Evaluation on the of Slip Critical Joints subjected to Variation of Bolt Holes

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1. Introduction

Because oversized and slotted holes are useful to fabricate steel members, extension of bolt holes occurs in construction field. It leads to the reduction of friction area and stress concentration. Due to these reasons, the reduction factor was adopted in AISC and Eurocode 3. But existing research results exhibited that oversized and slotted holes within specific limits have no significant influence on the slip load and slip coefficient of the bolted connection. While the existing researches have been confined on the static and fatigue behavior, there is few research on the characteristics and behavior after completion of tightening, especially relaxation. Moreover there are no domestic codes and specifications. This study was conducted to evaluate the relaxation influenced by the size of bolt-hole.

2. The Outline of Experiment

In order to analyze effects of the size of bolt holes on the behavior of bolted connections, the static test and 1,000 hours relaxation test were conducted like Table I. To prevent the earlier slip behavior due to plates yielding, all specimens were designed to yield after slip behavior. The thickness of inner plates and outer plates is 19mm and 12mm respectively. The Steel type is SM490A similar to ASTM A678. The Pitch between the centers of bolt holes was determined to be 70mm, defined on the specification. The high strength bolts for test specimen is the torque shear bolt defined on KS B 2819.

Table I: Specimen Details

Specimen	Bolt holes (mm)	Test Specimen Quantity	
		Static	Relaxation
2ST2	22 (d+2mm)	3	1
2OV4	24 (d+4mm)	3	1
2OV6	26 (d+6mm)	3	1
2SL1.3	22*26((d+2)*1.33d))	3	1
2SL2.5	22*50 ((d+2)*2.5d))	3	1

After setting up the specimen at the universal testing machine, LVDTs were installed. The tensile load was applied by the load control up to the major slip and then by the stroke control. The Static test was continued until the specimens fractured as shown like Photo 1.

Photo 1. Fractued specimen 2SL2.5-1

1,000 hours relaxation test was conducted to measure the decrease of the preload continuously throughout the strain gage attached on the surface of the bolts. To exclude the effect of a change of temperature, the relaxation test was conducted in the constant temperature and humidity condition.

3. Test Results

3.1 Static Test Results

Fig. 1. shows the load-displacement curve of the slotted holes (2SL2.5-1). The slip load of 2SL2.5-1 specimen with slotted holes was 419.6kN and slip coefficient was calculated to 0.589. The slip coefficient of 2ST2 series was 0.590 on average. The slip coefficient of 2OV4 and 2OV6 with oversized holes was 0.583 and 0.591, respectively on average. In case of the specimens with slotted holes, the slip load and slip coefficient was 465.9kN and 0.65 at 2SL1.3, 416.5kN and 0.585 at 2SL2.5, respectively on average. As compared with 2ST2, the slip coefficients and slip loads of the specimens with the oversized and slotted holes have the differences less than 1%. In this comparison, the size of bolt holes within the allowable limit does not have a significant influence on the slip load and slip coefficient.

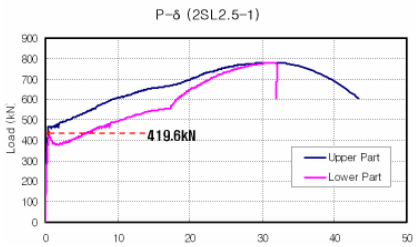

Fig. 1. load-displacement curve of 2SL2.5-1 Specimen

The specific aspect of the variation subjected to the size of bolt-hole can not be observed like Fig. 2. Excluding the outliers of 2SL1.3 and 2OV6, the variation remains within 5% of 2ST2 average value.

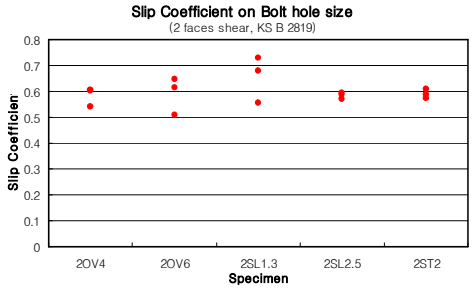

Fig. 2. Variation of the Slip Coefficient

As the net section area has influence on the ultimate loads, they were expected as shown like Fig. 3. But, the test results exhibited that the ultimate load of 2SL2.5 was 780.9kN on average and was lower than any other specimens. In case of the oversized hole, the net section area affected the ultimate load as predicted.

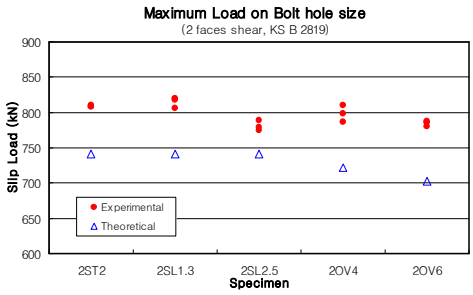

Fig. 3. Maximum load on bolt-hole parameter

2.2 Relaxation Test Results

Fig. 4. shows the relaxation-time curve of R2SL2.5 specimen as an example. Up to 24 hours right after completing the tightening, the initial clamping force decreased immediately and the relaxation value of each bolt was 1.39%, 2.50%, 1.60% and 1.76%, respectively.

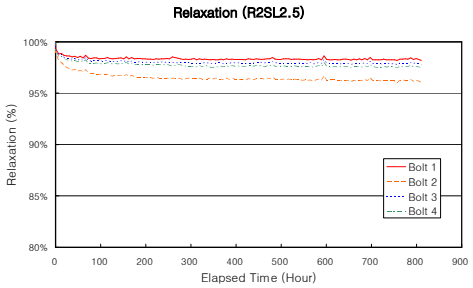

Fig. 4. Time-Relaxation curve of R2SL2.5 specimen

After that time, the rate of relaxation decreased. From a point of 500 hours, the relaxation nearly stopped. The last value up to 1,000 hours was 1.83%, 4.00%, 2.24% and 2.55%, respectively. The relaxation up to 168 hours was 2.07%, 1.87%, 3.25% and 1.54, respectively and 2.18% on average. This value accounts for 81.9% of the final values up to the 1,000 hours relaxation and this outcome was derived from almost all specimens. So it can be considered that the phase of the relaxation up to early 7 days accounts for the most portion of the whole relaxation.

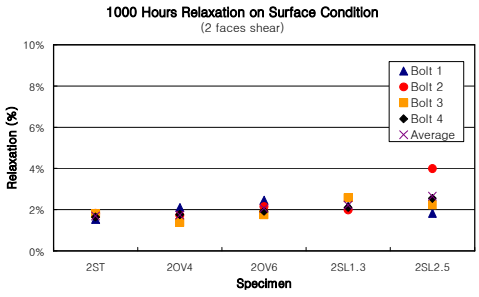

Fig. 5. Variation of the 1,000 hours relaxation

Relaxation of each specimen was shown in Fig 5. The relaxation of R2ST2 was 1.70% on average, while R2SL2.5 was 2.66% and 56% as high as R2ST2. In case of the specimens with oversized holes, 2OV6 was 1.74% and it showed an increase of 21% as compared with 2.07% of 2OV4. The bigger was the size of bolt holes, the higher was the relaxation. On grounds of the above results, it can be considered that the bolt-hole parameter has an effect on the relaxation

3. Conclusions

The 1,000 hours relaxation tests and the static tests were conducted to the structural behavior of the bolted connection affected by the hole-size of bolts. Based on this series of tests, the results suggest that :

(1) The variations of the slip loads and slip coefficients subjected to the bolt-hole parameter remains within 5% of standard specimen. The oversized and slotted holes within the allowable limit do not have notable influences on the slip behavior.
(2) Although the specimen with the bigger net section area exhibited the lower ultimate load as predicted, the ultimate load of 2SL2.5 which has the same as the one of 2ST2 was lower than any other specimens.
(3) The bigger size of bolt holes, the higher relaxation. The size of bolt holes has influence on the relaxation and the relaxation up to early 7 days accounts for the most portion of the whole relaxation.

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