Armatherm FRR Thermal Break Material in Shear Connections

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Introduction:

Thermal break material is adopted in beam-to-beam or beam-to-column connections to provide insulation between interior and exterior steel or concrete work to prevent excessive heat transfer due to thermal bridging. A common application is to provide a break between an exterior balcony support and interior frame. In such an application, the thermal break material is subjected to compression, shear, and flexural loads. The purpose of this testing program was to evaluate the performance of the thermal break material in connections under shear loading.

Thermal break material is considered a filler plate or packing in the U.S. and European design codes. The AISC code[5] section J5 requires a reduction in the shear strength of the bolts in the connection in the presence of filler greater than 1/4 in thick. Prior to the 2010 Code, reduction of the shear strength of the bolts was limited to fillers up to 3/4 inch. As an alternative to the bolt shear strength reduction, thicker fillers may be made continuous with one of the connecting elements by enlarging the filler and securing it with additional bolts. Or the designer may design for a slip-critical connection. European codes[6] also specify a strength reduction and also limit the filler to 25 mm (1 inch) for the 19 mm (3/4 inch) bolt commonly used in building construction. Thermal break material is often specified to be 1 or 2 inches in thickness.

Test Program:

The test matrix included testing of three distinct assemblage configurations. Duplicate tests were performed on each assemblage configuration to provide data redundancy. The test setup is shown in Figure 1 and includes:

- Configuration 1 - A base case of a stiffened built-up angle with a 1/2-in. x 10-in. x 6-in. vertical leg connected to a vertical column flange with four ASTM A325[1] structural bolts with standard ASTM F436[2] washers behind the nut;

- Configuration 2 - A second case of a stiffened built-up angle with a 1/2-in. x 10-in. x 6-in. vertical leg and 1 inch thick thermal break material of the same face dimensions connected to a vertical column flange with four ASTM A325[1] structural bolts with standard ASTM F436[2] washers behind the nut;

- Configuration 3 - A third case of a stiffened built-up angle with a 1/2-in. x 10-in. x 6-in. vertical leg and a 2 inch thick thermal break material of the same face dimensions connected to a vertical column flange with four ASTM A325[1] structural bolts with standard ASTM F436[2] washers behind the nut.

- Configuration 4 – A case similar to Configuration 2 but with a 1 inch thick high-weave thermal break material.

- Configurations 5 and 6 – Cases similar to Configurations 2 and 4, respectively, with the thermal break material having a high friction surface.

The first case provided a baseline case of the connection behavior without the presence of thermal break material. The remaining cases provided a comparison point for cases with varying thickness, grade, and surface condition of the thermal break material.

All four 3/4-in diameter structural bolts in each assembly were snugged. Then each bolt was tensioned to approximately 32,000 lb. using the tightening sequence shown in Figure 1. The initial tension of 32,000 lb. is approximately 15% above the RCSC minimum pretension[3] for a slip critical connection. This load was used to establish a common baseline for all testing and because of the potential slip-critical connection requirement. The bolt tension was measured using ultrasonic means[4]. The tension in each bolt was re-measured thirty minutes after initial tightening to determine the total clamping force in the assembly and then the vertical shear load was gradually applied to the connection until slip occurred. For the tests considered, the clamping force was between 114,000 lb. and 135,000 lb. with the exception of two tests in which the bolts were under-tightened.

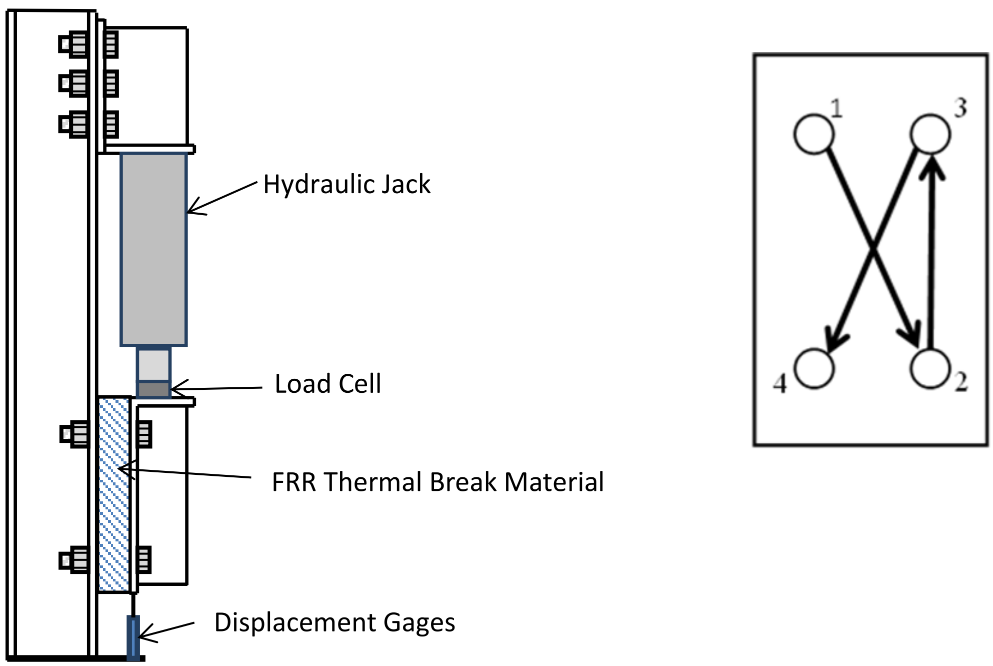

Figure 1. Test set-up schematic and bolt tensioning sequence.

Results and Discussion:

Forces in the bolts were measured during tensioning to obtain the target bolt load. The assemblies were then allowed to relax for thirty minutes, at which time the bolt tension was again measured to determine the assembly clamping force. A load was then applied to the top of the angle and gradually increased until the assembly slipped. The load versus displacement plot for examples of each assembly tested is shown in Figure 2. The loads at which slip occurs in the connections are evident in the figure. As would be anticipated, the stiffness of the connection prior to slip is reduced with the introduction of the thermal break material and the reduction is greater for the thickest material. This trend is caused by the shear deformation of the thermal break material. The shear deformations in the thickest material tested increased the vertical deflection of the connection by a maximum of 0.015 inches prior to slip occurring. While observable in this test configuration, the deformation is considered inconsequential to the behavior of the connection in the context of a real structure. Tests 2 and 3 of the series of 1 inch thermal break material had a lower initial clamping force. The lower clamping force did not influence the initial slope of the load-deflection curve.

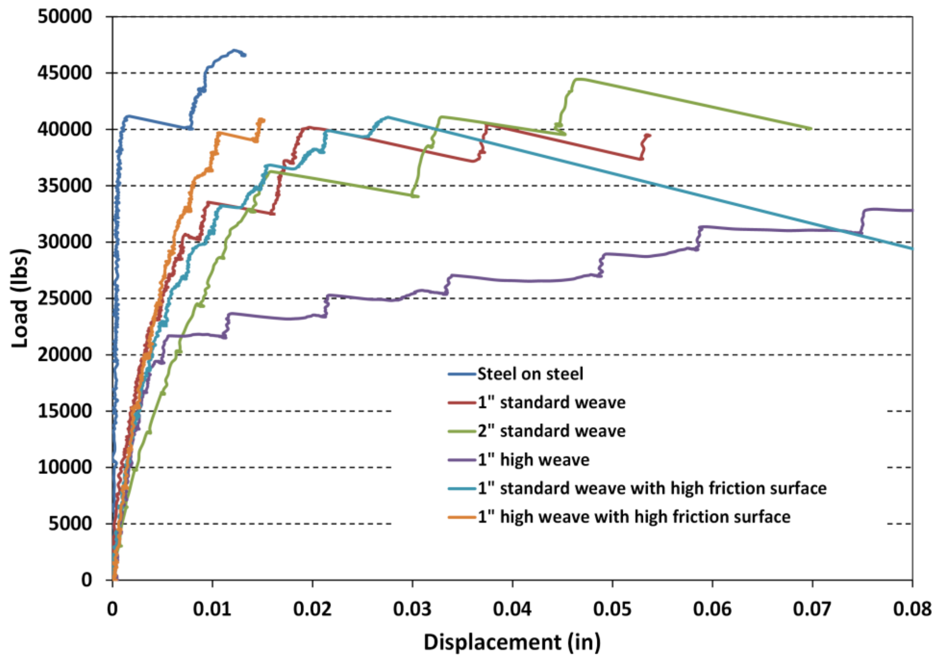

Figure 2. Load – displacement plots for each tested assembly.

The connection clamping force and the load at first slip are tabulated in Table 1 along with the coefficient of friction determined from these data. The measured coefficients of friction averaged 0.31, 0.23 and 0.17 for the steel on steel, standard weave thermal break material, and high weave thermal break material tests, respectively. Using a high friction surface thermal break material increased the coefficient of friction to nearly the same as or above that of the steel on steel connection. In the case of the standard weave plate with a high friction surface, the capacity of the loading equipment was reached prior to any slip occurring for two of the three samples tested. It is noted that the measured coefficient of friction was relatively consistent within assembly groups with the exception of Test 2 with the 1 inch thick lower weave material from which a high coefficient of friction was measured. This point was excluded from the average of that data set.

Table 1. Test results.

Configuration	Clamping Force (lbs)	Slip Load (lbs)	Coefficient of Friction
Steel			
Test 1	129400	36570	0.283
Test 2	133100	41150	0.309
Test 3	131600	44160	0.336
Test 4	**	30380	**
Test 5	99070	29080	0.294
Test 6	122700	41580	0.339
Average			**0.312**
1" standard weave FRR material			
Test 1	135100	35100	0.260
Test 2	77690	29100	0.375*
Test 3	80990	18260	0.225
Test 4	128500	30050	0.234
Test 5	121500	30450	0.251
Test 6	114400	24350	0.213
Average			**0.236**
2" standard weave FRR material			
Test 1	124800	35350	0.283
Test 2	126900	36260	0.286
Test 3	128300	27750	0.216
Test 4	124500	24480	0.197
Test 5	121700	21000	0.173
Average			**0.231**
1" high weave FRR material			
Test 1	124300	21600	0.174
Test 2	125700	20190	0.161
Test 3	126700	19740	0.156
Test 4	124800	20430	0.164
Test 5	124300	21030	0.169
Average			**0.165**
High friction 1" standard weave FRR material			
Test 1	113900	41050	0.360
Test 2	118200	46000	***
Test 3	110200	46000	***
Average			
High friction 1" high weave FRR material			
Test 1	113900	33960	0.298
Test 2	120500	38900	0.323
Test 3	113500	27280	0.240
Average			**0.287**

*1 inch thickness Test 2 excluded from the average;

**ultrasonic measurement failure lost clamp force data for steel on steel Test 4

***test load capacity reached prior to slip – load >46,000 lb.

The shear modulus of the thermal break material was determined from the load-displacement data and is provided in Table 2. For design purposes using a shear modulus of 100,000 psi would be appropriate.

Table 2. Measured shear modulus (psi).

	1" Standard Weave	2" Standard Weave	1" High Weave	1" Standard Weave High Friction Surface	1" High Weave High Friction Surface
Test 1	176,300	104,300	102,100	85,750	84,220
Test 2	177,900	119,600	89,200	101,200	96,960
Test 3	96,400	210,200	134,100	107,300	92,100
Test 4	123,100	129,100	134,700		
Test 5	144,400	97,500	152,000		
Test 6	101,500				
Average	**136,600**	**132,100**	**122,400**	**98,100**	**91,100**

Conclusions:

From the results of this experimental program the following conclusions were developed.

1. The friction coefficient is reduced from about 0.31 for steel-on-steel connections to about 0.23 for the standard weave Armatherm FRR material and to 0.17 for the high weave FRR material. Using a high friction surface on the material increased the coefficient to nearly the same as steel in the case of the high weave material and resulted in a coefficient exceeding that of the steel in the standard weave material.
2. The slight increase in the vertical deflection of the shear connections tested is insignificant for practical applications.
3. An elastic modulus of 100,000 psi is suitable for design applications in which a shear deformation needs to be considered.

References

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4. ASTM International (2006). ASTM Standard E1685 – 00 (2006) "Standard Practice for Measuring the Change in Length of Fasteners Using the Ultrasonic Pulse-Echo Technique," ASTM International, West Conshohocken, PA, www.astm.org.

5. American Institute of Steel Construction, Inc (2011). *Steel Construction Manual, 14th Edition*.

6. EN 1993-1-8 (2005). *Eurocode 3: Design of Steel Structures – Design of Joints*. European Committee for Standardization.