Experimental Study on Clamping force of ASTM A490 High Strength Bolts subjected to Construction field's Temperature

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1. Introduction

Although Torque control method and turn of nut method utilize the value of torque and turn of nut respectively, the clamping force of high strength bolts is influenced by variation of torque coefficient. Generally it is known that torque coefficient is effected by environmental factors; temperature, wet condition, etc. In this study, torque test of ASTM A490 high strength bolts is conducted in the various temperature conditions to observe the effect of temperature.

2. Experiment

2.1 Test Program

Considering various temperature conditions at construction sites, all specimens were exposed to the temperature ranging from -10℃ to 50℃ and specimen quantity is 10 sets per each condition like Table 1.

Table 1. Specimen List

Bolt Grade	Size (mm)	Temp. (℃)	Quantity (EA)
ASTM A490	M20×140	-10	10
		0	10
		10	10
		20	10
		30	10
		40	10
		50	10

2.2 Procedure

To maintaining specimen temperature, bolt sets were placed in a temperature incubator for 24 hours. After taken out the incubator, all specimens' temperatures were measured for accuracy right before torque test. After setting the specimen at the loadcell where is right side of torque test machine shown like Figure 1, the nut was clamped with the socket until the specimen broke down like Figure 2. While the process of clamping, torque, clamping force and turn of nut were measured through the loadcell.

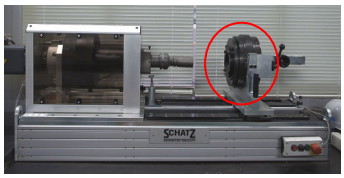

Figure 1. Torque Test Machine


2. Specimen after broken

3. Experimental Results

3.1 Trend of torque coefficient and Clamping force

On the authority of Steel Structure Design Manual and Specification, torque and turn of nut at the point of design and required strength in tension were recorded and torque coefficient was calculated at the point of 181.75kN, which is on the ground of KS B 1010 code.

As a result of test, torque which is needed for required strength in tension(178kn) is 639N·m at -10℃ condition, 618N·m at 0℃, 581N·m at 10℃, 565N·m at 20℃, 578N·m at 30℃, 570N·m at 40℃ and 551N·m at 50℃ on average.

Torque coefficient is 0.179 at -10℃ condition, 0.173 at 0℃, 0.163 at 10℃, 0.159 at 20℃, 0.162 at 30℃, 0.159 at 40℃ and 0.154 at 50℃ on average. Torque coefficient of -10℃ and 0℃ condition varied from

Table 2. Test Result

Temperature (℃)		Design Strength In Tension (162 kN)		Required Strength In Tension (178 kN)		Strength for calculating Torque Coefficient (181.75 kN)			Turn of nut (θ 180°)	
		T (Nm)	θ (°)	T (Nm)	θ (°)	T(Nm)	θ (°)	k	N (kN)	T (Nm)
-10	Average	589	156	639	170	649	173	0.179	190	674
	Deviation	26.0907	4.3276	25.9655	4.2016	27.9478	4.1417	0.0077	4.9364	31.0404
0	Average	570	155	618	168	627	171	0.173	192	659
	Deviation	20.7782	5.9862	20.6198	6.0424	20.2626	6.1912	0.0056	7.2752	33.4865
10	Average	537	155	581	168	592	171	0.163	192	619
	Deviation	13.3517	3.6473	14.7002	3.6056	13.9361	3.6249	0.0038	4.1695	20.6209
20	Average	521	157	565	170	577	173	0.159	190	598
	Deviation	13.6840	5.1986	14.2548	5.3151	14.0426	5.2991	0.0039	6.2765	21.5635
30	Average	531	172	578	187	588	190	0.162	171	556
	Deviation	16.0898	13.2461	17.0453	13.3106	16.4034	13.3339	0.0045	14.5567	50.1798
40	Average	530	172	570	186	578	190	0.159	171	549
	Deviation	26.1047	6.2191	17.9208	6.3182	20.4780	6.2252	0.0056	6.8651	34.0976
50	Average	522	185	551	199	560	203	0.154	157	512
	Deviation	49.4463	4.8646	34.6049	5.1373	36.7992	5.1210	0.0101	5.4274	46.4083

0.167 to 0.190, which was 15% much higher than normal condition(20℃) on average. At then 10℃ condition, torque coefficient ranged from 0.155 to 0.168. The overall trend is that torque coefficient decreased as temperature increased shown like Figure 3.

On the other hands, at the point of turn of nut 180°, clamping force of -10℃ and 20℃ condition is about 190kN. Clamping force is gradually decreased as temperature increased ranging from 20℃ to 50℃ shown like Figure 4 but this declination is confined to specific range of temperature.

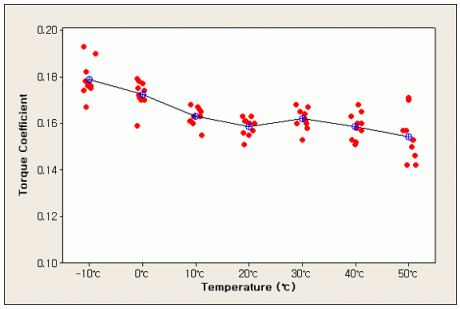

Figure 3. Trend of Torque coefficient

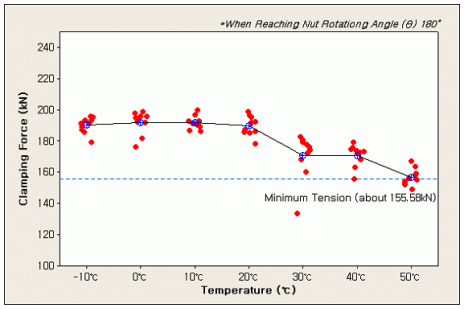

Figure 4. Trend of Clamping force at a point of turn of nut 180°

3.2 Comparison of Torque and Turn of nut

While scope of turn of nut which is needed for required strength(178kN) ranged from 170° to 199°, torque varied from 551N·m to 639N·m. Subtracting turn of nut for snug-tight, turn of nut needed for required strength in tension is 126° at -10℃, 125° at 0℃, 123° at 10℃, 121° at 20℃, 134° at 30℃, 134° at 40℃ and 143° at 50℃ respectively on average. Considering as above result, turn of nut subjected to temperature variables was fairly even. Torque is more fluctuated than turn of nut as temperature condition changed. Therefore as above, torque is more effected by temperature than turn of nut.

3.3 Mechanical Properties subjected to temperature

At an elastic limit, clamping force and turn of nut are 222.9kN~238.4kN and 213°~234° respectively. At a break point, turn of nut was 556°~983°, which was 2~3 rotation. which made regular pattern under various temperature condirions shown like Figure 5. And therefore mechanical properties of high strength bolt were not effected by temperature variable.

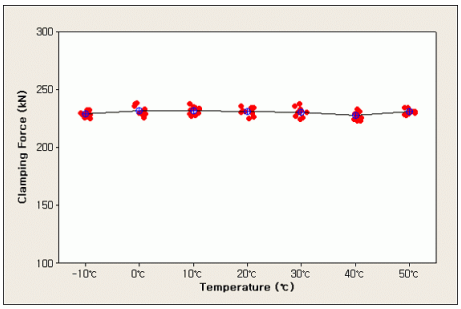

Figure 5. Trend of Clamping force at an elastic limit

4. Conclusions

As a temperature decreased, torque and torque coefficient increased. This is why the coeffiecient of friction between screw threads of bolt and nut is varied as temperature variables. To ensure required strength in tension at a low temperature, torque is much more needed than at a normal temperature. In case that clamping bolt sets by torque control method regarding torque coefficient as the value written on the product specification, required strength may be not ensured at a low temperature. Torque is more effected by variation of temperature than turn of nut. Mechanical properties of high strength bolt were not effected by temperature variable.

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