ASSESSMENT AND EVALUATION OF BOLT TENSIONING USING DIRECT TENSION INDICATING WASHERS WITH SILICONE RUBBER AS A VISUAL INDICATOR OF TENSION LEVEL

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Background

- ASTM F959 direct tension indicators (DTI) are devices which have been recognized as being capable of demonstrating that the required bolt tension has been achieved
- Use a feeler gauge to confirm that adequate DTI compression has occurred to demonstrate achieved bolt tension

Background Cont'd

- Applied Bolting Technologies has adapted DTI washers to incorporate a measured amount of silicone rubber in the depressions in the washer on the opposite face to the bumps
- Previous research had shown that this was capable of demonstrating to the operator that the necessary bolt tension had been achieved
- Inclusion of silicone does not violate the geometrical requirements of ASTM F 959. Squirt washers thus qualify as DTI washers, and thus, field verification can still be performed with a feeler gauge.

Certification of ASTM F959 DTI Washers

- ASTM F606 specifies a test procedure to confirm DTI performance is acceptable
- Washers loaded with DTI bumps in a depression to globally flatten the washer and zero the measuring device
- Washers are then flipped, and the bumps compressed to a gap of .015 inches
- The achieved load is measured, and must be within a defined range to be acceptable
- ASTM also specifies minimum sample size requirements for the test so that an accurate representation of the lot is achieved

Current Research

- Purpose of current research is to assess how effectively DTI squirt washers can be employed by experienced iron workers to achieve the minimum specified tension based on the achieved level of squirt
- Additionally, it was desired to investigate the response of washers when loaded, as well as any additional parameters which could influence the achieved bolt tensions

Washer Performance Tests

- Washer performance was established through direct compression tests
- Tests revealed that for the lot of washers employed with the iron workers, three typical characteristics to loading
- Overall washer flattening: dishing of washer from manufacturing process was removed
- DTI bump compression range: highly linear behaviour
- Complete bump compression: washer stiffness increases dramatically beyond the point of complete bump compression

Load-Displacement Relationship of 7/8” DTI Washers for A325 Bolts

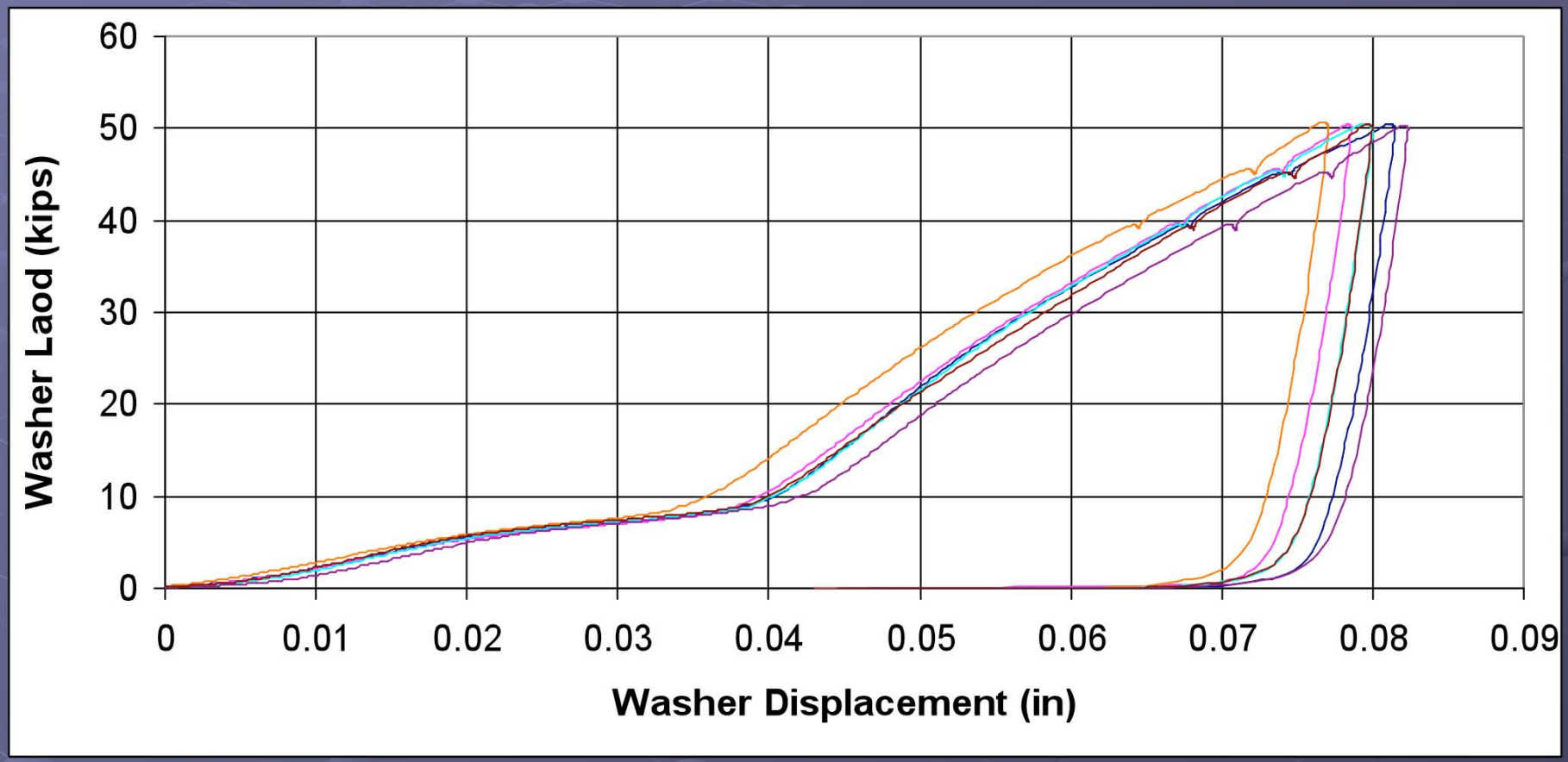
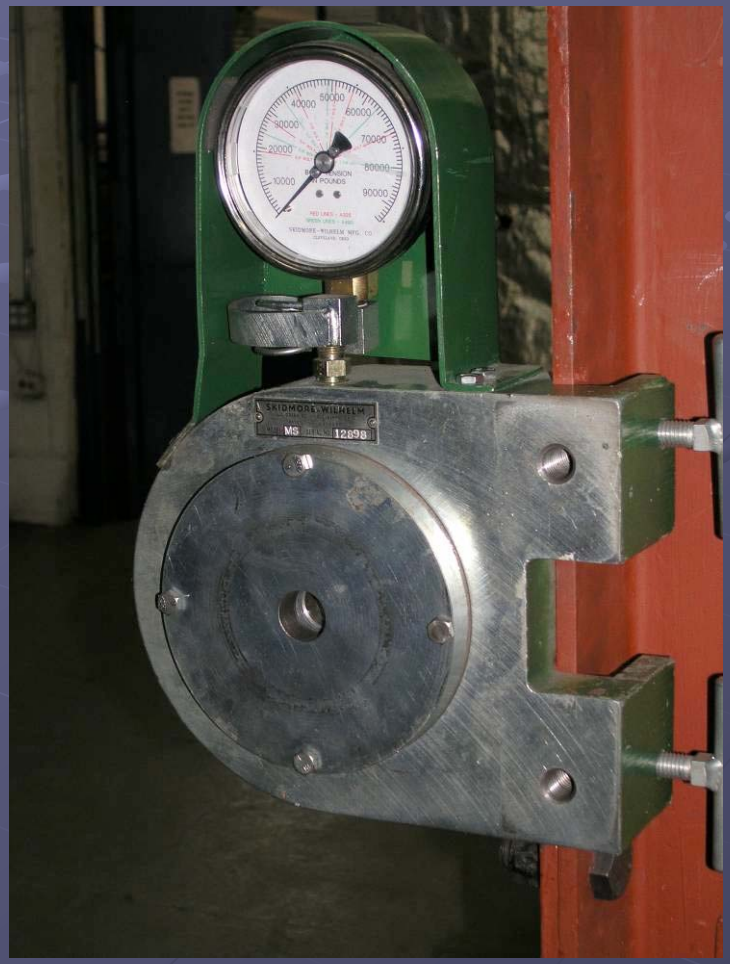


Plate Specimen Testing

- Tests were performed using engineering students as well as apprentices in the Toronto Iron Workers union local 721
- Plate specimens incorporating four 7/8” bolts and DTI washers were presented to participants for final tightening after a pre installation verification procedure.

Pre Installation Verification

- Iron workers instructed to use a Skidmore bolt calibrator to tension a series of 7/8” bolts with squirt washers to the specified target load of 45 kips: about 15% above the minimum specified tension of 39 kips.
- Upon completion of this exercise, iron workers were asked to compress more DTI washers with the Skidmore gauge covered until they could consistently achieve almost exactly 45 kips based on the achieved degree of squirt alone



Pre Installation Verification Cont'd

Pre Installation Verification Cont'd

- Workers were then asked to tension a series of four bolts in a plate specimen, and confirm adequate tension with a feeler gauge

Iron Worker Testing

- Participants were then asked to tension a series of twelve bolts
- Bolt heads were pre-machined to receive the transducer of an ultrasonic bolt gauge
- This bolt gauge was later employed to measure the bolt elongation when bolts loosened

Iron Worker Test Results

- Based on tension-elongation tests performed in a test frame and in conjunction with the bolt gauge, bolt stiffness coefficients for each lot of bolts used were calculated and used to determine the achieved bolt tensions based on the measured bolt elongations

Iron Worker Test Results Cont'd

- The mean bolt tension achieved by the collective series of test results from 20 iron workers (240 bolts) was 45.0 kips.
- The standard deviation for the entire group of test results was 5.0 kips.
- The average standard deviation for individual iron workers was 3.3 kips. The extreme values of individual worker standard deviations ranged from 2.1 kips to 5.7 kips

Iron Worker Test Results Cont'd

- Data analysis and report preparation is still in progress
- Initial results demonstrate that the target load of 45 kips was well matched by the iron workers
- Variability of results is similar to the results of previous bolt installation tests performed in repeated installations in a Skidmore

Preliminary Recommendations

- Testing to date has been performed with apprentice iron workers with an assortment of experience in bolting
- Future testing with fully qualified iron workers would be a further improvement on participant experience
- Ultimately, performing release stretch measurements in structures where DTI squirt washers have been employed would be the most accurate way to demonstrate their performance

Thank You

- Any Questions?