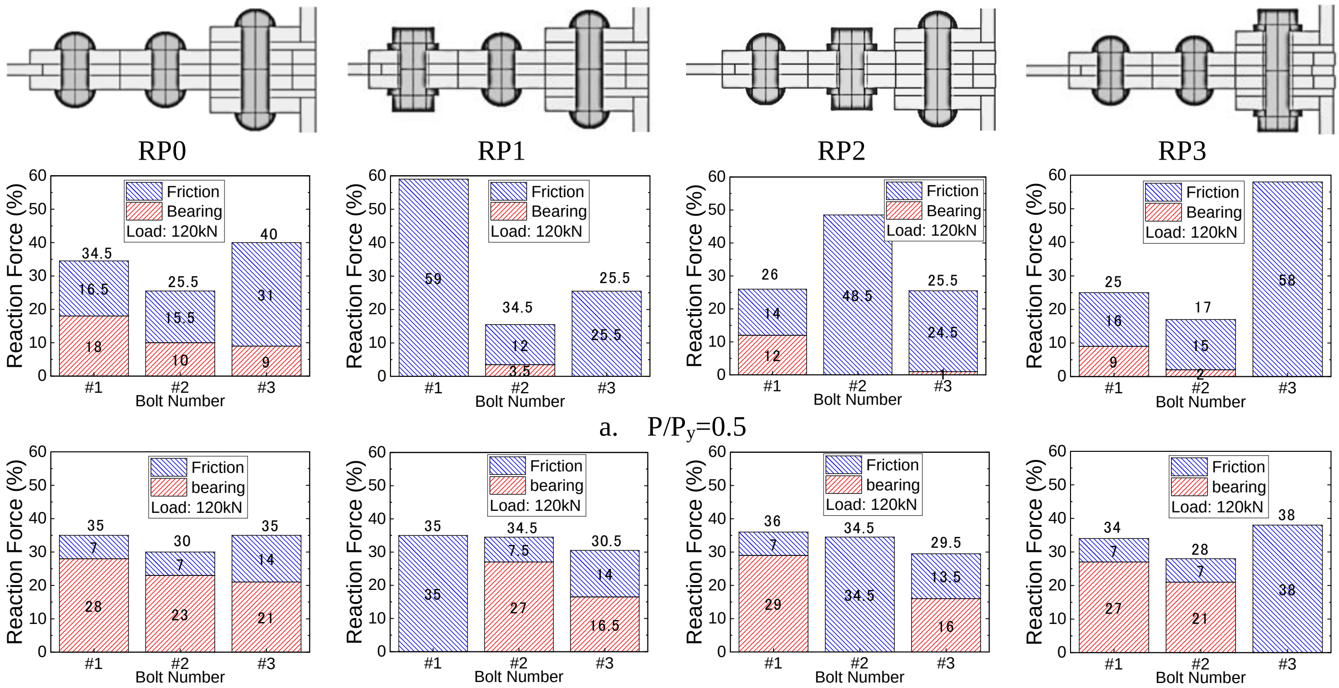

a. P/P_y=0.5

b. P/P_y=1

Fig. 3 Load sharing

3. Result of analysis

The relationship between load and displacement is shown in Fig. 2. The green and red dashed line represents the load of RP0 at 0.5 P_y and 1 P_y, respectively. The bearing yield strength P_y is taken from the load when the #3 fastener hole produces plastic strain.

Fig. 2 shows that the difference in the replacement position of the HTB has few effects on the bearing yield strength P_y of the joint, and it can be considered that this is because when the slip coefficient is 0.21, the friction resistance produced by an HTB is very close to the bearing resistance produced by the rivet. When the load before about 50kN, all the cases almost have the same stiffness. When the load is before 1Py, the order of the joints stiffness size is RPA>RP2>RP1>RP3>RP0. When the load is over P_y and the HTB is not yet in bearing, RP0s stiffness is higher than the replacement case, this is because HTB has reached the friction strength and cannot provide more resistance to the applied load.

Fig. 3 shows the load sharing at the ratio P/ P_y = 0.5,1 of the tensile load P and the bearing yield load P_y. Red represents friction resistance, and black represents bearing resistance. Friction resistance is calculated by friction stress at the contact area, bearing resistance is calculated by contact pressure at the wall of the fastener hole.

When P/P_y=0.5, HTB s friction resistance shares about 60% of the total load in the RP1 and RP3 cases and shares about 50% of the total load in the RP2. Although the rivets bearing resistance also resists a few loads, the load is shared by almost all friction resistance. This can also explain that the stiffness of all cases is the same before about 50kN. This is because the load is almost only resisted by friction, so it can be considered that when the applied load is lower than slip strength, the combined joints load transfer mechanism is consistent with the HTB friction joint.

When P/P_y=1, in each case, #1 fastener resists 35% resistance of the total load. The load sharing of RP0 and RP3 is almost the same, the bearing yield strength and stiffness are also close. So it can be inferred replacing the #3 rivets has few effects on the joint performance. The difference in load sharing ratio in each case is slight. This is because the rivets ability to resist the load becomes weaker due to the holes wall yielding. Joint load sha ring gradually approaches the same, which is very similar to the rivet joint. So, when close to the bearing yield strength, it can be considered that the combined joint has a similar load transfer mechanism with the rivet joint.

4. Conclusions

The main results of this research project are:

- Regardless of the replacement position, while the applied load is lower than the slip strength, the combined joint transmits the load by friction force, then the bearing force begins to transmit the load.
- When the slip coefficient is small, replacing rivet has few effects on bearing strength, but the overall stiffness of the joint was increased.
- Replacing the #2 rivet could be considered the most desirable method because it could provide more load resistance capacity to the #2 rivet which has low load sharing.

<Reference>

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