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FURTHER STATIC TENSION TESTS OF BOLTED JOINTS

A B S T R A C T

Tests of two joints using 1" and 1 1/8" bolts confirm the findings of previous tests using 7/8" high strength bolts. Balanced design can be achieved by using a T/S ratio of 1.00/1.10.

I. Introduction

Fritz Engineering Laboratory Report No. 271.1, "Static Tension Tests of Bolted Joints" reports on the strength of joints fastened with 7/8" high strength bolts. The most important information gained from those tests is that for a balanced design the Tension/Shear ratio should be about 1.00/1.10. To verify this finding two additional joints have been tested using 1" and 1 1/8" bolts at the above T/S ratio.

II. Description of Test Joints

The additional joints were similar in construction to those of the B series (7/8" bolts) in that they were half butt joints with the main plate made up of two 18" x 1" steel plates and the lap plates each an 18" x 1" plate.

Joint A3 used 16 - 1" bolts arranged in a compact pattern of 4 longitudinal lines at a gage of 4 1/2" and 4 transverse rows at a pitch of 4". Thus, g/d and p/d were in a range comparable to those of the B joints. The T/S equaled 1.00/1.10.

Joint G1 had 12 - 1 1/8" bolts in 4 lines and 3 rows. The gage and pitch dimensions were the same as for A3 hence g/d and p/d were slightly different but still within practice. The T/S equaled 1.00/1.11.

III. Material Properties

The plate used was ASTM-A7 structural steel as described in the report of the B-series. The properties may be formed in Table II of that report under A3B3 and G1B2.

The bolts used were ASTM-A325 high strength bolts (5 1/2" under head for 1" bolts and 6" for 1 1/8") These bolts were not as close to minimum strength as the 7/8" bolts used in the B-series. Load-elongation calibration curves determined by direct tension for 5 bolts of each lot showed that the bolts possessed the required minimum proof loads and the following ultimate loads.

Direct Tension Tests of Bolts

Bolt No.	Ultimate Load, lbs	Bolt No.	Ultimate Load, lbs.
A128	72,000	G15	88,750
A129	74,000	G24	93,750
A155	73,750	G28	90,000
A156	74,500	G29	91,500
A157	74,000	G30	92,000
Avg.	74,100	Avg.	91,200
Specs.	69,700	Specs.	80,100

Shear tests on individual bolts and mill scale faying surfaces have shown that the ultimate effective shear stress of the high strength bolt is about 70% of the ultimate tensile stress on the stress area. On that basis the effective shear strength of the A and G bolts would be 85.6 ksi and 83.7 ksi respectively.

IV. Fabrication of Test Joints

The shop fabrication of joint A3 was identical to that for the B series, the corner holes being subdrilled and reamed while all other holes were drilled thru 4 plies.

The procedure for G1 differed because that joint was made by altering joint A2(20 - 1" Bolts) which had been fabricated before it was decided that testing of it would be unnecessary. Thus, to produce G1, two rows of holes were burned off of A2 and the remaining 1 1/16" holes were reamed to 1 3/16".

Faying surfaces were mill scale.

An erection crew of Bethlehem Steel Company bolted both joints using their current field procedure which in this case meant turning the nut 1/2 turn from the snug position using the impact wrench.

Bolt lengths were measured before and after tightening and the elongations were converted to tension by means of a direct tension vs. elongation calibration curve. In Joint A3 bolt elongations varied from 0.0107" to 0.0395" with an average of 0.0317", or a clamping force per bolt of 60,500 lbs. In Joint G1 the range was from 0.390" to 0.715", and an average of 0.0519: converts to 78,000 lbs per bolt.

V. Instrumentation

The instrumentation was similar to that used on Joint B6 and consisted of SR4 gages, slide bar extensometer to measure pitch elongation, and dial gages to measure the total elongation of the bolt pattern.

VI. Test Procedure

The test procedure was the same as that employed for the B-series.

VII. Test Results

A summary of the results of these tests is given in Table I.

The behavior of these specimens under load was similar to the behavior of the B joints. In the early stages - minor slips, then the major slip distinguished by a loud noise, and then further scraping and grating as additional minor slips brought the joint into full bearing.

The failure of A3 took place in two stages which followed one another in a few seconds. At a load of 1820^k (Nominal bolt shear stress = 75.2 ksi, average tensile stress on net section = 66.2 ksi) the nut end of bolt # 160 (top, south corner) sheared off and before the testing machine could be unloaded all the remaining bolts sheared. Bolts in the upper three rows single sheared while those of the bottom row double sheared. The final configuration of the plates was similar to that for B3, one lap plate being very much bent.

The commercial length of thread on the 1" bolts placed the thread run out at the shearing plane so there was probably some reduced area effect. Each row of bolts showed a slightly different type of failure as follows:

Top row (end of lap plates)	rupture plane cut diagonally across two threads
Second row	rupture plane cut normal to bolt axis at thread run out but two threads down a crack developed at the root of the thread penetrating half way through the bolt

Third row	rupture plane cut normal to bolt axis at thread run out
Bottom row	bolts double sheared on planes normal to the axis

During the testing of G1 considerable dishing of the washer under top corner bolt #9 was noticed at a load of 1200 kips. This was the first time that a marked deformation had been noticed at such a low load. It was thought at the time that this portended a weakness and possibly an early failure. However, as the test turned out, there appeared to be no detrimental behavior of this bolt.

The rupture of G1 occurred at a load of 1798^k when all of the bolts sheared. (Nominal bolt shear stress = 75.2 ksi, average tensile stress on net section = 67.8 ksi) Once again the upper rows single sheared and three of the four bolts on the bottom row double sheared. The holes showed large deformations, particularly the corner holes in the main plate which became ellipses with major axes of 1 1/2" inclined inward at the top at about 10^o. The head end lap plate was bent as in B3 and A3 indicating a momentary change to a lap joint prior to complete disengagement of the plates.

The commercial thread length placed thread run out at the shearing plane and the bolt shears occurred normal to the shank at this point. Several of the bolts on the top row showed signs of tearing at the root two threads down as reported for A3.

The load-elongation curves for these joints are typical of those reported earlier. They show that in the elastic range the elongation that occurs is slightly less than that predicted by PL/AE where A is the gross area. Each joint showed a slip of about 0.08" and thereafter each curve proceeded upward at a much flatter slope than that of the elastic range.

VIII. Summary and Conclusions

The results of these two tests confirm the conclusions drawn from the tests on the 7/8" bolts.

The T/S of 1.00/1.10 produced bolt failures but at the same time the tensile stress on the net section was above the average coupon strength thus indicating for all practical purposes a balanced design.

Major slip occurred at nominal bolt shears well above the range of normal working loads.

Joint elongation may be predicted satisfactorily by considering the joint as solid material equivalent to the main material.

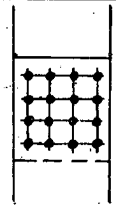
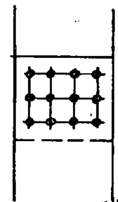
$\frac{72.5}{83.2} = .871$

The average nominal bolt shear stress at failure in A3 was 85% of a single bolt value and in G1 was 90%.

$\frac{75.2}{84.0} = .895$

As shown in 271.8

TABLE 1

RESULTS OF TESTS			
	Units	A3	G1
Pattern			
Number of A325 Bolts		16 - 1"	12 - 1$\frac{1}{8}$"
Nominal Gross Area	sq in	36.0	36.0
Nominal Net Area	sq in	27.5	26.5
Nominal Shear Area	sq in	25.1	23.9
Tension: Shear Ratio		1:1.10	1:1.11
Slip Load (Major)	kips	843	920
Nominal Bolt Shear	ksi	33.6	38.5
Tension on Net Section	ksi	30.7	34.7
Average Extension of Bolts	in	.0317	.0519
Initial Clamping Force	kips	968	936
Coefficient of Friction		0.435	0.491
Ultimate Load	kips	1820	1798
Nominal Bolt Shear	ksi	72.5	75.2
Tension on Net Section	ksi	66.2	67.8
Type of Failure		Shear of bolts	Shear of bolts