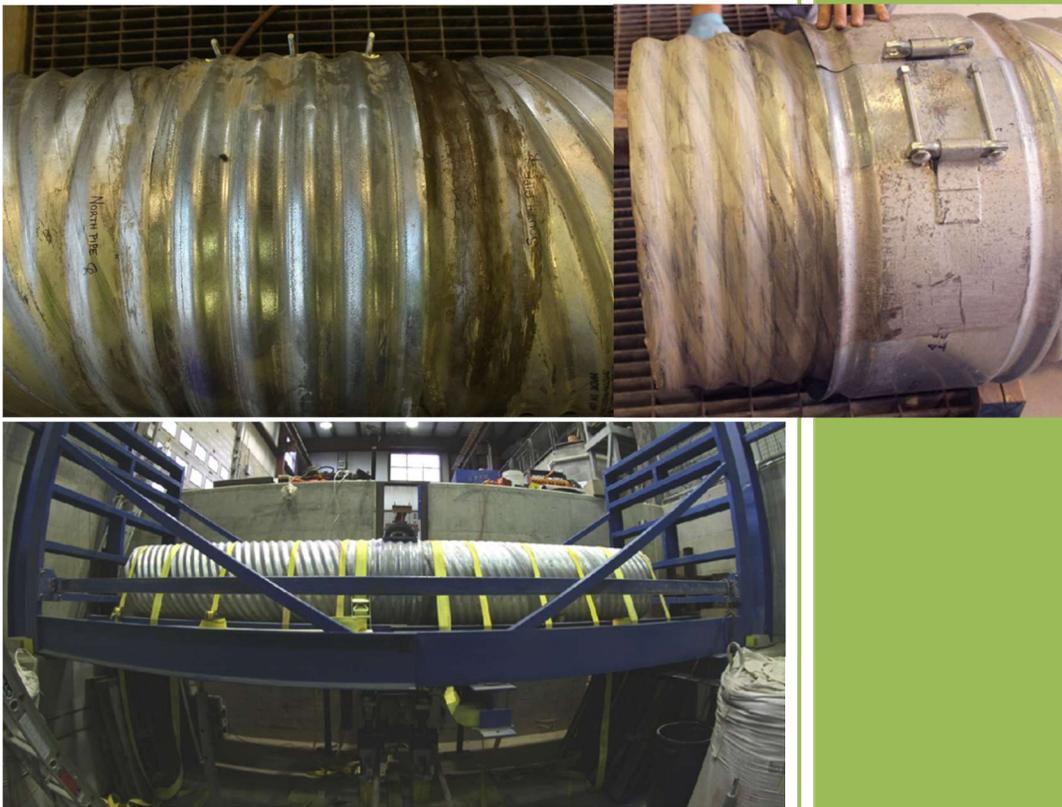


2016

JOINT LEAKAGE TESTING OF 24 INCH (0.6 M)
DIAMETER CORRUGATED STEEL PIPE UNDER
INTERNAL VACUUM



WRITTEN BY -



Prepared for:

NATIONAL CORRUGATED
STEEL PIPE ASSOCIATION

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September 2016

Joint leakage testing of 0.6m diameter (24 inch) corrugated steel pipe under internal vacuum

Conducted: December 8th and 9th, 2015

Ian D. Moore, PhD, PEng, Professor, Queen's University

Introduction.

Tests were conducted at Queen's University to examine the leakage of band connections in corrugated steel pipes. Specimens of 24 inch diameter gage 16 corrugated steel pipe were connected and tested under internal vacuum (i.e. external air pressure). Specimens had welded lock-seams, and were fitted with steel bulkheads, Figure 1. Gaskets meeting ASTM D1056, and 3/8" thick were employed, together with hugger and fully corrugated bands. Initial testing was undertaken for the pipes in straight alignment, and then one of the specimens was tested under three different loading scenarios using the pipe joint test frame developed at Queen's under NCHRP Project 20-07 Task 347 (Moore and Becerril García, 2015).



Figure 1. End-plate and pressure fittings on one of the corrugated steel pipe test samples.

Joint Configurations Tested.

Testing commenced with investigation of joint configurations that would support the vacuum pressures. After a few trials, two were selected for testing:

1. Five tests were conducted for the first configuration, Tests 1A to 1E, where a corrugated band joint was used with 3/8 inch thick sleeve gasket, Figures 2 and 3. Prior to placement of the sleeve, it was found that by placing geogrid across the joint between the ends of the two pipes being connected, Figure 4, the gasket was able to withstand the impact of the external air pressures that result from the internal vacuum.
2. Two tests were conducted for the second configuration, Tests 2A and 2B, where a hugger band joint was used with 3/8 inch thick sleeve gasket, Figure 5. Prior to placement of the sleeve, the same geogrid was placed across the joint between the ends of the two pipes being connected.

Table 1. List of tests conducted for the two joint configurations; none of the joints leaked for the joint and testing configurations employed in these evaluations.

Test	1A	1B	1C	1D	1E	2A	2B
Band	Corrugated	Corrugated	Corrugated	Corrugated	Corrugated	Hugger	Hugger
Alignment	Straight	Straight	Rotate 2.1°	Straight	Straight	Straight	Straight
Shear	0 kN	0 kN	0 kN	20 kN (4500 lbs)	0 kN	0 kN	0 kN
Ovality	0 %	0 %	0 %	0 %	5 %	0 %	0 %
Vacuum	20 kPa	50 kPa	35 kPa	35 kPa	35 kPa	20 kPa	50 kPa
Start Time and Date	12/8/2015 8:49:30 AM	12/8/2015 9:27:31 AM	12/8/2015 2:52:29 PM	12/8/2015 3:48:50 PM	12/9/2015 8:43:34 AM	12/8/2015 10:32:59 AM	12/8/2015 10:48:07 AM



Figure 2. Corrugated band connection after assembly.



Figure 3. 3/8 inch sleeve gasket in place and lubricated prior to placement of the band.

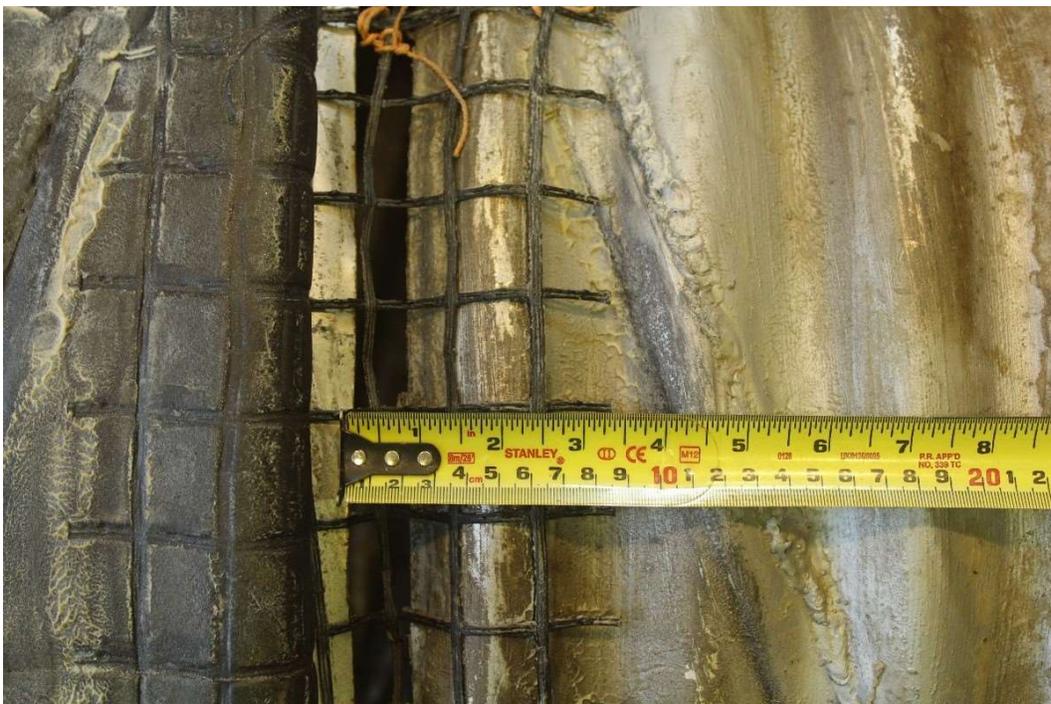


Figure 4. Geogrid in position after band and sleeve were removed after testing.

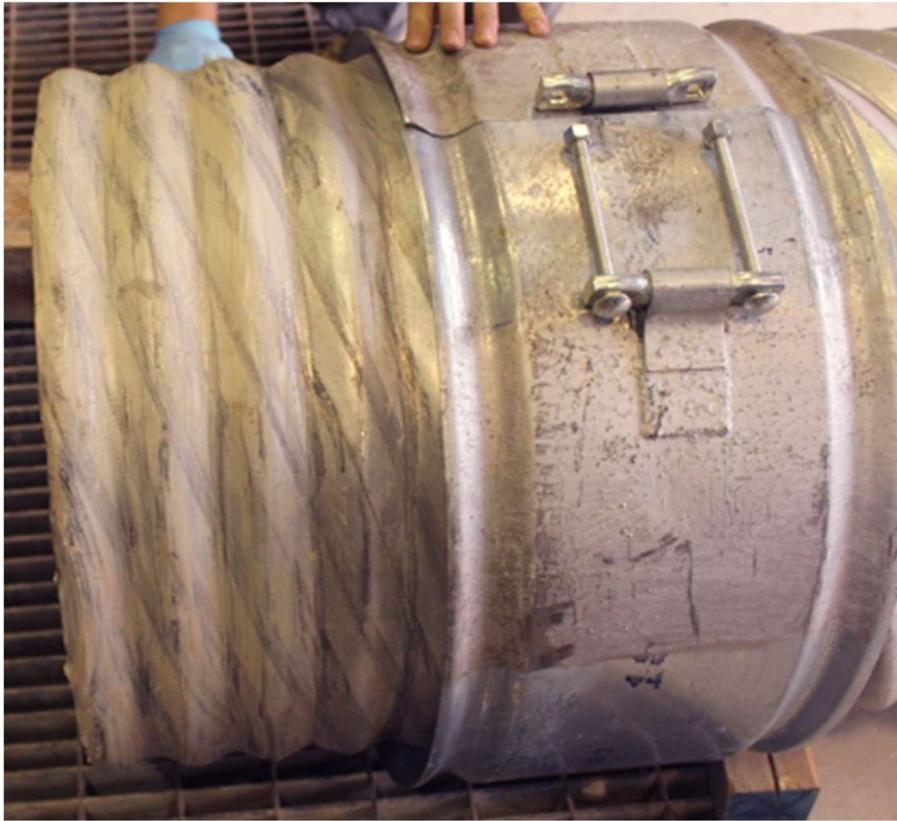
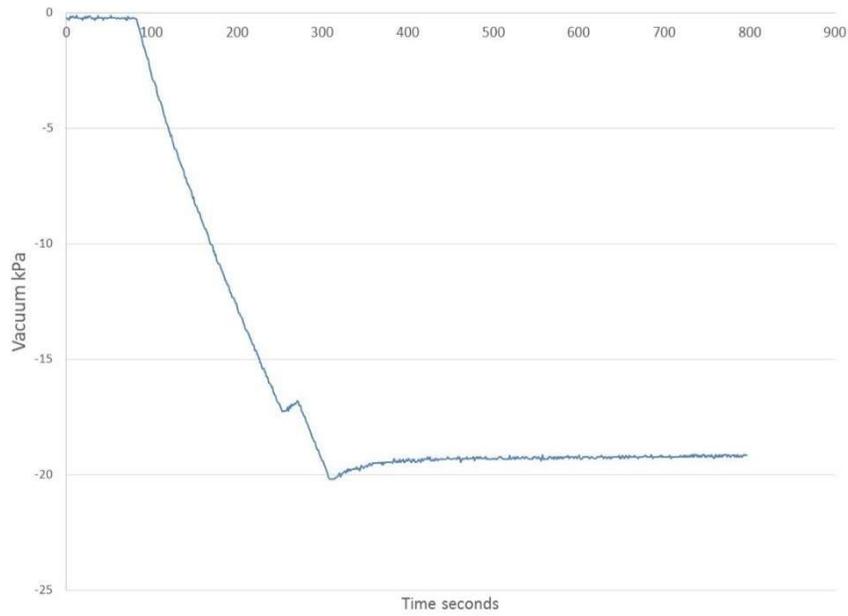


Figure 5. Hugger band and one of the rerolled pipe ends after lubrication (prior to placement of the 3/8 inch gasket).

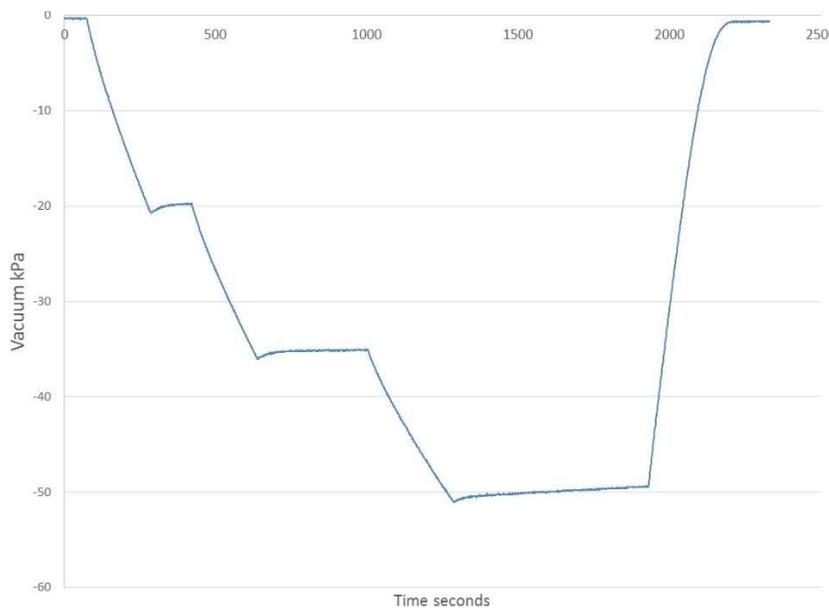
Testing in Straight Alignment

Tests 1A, 1B, 2A and 2B were undertaken in that sequence, where the pipes were assembled on the main floor of the GeoEngineering Laboratory (not in the joint testing frame), and internal vacuum of 20 kPa (3 psi) or 50 kPa (7 psi) was applied. This was the maximum pressure attainable with the laboratory equipment. Changes in that pressure were then observed over time, as shown in Figures 6a and 6b and 7a and 7b for the corrugated and hugger bands, respectively.

Each of these pressure histories indicates that there is some reduction in pressure immediately after each increment in vacuum is applied, and then slow decreases in pressure during the remainder of the test. Joint leakage in previous experiments (Moore and Becerril García, 2015) is evidenced by sudden and significant decreases in pressure. Likely the initial loss and slow subsequent reductions are associated with compliance in the joint system (e.g. time dependent response of the gasket or geogrid), and are not indicative of any joint leakage.

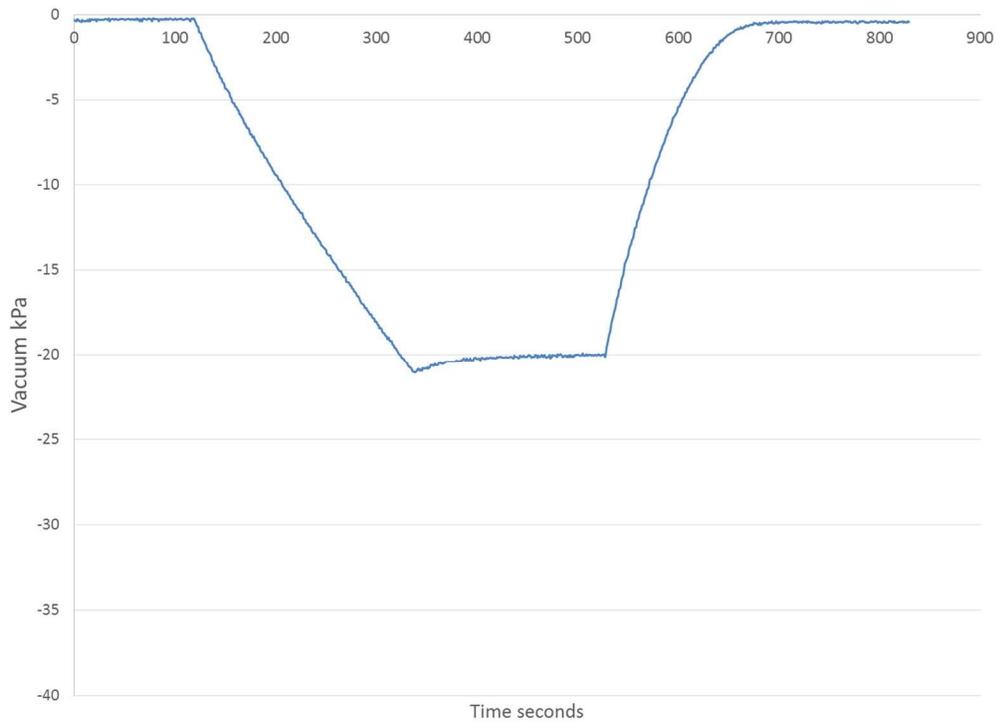


a. Pressure history for Test 1A conducted up to 20 kPa (3 psi) vacuum.

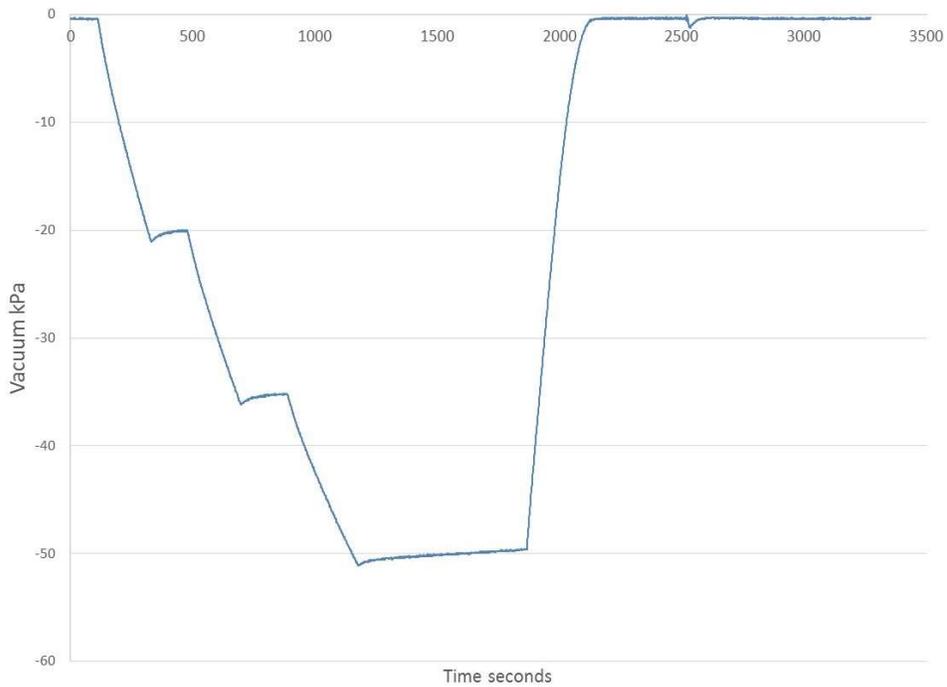


b. Pressure history for Test 1B conducted in three increments up to 50 kPa (7 psi) vacuum

Figure 6. Pressure histories recorded during the first two tests on the corrugated band joint.



a. Pressure history for Test 1A conducted up to 20 kPa (3 psi) vacuum.



b. Pressure history for Test 1B conducted in three increments up to 50 kPa (7 psi) vacuum

Figure 7. Pressure histories recorded during the first two tests on the hugger band joint.

Testing in the Joint Testing Frame

Tests 1C to 1E were conducted after placing the pipes connected by the corrugated band into the pipe joint testing frame developed by Moore and Becerril García (2015). As summarized in Table 1, these involved joint rotation (Test 1C), application of shear force across the joint (Test 1D), and application of ovaling distortion (Test 1E). In each case, joint leakage did not occur during testing.

Figures 8 and 9 show the test pipes with the joint assembled, mounted in the Joint Testing Frame. Both images were taken using a fisheye lens so as to capture the outer extremities of the testing frame, so straight lines are distorted in the images. Figure 8 is taken from the side, so the screw jacks and other testing apparatus can be seen. Figure 9 is taken from above, to show the yellow reaction beam installed over the crown (so that jack extension leads to ovaling deflection).



Figure 8. The two pipes connected with the corrugated band are strapped onto the Pipe Joint Testing Frame; this photograph was taken during preparation for test 1E before application of ovaling deflection or shear force.



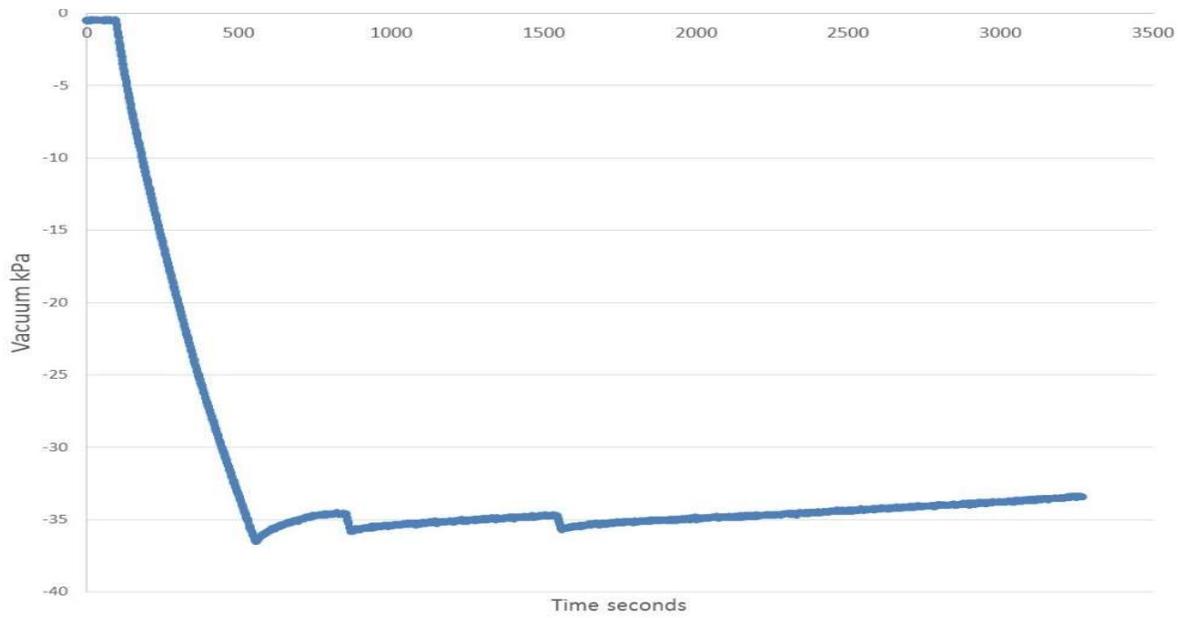
Figure 9. The two pipes connected with the corrugated band are shown during testing in the Pipe Joint Testing Frame; this was for test 1E under ovaling deflection; yellow beam acts to hold the top of the joint stationary so as the joint frame is raised (by extending the screw jacks), an ovaling deflection is imposed across the band and the pipes within.

Figures 10, 11 and 12 present the pressure histories and the screw jack deformations and forces measured during Tests 1C to 1E, respectively.

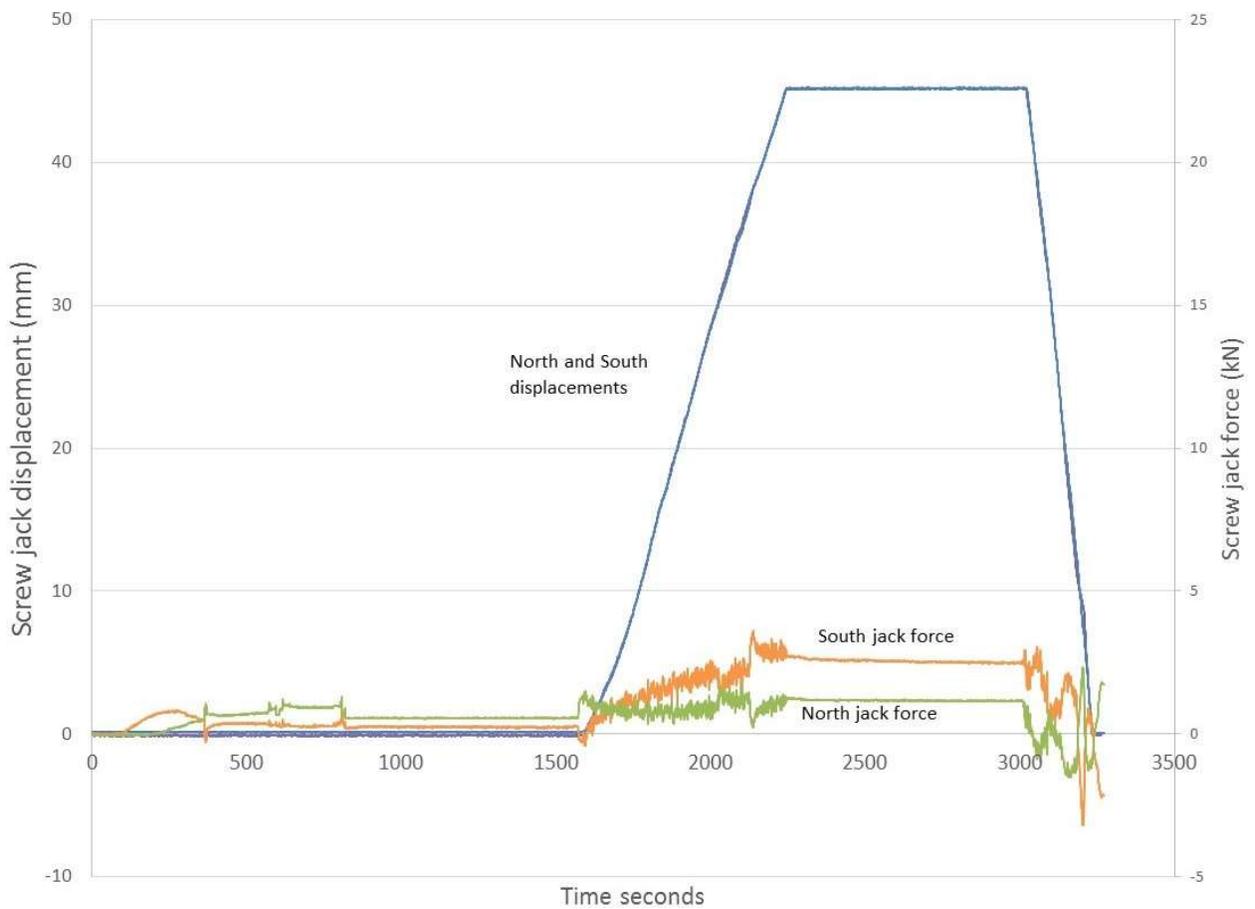
For Test 1C, the two jacks were lifted together so a rotation was imposed across the joint. No leakage was detected up to and including this level of rotation, Figure 10a. As seen in Figure 10b, the total uplift deflection was 46 mm (1.8 inches), corresponding to a joint rotation of 2.1 degrees. Small changes in force were recorded in the load cells mounted to the screw jacks, with differences between them of magnitude 3.0 kN (370 lbs). This means that small shear forces (magnitude of 1.5 kN, 330 lbs) developed across the joint during testing.

For Test 1D, the two jacks were moved in opposite directions, so that a pure shear force was applied across the joint. Once again, the record of pressure with time (Figure 11a) shows no leakage at magnitudes of applied shear force of up to 20 kN (4500 lbs), Figure 11b.

Finally, for Test 1E, the yellow reaction beam seen in Figure 10 was placed over the top of the band. No leakage is seen in the pressure history (Figure 12a) as the two screw jacks were lifted by 30 mm (1.2 inches), to raise the invert of the two pipes (Figure 12b) and impose a vertical diameter decrease of 5% (Figure 12c).

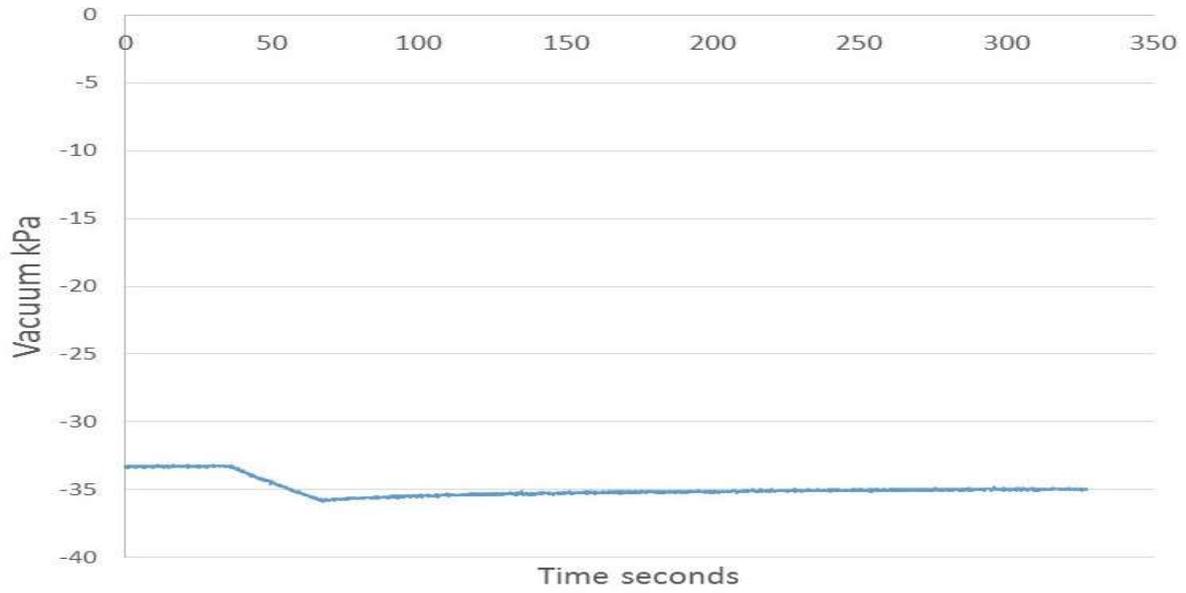


a. Pressure history.

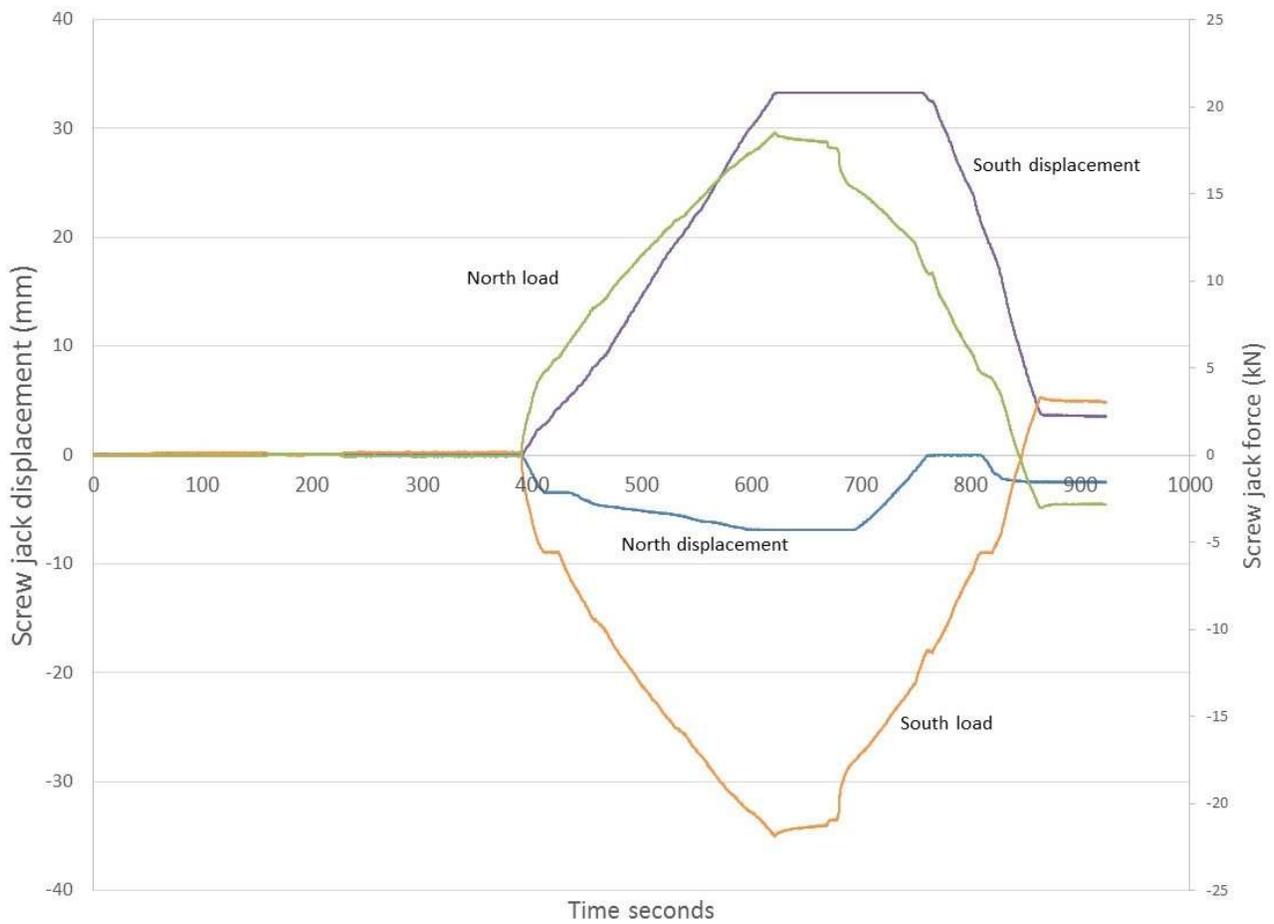


b. Load and deflection histories.

Figure 10. Data recorded during Test 1C (rotation test conducted without shear force).

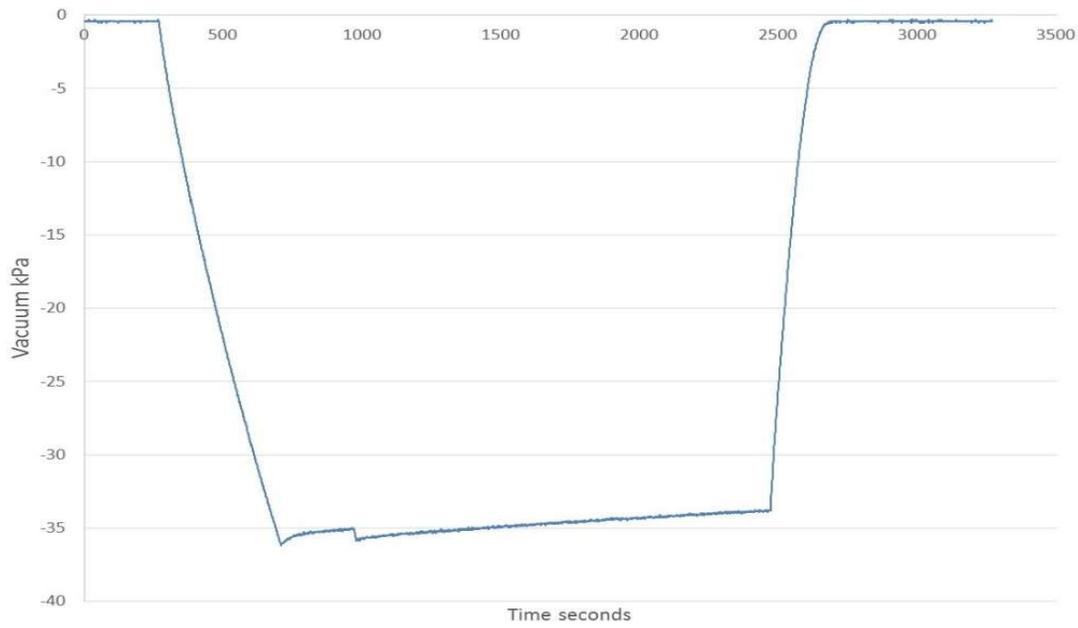


a. Pressure history.

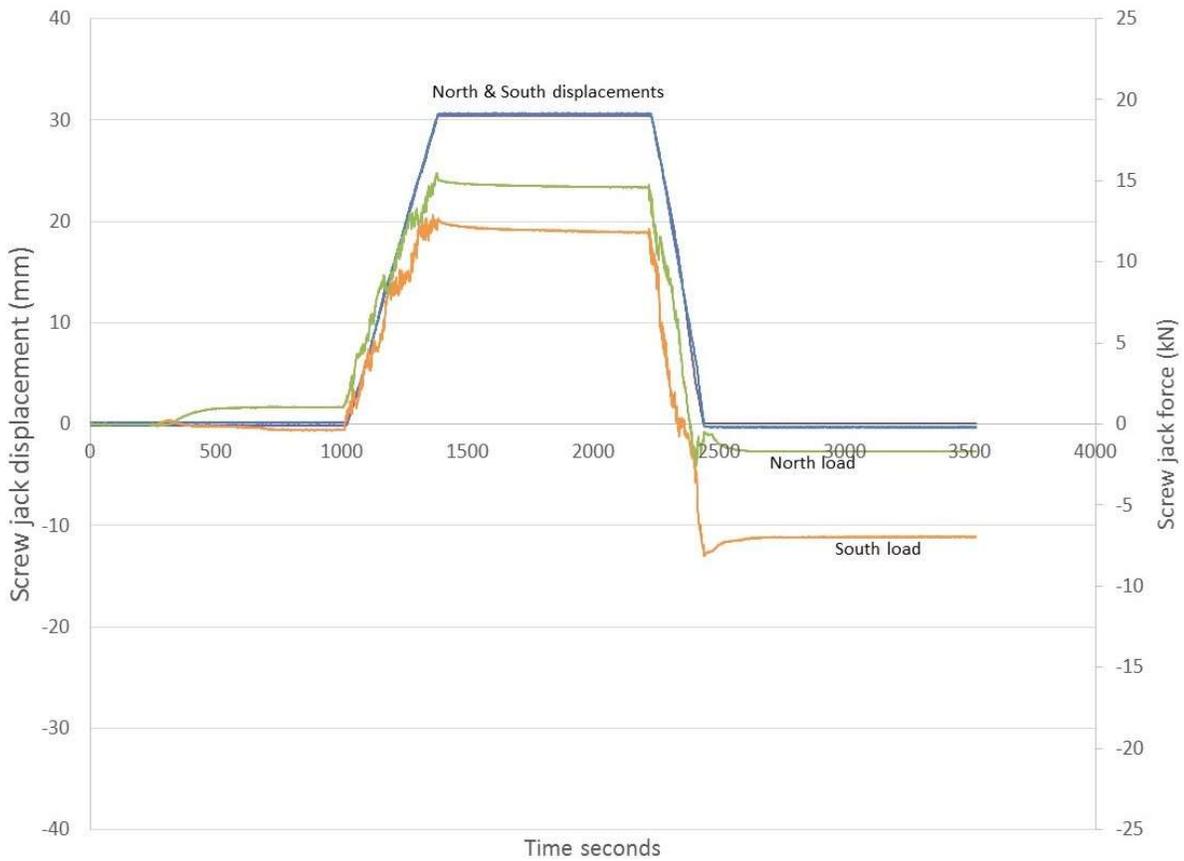


b. Load and deflection histories.

Figure 11. Data recorded during Test 1D (test conducted in straight alignment under shear force)

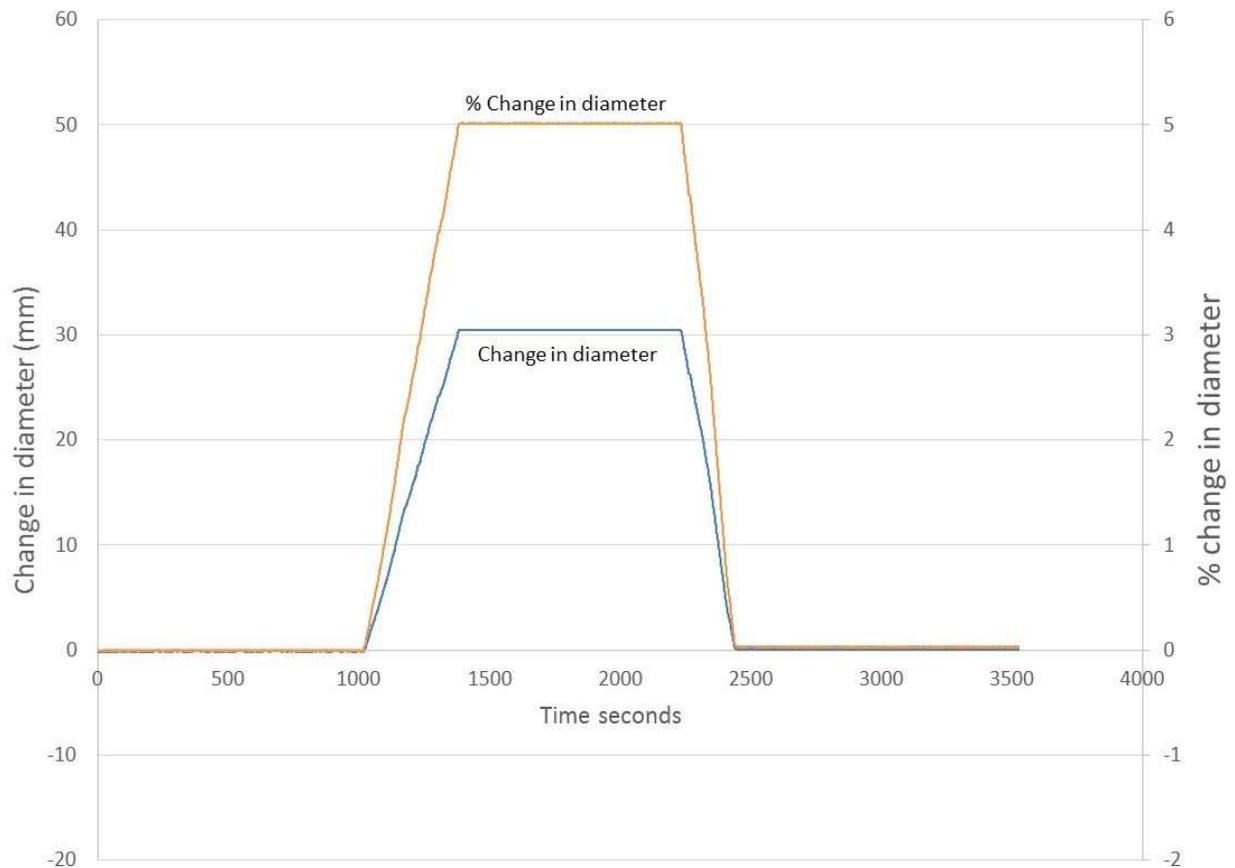


a. Pressure history.



b. Load and deflection histories.

Figure 12. Data recorded during Test 1E (test conducted with joint under ovaling deflection)



c. Imposition of ovaling deflection.

Figure 12 (cont'd). Data recorded during Test 1E (test conducted with joint under ovaling deflection)

Conclusions

Two banded joint configurations were found to produce a sealed connection able to resist 50 kPa (7 psi) of vacuum (external air pressure) without leakage, for the 24 inch (0.6 m) diameter corrugated steel test pipe when in straight alignment. The corrugated band and hugger band configurations both used a 3/8 inch thick gasket, with geogrid under the gasket spanning across the gap between the two pipes.

This same type of corrugated band connection was then examined and found to produce a sealed connection under rotation, shear force and ovaling. Each of these tests were imposed using the joint testing frame developed during NCHRP 20-07 Task 347. The first test involved imposing rotation of 2.1 degrees, the second test featured shear force exceeding 20 kN (4500 lbs), and the third test featured ovaling deflection of the joint (reduction in vertical diameter by 5%). The connection performed without leakage at 35 kPa of internal vacuum (external air pressure).

Acknowledgements

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Moore I.D. and Becerril García, D. (2015) Test methods for watertightness of culvert joints, Contractor's Final Report for NCHRP 20-07 Task 347, March 2015, National Cooperative Highway Research Program, National Academy of Sciences Transportation Research Board, Washington D.C. 159pp.