Study on Slip Behaviour of High Strength Bolted Friction Type Joint with Extremely Thick Plates by Using Finite Element Analysis

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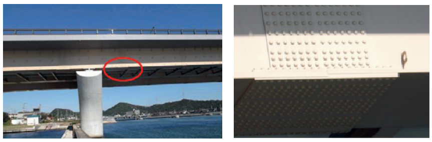
Summary

High strength bolted friction type joints are commonly used to join members of steel bridge structures. Recently, such joints have become larger, because members of bridges tend to be large to seek structural simplicity. Since large members consist of extremely thick plates, large size joints are needed with many bolts in a line, containing thick plates including splice plates. It is of concern that many bolts and thick plates affect the slip behaviour of such large size joints. So, FEA focused on joints with many bolts and thick plates is carried out. Based on the results, it is clear that a non-uniform distribution of friction force exists. And, it is also shown that a certain combination of thicknesses of connected plates and splice plates has the large capacity of slip resistance. It is concluded that such results can be explained by the influence of the additional moment due to thick plates.

Keywords: slip behaviour, high strength bolted friction type joint, extremely thick plate

1. Introduction

Recently in Japan, structurally rationalized and simplified steel bridges have been adopted in many cases. These bridges have 2 or 3 girders with large cross sections compared with traditional bridges to achieve cost reduction. The joints also become large with proportion as the size of the girder as shown in Fig. 1 and have many bolts in a line. In the case the joint has many bolts, it is well known that the slip coefficient becomes small compared to the case of several bolts in a line.



(a) Overview *(b) Detail view*

Fig. 1 An example of large size high strength bolted friction type joint [1]

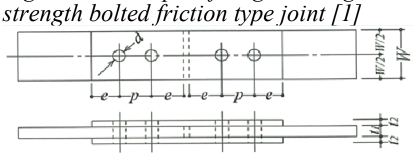


Fig. 2 Illustration of slip test specimen [2]

2. Standard slip test and FEA model

It is well known that the slip coefficient is one of the important characteristic values in friction type joints, because the coefficient affects directly the load carrying capacity of the joint. Most of design codes have specified standard slip tests to evaluate the slip coefficients [2]. One of the typical standard slip test specimens is shown in Fig. 2. Tensile load is gradually applied at each end of the specimen. The slip coefficient is defined as the ratio of tensile load at major slip occurrence to the sum of all bolt axial forces.

To evaluate detailed slip behaviour, FEA is carried out. The models are made referring to the specimens of the slip test by solid elements. As shown in Fig. 3, one eighth part of the specimen is modelled.

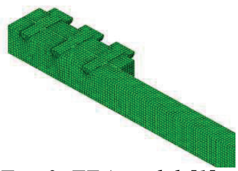


Fig. 3 FEA model [1]

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3. Distribution of friction force on the connected surface

It is well known that the slip coefficients of large size joints with many bolts in a line become smaller than those of joints with several bolts. FE analysis [1] has been conducted in order to clarify the slip behaviour of the large size joints with many bolts in a line. The joint with 12 bolts has been considered. The obtained friction forces of each bolt are shown in Fig. 4. These are calculated as a sum of the shear stress on the connected surface near the bolt.

Friction forces of each bolt are approximately the same. But, the forces at the middle part of the joint such as around bolt-6 are smaller than those on both sides. The reduction of the slip coefficient is caused by this non-uniform distribution of the forces. Furthermore, the friction force of bolt-1 is largest. That of bolt-12 is smaller than those of the neighbouring bolts. This tendency can be explained by an additional bending moment induced by eccentric load as shown in Fig. 5.

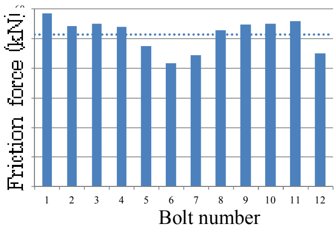

Fig. 4 Distribution of friction force at each bolt [1]

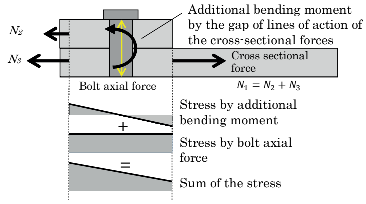

Fig. 5 Illustration of additional bending moment

4. Influence of the thickness of the splice plate to the slip coefficient

The slip coefficients of each γ case such as $\gamma = 1.08$ and 1.52 are shown in Fig. 6. γ denotes the ratio of the strength of the connected plate to that of the splice plate.

The slip coefficients of $\gamma = 1.52$ are larger than those of $\gamma = 1.08$, especially in many bolts case. It means that $\gamma = 1.52$ cases have larger capacity of slip resistance. It is considered that the strength ratio of the connected plate to the splice plate is one of the important factors to make the slip strength larger.

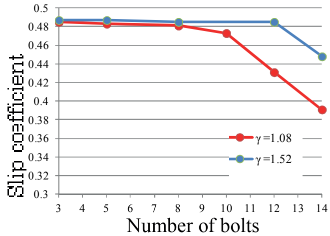

Fig. 6 Summary of slip coefficient

5. Conclusion

In this paper, some FEAs are carried out focusing on slip behaviour of high strength bolted friction type joints with extremely thick plates and many bolts in a line.

(1) The distribution of the friction force per bolt is non-uniform with the friction force of the bolt at the end of the connected plate being larger than those of the neighbouring bolts, and that of the bolt at the end of the splice plate being smaller than those of neighbouring bolts. This is caused by an additional bending moment due to the gap between the lines of actions of applied cross-sectional forces of the splice and connected plates. It is necessary to pay attention to the effect of additional bending moment in the case that the joint contains extremely thick plates.

(2) Focusing on the ratio between the yield strength of the splice plates and that of the connected plate, it is found that the slip coefficient for a large ratio is larger than that of a small ratio in the case the joint has many bolts in a line. The thick splice plate has an advantageous effect on preventing the reduction of the slip coefficient in the case of large size joints with many bolts in a line.

6. References

[1] Public Works Research Institute, *Cooperative Research Report on Rationalistic Design of High Strength Bolted Friction Type Joint*, No. 428, 2012, (in Japanese)

[2] Japan Society of Civil Engineers, *Recommendations on Design, Construction and Maintenance for Friction Type of High Strength Bolted Connections*, 2006, (in Japanese)