Finite element analysis of bolt shear connection of steel-concrete composite structure

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Abstract. Bolted shear connectors are an important component to ensure that steel-concrete composite structures can work together. High-strength bolt shear connectors can replace traditional stud connectors because of their disassembly, good mechanical performance and fatigue resistance. It applied to steel-concrete composite structure. In order to study the influencing factors of the bearing capacity of high-strength bolted shear connectors, this paper uses ABAQUS finite element simulation software as a research tool to establish a reasonable finite element model to study the influence of bolt strength, bolt diameter and concrete strength on bolted shear connectors. Studies have shown that increasing the diameter, strength, and concrete strength of bolted connections can effectively increase the bolt's shear capacity.

1 INTRODUCTION

The steel-concrete composite structure connects concrete and steel beams through shear connectors, so that it becomes a structural member that can work together. The steel-concrete composite structure can bring into full play the performance advantages of concrete and steel. Compared with the ordinary steel structure, it can save the amount of steel and reduce the costs. When pouring concrete, the steel beam part can serve as a support template for pouring concrete, saving cost and improving efficiency [1-3].

In order to enable the steel-concrete composite structure to form a better whole, people usually set up shear connectors between the steel beam and the concrete. The main function is tantamount to resist the slip and longitudinal shear between the steel beam and the concrete structure. It is an important part of the steel-concrete composite structure. In recent years, with the continuous deepening of the research on connectors, there are more and more types of shear connectors, which can be subdivided into channel steel connectors, PBL connectors, studs and bolt connectors [4,5]. This paper uses the verified finite element model to photometrically analyze the shear mechanical properties of high-strength bolts, analyzes the influence of bolt strength, bolt diameter, and concrete strength on the ultimate bearing capacity of bolts, and discusses its deformation characteristics with reference to Mises stress cloud diagram.

2 EXPERIMENTAL FINITE ELEMENT MODEL

This article refers to similar experiments conducted by other scholars, and the model parameters used are: I-beam size: HW250×9×14, concrete slab size: 600×460×150, and the steel bar diameter is 8mm. Based on the symmetry

of the specimen, this article will model a quarter of the test specimen. The model has four parts: concrete slabs, bolt shear connectors, I-beams and built-in steel bars. In order to ease the calculation of the model, this paper models the nut and the screw as a whole, and the steel as a part [6].

Concrete slabs Steel beam Bolt
Figure 1 Examples of finite element components

3 FINITE ELEMENT ANALYSIS

3.1 The influence of concrete strength on bolt shear capacity

Figure 2 The influence of concrete strength on the shear capacity of bolts

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This paper takes the high-strength bolt connection with bolt strength grade 8.8 and standard pre-tightening force as an example[7]. Figure 2 shows the influence of concrete strength on the shear bearing capacity of composite structural bolts. When the bolt diameter and strength remain unchanged, the concrete strength can be increased. Improve the shear capacity of bolts. When the concrete strength increases from C30 to C50[8], the bolt shear capacity increases by 10.4%, 5.8%, and 7.9%.

3.2 The influence of bolt diameter on bolt shear capacity

Figure 3 The effect of bolt diameter on the shear bearing capacity of bolts

Taking bolts with a screw length of 140mm, a concrete strength of C40, and a tensile strength of 800Mpa as the research object, a model of different bolt diameters is established for analysis. It can be seen from Figure 3 that when other parameters are the same, the shear capacity of the bolt connection varies with the increase in diameter has a significant improvement. When the bolt diameter increases from 14mm to 20mm, the bolt shear capacity increases by 19.2%, 16.1%, and 8.9%.

3.3 Influence of bolt tensile strength on bolt shear capacity

Taking the bolt screw length 140mm, concrete strength C40, bolt diameter 16mm high-strength bolt connection as the research object, the influence of different bolt tensile strength on the bearing capacity of shear connection is analyzed. It can be seen from Figure 4 that the shear capacity of high-strength bolts increases with the increase in tensile strength. Starting from the tensile strength of 400Mpa, the tensile strength of bolts increases by 200Mpa each time the shear capacity increases by 38%, 18.6% and 14.2%.

Figure 4 Effect of tensile strength of high-strength bolts

3.4 Effect of bolt pre-tightening force on bolt shear carrying capacity.

Figure 5 Influence of pretension of high-strength bolts

Taking concrete strength C40 and bolt strength class 8.8 as an example, figure 5 shows that the pre-tightening force of different strengths is against the high strength screw. The effect of bolt anti-shear carrying force, by Figure 5, it can be known that changing the bolt pre-tightening force size on the combined structure bolt anti-shear joint carrying force is not obvious, in the pre-tightening force to take 50kN-80kN, the limit carrying capacity change is not obvious. The finite meta-model cases in this paper are loaded by displacement, with the application of load, each contact surface between the model will produce the corresponding friction, because this study does not retain the gap on the reserved hole of the steel beam, so when the load is applied to overcome the friction force, there is no stage of the step platform, the bolt rod and the steel beam hole wall contact, the bolt directly into the pressure stage, with the increase of the load, the load at this time mainly depends on the compression of the bolt rod and the hole wall. Pre-tightening force has little effect on the bolt's limit shear carrying capacity.

3.5 The effect of the reserved hole clearance on the bolt's shear-resistant carrying capacity.

Figure 6 Impact of high-strength bolt reaming

It can be seen from the figure 6, with the increasing hole gap, the bolt's limit shear-resistant carrying capacity is decreasing, and when the bolt hole clearance reaches

4mm, the shear-resistant carrying capacity of the bolt components decreases by about 20%. There is a significant slip platform in the figure, which is due to the fact that the load applied by the roll-out test, after overcoming the bolt pre-tightening force, the bolt slides in the reserved steel beam hole, rather than being completely in the middle state as in the finite meta-model, so the slip platform in the load-slip curve of the test is not obvious. According to the load curve in the figure, it is recommended to keep the bolt reserved hole clearance at about 2mm, and for the case of the large hole in the reserved bolt hole, it is recommended to multiply the reduction factor when calculating the limit shear carrying capacity.

3.6 Bolt stress analysis

The stress of the bolt is concentrated on the contact surface between the bolt and the concrete, and the bolt is also damaged by cutting in this position during the test. In the pre-loading period, the bolts come into contact with the hole wall of the steel beam and the concrete surface, and are subjected to greater pressure of extrusion deformation. As the load increases, the stress between the bolt and the hole wall increases, causing the bolt to begin to deform. When the calculation is complete, the stress of the bolt is mainly concentrated in the position of the bolt and concrete contact surface and the middle of the screw, the bolt in the loading process to withstand the joint action of bending moment and shear force, deformation is mainly controlled by shear force [9].

This set of test pieces damage form is bolt cut damage, On the whole, the destructive form of the test piece is similar to that of the introduction test, both are bolted and there is a small amount of coagulation failure on the lower side of the bolt, so the maximum load can be taken as the peak load in this paper.

4 CONCLUSION

This paper uses ABAQUS software to establish steel-concrete composite structure bolt shear connectors and launch test models to discuss the influence of bolt diameter, bolt strength, and concrete strength on the shear performance of bolt connectors. The results show that: increase the diameter, strength and strength of bolt connectors, the strength of concrete can effectively improve the shear capacity of bolts.

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