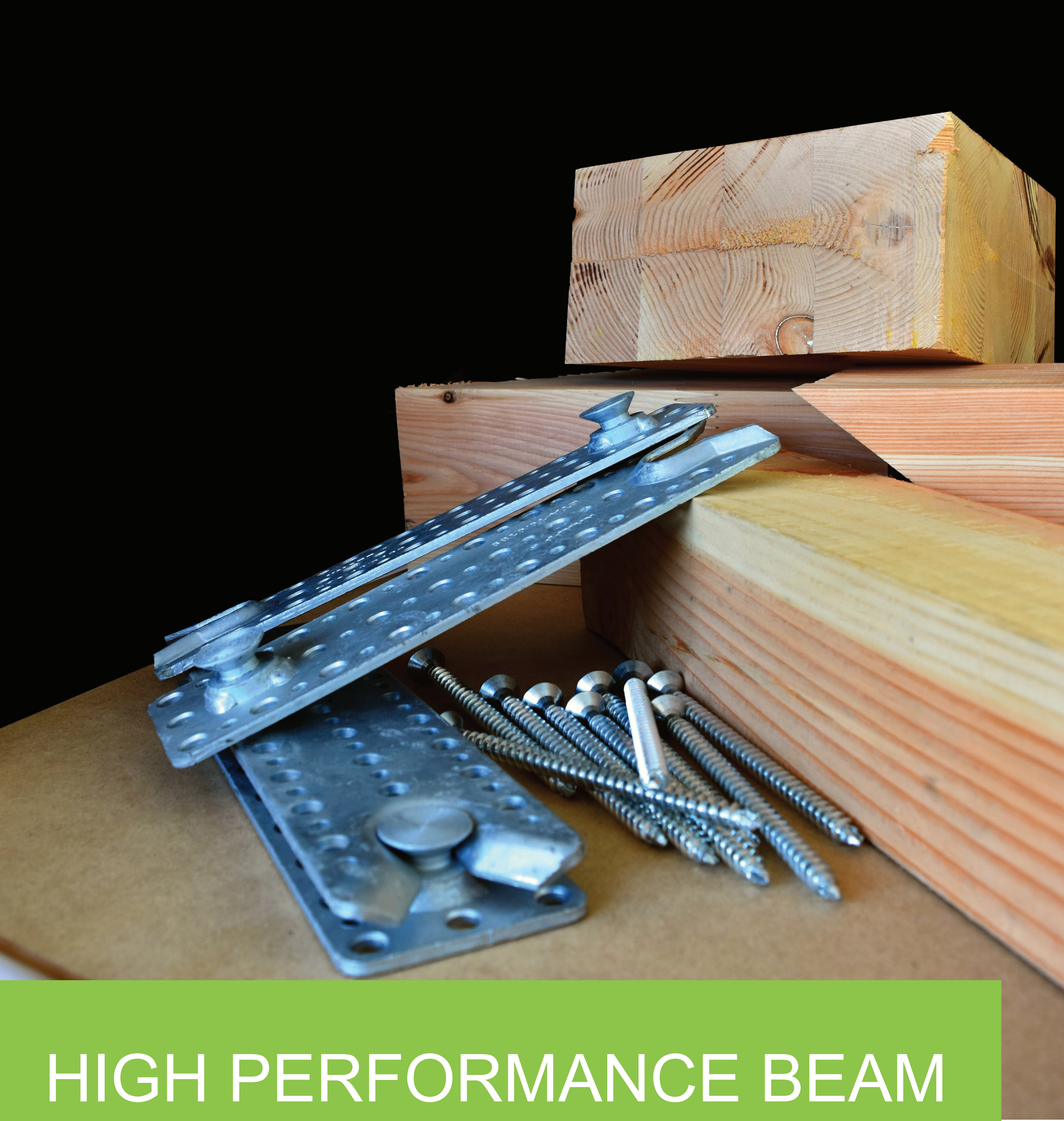

HIGH PERFORMANCE BEAM TO POST CONNECTIONS

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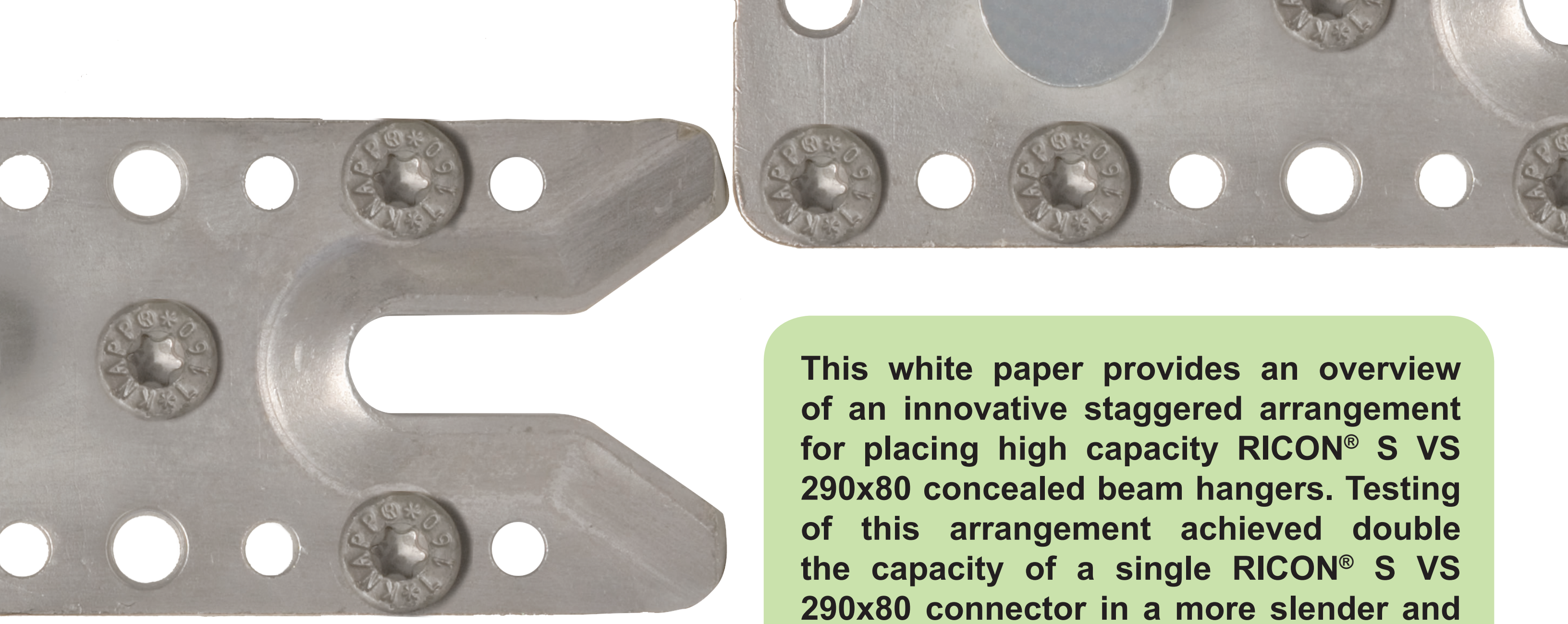

This white paper provides an overview of an innovative staggered arrangement for placing high capacity RICON® S VS 290x80 concealed beam hangers. Testing of this arrangement achieved double the capacity of a single RICON® S VS 290x80 connector in a more slender and economical beam design in addition to maintaining a one-hour fire resistance rating through sufficient wood cover.

The KNAPP RICON® S VS series of beam hangers offers high capacity connections with quick and simple installation mixed with ease of design. A single RICON® S VS 290x80 connector provides an LSD factored design resistance of up to 75.2 kN (16,905 lbs)[1] (force F2, Figure 1). Two RICON® S VS connectors can be placed side-by-side to double the design capacity, although the minimum width of the secondary beam must also double[2] in accordance with the minimum spacing and edge distance requirements of the fasteners (Figure 2).

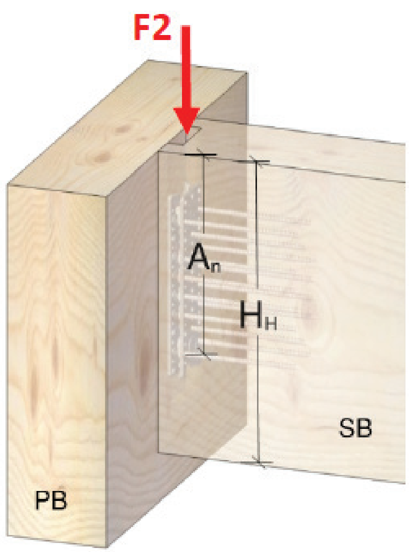

FIGURE 1, Design force F_2 with single RICON® S VS connector [PB="primary beam" (or column)," SB="secondary beam"]

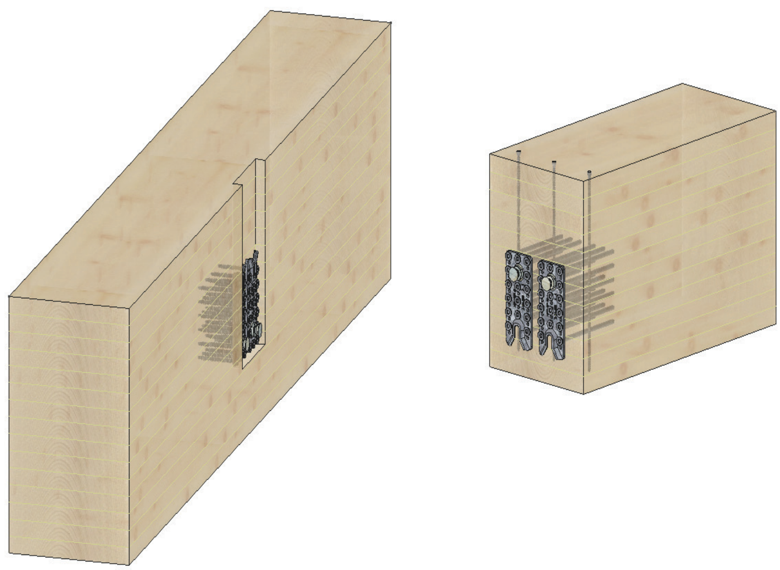

FIGURE 2, Conventional Double RICON® S VS layout[2]

The designer, however, may wish to achieve the same capacity with a more slender beam profile, especially in the case where char layers are calculated for fire protection. The minimum beam width for the conventional double RICON® S VS connection would be 9-5/8 in. (246 mm). The staggered arrangement discussed in this newsletter allows for the connection to be made using 8-3/4 in. (222 mm) wide glulam beams, which can be manufactured from single widths of lamstock, which is economically advantageous and provides additional char layer thickness as connectors are moved towards the centre of the beam. Furthermore it allows one to avoid the challenging gaps typical for split lam beams in between the adjacent laminations. The staggered arrangement is shown in Figure 3. Since the RICON® connectors are not placed directly over top of one another, ease of beam installation is maintained in the design, as the connectors can be installed from above maintaining the char layer from below, the left and the right side.

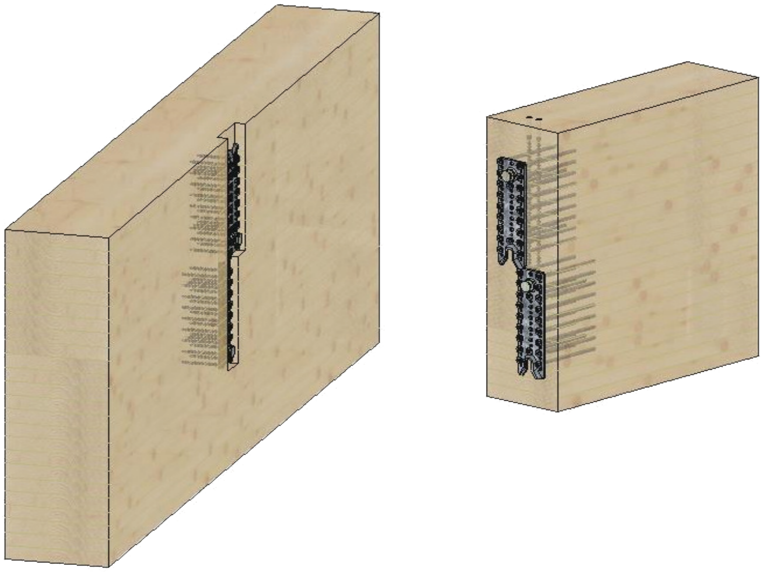

FIGURE 3, Staggered RICON® S VS 290x80 arrangement

The staggered concealed RICON® S VS arrangement also achieves a one-hour fire resistance rating (FRR) with an 8-3/4 in. (222 mm) wide beam. Using the approach outlined in TR10[3], a one-hour fire resistance rating for exposed wood members corresponds to an effective char layer depth (a_{char}) of 1.8 inch. In accordance with TR10, we estimate the required cover for a concealed beam to girder (or beam to column) wood connection with the following equation:

$$\textit{Wood cover} \geq \frac{a_{char}}{1.2}$$

Which works out to:

$$\textit{Wood cover} \geq \left[\frac{1.8}{1.2} = 1.5\right] \textit{(inch)}$$

As seen in Figure 4, the staggered arrangement on an 8-3/4 in. (222 mm) wide beam still provides a 1.62 in. (41 mm) wood cover layer for an exposed beam.

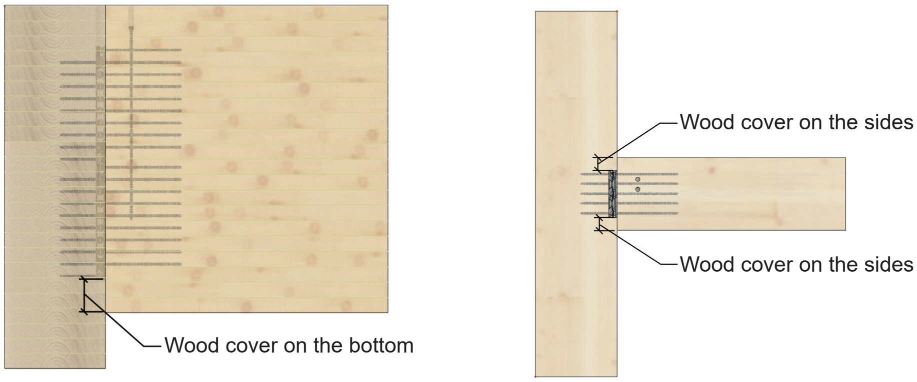

FIGURE 4, Wood cover providing one-hour FRR with an 8-3/4in beam. (left) side view, (right) top view

Full-scale testing was performed at the University of British Columbia Civil Engineering Laboratories to study the staggered RICON® S VS 290x80 connection performance.

The connectors are fastened to Canadian Douglas Fir Glulam members using five rows of screws. The metal plates of both connectors are bearing on top of each other, contributing to a precise fit between each pair. Assembly and fastener details for the RICON® S VS connectors are outlined in Table 1 and screw placement is shown in Figure 5. Connector placement geometry is shown in Figure 6.

Table 1, Assembly and fastener details

Connector	Screw	Member	Face	Diameter mm [inch]	Length mm [inch]	Qty
RICON S VS 290x80	VG CSK	Secondary Beam	End	10 [3/8]	200 [7-7/8]	20
RICON S VS 290x80	VG CSK	Primary Beam/Column	Side	10 [3/8]	100 [4]	20

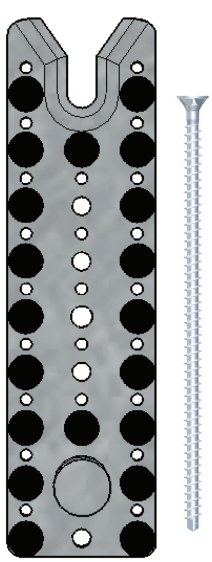

FIGURE 5, Selected screw pattern in full scale testing

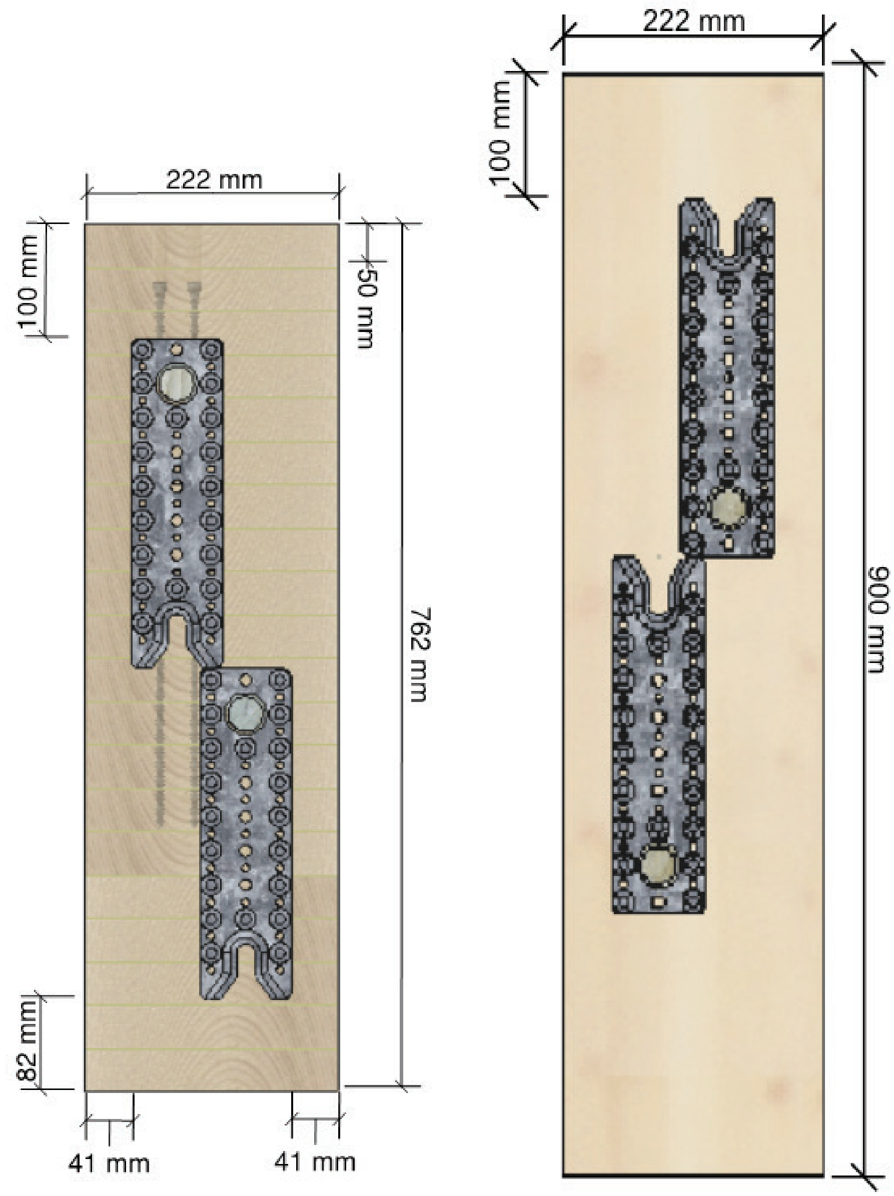

FIGURE 6, RICON® placement geometry for secondary beam (left) and column test members (right)

Perpendicular to grain reinforcing screws SWG ASSY VG CYL (ICC ESR 3178, CCMC 13677-R) were applied as outlined in Figure 8.

Table 2, Fastener details for secondary beam reinforcement against splitting.

Screw	Member	Diameter mm [inch]	Length mm [inch]	Qty
VG CYL	Secondary Beam	10 [3/8]	480 [19]	2

FIGURE 7, Installation of VG CYL reinforcing screw into beam member.

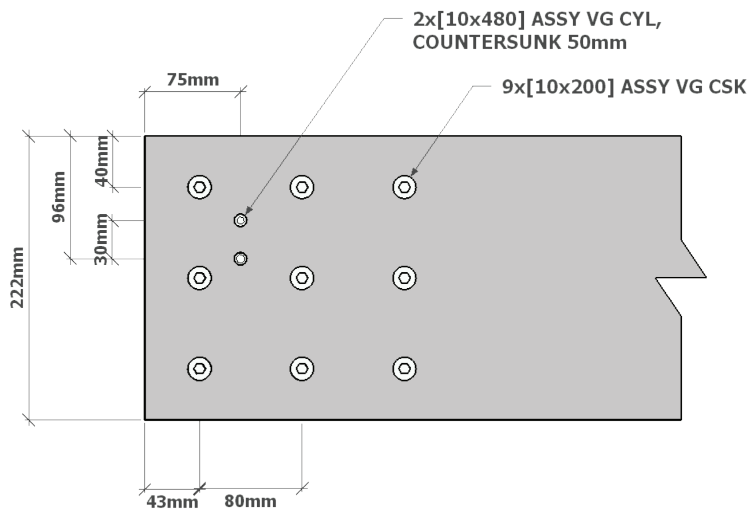

FIGURE 8, Geometry of reinforcement screws used for testing on top of secondary beam.

To protect the beam against wood crushing effects during testing, ASSY® VG CSK screws are embedded in the beam at the points of applied loads as outlined in the MyTiCon Timber Connectors White Paper, "Full Thread SWG ASSY® Screws as Reinforcement" under "Compression reinforcement perpendicular to grain." The geometry of the compression reinforcement screws for the top of the beam is illustrated in Figure 8. (To appreciate the effectiveness of compression reinforcement, observe the effects of crushing in the dummy test beam without compression reinforcement compared to a test beam with reinforcement in Figures 9, 10, 11, and 12).

FIGURE 9, Top of beam after test with compression reinforcement.

FIGURE 10, Top of dummy test beam after test without compression reinforcement.

FIGURE 11, Bottom of beam after test with compression reinforcement.

FIGURE 12, Bottom of dummy test beam after dummy test without compression reinforcement.

The test setup is shown in Figures 13 and 14. Displacement gauges are placed on both sides of the beam to monitor rotation and displacement during loading.

FIGURE 13, Test setup (column left, beam right) showing one of two symmetrically placed displacement gauges.

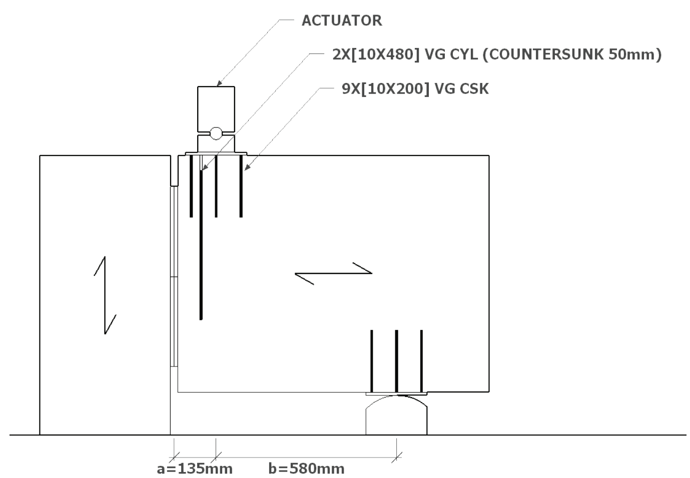

FIGURE 14, Test setup geometry with reinforcing screws shown. Loading applied downward through actuator.

Based on the geometry of the test setup, the total force applied to the connectors along the shear plane is calculated as follows:

$$F_2 = \frac{F_{act}(b)}{(a+b)} = F_{act}(0.811)$$

Where:

F_2 = Estimated shear force at the connectors
F_{act} = force applied to top of beam through actuator

The connection assembly was loaded at a rate of approximately 0.05 in/min (1.2 mm/min), with two tests performed to the point of failure. Load-displacement curves are illustrated in Figure 15. The elastic limit is estimated by examining the curves between 0.4 F_u (ultimate force) and 0.7 F_u (Figure 16). A change of slope (visible as a small "kink") is observed at approximately 200kN (44,960 lbs) for the connector set. Plastic deformation is therefore generally assumed to begin at 200kN.

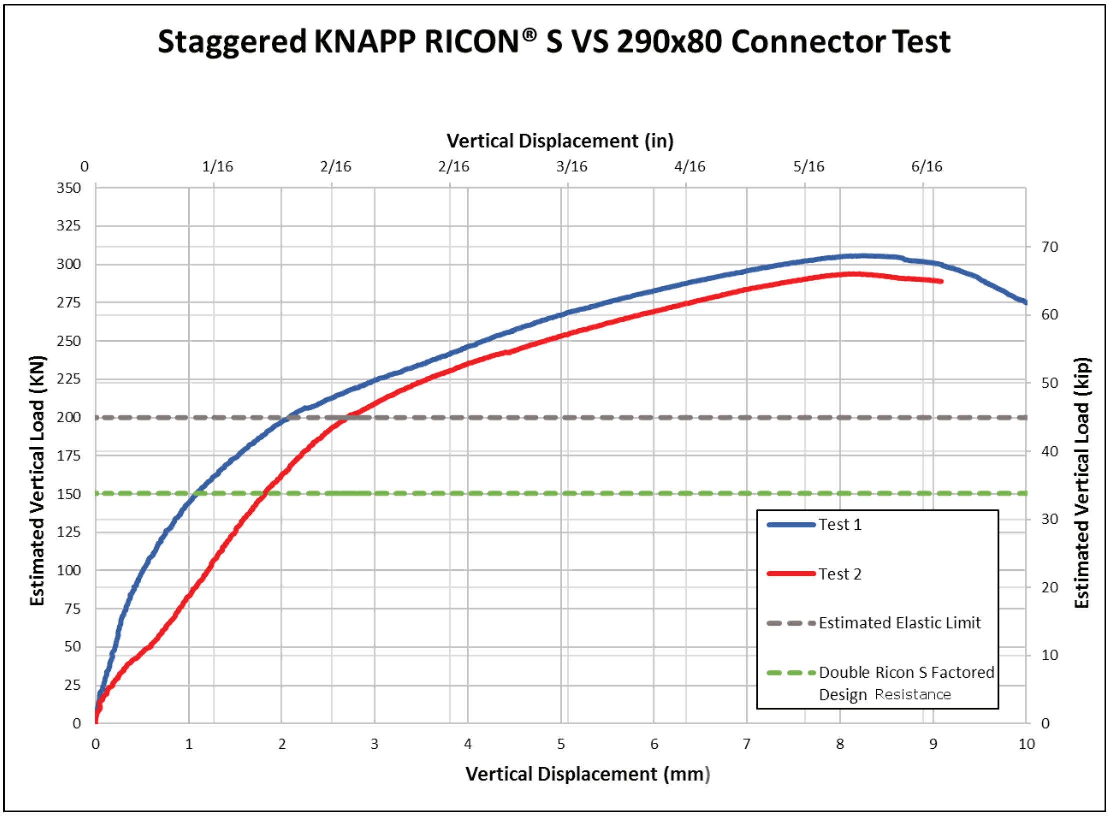

FIGURE 15, Load-displacement curve for Staggered RICON® S VS 290/80 connector tests.

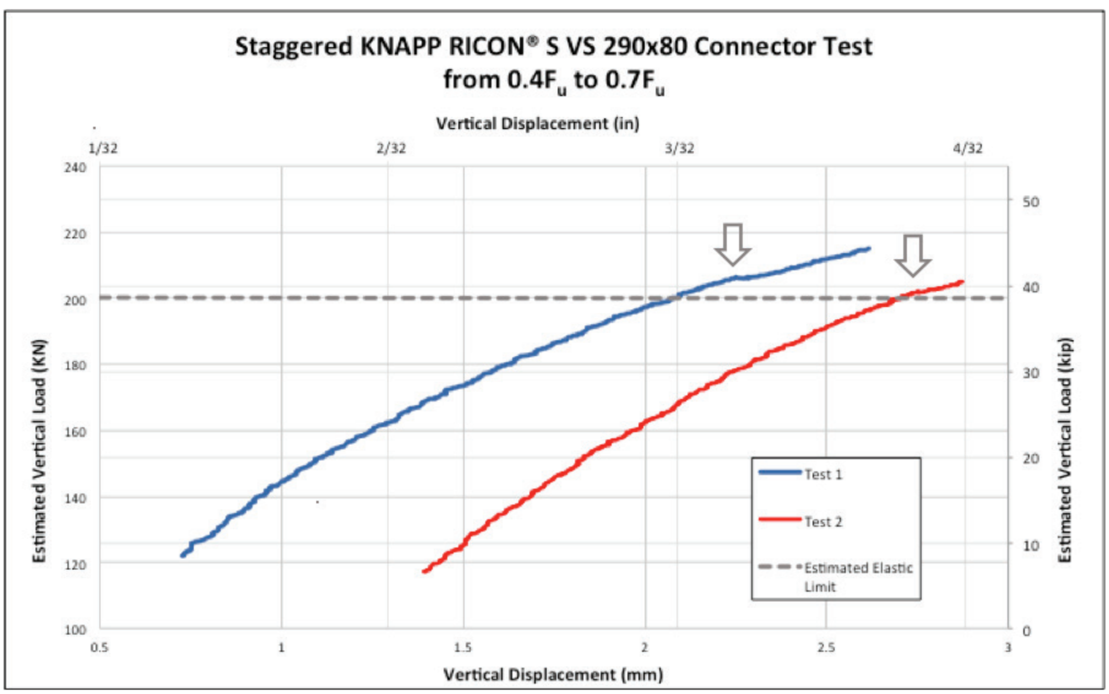

FIGURE 16, Load-displacement curves between 0.4 F_u and 0.7 F_u (change in slope indicated by arrows).

Any difference in vertical displacement observed between the two sides of the beam was negligible. Rotation of the beam about its longitudinal axis is therefore assumed to be negligible as well. Vertical displacement is taken to be the average reading of the displacement gauges on both sides of the beam throughout loading. The tests results are recorded in Table 3.

Table 3, Performance of staggered RICON® S VS arrangement.

TEST	F_u kN [kip]	Estimate Elastic Limit kN [kip]	0.4 F_u kN [kip]	0.7 F_u kN [kip]
1	305.8 [68.7]	206.0 [46.3]	122.3 [27.5]	214.0 [48.1]
2	293.9 [66.1]	201.0 [45.2]	117.6 [26.4]	205.7 [46.2]

Failure in both tests occurred through yielding of both the welded collar bolt and the V-notch in the RICON® connectors with subsequent collar bolt breakage (Figures 17, 18). After testing, the wood showed no visible signs of crushing failure (Figure 19). The screws themselves also exhibited no signs of yielding.

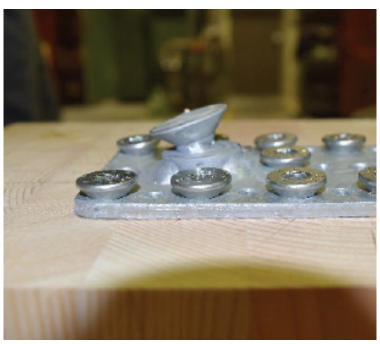

FIGURE 17, Yielding of collar bolt.

FIGURE 18, Breakage of collar bolt. Yielding of V-notch area on a connector also visible.

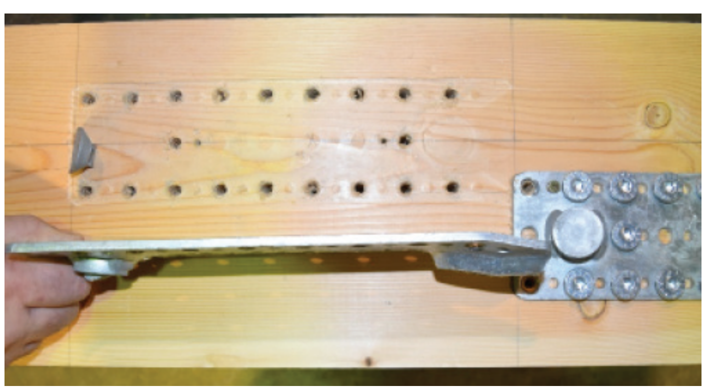

FIGURE 19, Condition of wood after testing. No wood embedment failure evident.

A RICON® S VS connection typical failure can occur either through wood embedment failure, wood splitting, screw yielding, v-notch yielding, metal plate buckling, or collar bolt yielding and breakage. The connection arrangement described in this newsletter (with the maximum recommended screw placement for each connector, and the specific screw sizes outlined in Table 1) forces the failure of the RICON® S VS connectors to occur in the welded collar bolt. The advantages of forcing the failure to the collar bolt are twofold. First, collar bolt failure represents a more ductile failure mode than other described failure modes. Second, steel failure produces highly predictable performance values for the connectors due to its typically low coefficient of variation when compared to wood (note that values for F_u and the elastic limit in Table 2 differ between tests by only 4.0% and 2.4%, respectively).

The Canadian factored design capacity of a Double RICON® S VS 290x80 connector pair is estimated to be 150.4 kN (33,809 lbs).

[For those working with Allowable Stress Design (ASD), a resistance of 22kips (98kN) for the staggered arrangement may be estimated by taking the lowest ultimate load and dividing it by three, as per ASTM D7174-11]

SUMMARY

- **High capacity connection made possible on slender beam with one-hour FRR.**
- **Double the design capacity of single RICON® S VS 290x80 connector is achieved with staggered arrangement during testing.**
- **Failure governed by ductile yielding of welded collar bolt.**
- **No out of plane rotation observed.**
- **No screw yielding or wood embedment failure due to increased group action effects visible during testing.**

1. See MyTiCon Timber Connectors “Pre-Engineered Connector Systems” Design Guide for parameters
2. ETA-10/0189, p. 142
3. CSA-086 B.9 directs to TR-10, “Calculating the Fire Resistance of Exposed Wood Members”
4. ETA-10/0189, p. 46
5. MyTiCon Design Guide for Pre-Engineered Connector Systems
6. Note that compression reinforcement design described in newsletter is particular to the testing setup, and is not necessary for normal beam design where stresses do not exceed compressive strength of wood perpendicular to grain.

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