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Inter-Story Drift Testing of KNAPP RICON S VS Connectors

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Introduction

RICON® S VS wood connectors were tested in the laboratory of the University of British Columbia with a quasi-static rotation test at the maximum permissible rated load. 3 tests were carried out for each connector size. This report provides all the relevant data and a summary of the test results.

The performance based design of tall wood buildings and their associated interstory drift demands are an important design consideration. On the west coast of North America, tall wood buildings may be subject to dynamic loading scenarios throughout their service life. A typical post and beam glulam structure will, depending on the selection of the seismic force resisting system, experience story drifts which are typically limited to 2% by design codes. This story drift will also subject the respective post and beam connection to additional stresses. These stresses are a result of the gravity load and the rotation of the beams against the post. Since the connection will have to resist the gravity load while a major loading event such as an earthquake occurs, it is required to prove that the connection at major structural members can satisfy these demands. In order to provide respective data quasi-static rotational testing under the maximum design load of KNAPP RICON® S VS connectors was conducted at the structures lab of the University of British Columbia.

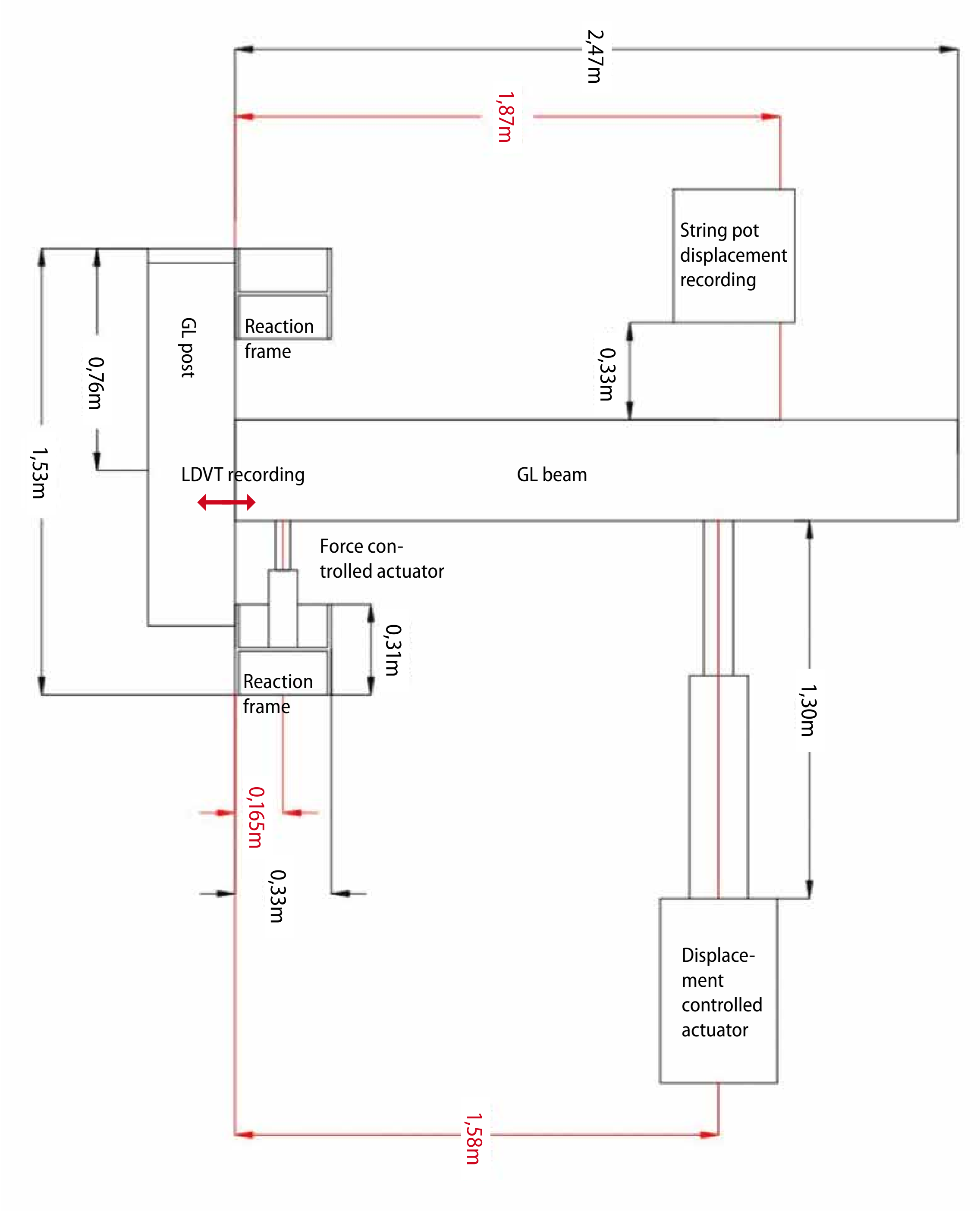
A T-shape post to beam connection test setup (Figure 1) with a 9′ long beam member and a 4′ long post member was selected and subjected to a quasi-static reversed cyclic procedure. Two different D-Fir glulam cross sections were selected to receive the RICON® S VS 200x60 and RICON® S VS 200x80 connectors. A 6 3/4″ x 13 1/2″ D-Fir glulam received the small RICON® S VS 200x60 connector to resist a factored design load of 9.6kips (42kN) and a 6 3/4″ x 15″ D-Fir glulam was selected to receive the larger RICON® S VS 200x80 connector to resist a factored design load of 13.7kips (61kN). The required design load was constantly applied as a static shear load near the interface of post and beam. A second actuator applied a reversed cyclic (quasi-static) rotation at 65 1/4″ distance to the interface of post and beam. Actuator displacements and forces were recorded. Furthermore the rotation at the interface was recorded. A total of 3 tests with each connector size were conducted. A summary of the findings is presented in this report.

Figure 1: General Test setup and typical RICON® S VS connector

RICON® S VS connector

Report

Figure 2: General Test setup distances and measurements



Report

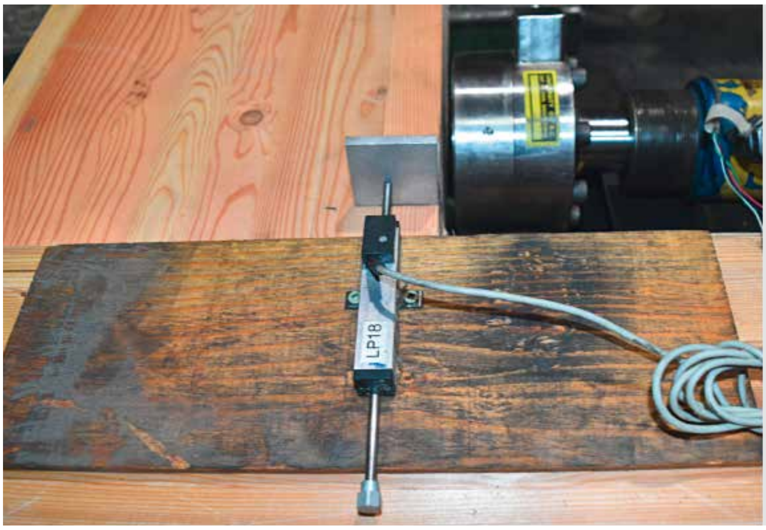


Figure 3: Displacement recording (#1) at interface of beam and column and constant design shear load application actuator (#2)

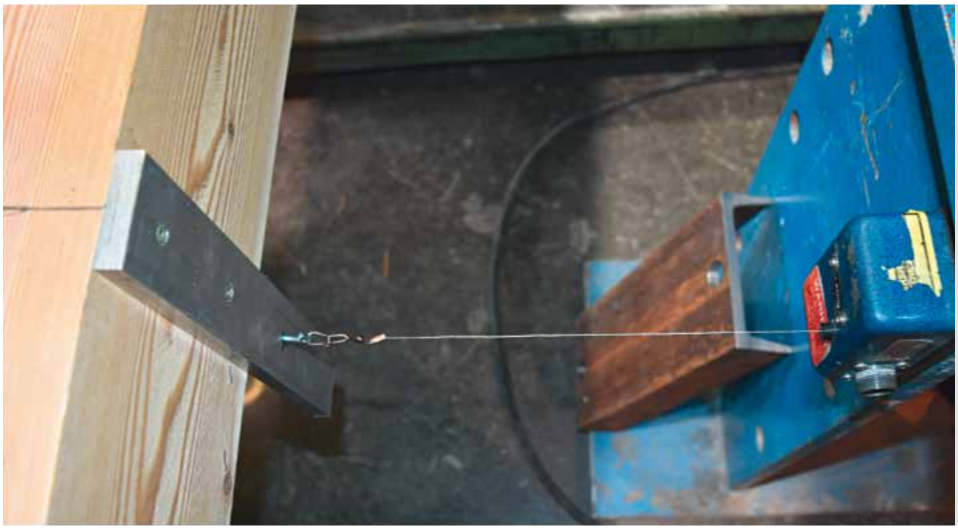


Figure 4: Displacement recording 73 1/2″ away from interface of beam and post (near actuator applying rotation to beam)

Figure 5: Displacement application actuator (#3) at 65 1/4″ away from interface of beam and post

Figure 6: Threaded rod tie to reaction frame at post member

Figure 7: Lateral bearing point at post to reaction frame

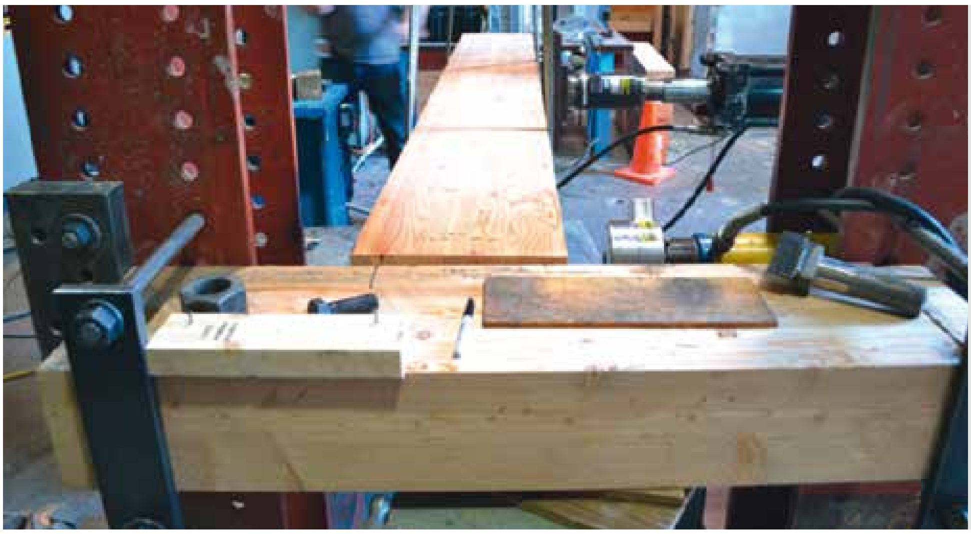


Figure 8: Reaction frame with specimen

Summary and conclusions

Three post to beam specimen of RICON® S VS 200x60 and RICON® S VS 200x80 under the specified design load has indicated that RICON connectors can resist static forces while subjected to a reversed cyclic rotational force. During testing two out of three RICON® 200x60 connectors observed ultimate failure at the collar bolt through a combined tension and shear fracture of the bolt. Ultimate failure occurred after the 2.5° rotation and full actuator displacement in reversed cyclic fashion was applied. The actuator pushed the beam member 3" one directional and failure occurred before 3" of displacement was reached in the opposing cycle. A picture of the collar bolt failure is shown in Figure 15. Failure on the load bearing full thread ASSY VG CSK screws was not visually observed. An inter-story drift value of approximately 4% was calculated with the recorded string pot measurement divided by the distance of the string pot to the center of rotation (see Figure 2 for detailed measurements). The applied reinforcing screws perpendicular to the grain of the beam member avoided tension perpendicular to grain failure effectively and no failure was observed in the glulam members. The loading protocol was stopped after ultimate failure occurred or the maximum actuator stroke was reached (as reflected in the plots shown in this report).

During testing of the RICON® S VS 200x80 connectors no ultimate failure was observed at the connectors, the ASSY VG CSK screws or the timber members. Intended damage on the connectors such as plastic yielding of the collar bolt, plastic deformation of the V-notch and early indication of perpendicular to grain splitting failure in the beam member was however noticed. The loading protocol was completed as desired after approximately 10 minutes of loading while the full actuator stroke was reached.

TABLE 1: SUMMARY OF TEST RESULTS

Test	Test connector type	Max Gap* [Zoll]	Max Rotation** + [°]	Max Total Shear [kip]	Max. Moment*** [kip-in]	**Max Static Design Shear Resistance**** [kip]**
Small-1	200x60-1	0,37	2,5	10,8	123,5	9,6 42,7 kN
Small-2	200x60-2	0,43	2,5	10,5	124,4	
Small-3	200x60-3	0,40	2,6	10,5	119,9	
	Average 200x60	0,40	2,5	10,6 47,2 kN	122,6 13,8 kNm	
	COV 200x60 [%]	7%	1%	2 %	2%	
Large-1	200x80-1	0,43	2,5	15,7	169,8	13,7 60,9 kN
Large-2	200x80-2	0,49	2,6	13,7	168,9	
Large-3	200x80-3	0,42	2,5	14,8	162,4	
	Average 200x80	0,44	2,5	14,7 65,4 kN	167,0 18,9 kNm	
	COV 200x80 [%]	9 %	1%	7 %	2%	

1 kip => 4,45 kN

1 inch => 0,0254 m

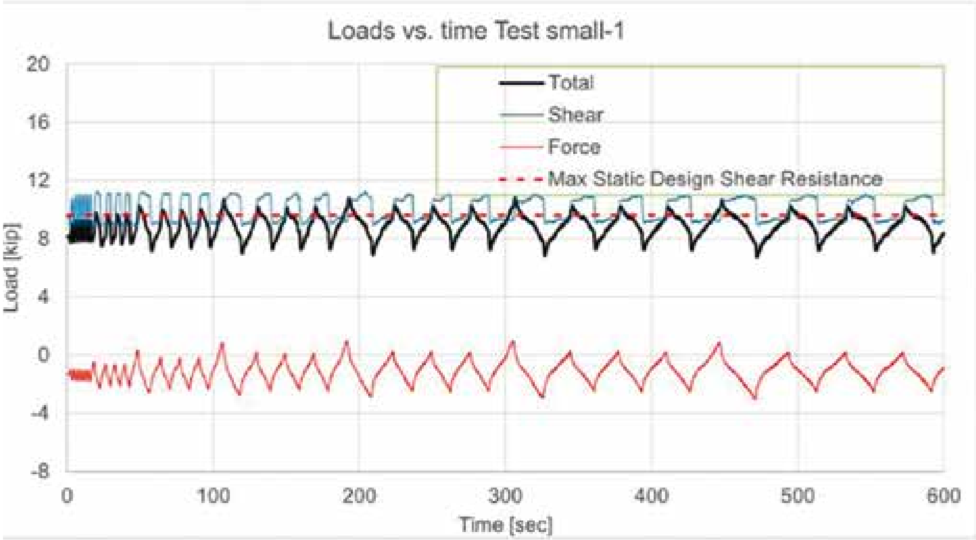
*The term "Gap" refers to the LDVT recording at the connection (see Figure 3)

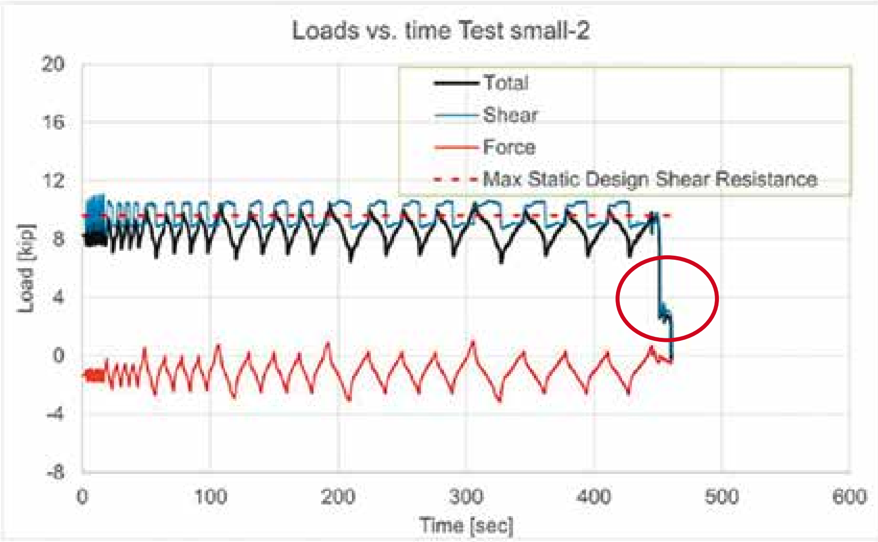
**The beam rotation was calculated based on the distance of the string pot recoding and its distance to the center of the connection

***The Max moment is calculated as the sum of moments caused by the static force and dynamic force times the respective lever arm

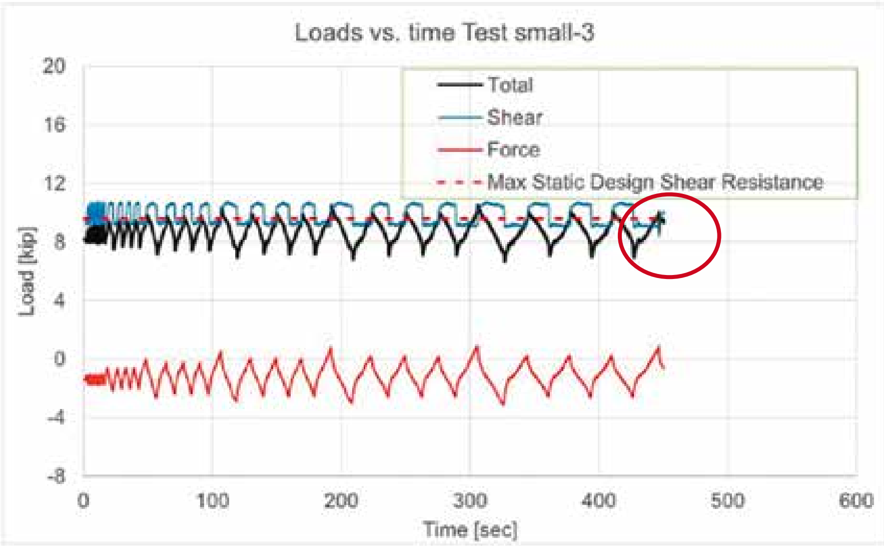
****Refers to the factored resistance of the connector under standard term loading conditions

Results



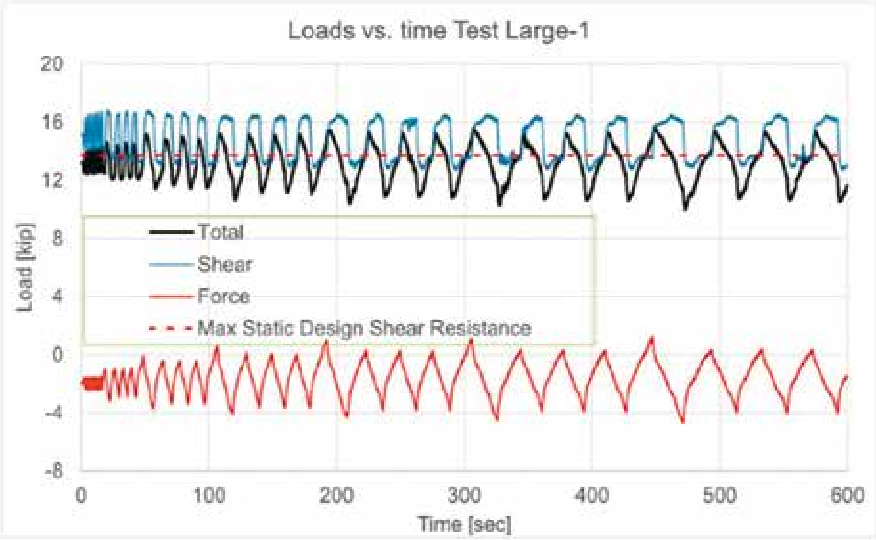


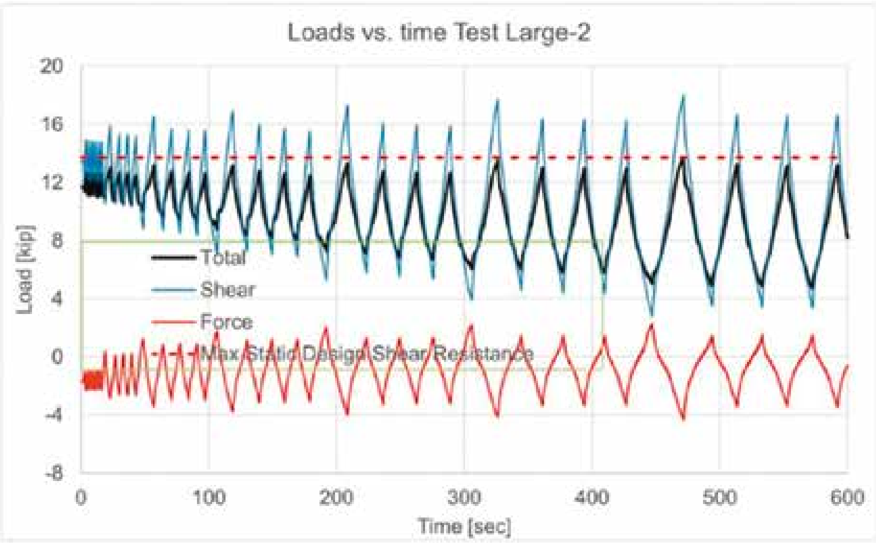
Note: RICON® S VS 200x60 collar bolt fracture observed in test and respective machine recordings

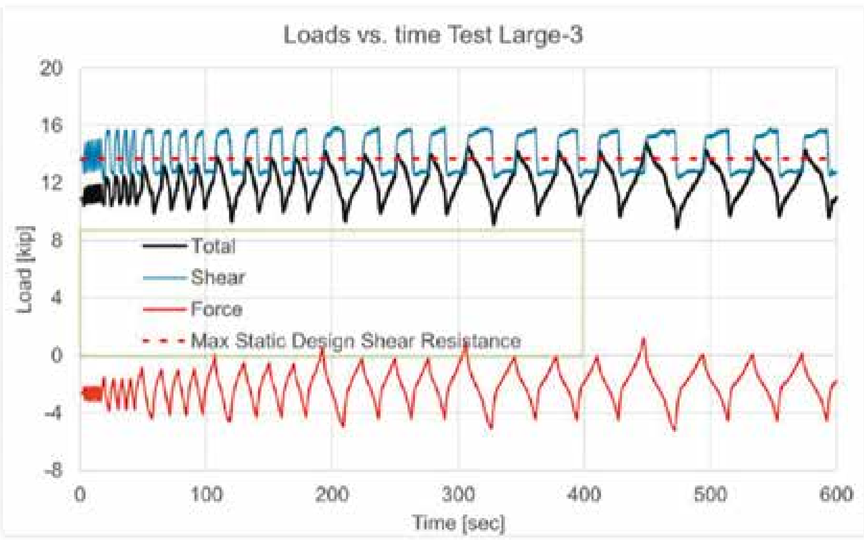


Note: RICON® S VS 200x60 collar bolt fracture observed in test and respective machine recordings.

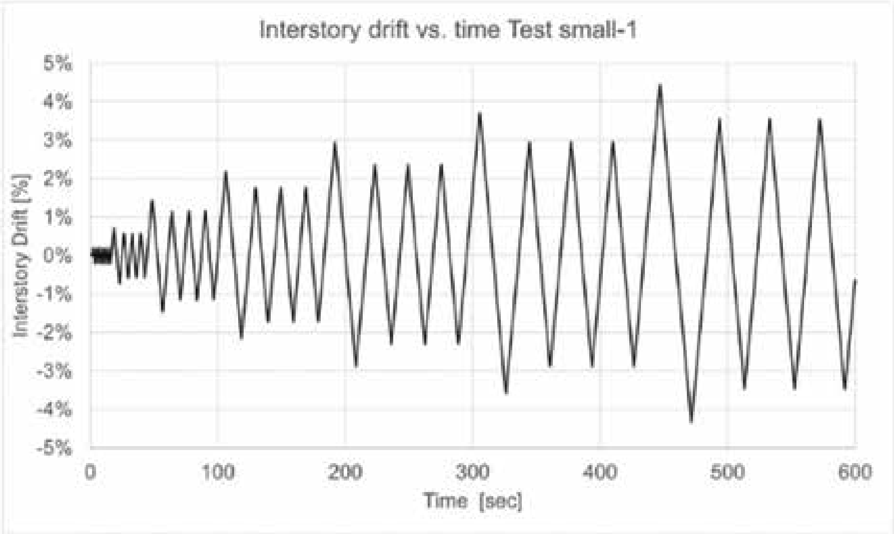
Results

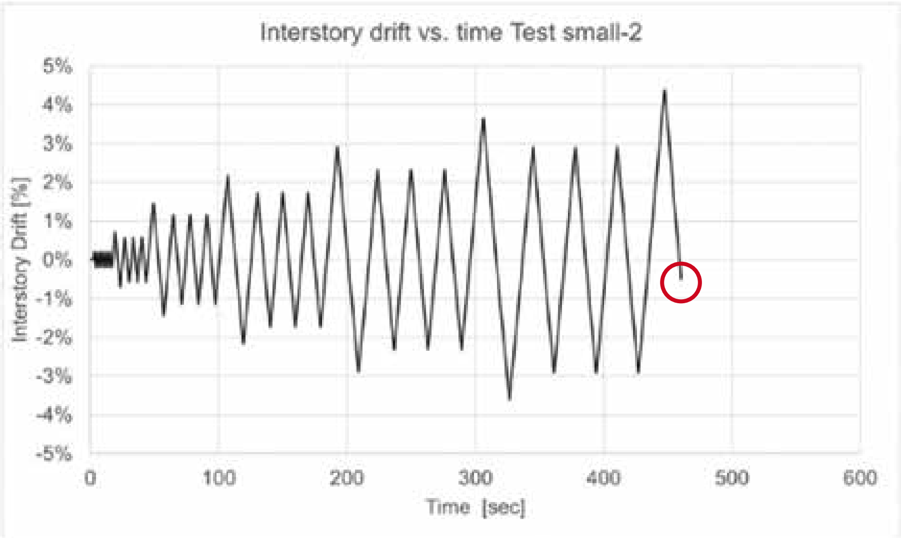


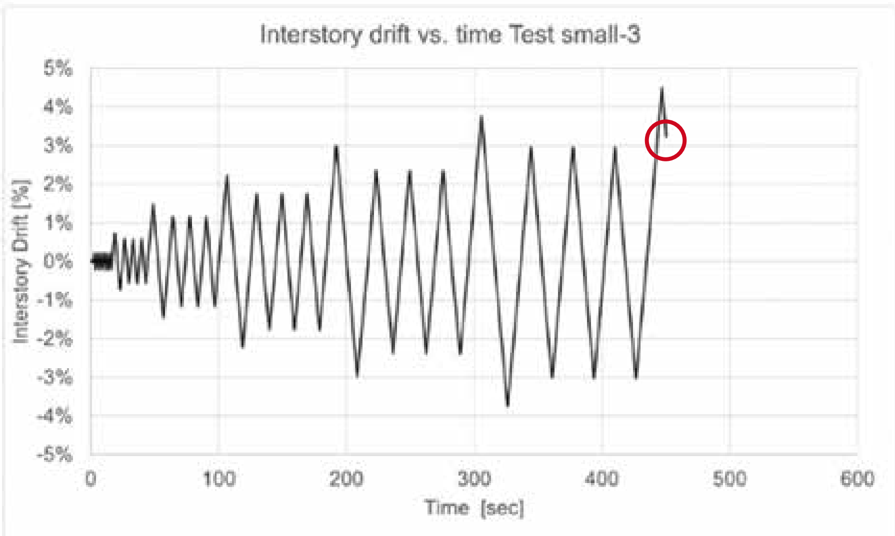




Note: RICON® S VS 200x80 connectors without apparent connector failure

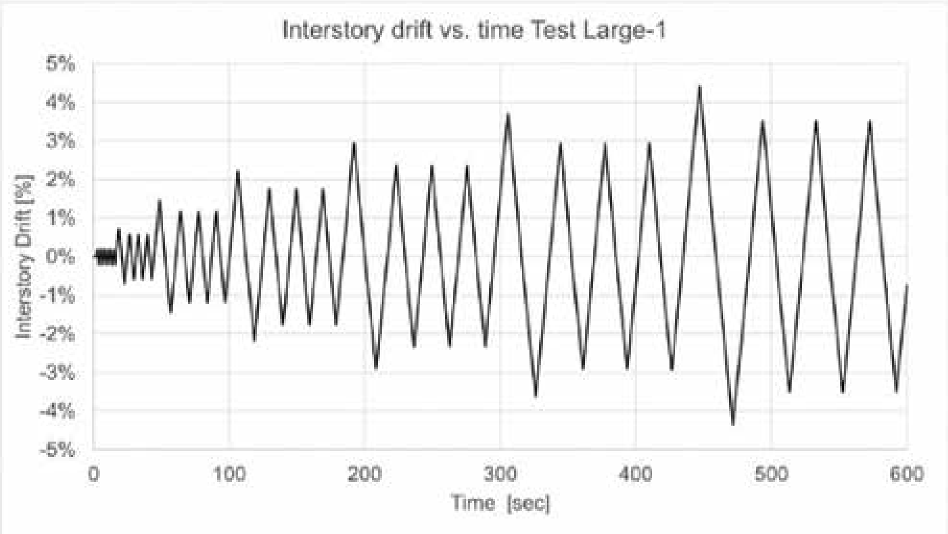


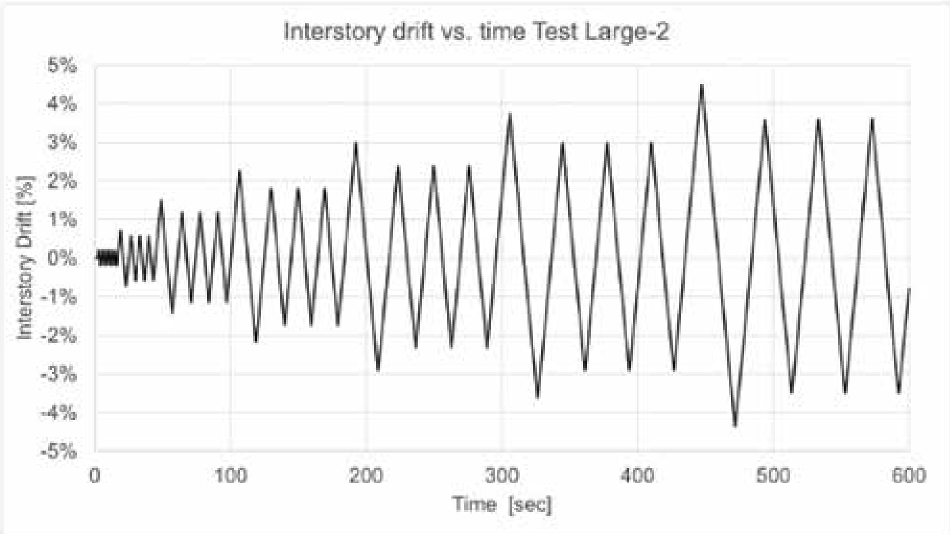


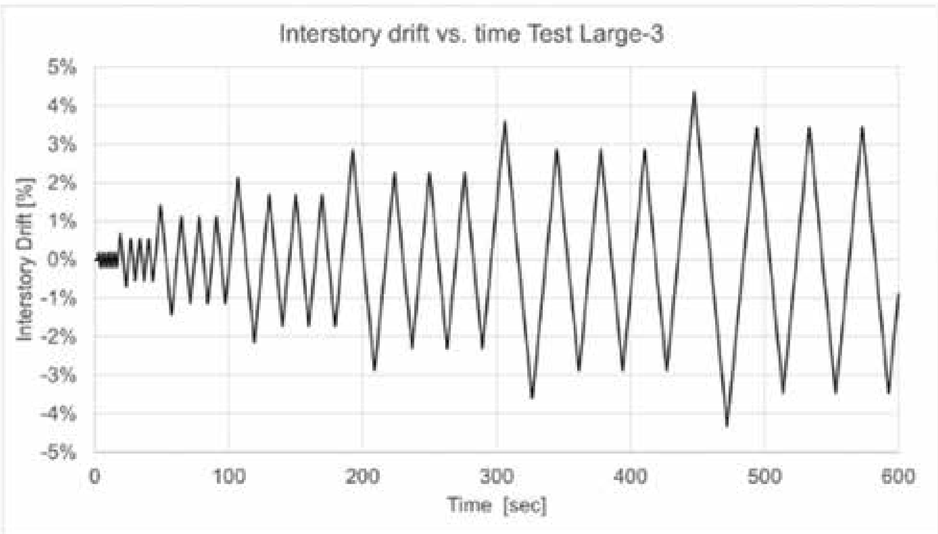


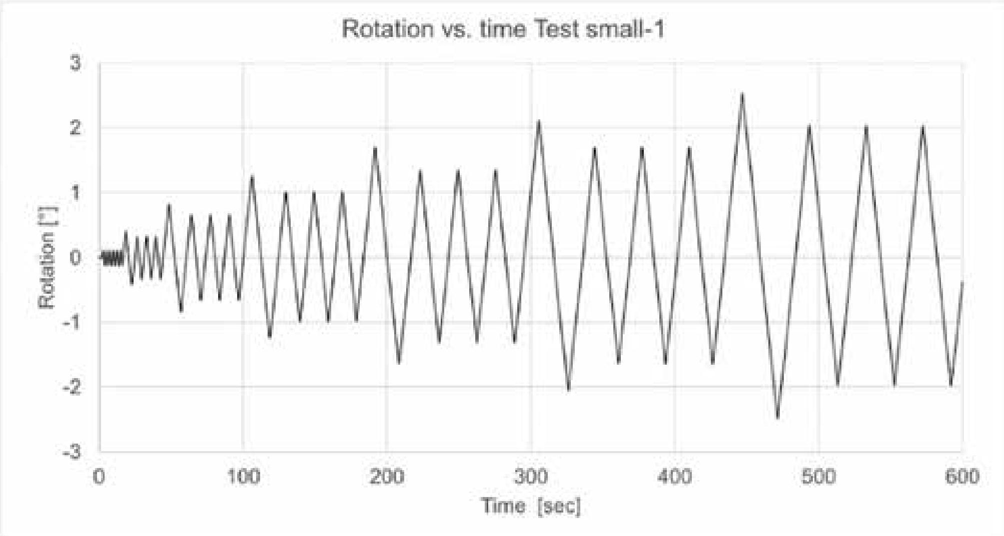
Note: RICON® S VS 200x60 collar bolt fracture observed in test and respective machine recordings with failure indication

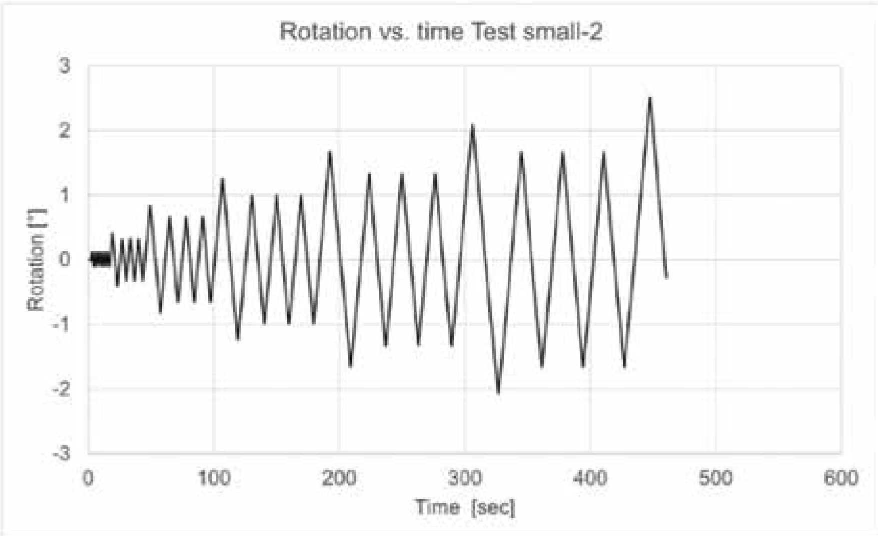
Results

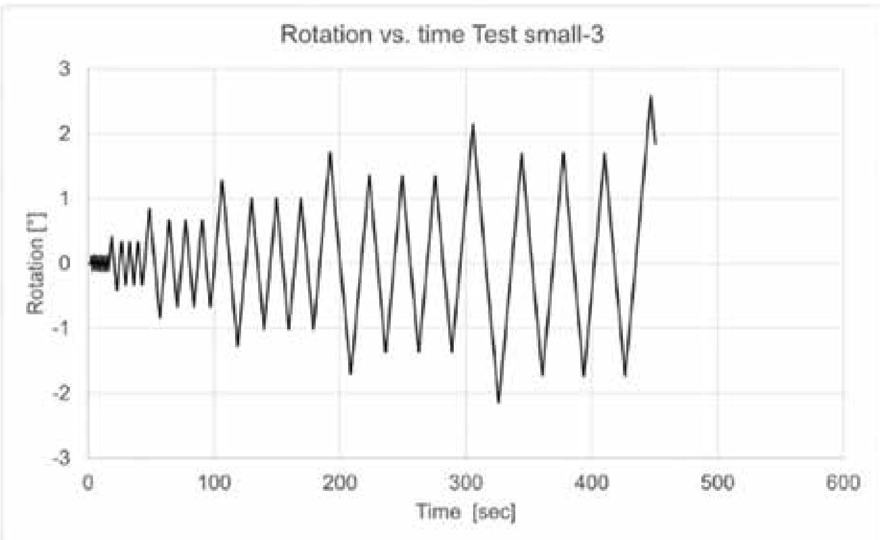

Interstory drift vs. time Test Large-1
Interstory Drift [%]
5%
4%
3%
2%
1%
0%
-1%
-2%
-3%
-4%
-5%
0
100
200
300
400
500
600
Time [sec]


Interstory drift vs. time Test Large-2
Interstory Drift [%]
5%
4%
3%
2%
1%
0%
-1%
-2%
-3%
-4%
-5%
0
100
200
300
400
500
600
Time [sec]

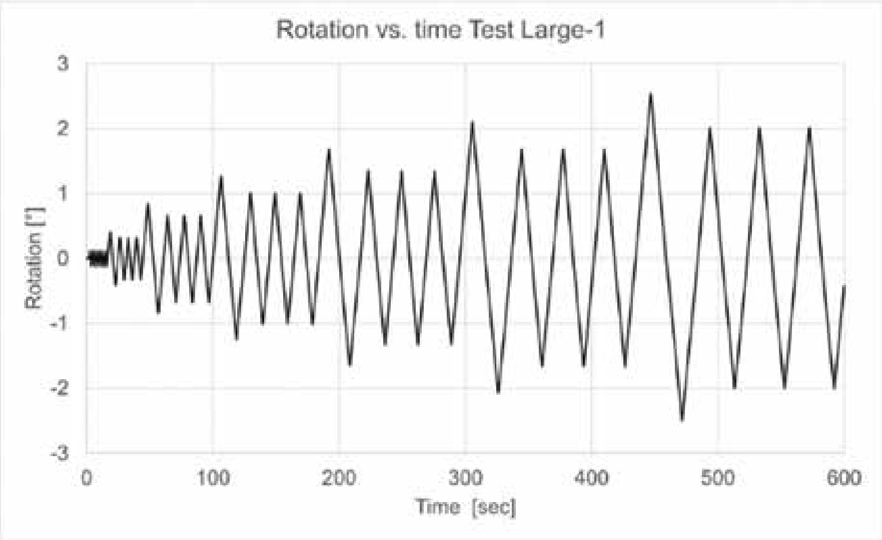

Interstory drift vs. time Test Large-3
Interstory Drift [%]
5%
4%
3%
2%
1%
0%
-1%
-2%
-3%
-4%
-5%
0
100
200
300
400
500
600
Time [sec]

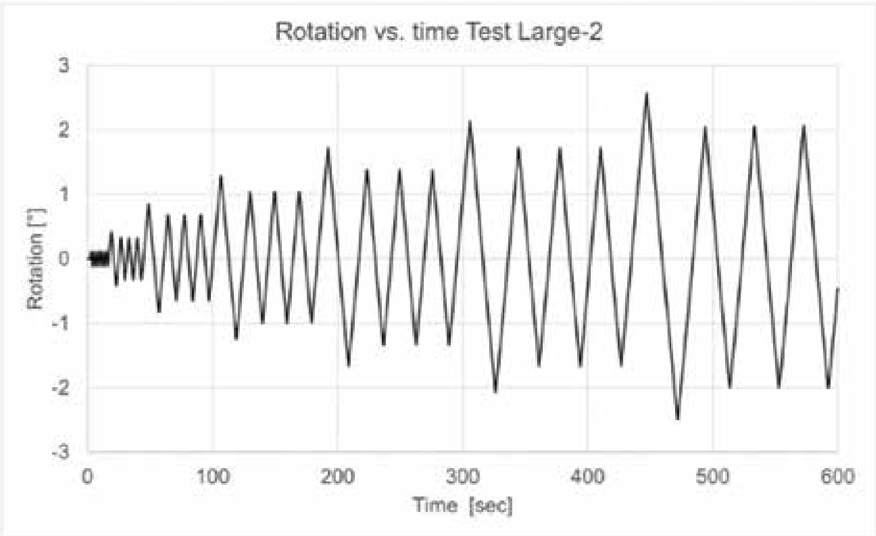

Rotation vs. time Test small-1
Rotation [°]
3
2
1
0
-1
-2
-3
0
100
200
300
400
500
600
Time [sec]

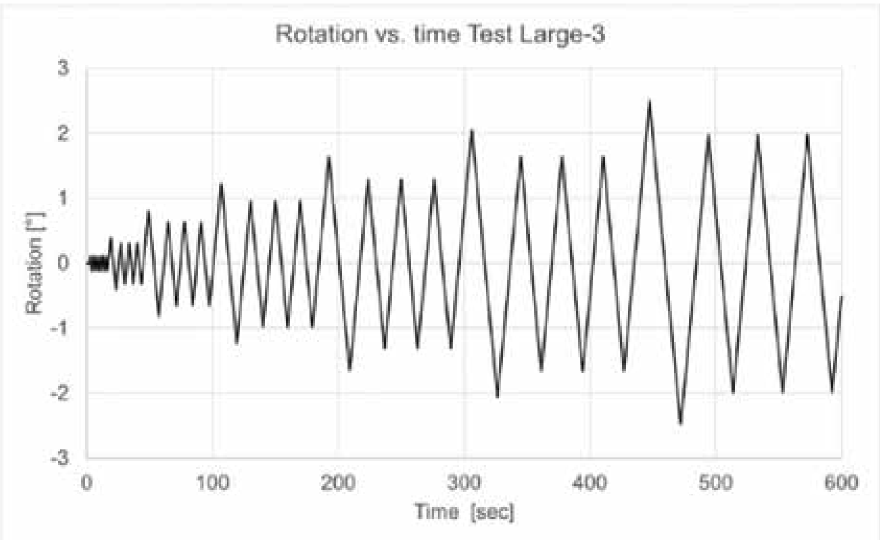

Rotation vs. time Test small-2
Rotation [°]
3
2
1
0
-1
-2
-3
0
100
200
300
400
500
600
Time [sec]

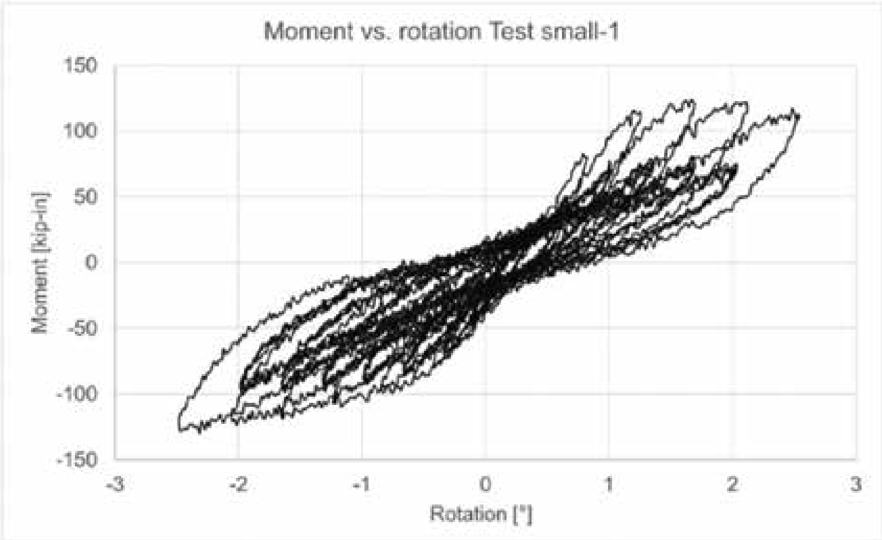

Rotation vs. time Test small-3
Rotation [°]
3
2
1
0
-1
-2
-3
0
100
200
300
400
500
600
Time [sec]

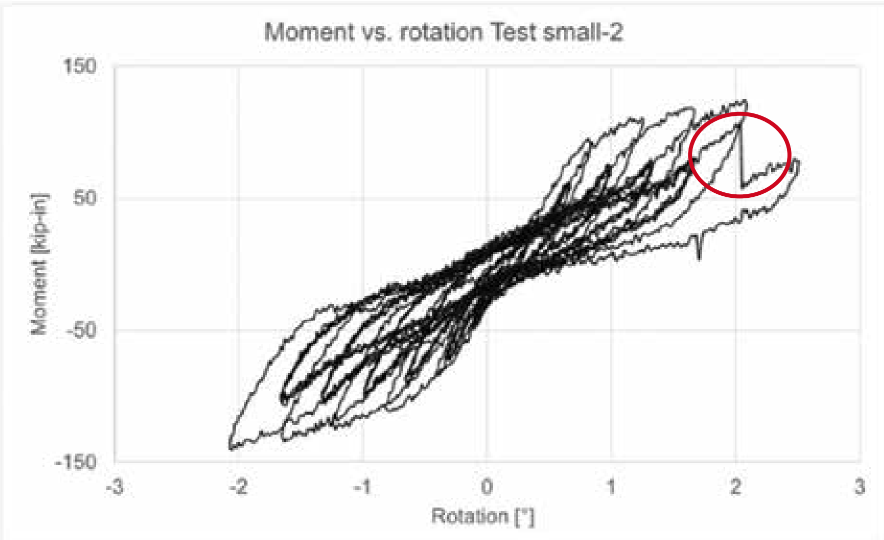
Results

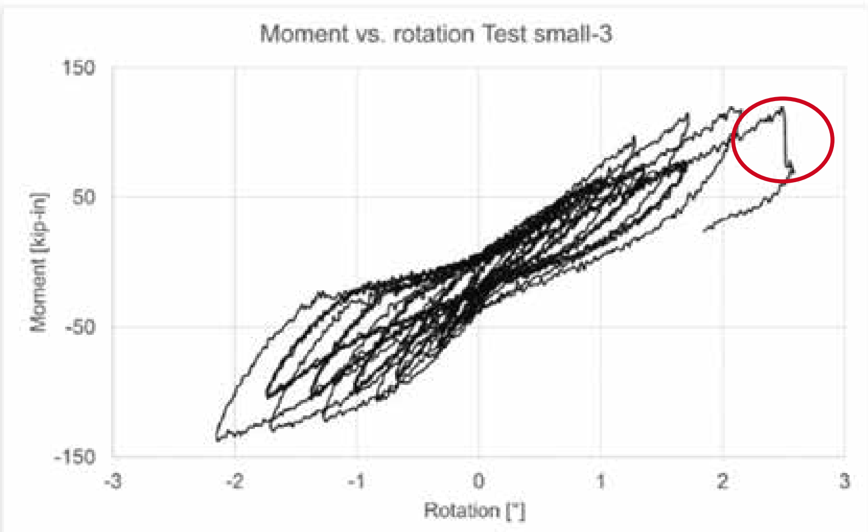

Rotation vs. time Test Large-1
Rotation [°]
3
2
1
0
-1
-2
-3
0
100
200
300
400
500
600
Time [sec]


Rotation vs. time Test Large-2
Rotation [°]
3
2
1
0
-1
-2
-3
0
100
200
300
400
500
600
Time [sec]


Rotation vs. time Test Large-3
Rotation [°]
3
2
1
0
-1
-2
-3
0
100
200
300
400
500
600
Time [sec]



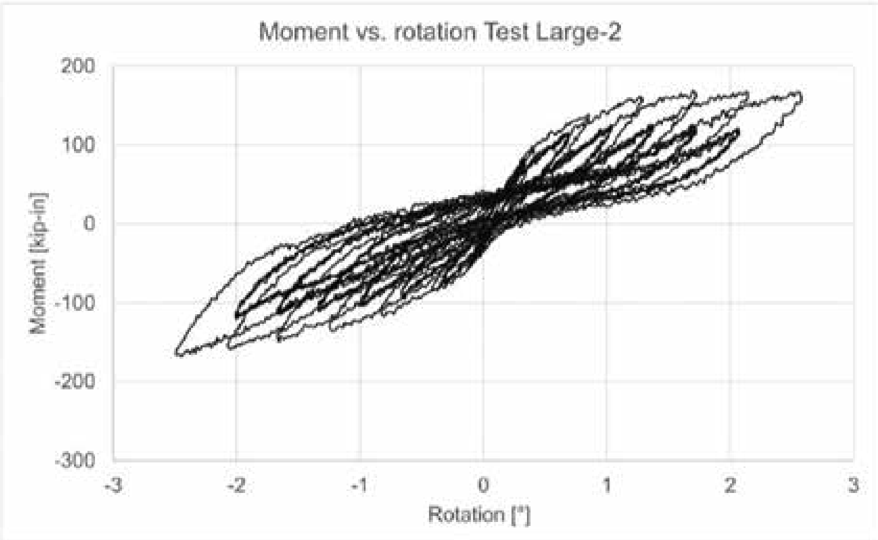


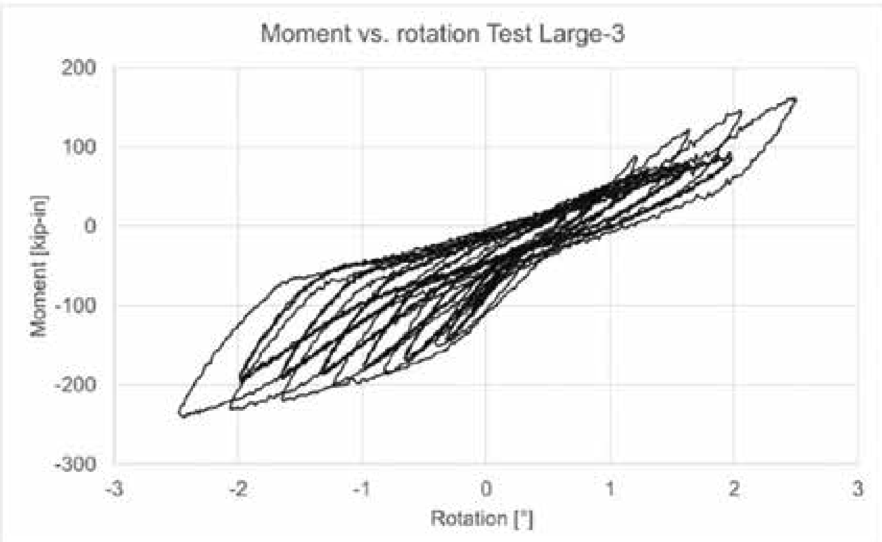


RICON® S VS 200x60 collar bolt fracture observed in test and respective machine recordings with failure indication

Results


Moment vs. rotation Test Large-1
Moment [kip-in]
200
100
0
-100
-200
-300
-3
-2
-1
0
1
2
3
Rotation [°]


Moment vs. rotation Test Large-2
Moment [kip-in]
200
100
0
-100
-200
-300
-3
-2
-1
0
1
2
3
Rotation [°]


Moment vs. rotation Test Large-3
Moment [kip-in]
200
100
0
-100
-200
-300
-3
-2
-1
0
1
2
3
Rotation [°]

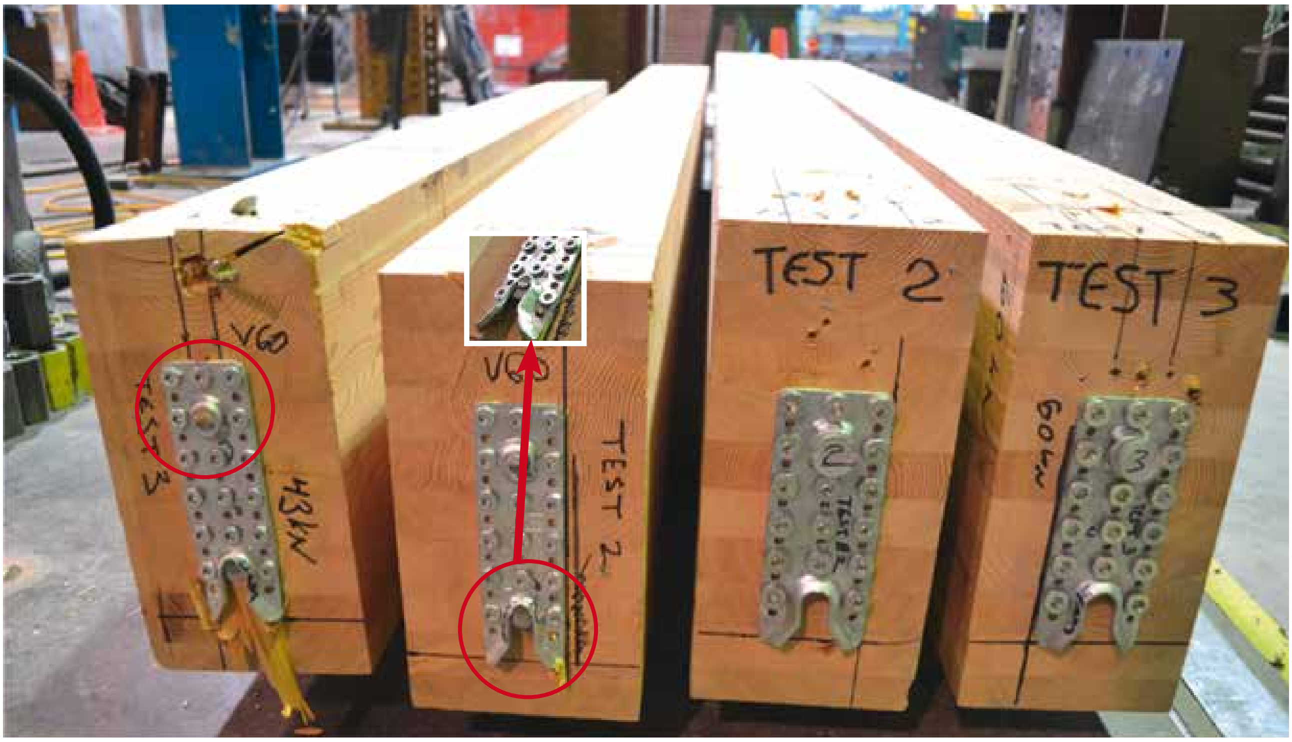


Figure 9: Example of collar bolt failure at maximum drift and load in beam member RICON® S VS 200x60 in 2 out of three tests.

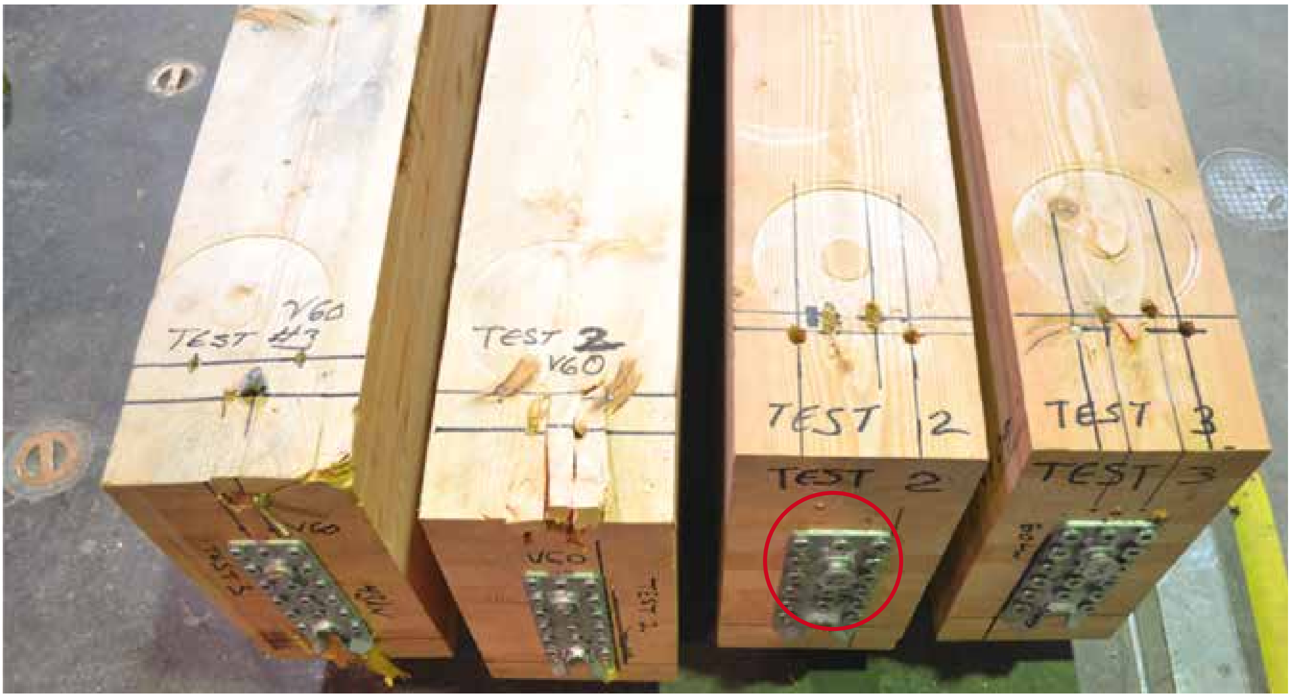


Figure 10: Example of collar bolt yielding at maximum drift and load in beam member RICON® S VS 200x80 in 3 out of three tests

Results

Figure 11: Example of tested connectors in post member

Figure 12: Example of uplift toe screw install

During construction of a tall wood building wind suction may result in net uplift. To secure the assembly against uplift two toes screws were also installed into test specimen to simulate a full connection assembly (see Figure 12)

Figure 13: Collar bolt yielding in beam member

Figure 14: Collar bolt yielding post member

Figure 15: Collar bolt failure in beam member RICON® S VS 200x60

Figure 16: V-notch yielding in post member and yielding toe screws

Results

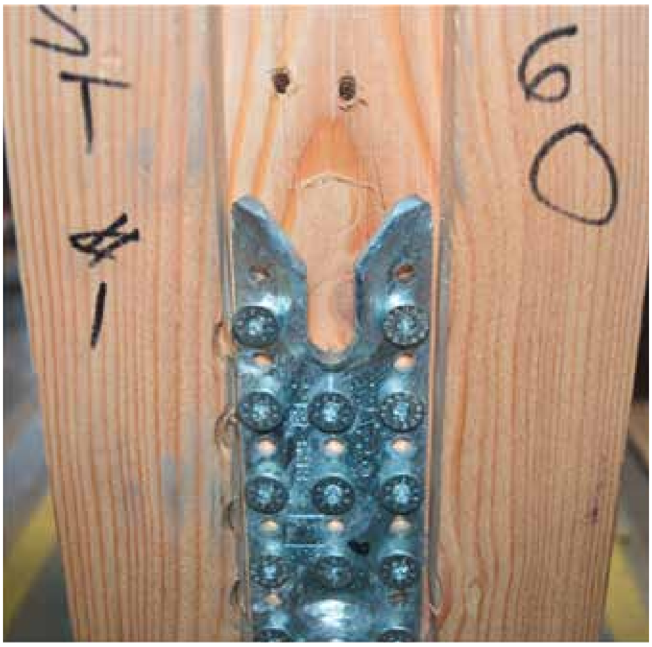


Figure 17: V-notch without damage on RICON® S VS 200x60

Figure 18: Splitting of beam edge after failure occurred in collar bolt. Uplift toe screws yield

Figure 19: Collar bolt yielding at RICON® S VS 200x80 connector

Figure 20: Flange yielding at RICON® S VS 200x80

Figure 21: Elastic deformation at V-Notch

Figure 22: Weld failure at collar bolt starting to occur

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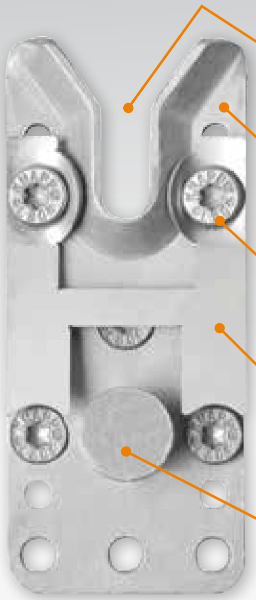

The V-shape molding provides perfect catch of the collar bolt. The strong tension and the short slide-in alleviate the connecting and guarantees joint sealing.

RICON® S is made of premium quality steel, hot-dip galvanized and produced in Germany.

KNAPP® CS-screws with cut point for extra fast starts and screwing. The reinforced shaft provides force-fit connection.

The RICON®S clip lock, made from stainless spring steel, locks the connection against slide-in direction and can optionally be used for stress against slide-in direction or wind suction.

There are different versions of the collar bolt available for RICON® S which offers four different connection options.

ETA

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