Discussion on Influence of High Strength Bolt’s Parameters on the Weld Reinforced Combined Connection with Bolts and Welds

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Abstracts: In the process of existing steel structure operation, in order to prevent the bolted joints from being damaged by insufficient carrying capacity, welds can be used for reinforcement. Weld reinforced combined connection with bolts and weld consists with high strength bolts and side fillet weld composition. The parameters and properties of high strength bolts and fillet welds have a direct effect on the connection. Based on the test results, we explore the influence that welding seam reinforcement and the performance of the connection between the number of high strength bolts and specifications changes in this paper. It will provide a theoretical reference for the design of connection nodes of steel structure reinforcement project.

1. Introduction
The construction sequence of weld reinforced combined connection with bolts and welds is welding after bolts connecting. Details as follows: give the high strength bolt specimen a load and keep the load unchanged, then put a certain size of side weld reinforcement; after waiting for weld cooling continues, give the connection load continuously until the specimen damaged11[6]. In this paper, the high strength bolt specifications are M20, M22 and M24 respectively. The number of high-strength bolts is 2, 4 and 6 respectively. After the test piece of the pure high-strength bolt is subjected to 0.5Ps, the load remains unchanged. The reinforced weld consists with four side fillet weld ($hf\times lw=6mm*80mm$). Through the tests we explore the impact of the number of high-strength bolts and specifications on the performance of the connection.

2. Experiment overview
2.1. Specimen design
For this trial, we used nine sets of connections. The splicing form is a double - cover plate. The steel is Q345B, the thickness of the core plate is 18mm and the thickness of the cover plate is 14mm. Bolts are M20 (8.8), M22 (8.8) and M24 (8.8) high strength hexagonal head bolts. The screw hole diameter is 22mm, 24mm and 26mm respectively. Connection board grit blasting, the friction coefficient is 0.45. Use E43-type welding rod. In order to ensure non-destructive destruction of non-end damage, the test
will be carried out in the end of the three sides welding fillet weld connection, welding foot size of 10mm. See figure 1, 2, 3 for the specimen form and size.

**Figure 1.** Two bolts specimen design and physical drawings

**Figure 2.** Four bolts specimen design and physical drawings

**Figure 3.** Six bolts specimen design and physical drawings
The strength of the test pieces and the size and form of the weld are different according to the test pieces of each group, as shown in table 1.

Table 1. Specimen reinforcement and number

| Test piece number | Bolt specifications | Weld size (mm) | Bolt stress before reinforcing |
|-------------------|---------------------|----------------|-----------------------------|
| 1#                | 2M20                | CW6×80         | 0.5Ps                       |
| 2#                | 4M20                | CW6×80         | 0.5Ps                       |
| 3#                | 6M20                | CW6×80         | 0.5Ps                       |
| 4#                | 2M22                | CW6×80         | 0.5Ps                       |
| 5#                | 4M22                | CW6×80         | 0.5Ps                       |
| 6#                | 6M22                | CW6×80         | 0.5Ps                       |
| 7#                | 2M24                | CW6×80         | 0.5Ps                       |
| 8#                | 4M24                | CW6×80         | 0.5Ps                       |
| 9#                | 6M24                | CW6×80         | 0.5Ps                       |

Note: Ps—The maximum tension of the bolt specimen theory.

2.2. Test equipment
This test uses 500t hydraulic jack, the displacement of the test end is measured by the YHD-20 guide rod extensor. The physical graph is shown in figure 4.

Figure 4. Guide rod extensometer arrangement figure

3. Test results and analysis of results

3.1. Ultimate carrying capacity
The ultimate carrying capacity of each specimen is shown in table 2.

Table 2. Test piece connection form and carrying capacity

| Test piece number | Bolt specification | Weld size (mm) | Bolt stress before reinforcing | Ultimate load capacity / kN |
|-------------------|--------------------|----------------|-------------------------------|-----------------------------|
| 1#                | 2M20               | CW6×80         | 0.5Ps                         | 1080                        |
| 2#                | 4M20               | CW6×80         | 0.5Ps                         | 1179                        |
| 3#                | 6M20               | CW6×80         | 0.5Ps                         | 1304                        |
| 4#                | 2M22               | CW6×80         | 0.5Ps                         | 1158                        |
| 5#                | 4M22               | CW6×80         | 0.5Ps                         | 1245                        |
| 6#                | 6M22               | CW6×80         | 0.5Ps                         | 1378                        |
| 7#                | 2M24               | CW6×80         | 0.5Ps                         | 1221                        |
| 8#                | 4M24               | CW6×80         | 0.5Ps                         | 1310                        |
| 9#                | 6M24               | CW6×80         | 0.5Ps                         | 1445                        |
3.2. Test load - displacement curve
The load-displacement curve of the tests are shown in Figure 5(a)-(i).

(a) 1#-2M20-CW6-80-0.5Ps Specimen load - displacement curve
(b) 2#-4M20-CW6-80-0.5Ps Specimen load - displacement curve
(c) 3#-6M20-CW6-80-0.5Ps Specimen load - displacement curve
(d) 4#-2M22-CW6-80-0.5Ps Specimen load - displacement curve
(e) 5#-4M22-CW6-80-0.5Ps Specimen load - displacement curve
(f) 6#-6M22-CW6-80-0.5Ps Specimen load - displacement curve
3.3. The influence of high strength bolt specification on connections
The tensile load displacement curve is shown in figure 6, 7 and 8.

**Figure 5.** Specimen load - displacement curve

- (g) 7#-2M24-CW6-80-0.5Ps
- (h) 8#-4M24-CW6-80-0.5Ps

**Figure 6.** The load-displacement curve comparison chart of specimen contains two high-strength bolts

**Figure 7.** The load-displacement curve comparison chart of specimen contains four high-strength bolts
3.4. The influence of the number of high strength bolts on bolting and connecting

The tensile load displacement curve is shown in figure 9(a)-(c).

(a). Specimens with different number of M20

(b). Specimens with different number of M22

(c). Specimens with different number of M24

Figure 9. Load - displacement curve comparison chart
It can be seen from figure 9, the change of bolt number has obvious influence on the test results for the different number of high strength bolts. As the number of bolts increases, the ultimate carrying capacity of the specimen is improved.

4. Conclusion
(1) In this paper, through the tests of the combined connections with bolts and welds, the load-displacement curves are obtained.
(2) By comparing the sample load-displacement curves of different bolt specifications, the following results are obtained: the change of bolt specification has obvious effect on test results with two high strength bolts. For specimens with four and six high-strength bolts, changes in bolt specifications have a more modest effect on the test results, primarily because the strength of the reinforcement weld is more compatible with the two high-strength bolts.
(3) By comparing the sample load-displacement curves of different bolt number, the results show that the change of bolt number has obvious influence on the test results for different high strength bolts. As the number of bolts increases, the ultimate carrying capacity of the specimen is improved.

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