Experimental study on the mechanical and clamping properties of F13T high strength bolt

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1. Introduction

High strength bolts are the chief mechanical fasteners used for making connections for steel structures. And the high strength bolt has many advantages as the tensile strength of bolt is higher. Clamping force of high strength bolt is greater as the bolt strength is higher. Furthermore, it is available that the stiffness and reliability of the joint is great. The use of high strength bolts results in saving money and time for construction by decreasing the number of bolts. The size of joints can be decreased and the mass of the structure is slight as the strength of bolts is higher.

From these backgrounds, F13T grade bolt was developed. Therefore, this study is, as a fundamental study, aimed at the commercialization of the newly developed F13T high-strength bolts and the quantitative studies on the design guides of the connection of high-strength bolts for steel structures. For these purposes of the research, tensile test of material of high strength bolts, the test for tensile strength and torque of the product was carried out.

2. Tests of mechanical properties of high strength bolts

2.1 Tests on mechanical properties

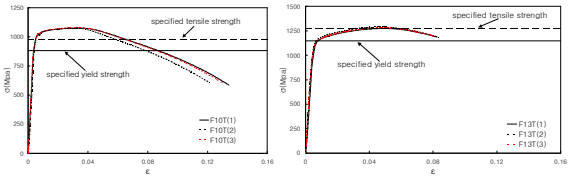
The objective of this test is to estimate mechanical properties of newly developed material for the bolt. The procedure of the test and specimens is specified in KS B 1010. Three specimens were tested, and the average test results are summarized at Table 1. The stress versus strain relationships curves are shown at Figure 1a, b.

Test results of both F10T and F13T are satisfied with KS specification of yield and tensile strength and in case of F13T, the ratio of the yield strength is 0.90, which is satisfied with the calculated value, by using the standard yield ratio of F10T, 0.9, as specification in KS. But there are few safety margins in the yield strength and tensile strength of F13T bolts as compared with that of F10T. And also in case of F13T elongation and area reduction shows small value, compared with that of F10T.

Table 1. Test results of mechanical properties.

bolt grade	Yield Strength	Tensile Strength	Elongation	Area Reduction
	MPa	MPa	%	%
F10T	1007	1075	18.7	67.1
F13T	1150	1281	11.2	27.9

*0.2% offset value



(a) F10T bolts (b) F13T bolts

Figure 1. Stress-strain curves

2.2 Tensile test of bolt products

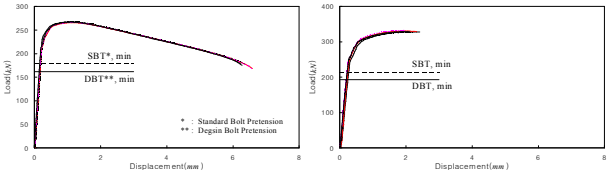
To clarify tensile load and deformation capacity of F13T bolt products, this test of five specimens were conducted. And also to identify whether the part of the head was separated the tensile test of bolt products with taper washer were carried out as specified in KS code.

The test results are summarized at Table 2 and all the presented value are the average test results of both and F10T and F13T bolt products. In case of F10T and F13T with taper washer, the part of the head was no separated. The relationships of load versus displacement are shown at figure 2a,b. The standard design strength in figure 2a, b is equal to 0.75 of yield strength, as specified in KS specification. Additionally to consider relaxation of the joints and errors while construction, the standard design strength in KS is specified as the value which is increased by 10% of the strength of bolts. Therefore, the standard design strength of F13T in figure 2b is calculated on a basis of the specification for the F10T. As shown at figure 2a,b, the yield and tensile load of each bolt product are higher than design and standard pretension with many safety margins. But the elongation of F13T bolt products is very low, as compared with that of F10T. This is caused by the mechanical properties of F13T bolt.

Table 2. Results of the test for the tensile strength of bolt products.

bolt grade	Yield Load	Maximum tensile Load	Elongation
	Kn	kN	%
F10T	246	267	10.1
F13T	279	329	3.5

*0.2% offset value



(a) F10T products (b) F13T products

Figure 2. Load-displacement curves

2.3 Torque Tests

In torque control method, the relationship of pretension load, torque and rotation must be proved. In usual practice, preload force is usually introduced by tightening the nut against the connected material. This procedure for tightening bolts results in a combination of tensional and torsional stress condition in the bolt. Therefore, torquing a bolt until failure results in both reduction in ultimate load and deformation as compared with the corresponding values determined from the tensile test of bolt products. This is considered in determination of minimum required pretension. To investigate this characteristic, therefore, torque test should be conducted.

Four specimens were tested and the average results of the test are summarized at Table 3. The clamping force-rotation of nut and clamping force-torque curve are shown at Figure 3a-b. In the test results, the maximum clamping force of both F10T and F13T bolt are higher than the required bolt pretension.

As the test results, the average torque coefficient of F10T bolt , 0.16, belongs to B grade and there is few deviation. Although the average torque coefficient of F13T bolt is 0.16, the data is various with wide range. Thus, in order to make sure of constant torque coefficient of F13T bolt product, it is necessary that the mechanical properties of F13T bolt and quality control method for bolts products be improved.

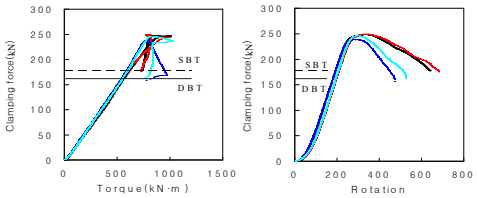
As torquing F10T bolt to failure, the reduction in ultimate strength by 7-10% was appeared in this test and F13T was 6-8%. And the average reduction of F10T and F13T bolt is 8% and 6% respectively. Usually reduction in ultimate strength of between 5 and 25% was experienced in the tests on both A325 and A490 bolts and average reduction is equal to 15% in the reference, Geoffry L. Kulak & et al. 1987. But there are many variations in this results and so this can't be directly compared with the results of the reference in USA. But this is considerably affected results as the reductions is smaller than that of the reference in USA. However, there is no definite theory for this behavior. And therefore according to the tensile strength of bolt, the various tests and analysis of relaxation must be performed in the near future. Anyway this test result guarantees that F13T bolt ensures the required performance of torque test as specified in KS.

Table 3. Test results of torque test.

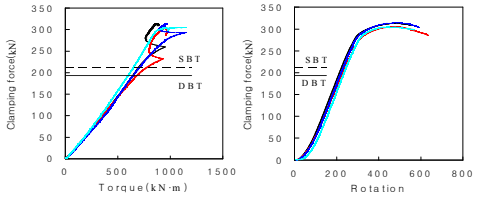
bolt grade	Maximum clamping force	Torque coefficient	Reduction in ultimate strength*
	kN	·	%
F10T	246	0.16	92
F13T	310	0.16	94

*:

$$\frac{\text{maximum clamping force in torque test}}{\text{maximum tensile load in tensile test of bolt products}} \times 100$$



a. F10T bolt products



b. F13T bolts products

Figure 3. Clamping force-Torque & Rotation curve.

3. Conclusion

According to test results and discussions presented in this paper, the conclusions can be presented as follows:

1. As the results of the tensile test for F13T bolt, the average yield and tensile strength are 1150Mpa and 1281Mpa respectively. This yield strength is satisfied with the minimum required strength specified at the F10T specification, 0.9 of yield strength ratio, as specified in KS.

2. The average tensile load of F13T products is 329kN, which higher value than the minimum tensile load to meet KS code. And there was not separation at the head of F10T and F13T bolt products in the test with taper washer used.

3. In the results of the torque test, the average of values for torque coefficient is 0.16 which is within the range of the torque coefficient as specified in KS code. Furthermore, It is identified that the range of torque coefficient in F13T bolt is wider than that of F10T bolts.

REFERENCES

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