ARMATHERM™
THERMAL BREAK SOLUTIONS

EXPLANATION OF HOW TO CHECK COMPRESSION AND ADDED CONNECTION ROTATION USING FRR THERMAL BREAK MATERIAL

The total end deflection of the beam is assumed to result from Timoshenko beam theory deflections of a cantilever beam and a concentrated rotation at the connection. Figures 1 and 2 show the joint flexibility of a moment connection as measured in an experimental program. The test configuration used is shown in Figures 3 and 4. The total flexibility was obtained from the inverse of the slope of the experimentally measured load- deflection curves, using the portion of the final unloading cycle between 8900 N (2000 lb) and 26700 N (6000 lb). From this total flexibility, the theoretical flexibility of a cantilever beam with a rigid connection–including shear deformation–was subtracted. The remaining flexibility term, attributed to a concentrated rotation at the joint, was then scaled by the length measurement from the connection to the point of loading of the beam to obtain a connection flexibility term with units of rotations per moment. The resulting flexibilities are plotted in Figures 1 and 2 for steel on steel, as well as high weave and standard weave for both 25 mm (1-in) and 50 mm (2-in) thicknesses. The linear fit lines in Figures 1 and 2 include the steel-only data as zero thickness plates for both standard and high weave cases. The steel connection averaged a flexibility of 3.8×10^{-7} radians/N-m (5.2×10^{-7} radians/ft-lb) of applied moment. Addition of the barrier plates increased the rotation by 2.35×10^{-9} to 2.03×10^{-9} radians/N-m per mm (4.6×10^{-8} to 6.9×10^{-8} radians/ft-lb per inch) of plate thickness incorporated in the connection. The additional rotation attributed to the barrier plate was an order of magnitude lower than the rotation associated with the base case connection.

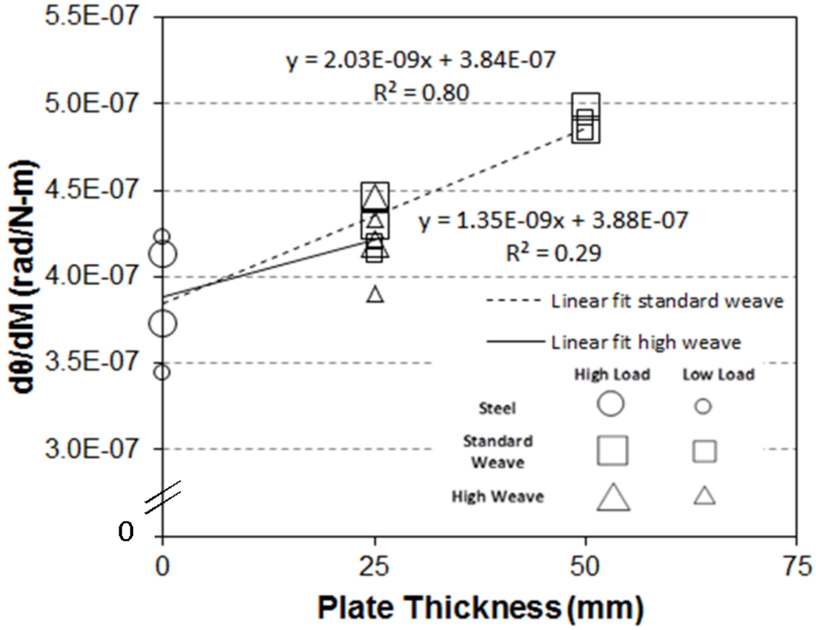

Figure 1. Connection flexibility (SI).

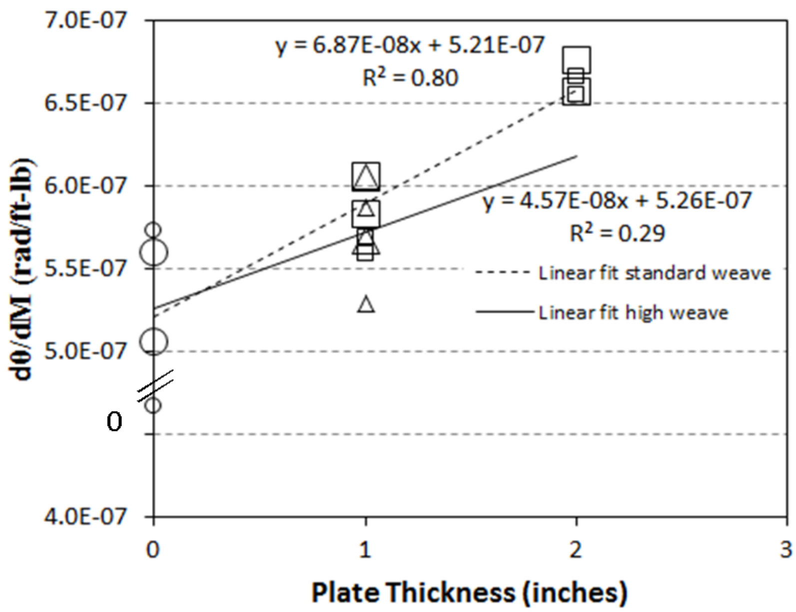

Figure 2. Connection flexibility (U.S. Customary).

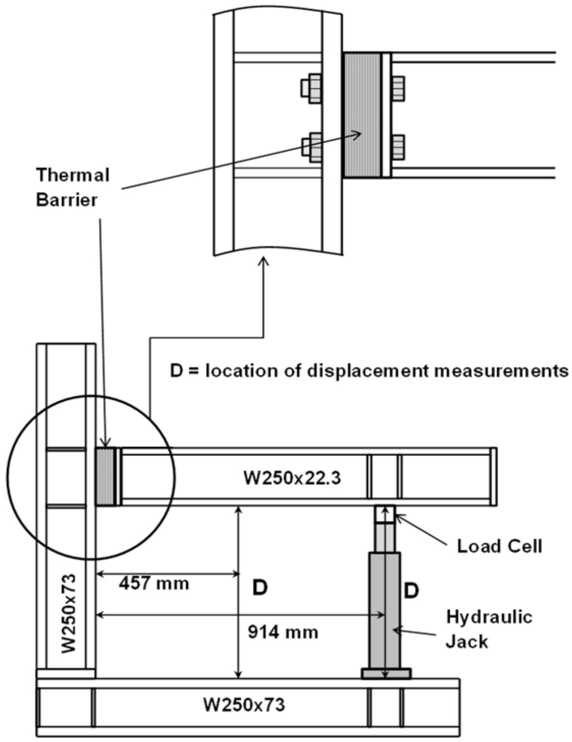

Figure 3. Moment test setup schematic (member specifications in SI).

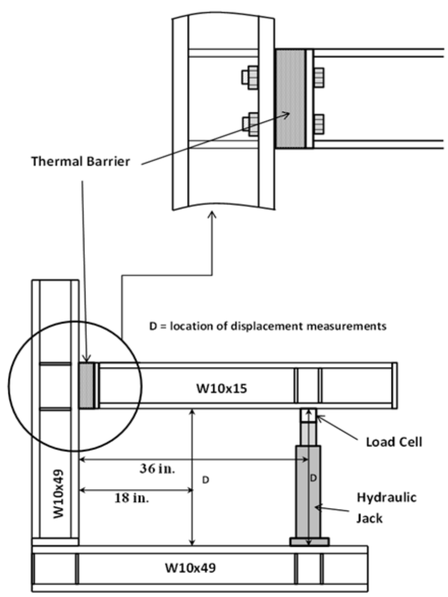

Figure 4. Moment test setup schematic (member specifications in U.S. Customary).

The results of flexibility analysis can be used to validate a relatively coarse model to check compression stress in the FRR filler plate and the additional rotation at the connection resulting from inclusion of the FRR plate. Referring to Figures 5 and 6, assume the moment on the connection is balanced by a tensile force in a row of bolts and a compression force assumed to be uniformly distributed across an area of the FRR plate equal to B x L where:

$B = t_f + a + t_p$
$L = b_f + 2t_p$
t_f= beam flange thickness
a = weld leg size
t_p = end plate thickness
b_f = beam flange width.

It should be noted that the length B is shown for the configuration used in this testing and should be modified in instances in which the end plate extends below the beam flange. Then the compression force in the flange, F_c is equal to M divided by $(d – B/2)$ where d is the distance from the compression face to the row of tension bolts. The compression stress in the FRR plate can then be compared to an allowable compression stress.

The average compression shortening of the FRR plate is calculated as

$$\delta_c = \frac{t_b \times \sigma_c}{E_b} \text{ where:}$$

t_b = thickness of the FRR filler plate
σ_c = compressive stress in the FRR filler plate = $\frac{F_c}{BL}$
E_b = elastic modulus of the FRR filler plate.

The additional joint rotation due to the FRR plate is

$$\theta = \sin^{-1}\left(\frac{\delta_c + \delta_T}{d - \frac{B}{2}}\right) \text{ where:}$$

δ_T = elongation of the bolts in tension determined from elastic theory and
$\delta_T = \frac{\Delta T \times L_b}{A_b \times E_b}$ and
$\Delta T = F_c$
L_b = the grip length of the bolt
A_b = the area of the bolt
E_b = the elastic modulus of the bolt material.

Working from the dimensions from the moment tests with t_f = 6.9 mm (0.27-in), a = 6.4 mm (0.25-in), t_p = 25.4 mm (1-in), and b_f = 102 mm (4-in) results in B = 25.9 mm (1.02-in) and L = 127 mm (5-in). At an applied load of 48.9 kN (11,000 lb) the resulting compression force is 235.3 kN (52.9kip), the compression stress in the FRR plate is 71.5 MPa (10.37 ksi), and the compression shortening of the FRR plate is 0.391 mm (0.0154-in). The bolt elongation is 0.117 mm (0.0046-in). The additional end rotation due to the FRR plate is 0.00267 radians. This can be compared to the additional rotation measured at the same load as determined from Figure 1 as $5.075\text{x}10^{-8}$ radians/N-m ($6.87\text{x}10^{-8}$ radians/ft-lb) or 0.00227 radians at an applied moment of 44740 N-m (33,000 ft-lb).

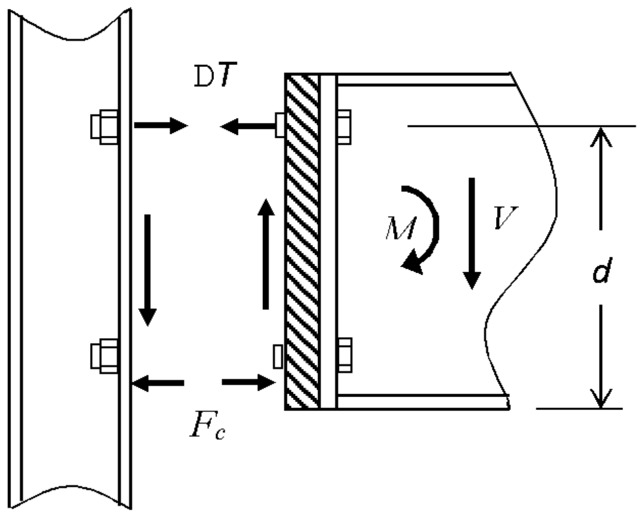

Figure 5. Forces in the moment connection.

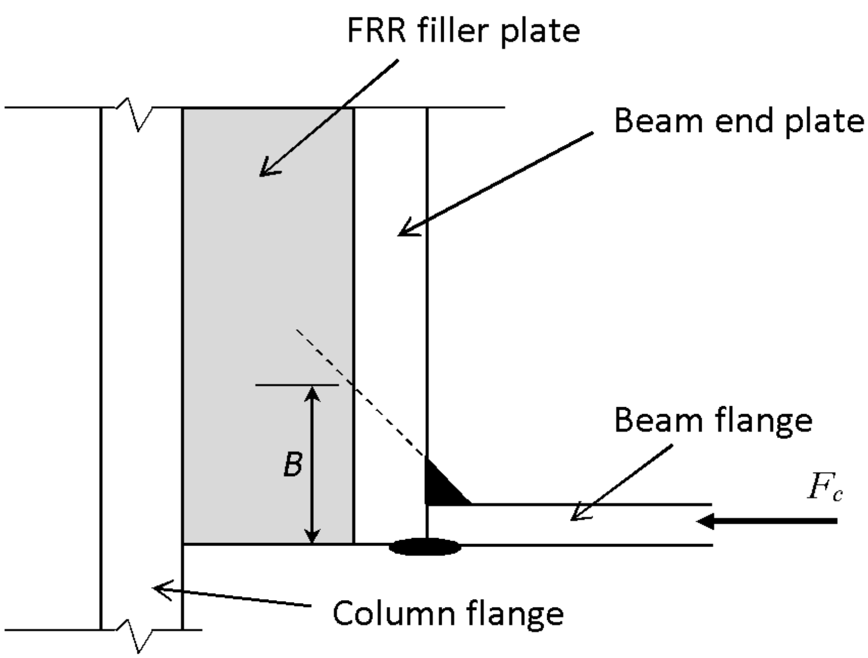

Figure 6. Dispersion of force through the connection compression zone.