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Report on Laboratory Testing of Fastening of CFS Track to Concrete Base Materials with PAFs, with Revision

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research report

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RESEARCH REPORT RP13-3

September, 2013
With Revision 2018

Committee on Specifications
for the Design of Cold-Formed
Steel Structural Members

American Iron and Steel Institute

The following Revision is made to the report on March 2018:

On Page 12 of 63, line 14 from bottom, the following change is made:

d_s > ~~0.118~~0.157 in. (3.99 mm)

The above change is based on the fact that the value of P_{nos} = 1,450 lbs (6,450 N) was based on PAFs with diameters of 0.157 in.

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September 9, 2013

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Abstract

The 2012 AISI S100 Section E5 includes design provisions for power-actuated fasteners (PAFs) for connection of cold-formed steel (CFS) to steel base materials. However, a need exists to develop an in-depth understanding when CFS wall tracks are attached to concrete base materials as part of interior and exterior wall framing applications. Current code requirements, as specified by ASCE 7 - 2010 Chapter 13 (Exception to Section 13.4.5), limit individual PAFs in nonstructural component connections as part of distributed systems, to a sustained tension service load of 90 lbs in concrete and 250 lbs in steel in Seismic Design Categories D, E and F. Although the use of PAFs is very common in CFS wall framing applications, there is a need for an in-depth system study examining the cyclic / seismic lateral performance using this connection method.

This experimental test program demonstrates that tested capacities of the CFS track-to-concrete PAF connections exceed those used for design, under the current ASCE 7 (2010) provisions. Experimental data further demonstrates that ductile steel failure modes limit the capacity of the connection with 33 mil and thinner CFS track. Where this failure mode is dominant, the use of

AISI S100-12 Section E5.3.2 to determine the capacity of the CFS track connection is appropriate and further limiting the capacity to current standards is not warranted. Where this failure mode is not dominant, and PAF failure modes control the system behavior, the capacity of the CFS track connections should be more accurately described in AISI S100-12 Section E5 and the International Building Code (ICC, 2012).

Introduction

Currently, PAFs are outside the scope of ACI 318 (2011) Appendix D provisions. However, PAFs are used in a widespread manner in both seismic and non-seismic CFS interior and exterior wall framing applications. PAFs are a proven, safe and very cost effective installation option for fastening of CFS track sections to steel, concrete and masonry base materials. In order to justify extended use of PAFs in higher Seismic Design Categories D, E and F as an alternative to post-installed or cast-in concrete anchors for CFS track fastening, a test program was developed to investigate a variety of influencing parameters.

The test set-up and protocol used for this research program replicated a previous test program summarized by AISI Research Report RP 10-3, "Testing of Anchor Bolts Connecting Cold-Formed Steel Track to Concrete with Minimum Edge Distance" (AISI, 2010). Along with previous research reported in the AISI COFS Lateral Design Subcommittee on wood sill plate anchorage, the RP10-3 project was used to support changes in the International Building Code (IBC) for CFS track sill plate anchor bolt attachments at close edge distance.

Lacking specific test data to develop consistent and accurate design capacities for PAFs beyond single point fastener static capacities in concrete, the AISI Project Monitoring Task Group (PMTG) undertook this study to characterize typical PAF connections through an experimental testing program including monotonic and cyclic / seismic in-plane shear load tests of CFS tracks fastened to concrete with PAFs with the following goals:

- Demonstrate correlation between tested connection capacities with AISI S100-12 nominal Section E5 design strengths;
- Propose rational design capacities for cold-formed steel track connections to concrete.

Test Specimens

Twenty-five CFS track to concrete configurations were tested, with a portion tested in duplicates. Figure 1 depicts a typical cross section of the specified test specimen. Table 1 summarizes the parameters for each of the twenty-five test configurations.

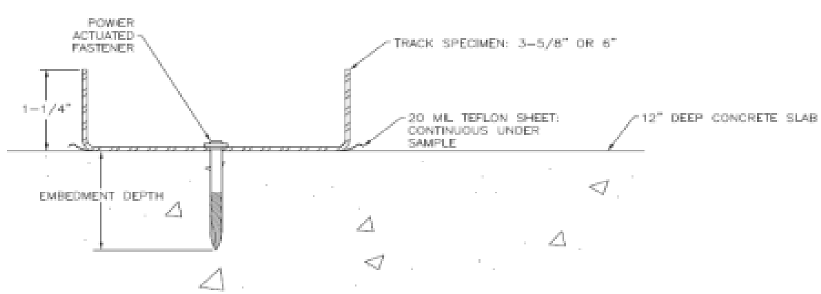

Figure 1: Typical Cross Section of Test Specimen

Table 1: Summary of Tests

Test Series Number	**1**	**2**	**3**	**3a**	**3b**	**6**	**7**
Track Thickness (in.)	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Track Depth (in.)	3-5/8	3-5/8	3-5/8	3-5/8	3-5/8	3-5/8	3-5/8
Track Length (ft)	4	8	4	8	4	4	4
PAF Diameter (in.)	0.157	0.157	0.157	0.157	0.157	0.118	0.118
Nominal Embedment (in.)	1	1	1	1	1	1	1
PAF Spacing (in.)	12	12	12	12	12	12	12
Loading Protocol	mono	mono	cyclic	cyclic	cyclic	mono	cyclic

Test Series Number	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Track Thickness (in.)	0.069	0.069	0.069	0.069	0.059	0.059	0.045
Track Depth (in.)	6	6	6	6	3-5/8	3-5/8	3-5/8
Track Length (ft)	4	4	4	4	4	4	4
PAF Diameter (in.)	0.157	0.157	0.157	0.157	0.157	0.157	0.157
Nominal Embedment (in.)	1	1	1.25	1.25	1	1.25	1
PAF Spacing (in.)	12	12	12	12	12	12	12
Loading Protocol	mono	cyclic	mono	cyclic	mono	mono	mono

Test Series Number	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Track Thickness (in.)	0.045	0.045	0.069	0.069	0.069	0.069	0.045
Track Depth (in.)	3-5/8	3-5/8	6	6	6	6	3-5/8
Track Length (ft)	4	4	4	4	4	4	4
PAF Diameter (in.)	0.157	0.157	0.157	0.157	0.157	0.157	0.157
Nominal Embedment (in.)	1.25	1.25	1.25	1.25	0.625	0.625	1.25
PAF Spacing (in.)	12	12	6	6	12	12	6
Loading Protocol	mono	cyclic	mono	cyclic	mono	cyclic	mono

Test Series Number	**24**	**25**
Track Thickness (in.)	0.059	0.045
Track Depth (in.)	3-5/8	3-5/8
Track Length (ft)	4	4
PAF Diameter (in.)	0.157	0.157
Nominal Embedment (in.)	1.25	1.25
PAF Spacing (in.)	6	6
Loading Protocol	mono	cyclic

Two power-actuated fastening systems were used in this test program. Most tests involved a low-velocity, 0.27 caliber powder-actuated tool, but two test series involved a low-velocity compressed gas tool. Common fastener types were selected for general purpose fastenings to concrete base materials. Two different fastener shank diameters were used, 0.157 inch (4 mm) with the powder-actuated fastening system and 0.118 inch (3 mm) for the compressed gas fastening system. Each of these fasteners has a variable shank length to satisfy different embedment requirements, as specified by the test scope (Appendix B). Concrete specimens were tested "as-cast" which was consistent with similar anchor bolt cyclic / seismic tests conducted previously (AISI, 2010).

CFS tracks tested had nominal depths of 3-5/8 inch and 6 inch with nominal thicknesses of 33 mil, 43 mil, 54 mil and 68 mil. CFS track lengths of 4'-0" or 8'-0" were used to satisfy PAF spacing conditions along with the total number of fasteners used per test assembly. Although most test series indicated track lengths of 4'-0", two duplicate test (Series 2 and 3a) were conducted with 8'-0" track length to investigate possible length effects.

<u>**Component Descriptions**</u>

Concrete: A compressive strength (f'_c) of 2,500 psi to 3,000 psi was specified for the tests to represent concrete typical of light-frame construction. This is consistent with similar anchor bolt cyclic / seismic tests conducted previously (AISI, 2010). Cylinder tests, reported in Appendix E, showed actual f'_c values of 2,550 psi. The 9'-0" x 7'-0" concrete test slab was unreinforced and had a 12" thickness.

Steel Plate: ASTM A36 plate with 40 ksi yield strength was used to represent a typical light-frame steel construction. The 4'-0" x 2'-0" steel plate had a thickness of 3/8". Tensile testing (ASTM E8/E8M-11) reported in Appendix E showed actual tensile strength F_u= 65 ksi.

0.157 Inch Diameter PAF: A 0.157 inch diameter, knurled shank PAF for high performance in both tension and shear fastening applications was selected for most test series. The fastener performs equally well in both high and standard strength concrete and steel. The fasteners specified for the testing conducted were Hilti X-U27 powder-actuated type fastener with a shank length of 1 inch, along with the X-U32 type fastener with a shank length of 1.25 inch. Average embedment for X-U27 fastener was 0.906 inch while average embedment for X-U32 fastener was 1.223 inch. For tests in steel base materials, a smaller X-U16 type fastener with a shank length of 0.625 inch was used, with an average embedment of 0.453 inch.

Figure 2: Typical 0.157 inch Diameter PAF

0.118 inch Diameter PAF: A 0.118 inch diameter, smooth shank PAF for standard performance in both tension and shear fastening applications was also used for Test Series 6 and 7 in order to establish a lower bound on the fastener diameter size. The fastener also performs well in standard strength concrete. The fasteners specified for the testing in Test Series 6 and 7 were Hilti X-GN27 compressed gas type fasteners with a 1 inch shank length. Average embedment achieved with the X-GN27 fastener was 0.971 inch.

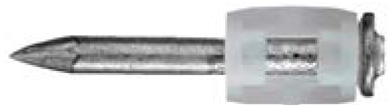

Figure 3: Typical 0.118 inch Diameter PAF

CFS Track: Figure 4 depicts the cross section of the typical CFS track section that was tested. CFS track sections have nominal depths of 3-5/8 and 6 inches, which means the web depth (inside to inside of flange) was 3-5/8 or 6 inches. Cold-formed steel material was standard galvanized steel with a G60 zinc coating. Mechanical properties of the CFS track were verified by laboratory tests and are reported in Appendix E. Material was tested in “as received” condition.

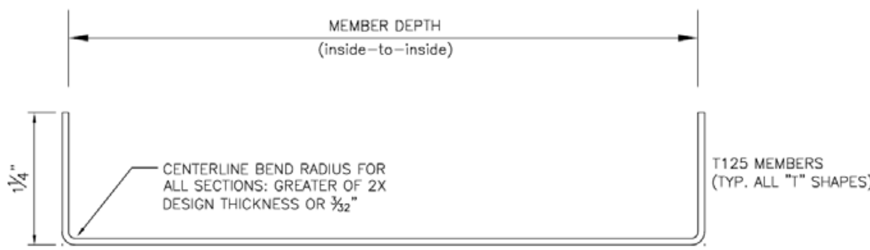

Figure 4: Cross Section of CFS Track

Membrane: Similar to previous anchor bolt testing (AISI, 2010), a slip membrane between the CFS track and the concrete was installed on all tests for a conservative test condition removing any friction influence. The membrane was comprised of a single, 0.020 inch thick Teflon® sheet, to approximate an idealized “frictionless” plane.

<u>Test Set-Up and Procedure</u>

All tests were conducted at the testing laboratory of Hilti North America in Tulsa, Oklahoma between July 2013 and August 2013. Figure 5 shows the set-up for a typical test.

Monotonic load tests were performed at a loading rate of between 1 and 3 minutes to failure. Cyclic / seismic load tests were conducted with a force controlled cyclic testing protocol (sine wave) at a frequency of 0.1 Hz (1 cycle every 10 seconds). Loading for the cyclic tests was five (5) repetitions at six (6) different and increasing percentages (67, 75, 85, 95 100 and 110 percent) of the reference load. The reference load was taken as 40% of the ultimate monotonic load.

Each specimen was tested as a single element connecting a 4’-0” or 8’-0” long CFS track to the larger concrete “foundation” element. Figure 6 shows the fixture that was fabricated to introduce loads into the CFS track section. A schematic of the fixture is shown in Appendix A. The fixture was attached to the CFS track with ten (10) 1/4 inch screws from the track to the interior side-plates and eight (8) 5/16 inch cap screws through the side-plates and CFS track flanges directly into the end blocks. The end blocks were then connected to the exterior side plates through four (4) 1/4 inch diameter threaded steel rods. No vertical loads were introduced to the test specimen, and any vertical displacements caused during cyclic testing were restricted by two mechanical rollers anchored into the concrete.

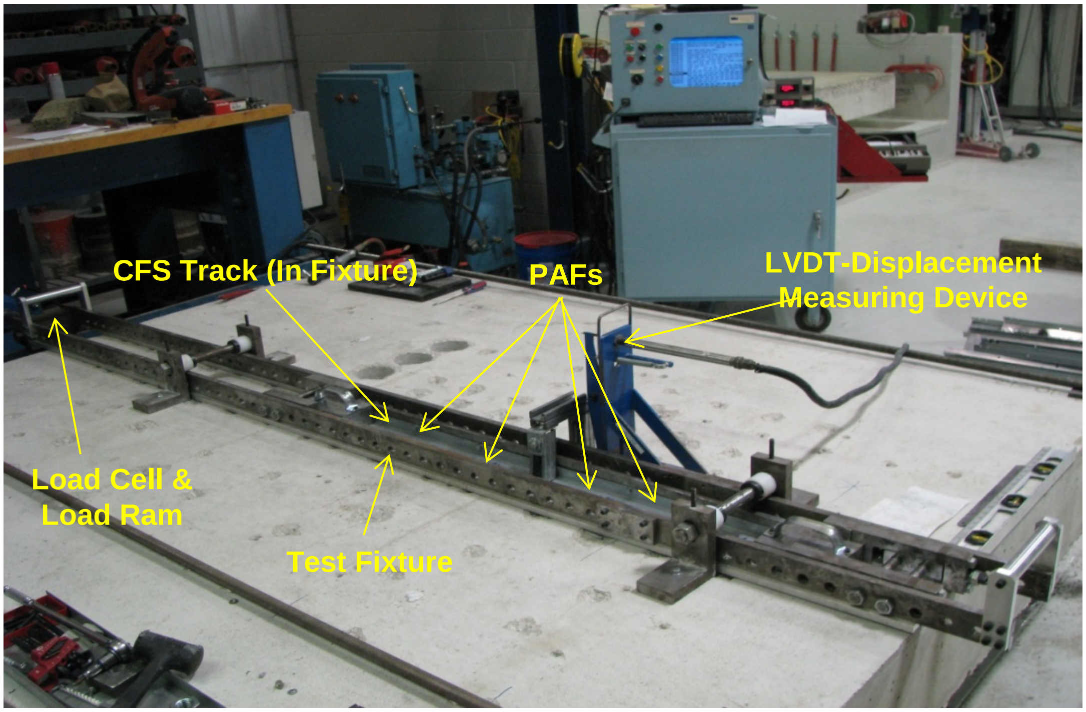

Figure 5: Typical Test Set-up

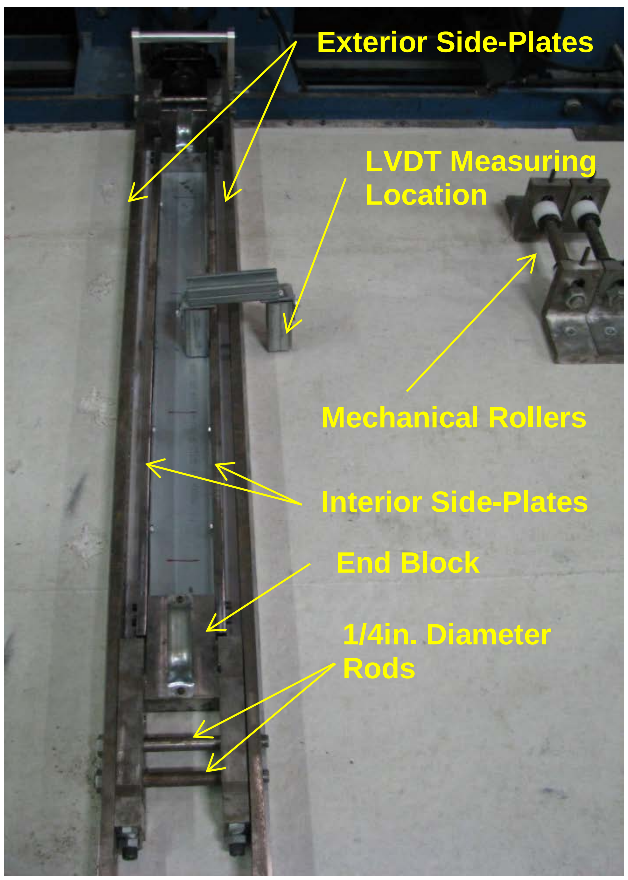

Figure 6: Close-up View of Test Fixture (prior to fastening)

Displacement was measured at mid length of the CFS track using a Linear Variable Differential Transformer (LVDT) reader. All loads and displacements were collected via a digital data acquisition system. The data was analyzed as it was logged. For cyclic loading conditions, the minimum and maximum data points for load and displacement were recorded. After application of the six different cyclic / seismic load levels was completed, a residual monotonic load test was conducted to determine the ultimate failure load of the test specimen. The maximum load and corresponding displacement were also recorded.

Monotonic Load Test Results

The detailed results for the monotonic load tests are found in Appendix C. The results are summarized in Table 2, which provides a comparison with predicted values that are calculated in accordance with the bearing and tilting strength provisions in Section E5.3.2 of AISI S100 (AISI, 2012). Table 2 also includes the calculated AISI nominal strength (no safety factor applied) and design strength (safety factor applied).

Table 2: Summary and Comparison of Monotonic Test Results

Test Series Number	Ultimate Tested Load (lbs)	Calculated Nominal Strength for Bearing and Tilting[1] (lbs)	Tested/Calculated Ratio	AISI Design Strength[2] (lbs)
1	2969	2492	1.19	1216
	3041	2492	1.22	1216
2	4256	4984	0.85	2431
	4543	4984	0.91	2431
6	2370	1873	1.27	914
10	3713	11033	0.34	5382
12	4977	11033	0.45	5382
14	6228	10027	0.62	4891
15	7830	10027	0.78	4891
16	5289	5474	0.97	2670
17	6733	5474	1.23	2670
	4600	5474	0.84	2670
19	12375	22066	0.56	10764
21	11621	11033	1.05	5382
23	13533	10948	1.24	5340
24	11115	20054	0.55	9782

Notes:

1) The AISI nominal strength is calculated for PAF determined in accordance with AISI S100 -12 Section E5.3.2 for a limit state of bearing and tilting. Where applicable, AISI S100 Section A2.3.2 was considered.
2) The tested / calculated ratio is the ultimate residual test load divided by the AISI nominal strength.

Initial comparisons between 4'-0" and 8'-0" CFS track lengths (Test Series 1 and 2) demonstrated that even though both had the same PAF spacing; only the samples with 4'-0" CFS track length exceeded the predicted strength. While tests with 8'-0" CFS track did not exceed the predicted strength determined by AISI S100-12, the controlling failure mode was still shear bearing of CFS track as described in the data summary table (Appendix B).

Ultimate loads also confirmed, in Test Series 6, that the predicted strength determined by AISI S100-12 Section E5.3.2 can be satisfied with a smaller shank diameter PAF as well as with a larger shank diameter PAF. Test Series 6 used a 0.118 inch fastener type and these also exceeded the predicted strength by 27%.

Cyclic / Seismic Load Test Results

The detailed results for the cyclic / seismic load tests are provided in Appendix D. The results are summarized in Table 3, which provides a comparison with the calculated AISI nominal strength (no safety factor applied) and design strength (safety factor applied).

Table 3: Summary and Comparison of Cyclic Test Results

Test Series Number	Ultimate Tested Residual Load (lbs)	Calculated Nominal Strength for Bearing and Tilting (lbs)	AISI Design Strength[1] (lbs)	Tested/Design Ratio[2]
3	2109	2492	1216	1.73
	1731	2492	1216	1.42
3a	3983	4984	2431	1.64
	3817	4984	2431	1.57
3b	4093	2492	1216	3.37
	3823	2492	1216	3.14
7	2454	1873	914	2.68
	1935	1873	914	2.12
11	5107	11033	5382	0.95
	5137	11033	5382	0.95
13	4438	11033	5382	0.82
	6303	11033	5382	1.17
18	5774	5474	2670	2.16
	5385	5474	2670	2.02
20	13185	22066	10764	1.22
	14475	22066	10764	1.34
22	11608	11033	5382	2.16
	10301	11033	5382	1.91
25	12038	10948	5340	2.25
	12016	10948	5340	2.25

Notes:

1) The AISI design strength is calculated for PAF determined in accordance with AISI S100 -12 Section E5.3.2 for a limit state of bearing and tilting using a safety factor of 2.05.
2) The tested / design ratio is the ultimate tested residual load divided by the AISI design strength.

Throughout the overall test program, different failure modes were observed with respect to each of the test specimens (see Appendix B). For tests conducted with 33 mil CFS track, the failure mode was dominated by shear bearing deformation of the CFS track. Although no major deformations were noticed during the cyclic / seismic loading, when conducting the monotonic ultimate load test, major shear bearing failure of the CFS track was noticed between the bearing surface of the CFS track and the PAF shanks, see Figure 7.

While 33 mil CFS track sections were dominated by the shear bearing failure mode, thicker CFS track sections were subjected to more varied failure modes mainly dependent on the PAF embedment. Specimens with CFS track thickness of 43 mils or thicker and nominal PAF embedment of 1 inch had a dominant controlling failure of tilting / pull-out of PAFs, see Figure 8. While no deformation was noticed on the CFS track or fastener during cyclic / seismic loading, fastener deformation was evident when an ultimate load test was conducted on an additional test specimen.

Shear bearing in the CFS track was only visible in thicker track when a deeper PAF embedment of 1.25 inch was introduced. This failure mode was evident only in 43 mil track where most tests displayed combinations of initial shear bearing of CFS track along with PAF tilting / pull-out. 54 mil and 68 mil CFS track sections all displayed failure in PAF tilting / pullout with both 1 inch and 1.25 inch embedment into a concrete base material. While PAFs embedded into concrete were not able to produce shear bearing failure of the CFS track, tests with thicker than 43 mil CFS track with steel base material (Series 21 and 22) produced shear bearing failure. Figure 9 shows an X-U16 PAF that was able to produce shear bearing of a 4'-0" 68 mil CFS track when fastened into a 3/8 inch thick ASTM A36 steel plate.

Figure 7: Shear Bearing of 33 mil CFS track (concrete base material)

Figure 8: PAF Tilting/Pullout in 43 mil CFS Track (concrete base material)

Figure 9: Shear Bearing of 68 mil CFS Track (ASTM A36 steel base material)

Local spalling occurred when the controlling failure was tilting / pull-out of the PAF in concrete. Although there was visible concrete damage around the PAF during shear bearing of CFS track, the damage was very minimal and in some cases no damage was noticed.

Conclusions and Recommendations

This research test program was designed to achieve the following primary goals:

1. **Demonstrate correlation between tested connection capacities with AISI S100-12 Section E5.**

Analyzing the cyclic / seismic load tests of 4'-0" 33 mil CFS tracks fastened with PAFs without a washer into concrete base material (Series 3 and 7), shear bearing was the predominant failure mode. Comparing ratios of tested vs. predicted nominal strengths; there is a clear indication that the AISI S100 Section E5.3.2 prediction produces strengths which can be applied to 33 mil CFS track. Analyzing the cyclic / seismic load tests of 4'-0" 68 mil CFS tracks fastened with PAFs into ASTM A36 steel plate (Series 21), shear bearing was the predominant failure mode. Comparing ratios of tested vs. predicted nominal strengths; there is a clear indication that the AISI S100 Section E5.3.2 prediction produces load values which can be applied to 68 mil CFS track.

Although the predicted strength was not met with 8'-0" track length (Series 2 & 3a), further research into the effects of track length greater than 50 inches should be considered in order to determine whether a length adjustment factor is necessary as indicated by the AISC Specification for Structural Steel Buildings Table J3.2 (AISC, 2010). Additionally, the use of a pre-mounted 15 mm diameter steel washer on the PAF was evaluated (Series 3b). In this case, an increase in residual monotonic load capacity was observed.

2. **Propose rational design capacities for cold-formed steel track connections.**

It is conclusive that shear bearing of the CFS track was the dominant controlling failure mode with all 33 mil CFS track tests. Within this limit state, the ultimate monotonic and cyclic / seismic residual loads exceeded the predicted design strengths set by AISI S100-12 when using PAFs with a nominal embedment greater than or equal to 1 inch. Therefore, a recommendation to modify AISI S100-12 Section E5 to include the use of PAF with 33 mil CFS track in concrete with compressive strength greater than or equal to f'_c=2,500 psi and nominal embedment greater than or equal to 1.00" should also be made.

Table 4: Summary and Comparison of Cyclic Test Results (Track thicker than 33 mil)

Test Series Number	Number of Fasteners	Tested Ultimate Load (lbs)	Tested Ultimate Load Per Fastener (lbs)
11	4	5107	1277
		5137	1284
13	4	4438	1110
		6303	1576
18	4	5774	1444
		5385	1346
20	8	13185	1648
		14475	1809
25	8	12038	1505
		12016	1502
Average Load Per Fastener			1450
Standard Deviation			204
Coefficient of Variance (COV)			14%

For the connection of CFS track to concrete with PAFs, the connections exhibited the ability to sustain high magnitude, repeated load cycles, even when the controlling failure mode was PAF tilting / pullout, as shown in the load-displacement curves (Appendices C and D). Regardless of the CFS track thickness, the ultimate loads substantially exceeded the 90 lbs service load specified by ASCE 7 - 2010 Chapter 13 (Exception to Section 13.4.5). From Table 4, it is further conclusive that the average load capacity per fastener taken from the ten cyclic / seismic tests, when divided by a safety factor of 3.25 determined in accordance with AISI S100 Section F using the statistical values for structural concrete filled diaphragms from the AISI S310 Standard Table E1.2.2-1 Calibration Parameters (see Appendix F), is set at 446 lbs. This is still substantially higher than the 90 lbs specified by ASCE 7-2010. Therefore, it is recommended that for all CFS track thicknesses, a revision to AISI S100-12 Section E5 be developed to more accurately represent the load capacity to a higher shear capacity consistent with the findings of this research program.

The specific proposal for revision to AISI S100-12 Sections E5, E5.3.3 and Commentary is as follows:

E5 Power Actuated Fasteners

The provisions of this section shall apply to *power actuated fasteners* (*PAFs*) that are driven into steel or concrete substrates. If the substrate is steel, the *thickness* of the substrate not in contact with *PAF* head shall be limited to a maximum of 0.75 in. (19 mm). The *thickness* of the substrate in contact with *PAF* head shall be limited to a maximum of 0.06 in. (1.52 mm). The washer diameter shall not exceed 0.6 in. (15 mm) in computations, although the actual diameter may be larger. *Power-actuated fastener* diameter shall be limited to a range of 0.11 in. (2.8 mm) to 0.21 in. (5.3 mm).

E5.3.3 Pull-out Strength [Resistance] in Shear

For *PAFs* driven in steel through a depth of at least $0.6t_2$, the *nominal pull-out strength* [*resistance*] in shear is permitted to be computed in accordance with Eq. E5.3.3-1 and the following *safety factor* and the *resistance factor* shall be applied to determine the *available strength* [*factored resistance*] in accordance with Section A4, A5 or A6:

$$P_{nos} = \frac{d_{ae}^{1.8} t_2^{0.2} \left(F_{y2} E^2\right)^{1/3}}{30} \qquad (Eq.\ E5.3.3\text{-}1)$$

Ω = 2.55 (*ASD*)
ϕ = 0.60 (*LRFD*)
= 0.50 (*LSD*)

Eq. E5.3.3-1 shall apply for *connections* within the following limits:
0.113 in. (2.9 mm) $\leq t_2 \leq$ 3/4 in. (19 mm)
0.106 in. (2.7 mm) $\leq d_s \leq$ 0.206 in. (5.2 mm).

For *PAFs* driven in concrete a minimum embedment depth of 1 in. (25.4 mm), the *nominal pull-out strength* [*resistance*] in shear is permitted to be computed in accordance with Eq. E5.3.3-2, and the following *safety factor* and *resistance factor* shall be applied to determine the *available strength* in accordance with Section A4, A5 or A6:

P_{nos} = 1,450 lbs (6,450 N) (*Eq*. E5.3.3-2)

Ω = 3.25 (*ASD*)
ϕ = 0.50 (*LRFD*)
= 0.40 (*LSD*)

Eq. E5.3.3-2 shall apply for connections within the following limits:
$d_s \geq$ 0.118 in. (3 mm)
$f'_c \geq$ 2.5 ksi (17 MPa)

Change ds >=0.188 in. (3 mm) to
ds >=0.157 in.(3.99 mm)

COMMENTARY

In 2013, provisions were added to Section E5.3.3 for power-actuated fasteners (PAFs) for connection of cold-formed steel (CFS) to concrete base materials. These provisions are based on an experimental study where CFS wall tracks were attached to concrete base materials and subjected to monotonic and cyclic / seismic test loads (AISI Research Report RP13-3). The experimental data demonstrated that residual monotonic shear strength of power-actuated fastener connections after cyclic / seismic loading closely matched the reference monotonic shear strength.

The experimental data further demonstrated that ductile steel failure modes limit the capacity of the connection with thinner cold-formed steel track. Where this failure mode is dominant, the use of AISI S100-12 Section E5.3.2 to determine the capacity of CFS track connection is appropriate. For thicker track, the limit state was shear pull-out of the fastener. The nominal value given by

Section E5.3.3 is considered a lower bound strength based on the concrete strength used in the test program.

REFERENCE
"Report on Laboratory Testing of Fastening of CFS Track to Concrete Base Material with PAFs, AISI Research Report RP13-3."

References

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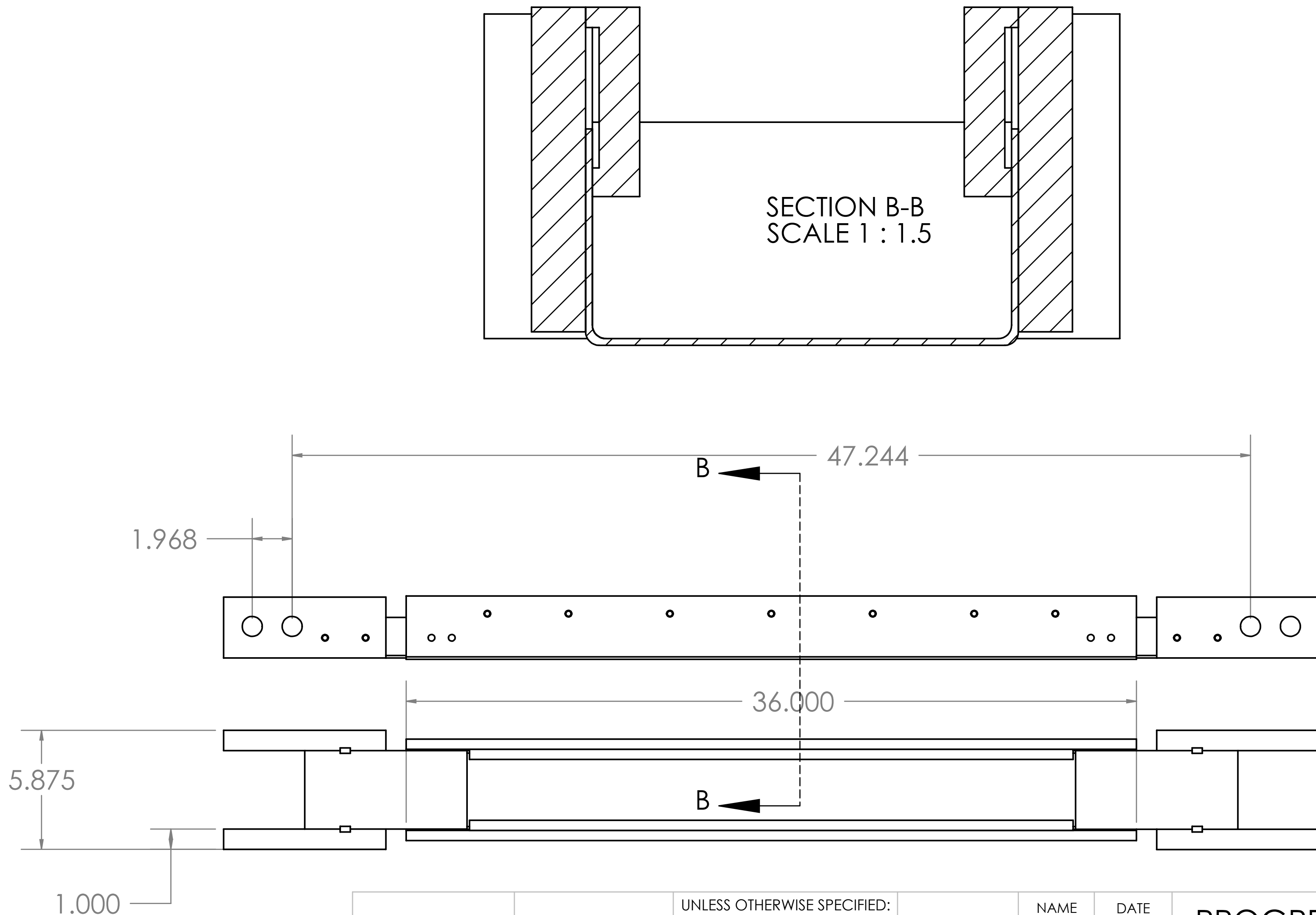
(ICC, 2012), *International Building Code*, International Code Council, Washington, DC, 2012.

(RP10-3, 2010), *Report on Laboratory Testing of Anchor Bolts Connecting Cold-Formed Steel Track to Concrete with Minimum Edge Distances*, American Iron and Steel Institute, Washington, DC, 2010.

Appendix A – Schematic of Test Fixture



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

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TITLE:

SIZE **A** DWG. NO. Assem1 REV

SCALE: 1:12 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

Appendix B – Test Scope with Summary of Results Table

Test Series[4]	Date Tested	CFS Track Nominal Thickness (mils)	CFS Track Web (in)	Track Length	PAF Shank Diameter (in)	Nominal Embedment (in)	Spacing (in)	No. of PAF	Load Type	CFS Track Tested Thickness (in)	CFS Track Tested Strength[2] (psi)	Predicted Bearing Strength[3] (lbs)	Sample No.	Avg. PAF Embedment (in)	V_{ult} (lbs)	.40 V_{ult} (lbs)	V_{res} (lbs)	$P_{tested}/P_{computed}$	$P_{fastener}$ (lbs)	Failure Mode[1]
1	7/3/2013	33	3-5/8"	4'-0"	0.157	1	12	4	Monotonic	0.02	102466	2492	1	n/a	2969	-	-	1.19	742	Shear Bearing of CFS Track at all four PAF
													2	n/a	3041	-	-	1.22	760	Shear Bearing of CFS Track at all four PAF
3	7/8/13-7/9/13	33	3-5/8"	4'-0"	0.157	1	12	4	Cyclic	0.02	102466	2492	1	0.882	-	1202	2109	0.85	527	Shear Bearing of CFS Track at PAF #1,3,4; PAF #2 tilting / pullout
													2	0.860	-	1202	1731	0.69	433	Shear Bearing of CFS Track at all four PAF
2	7/10/2013	33	3-5/8"	8'-0"	0.157	1	12	8	Monotonic	0.02	102466	4984	1	0.882	4256	-	-	0.85	532	Shear Bearing of CFS Track at PAF #2-8; PAF #1 tilting / pull out
													2	0.914	4543	-	-	0.91	568	Shear Bearing of CFS Track at PAF #1-3,5-8; PAF # 4 tilting / pull out
3a	7/11/2013	33	3-5/8"	8'-0"	0.157	1	12	8	Cyclic	0.02	102466	4984	1	0.773	-	1760	3983	0.80	498	Shear Bearing of CFS Track at all eight PAF
													2	0.919	-	1760	3817	0.77	477	Shear Bearing of CFS Track at all eight PAF
3b	7/15/13 - 7/16/13	33	3-5/8"	4'-0"	0.157 w/ 15 mm washer	1	12	4	Cyclic	0.02	102466	2492	1	0.805	-	1202	4093	1.64	1023	Shear Bearing of CFS Track at PAF #1; PAF #2,3,4 tilting/pullout
													2	0.846	-	1202	3823	1.53	956	Shear Bearing of CFS Track at PAF # 1,4; PAF #2,3 tiliting/pullout
6	7/16/2013	33	3-5/8"	4'-0"	0.118	1	12	4	Monotonic	0.02	102466	1873	1	0.905	2370	-	-	1.27	593	Shear Bearing of CFS Track at PAF #2,4; PAF #1,3 tilting/pullout
7	7/16/13 - 7/17/13	33	3-5/8"	4'-0"	0.118	1	12	4	Cyclic	0.02	102466	1873	1	0.844	-	948	2454	1.31	614	Shear Bearing of CFS Track at all four PAF
													2	0.873	-	948	1935	1.03	484	Shear Bearing of CFS Track at all four PAF
10	8/8/2013	68	6"	4'-0"	0.157	1	12	4	Monotonic	0.069	79567	11033	1	0.904	3713	-	-	0.34	928	Tilting/pullout on all PAF
11	8/20/13 - 8/21/13	68	6"	4'-0"	0.157	1	12	4	Cyclic	0.069	79567	11033	1	0.898	-	1485	5107	0.46	1277	Tilting/pullout on all PAF
													2	0.885	-	1485	5137	0.47	1284	Tilting/pullout on all PAF
12	8/8/2013	68	6"	4'-0"	0.157	1.25	12	4	Monotonic	0.069	79567	11033	1	1.157	4977	-	-	0.45	1244	Tilting/pullout on all PAF
13	8/19/13 - 8/20/13	68	6"	4'-0"	0.157	1.25	12	4	Cyclic	0.069	79567	11033	1	1.039	-	1991	4438	0.40	1110	Tilting/pullout on all PAF
													2	1.137	-	1991	6303	0.57	1576	Tilting/pullout on all PAF
14	8/9/2013	54	3-5/8"	4'-0"	0.157	1	12	4	Monotonic	0.059	84567	10027	1	0.937	6228	-	-	0.62	1557	Tilting/pullout on all PAF
15	8/12/2013	54	3-5/8"	4'-0"	0.157	1.25	12	4	Monotonic	0.059	84567	10027	1	1.171	7830	-	-	0.78	1958	Tilting/pullout on all PAF
16	8/9/2013	43	3-5/8"	4'-0"	0.157	1	12	4	Monotonic	0.045	60533	5474	1	0.940	5289	-	-	0.97	1322	Tilting/pullout on all PAF with Minimal Shear Bearing of CFS Track
17	8/12/2013	43	3-5/8"	4'-0"	0.157	1.25	12	4	Monotonic	0.045	60533	5474	1	1.292	6733	-	-	1.23	1683	Tilting/pulled under on all PAF
													2	1.163	4600	-	-	0.84	1150	Tilting/pullout on PAF#1,2,4; PAF 3 Tilting/pulled under
18	8/19/2013	43	3-5/8"	4'-0"	0.157	1.25	12	4	Cyclic	0.045	60533	5474	1	1.183	-	2267	5774	1.05	1444	Initial Shear Bearing of CFS Track at PAF #1,4; PAF #2,3 tilting/pullout
													2	1.183	-	2267	5385	0.98	1346	Initial Shear Bearing of CFS Track at PAF #3; PAF #1,2,4 tilting/pullout
19	8/21/2013	68	6"	4'-0"	0.157	1.25	6	8	Monotonic	0.069	79567	22066	1	1.182	12375	-	-	0.56	1547	Tilting/pullout on all PAF
20	8/21/2013	68	6"	4'-0"	0.157	1.25	6	8	Cyclic	0.069	79567	22066	1	1.192	-	4950	13185	0.60	1648	Tilting/pullout on all PAF
													2	1.177	-	4950	14475	0.66	1809	Tilting/pullout on all PAF
21[5]	8/22/2013	68	6"	4'-0"	0.157	0.63	12	4	Monotonic	0.069	79567	11033	1	0.480	11621	-	-	1.05	2905	Tilting/pullout on all PAF
22[5]	8/22/2013	68	6"	4'-0"	0.157	0.63	12	4	Cyclic	0.069	79567	11033	1	0.450	-	4649	11600	1.05	2900	Tilting/pullout on all PAF
													2	0.430	-	4649	10301	0.93	2575	Tilting/pullout on all PAF
23	8/26/2013	43	3-5/8"	4'-0"	0.157	1.25	6	8	Monotonic	0.045	60533	10948	1	1.191	13533	-	-	1.24	1692	Shear Bearing of CFS Track at PAF #1,5,6,7,8; PAF #2,3,4 tilting/pullout
24	8/27/2013	54	3-5/8"	4'-0"	0.157	1.25	6	8	Monotonic	0.059	84567	20054	1	1.162	11115	-	-	0.55	1389	Tilting/pullout on all PAF
25	8/27/2013	43	3-5/8"	4'-0"	0.157	1.25	6	8	Cyclic	0.045	60533	10948	1	1.170	-	5413	12038	1.10	1505	Shear Bearing of CFS Track at PAF #4,5,6,7,8; PAF #1, 2,3 tilting/pullout
													2	1.204	-	5413	12016	1.10	1502	Shear Bearing of CFS Track at PAF #2,6,8; PAF #1,3,4,5,7 tilting/pullout

Notes:

1. Fasteners were numbered in the same order for all tests. # 1 is fastener located closest to the loading ram and the remainder are numbered with respect to this.
2. Tested CFS Track Strength is obtained from material test reports (refer to Attachments in Appendix E)
3. Predicted Bearing Strength is calculated per AISI-S100 (E5.3.2): $P_{nbp}=\alpha_b*d_s*t*Fu$

   Where: α_b=3.2

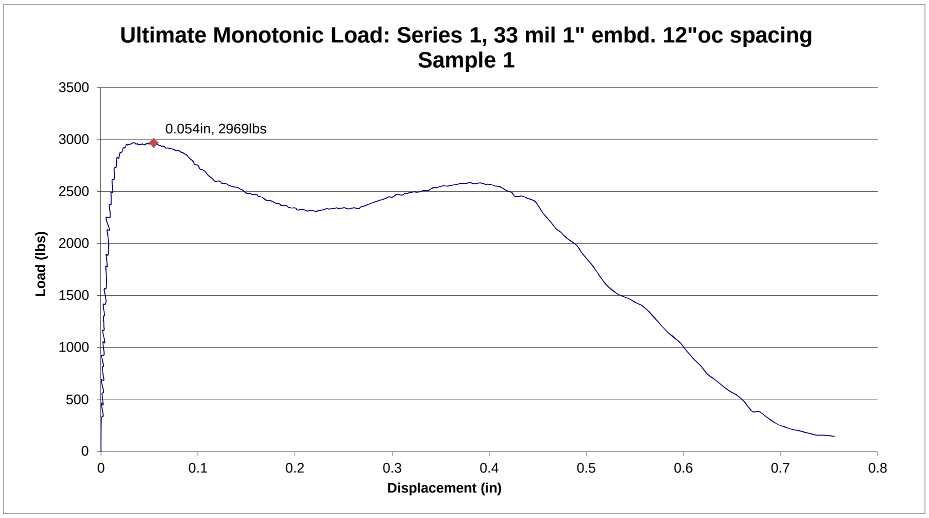
   d_s=shank diameter (in)

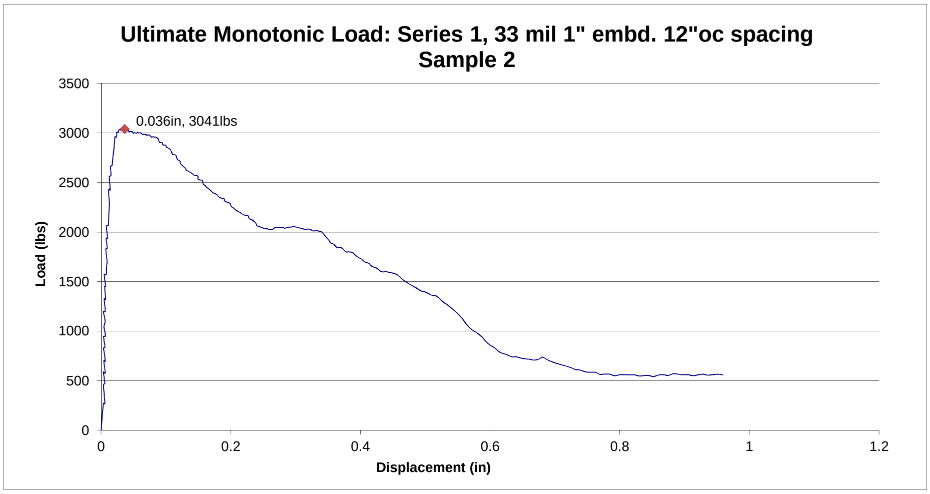
   t=track tested thickness (in)

   F_u=track tested strength (psi) (F_u is taken as 75% of the specified minimum tensile strength or 62 ksi, whichever is less for 33 mil CFS track)
4. Test performed with Normal Strength Concrete (f'_c=2500psi as specified) as base material unless otherwise noted.
5. Test performed with ASTM A36 Steel Plate as base material.

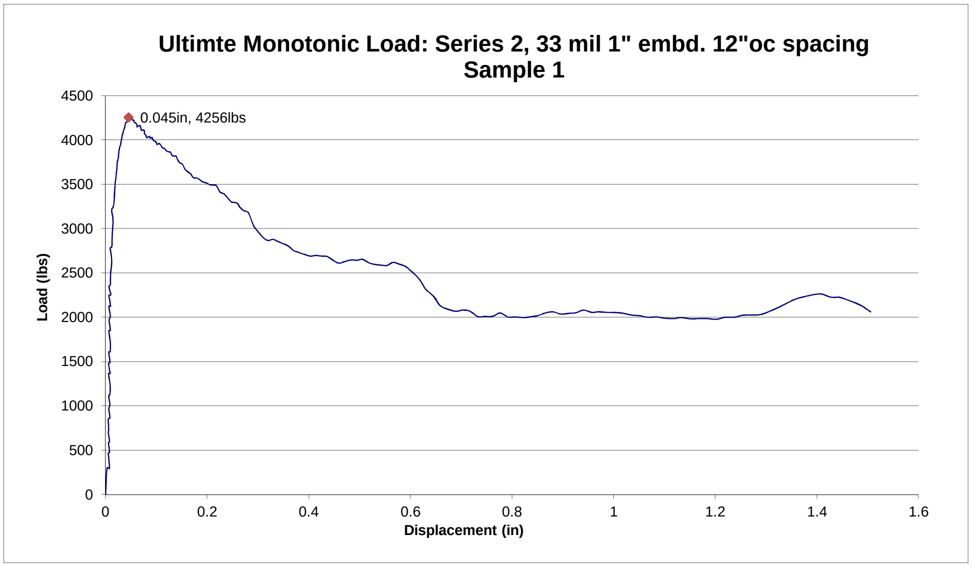
Appendix C – Monotonic Test Results

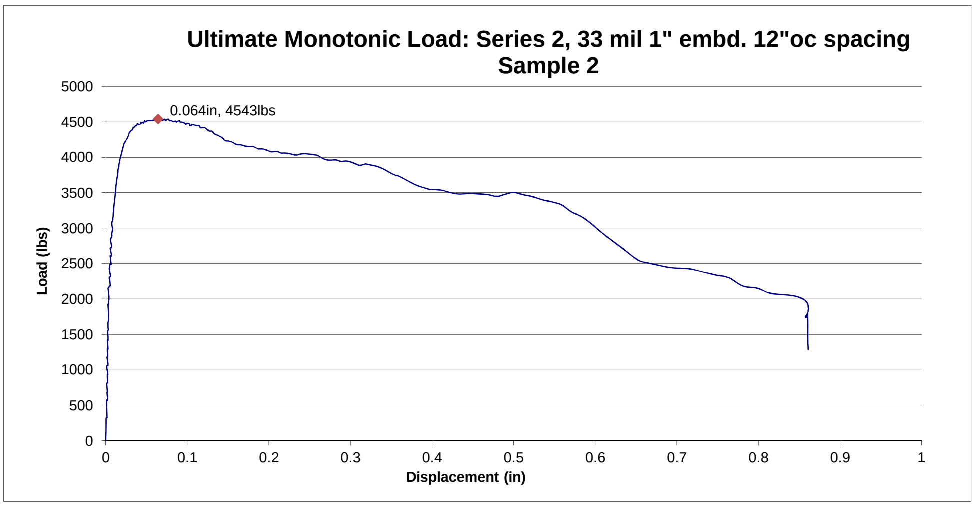
AISI Project-Monotonic Load Graph							7/3/2013
TEST PARAMETERS				Track Length (ft)	4	Embedment	1.00"
Test Series	**1**	Min. Yield Strength (50 KSI)	50	PAF spacing (in)	12	Avg. concrete strgth. (psi)	2,550
Track Thick. (mils)	33	Track width (3-5/8 or 6 in.)	3 5/8	No. of PAF	4	Teflon used?	Yes
Track Ga.	20	Loading protocol	monotonic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1



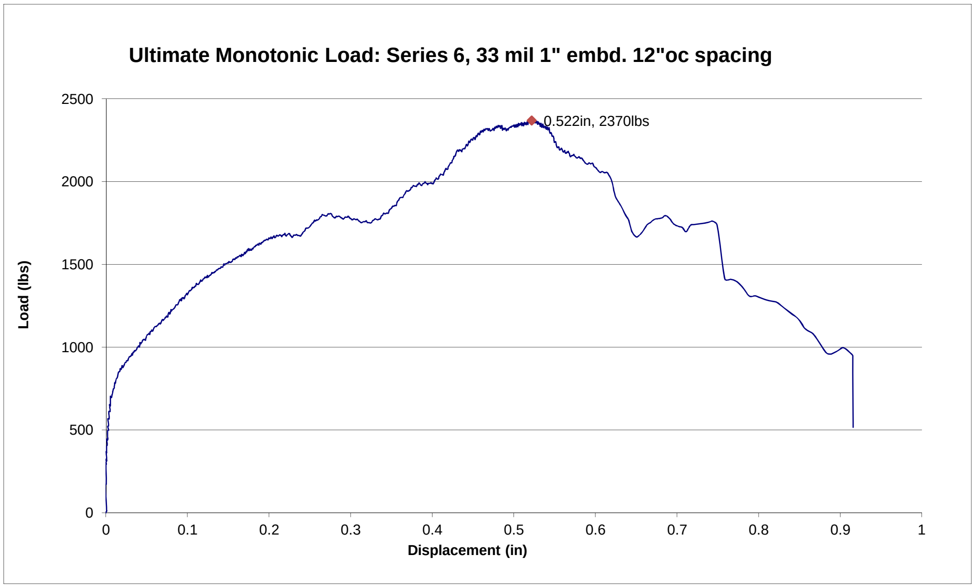


AISI Project-Monotonic Load Graph							7/10/2013
TEST PARAMETERS				Track Length (ft)	8	Embedment	1.00"
Test Series	2	Min. Yield Strength (50 KSI)	50	PAF spacing (in)	12	Avg. concrete strgth. (psi)	2,550
Track Thick. (mils)	33	Track width (3-5/8 or 6 in.)	3 5/8	No. of PAF	8	Teflon used?	Yes
Track Ga.	20	Loading protocol	monotonic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1

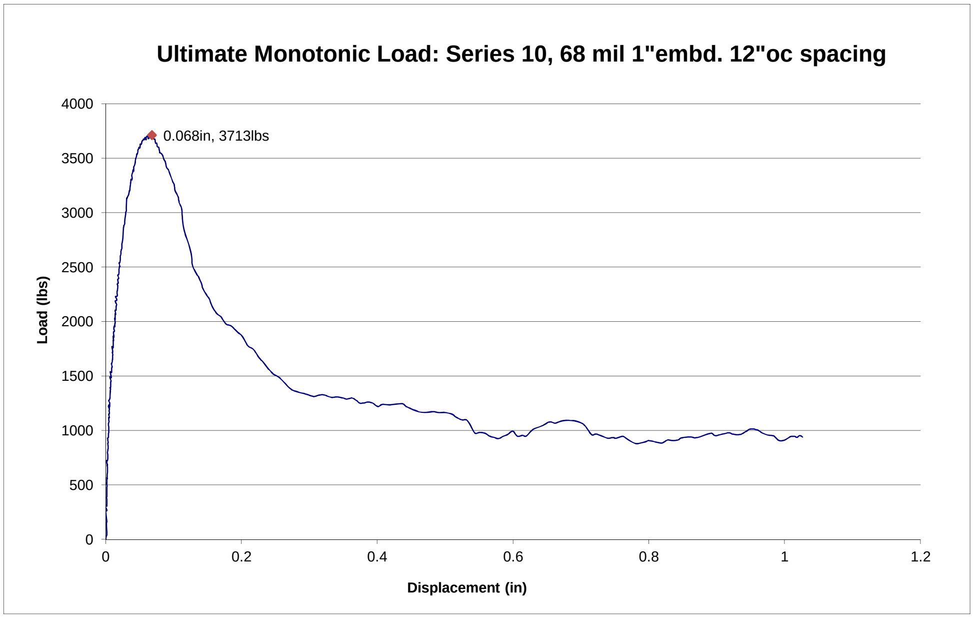




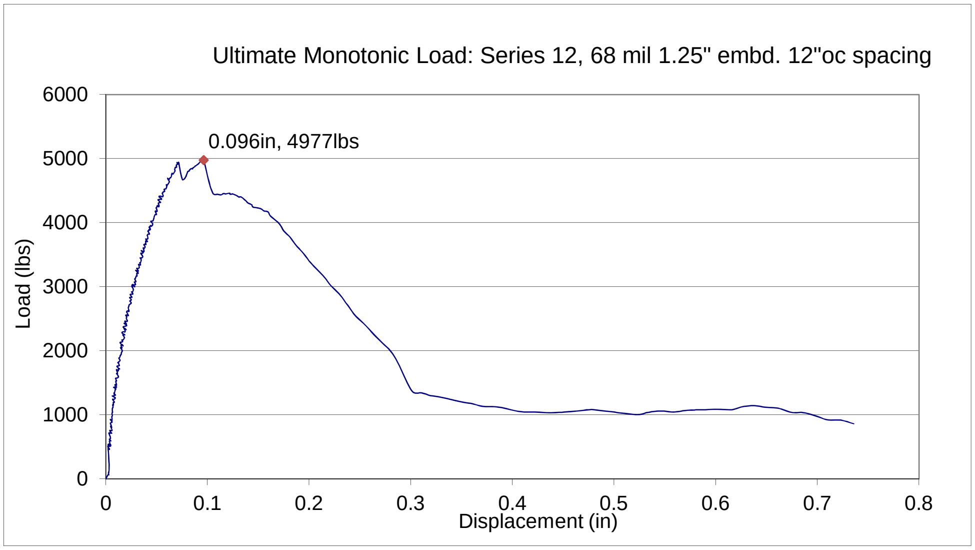
AISI Project-Monotonic Load Graph								7/16/2013
TEST PARAMETERS				Track Length (ft)	4	Embedment	1.00"	
Test Series	6	Min. Yield Strength (50 KSI)	50	PAF spacing (in)	12	Avg. concrete strgth. (psi)	2,550	
Track Thick. (mils)	33	Track width (3-5/8 or 6 in.)	3 5/8	No. of PAF	4	Teflon used?	Yes	
Track Ga.	20	Loading protocol	monotonic	PAF dia. (in)	0.118	Cyclic frequency (Hz)	0.1	



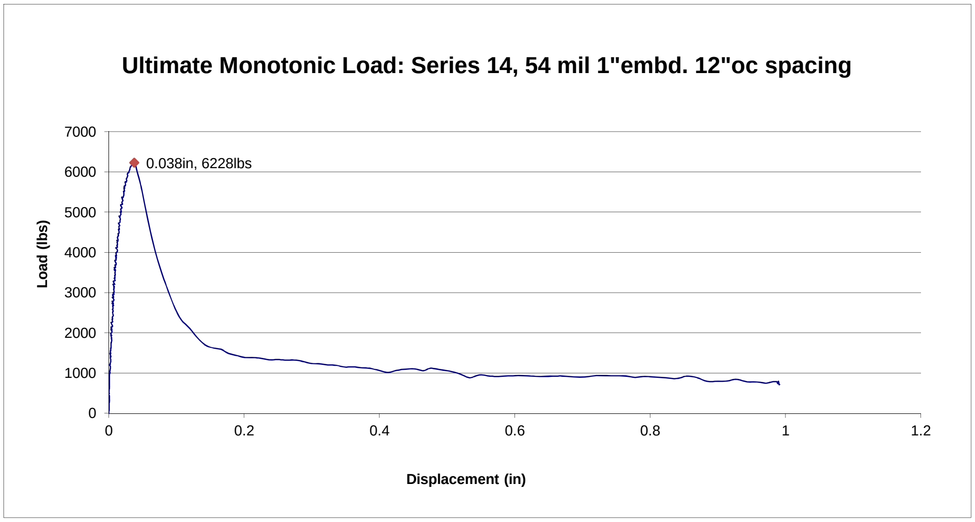
AISI Project-Monotonic Load Graph							8/8/2013
TEST PARAMETERS				Track Length (ft)	4	Embedment	1"
Test Series	**10**	Min. Yield Strength (50 KSI)	50	PAF spacing (in)	12	Avg. concrete strgth. (psi)	2,550
Track Thick. (mils)	68	Track width (3-5/8 or 6 in.)	6	No. of PAF	4	Teflon used?	Yes
Track Ga.	14	Loading protocol	monotonic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1



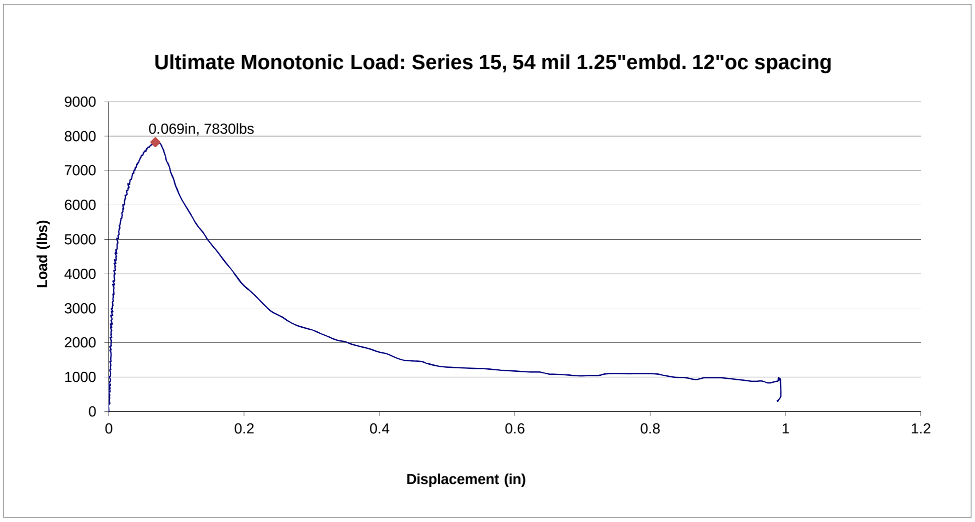
AISI Project-Monotonic Load Graph								8/8/2013
TEST PARAMETERS				Track Length (ft)	4	Embedment	1.25"	
Test Series	**12**	Min. Yield Strength (50 KSI)	50	PAF spacing (in)	12	Avg. concrete strgth. (psi)	2,550	
Track Thick. (mils)	68	Track width (3-5/8 or 6 in.)	6	No. of PAF	4	Teflon used?	Yes	
Track Ga.	14	Loading protocol	monotonic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1	



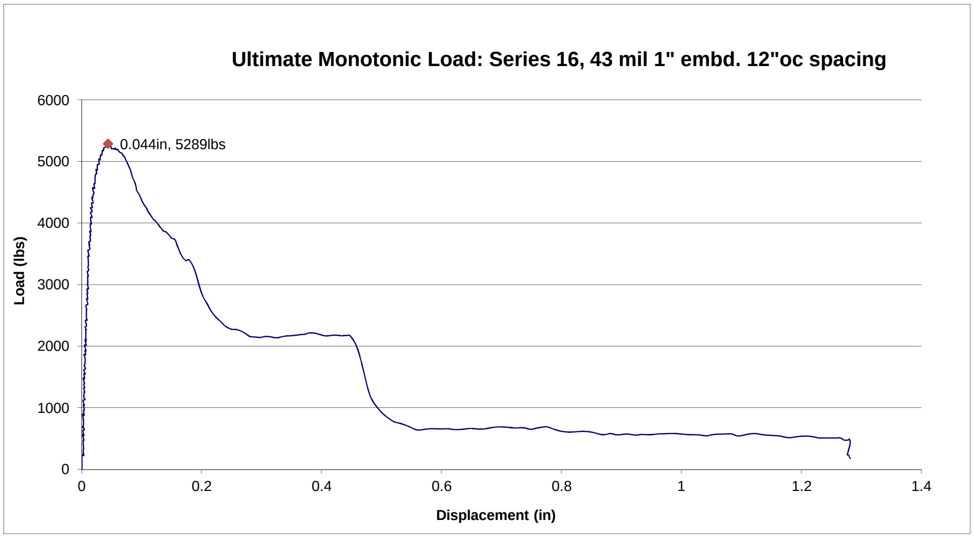
AISI Project-Monotonic Load Graph								8/9/2013
TEST PARAMETERS				Track Length (ft)	4	Embedment	1.00"	
Test Series	**14**	Min. Yield Strength (50 KSI)	50	PAF spacing (in)	12	Avg. concrete strgth. (psi)	2,550	
Track Thick. (mils)	54	Track width (3-5/8 or 6 in.)	3 5/8	No. of PAF	4	Teflon used?	Yes	
Track Ga.	16	Loading protocol	monotonic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1	



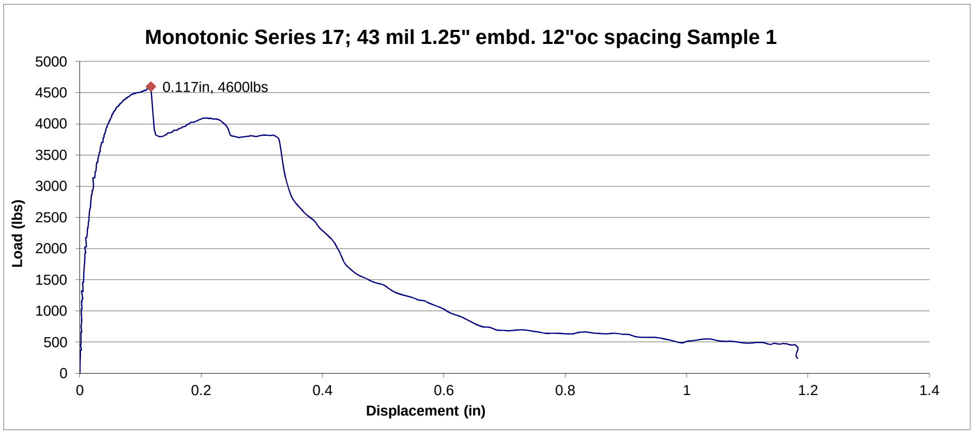
AISI Project-Monotonic Load Graph								8/12/2013
TEST PARAMETERS				Track Length (ft)	4	Embedment	1.25"	
Test Series	**15**	Min. Yield Strength (50 KSI)	50	PAF spacing (in)	12	Avg. concrete strgth. (psi)	2,550	
Track Thick. (mils)	54	Track width (3-5/8 or 6 in.)	3 5/8	No. of PAF	4	Teflon used?	Yes	
Track Ga.	16	Loading protocol	monotonic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1	

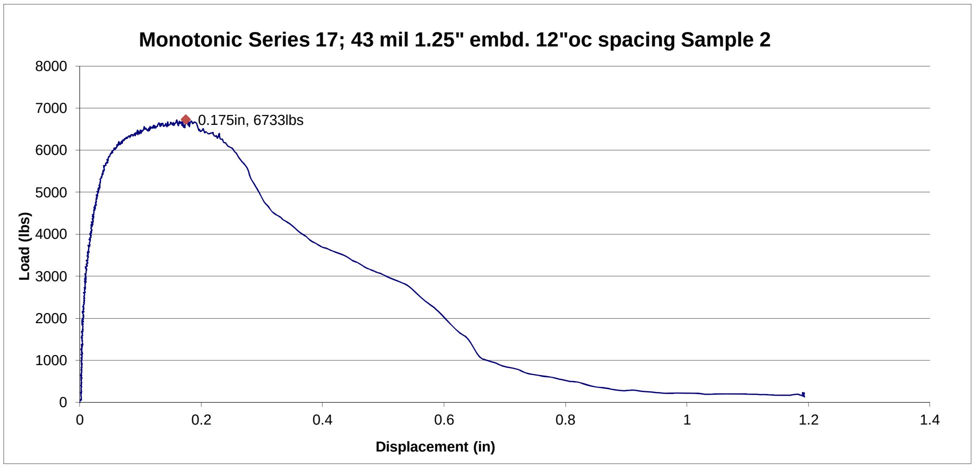


AISI Project-Monotonic Load Graph								8/9/2013
TEST PARAMETERS				Track Length (ft)	4	Embedment	1.00"	
Test Series	**16**	Min. Yield Strength (50 KSI)	50	PAF spacing (in)	12	Avg. concrete strgth. (psi)	2,550	
Track Thick. (mils)	43	Track width (3-5/8 or 6 in.)	3 5/8	No. of PAF	4	Teflon used?	Yes	
Track Ga.	18	Loading protocol	monotonic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1	

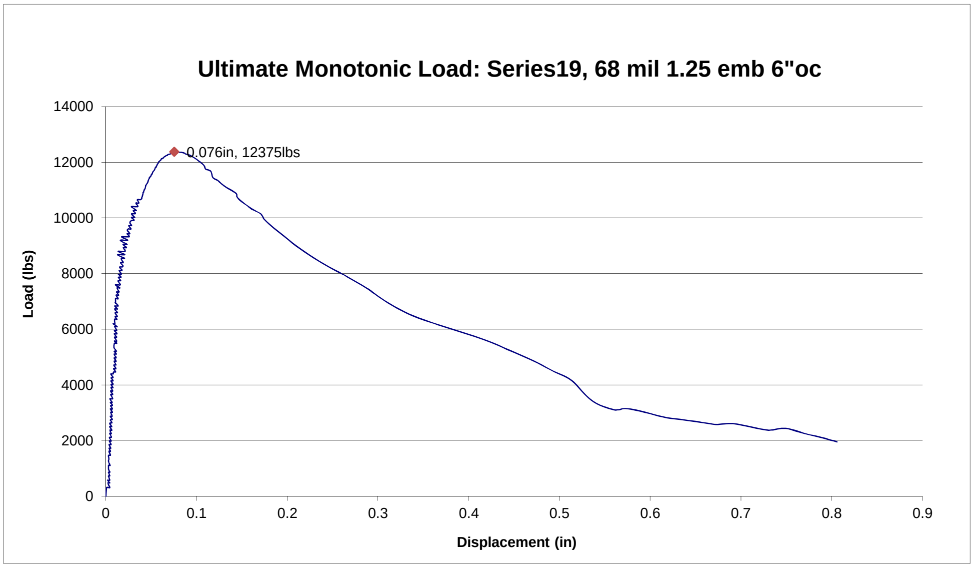


AISI Project-Monotonic Load Graph								8/12/2013
TEST PARAMETERS				Track Length (ft)	4	Embedment	1.25"	
Test Series	**17**	Min. Yield Strength (50 KSI)	50	PAF spacing (in)	12	Avg. concrete strgth. (psi)	2,550	
Track Thick. (mils)	43	Track width (3-5/8 or 6 in.)	3 5/8	No. of PAF	4	Teflon used?	Yes	
Track Ga.	18	Loading protocol	monotonic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1	

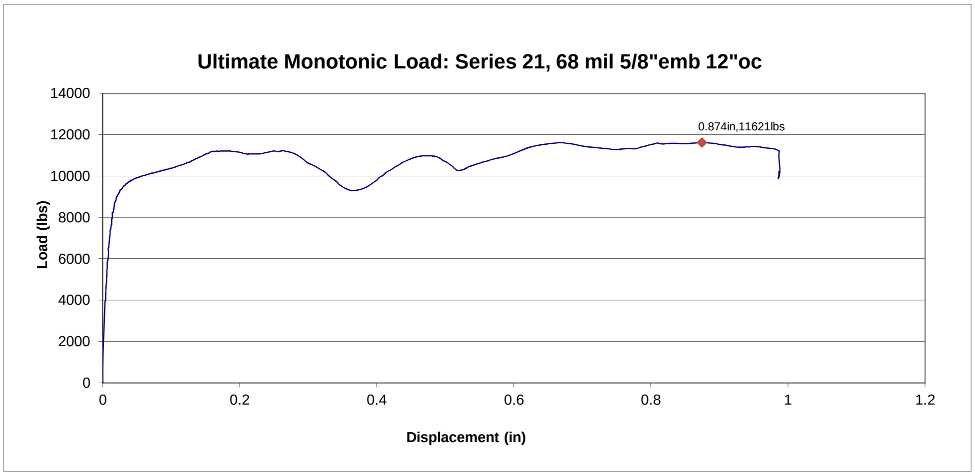




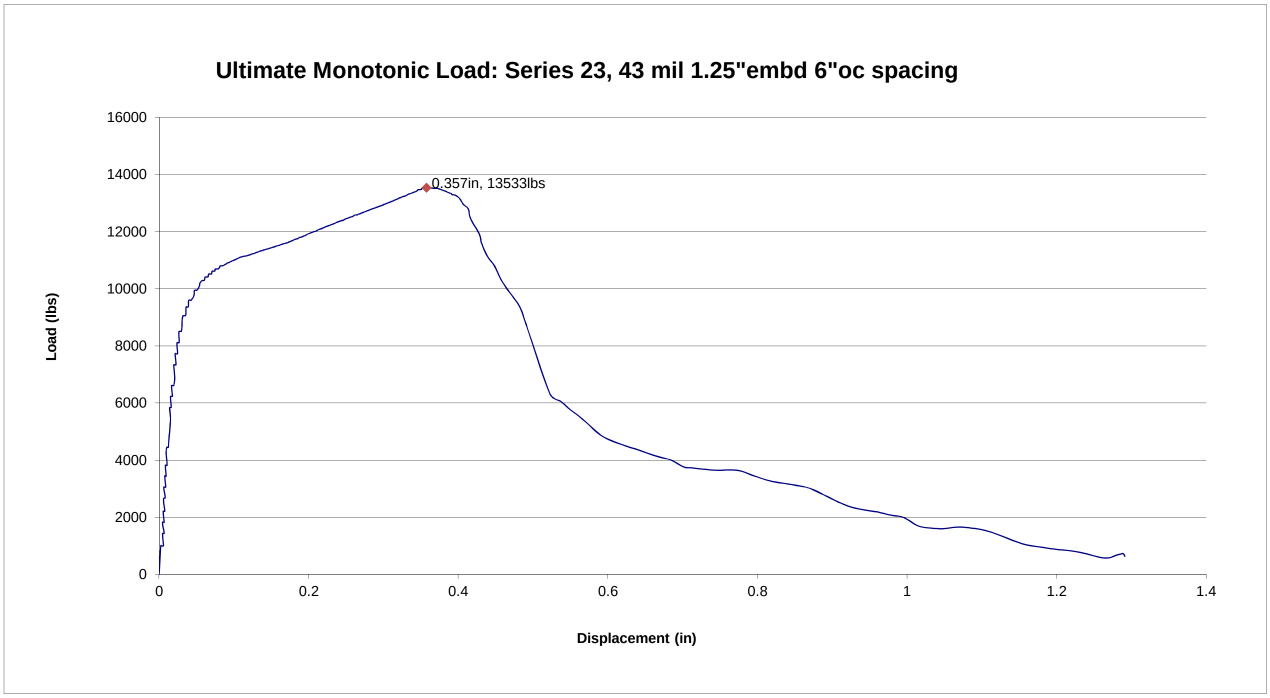
AISI Project-Monotonic Load Graph								8/21/2013
TEST PARAMETERS				Track Length (ft)	4	Embedment	1.25"	
Test Series	**19**	Min. Yield Strength (50 KSI)	50	PAF spacing (in)	6	Avg. concrete strgth. (psi)	2,550	
Track Thick. (mils)	68	Track width (3-5/8 or 6 in.)	6	No. of PAF	8	Teflon used?	Yes	
Track Ga.	14	Loading protocol	monotonic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1	



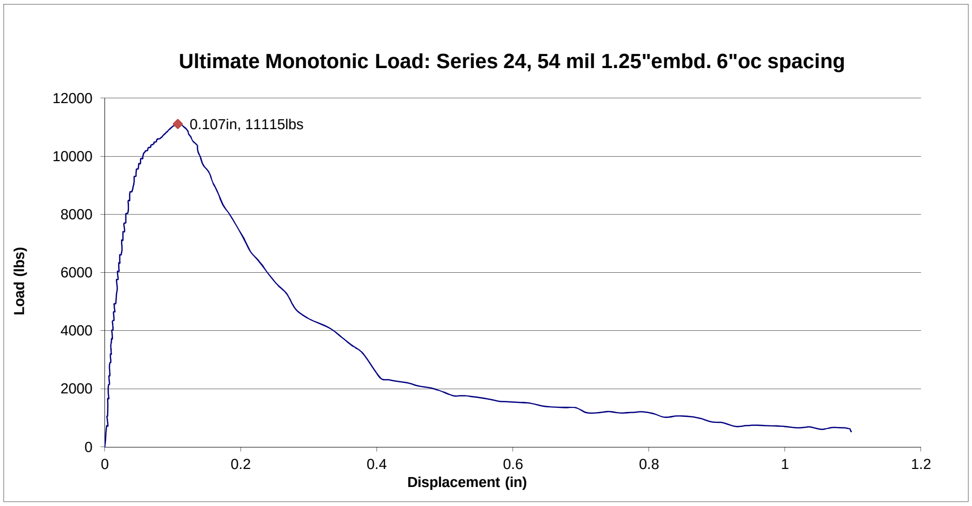
AISI Project-Monotonic Load Graph								8/22/2013
TEST PARAMETERS				Track Length (ft)	4	Embedment	.625"	
Test Series	**21**	Min. Yield Strength (50 KSI)	50	PAF spacing (in)	12	Avg. concrete strgth. (psi)	2,550	
Track Thick. (mils)	68	Track width (3-5/8 or 6 in.)	6	No. of PAF	4	Teflon used?	Yes	
Track Ga.	14	Loading protocol	monotonic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1	



AISI Project-Monotonic Load Graph								8/26/2013
TEST PARAMETERS				Track Length (ft)	4	Embedment	1.25"	
Test Series	**23**	Min. Yield Strength (50 KSI)	50	PAF spacing (in)	6	Avg. concrete strgth. (psi)	2,550	
Track Thick. (mils)	43	Track width (3-5/8 or 6 in.)	3 5/8	No. of PAF	8	Teflon used?	Yes	
Track Ga.	18	Loading protocol	monotonic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1	



AISI Project-Monotonic Load Graph							8/27/2013
TEST PARAMETERS				Track Length (ft)	4	Embedment	1.25"
Test Series	**24**	Min. Yield Strength (50 KSI)	50	PAF spacing (in)	6	Avg. concrete strgth. (psi)	2,550
Track Thick. (mils)	54	Track width (3-5/8 or 6 in.)	3 5/8	No. of PAF	8	Teflon used?	Yes
Track Ga.	16	Loading protocol	monotonic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1



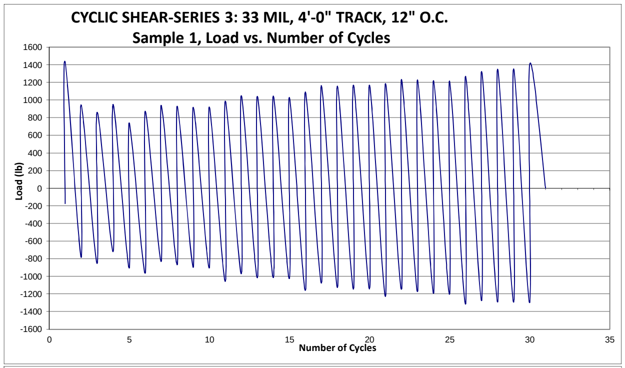
Appendix D – Cyclic / Seismic Test Results

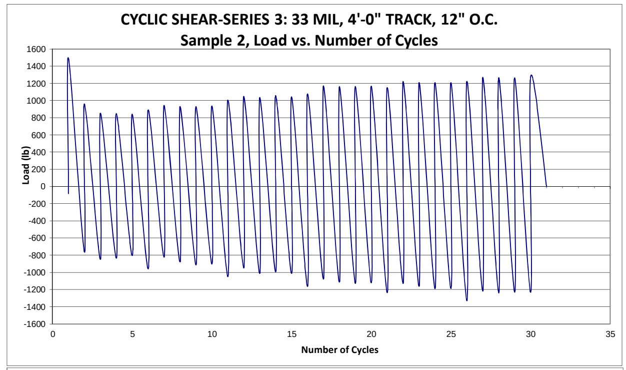
AISI Project-Cyclic Test Load Graphs — **7/8/13-7/9/13**

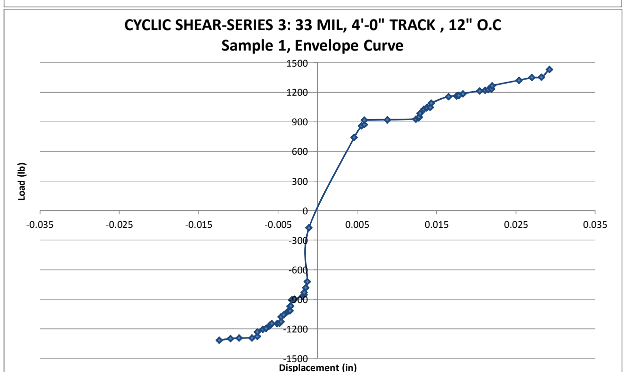
TEST PARAMETERS				Track Length (ft)	4	Nominal Embedment	1.00"
Test Series	**3**	Min. Yield Strength (50 KSI)	50	PAF Spacing (in)	12	Teflon used?	Yes
Track Thick. (mils)	33	Track width (3-5/8 or 6 in.)	3-5/8"	No. of PAF	4	Avg. concrete strgth. (psi)	2,550
Track Ga.	20	Loading protocol	cyclic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1
5 ea.cyclic loads @ approx. 67, 75, 85, 95, 100, 110% of 1202lbs							

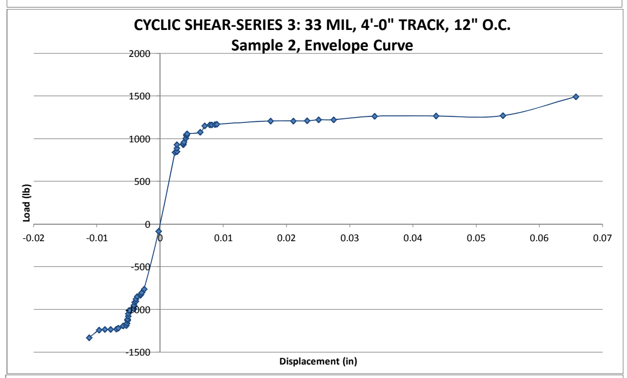
Sample 1:

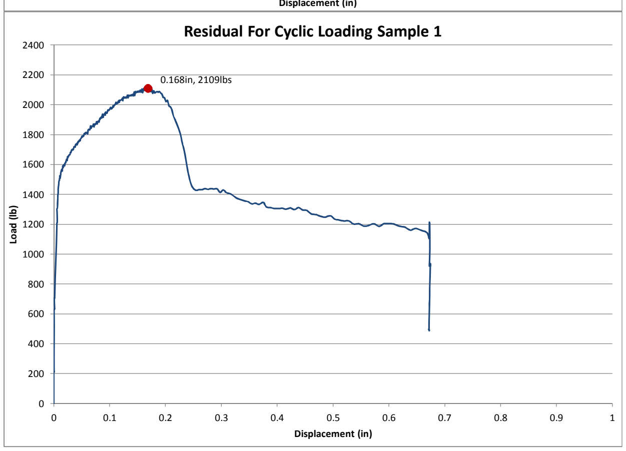
Sample 2:

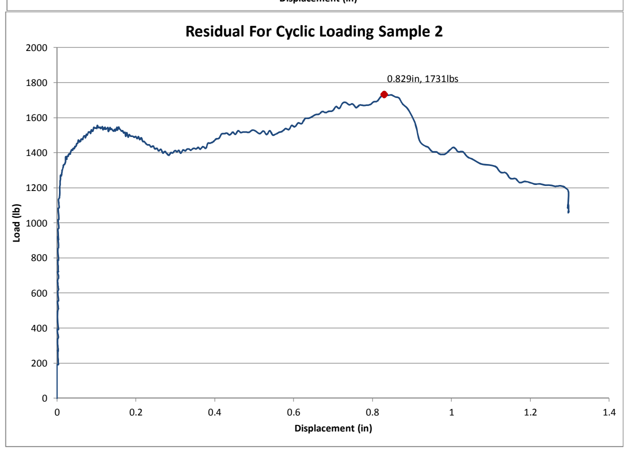






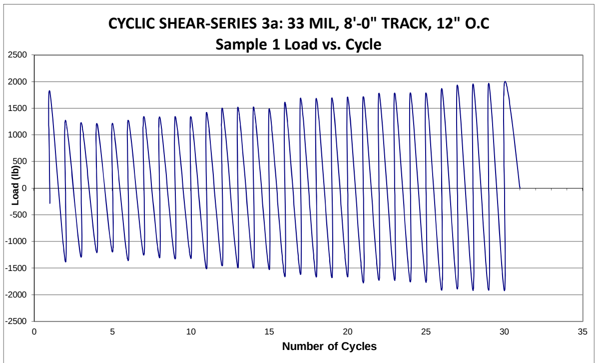


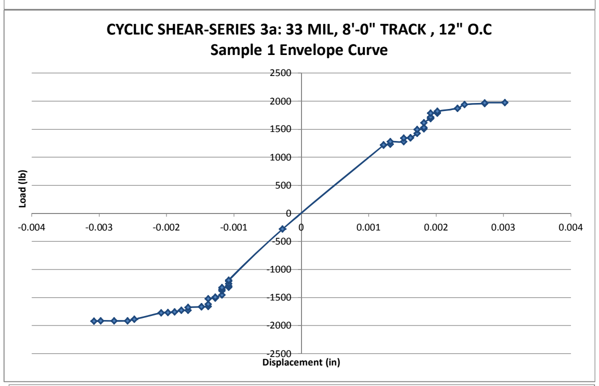


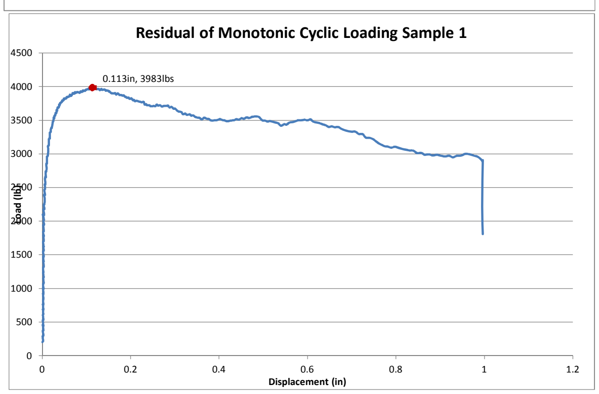


AISI Project-Cyclic Test Load Graphs							7/11/2013
TEST PARAMETERS				Track Length (ft)	8	Nominal Embedment	1.00"
Test Series	**3a**	Min. Yield Strength (50 KSI)	50	PAF Spacing (in)	12	Teflon used?	Yes
Track Thick. (mils)	33	Track width (3-5/8 or 6 in.)	3-5/8"	No. of PAF	4	Avg. concrete strgth. (psi)	2,550
Track Ga.	20	Loading protocol	cyclic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1
5 ea.cyclic loads @ approx. 67, 75, 85, 95, 100, 110% of 1760lbs							

Sample 1:







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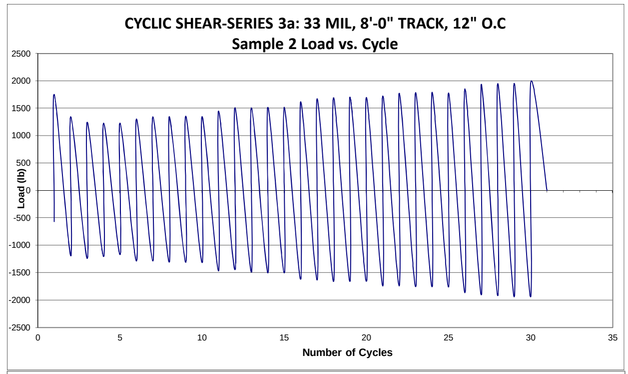
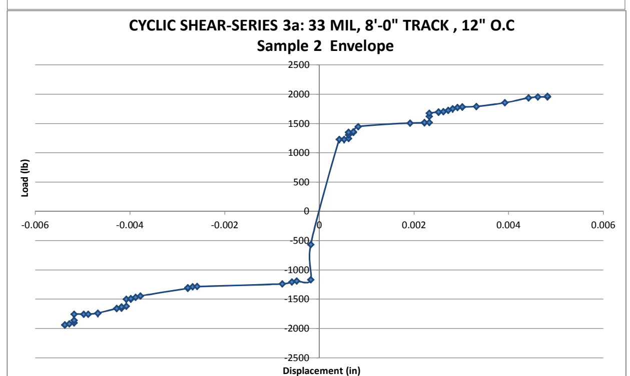
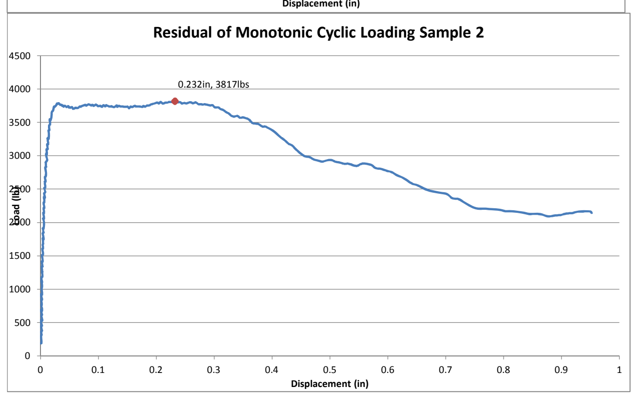


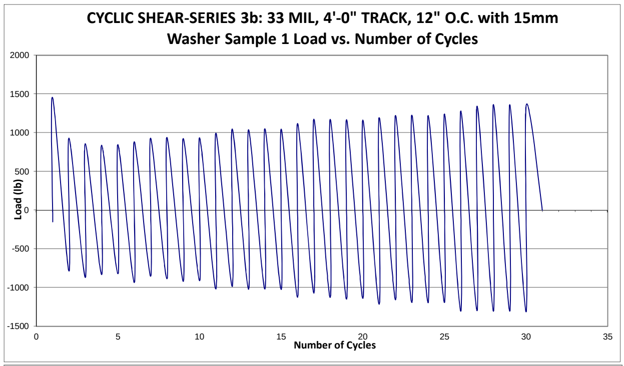


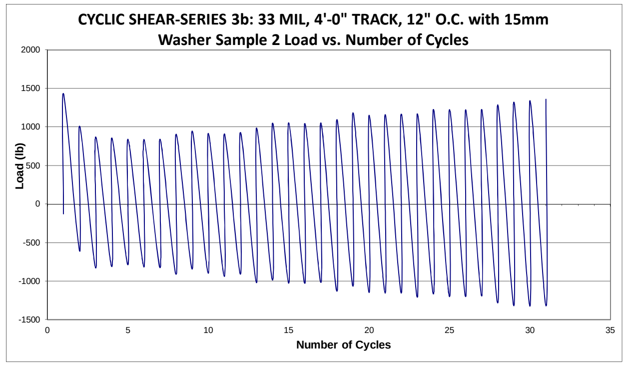


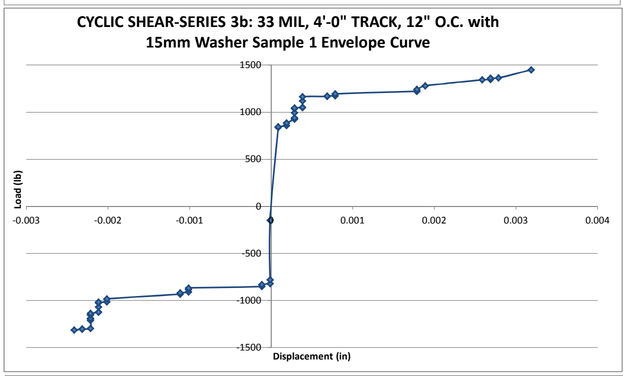
AISI Project-Cyclic Test Load Graphs							7/15/13-7/16/13
TEST PARAMETERS				Track Length (ft)	4	Nominal Embedment	1.00"
Test Series	3b	Min. Yield Strength (50 KSI)	50	PAF Spacing (in)	12	Teflon used?	Yes
Track Thick. (mils)	33	Track width (3-5/8 or 6 in.)	3-5/8"	No. of PAF	4	Avg. concrete strgth. (psi)	2,550
Track Ga.	20	Loading protocol	cyclic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1
5 ea.cyclic loads @ approx. 67, 75, 85, 95, 100, 110% of 1202bs							

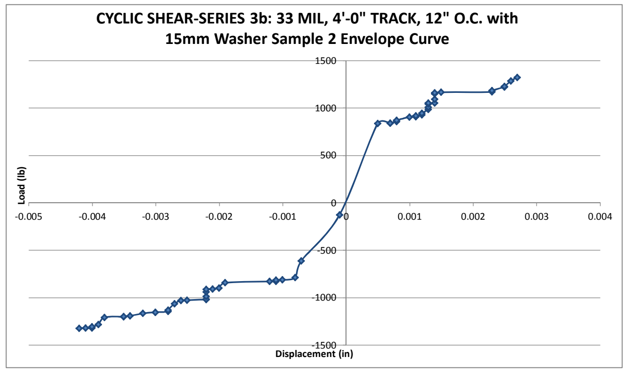
Sample 1:

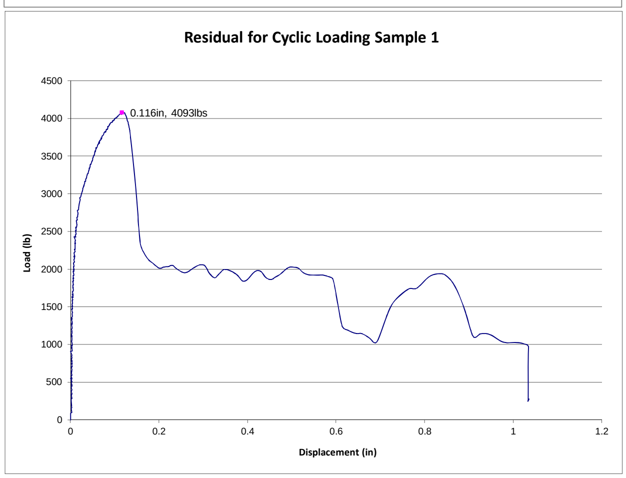
Sample 2:

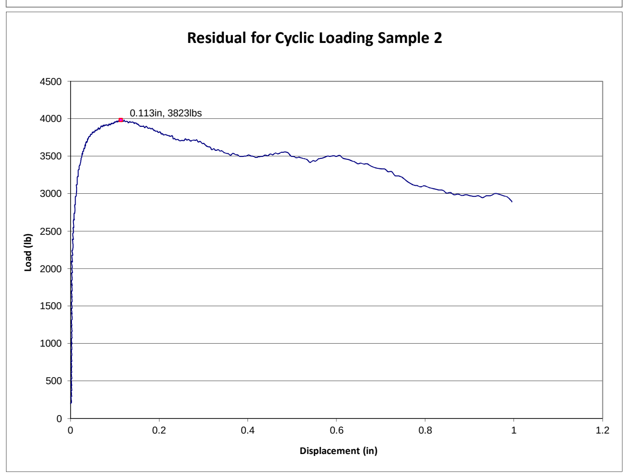






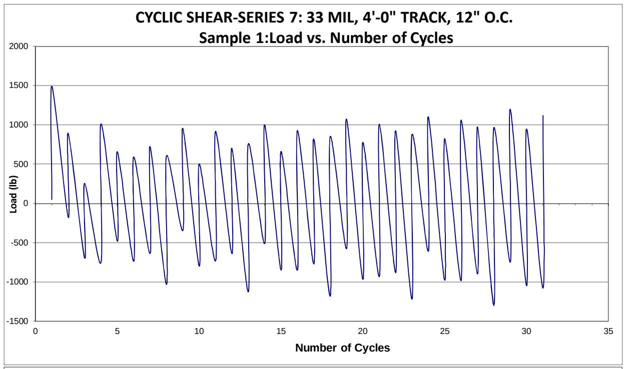


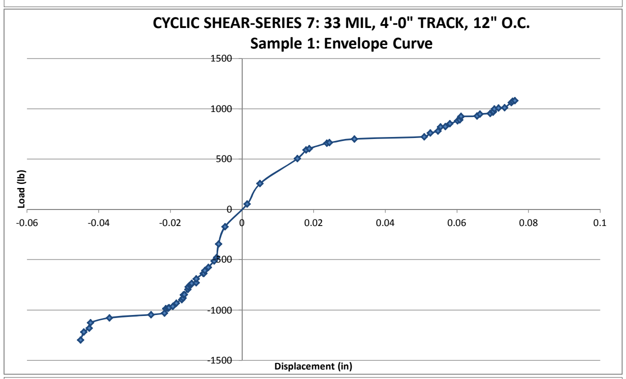


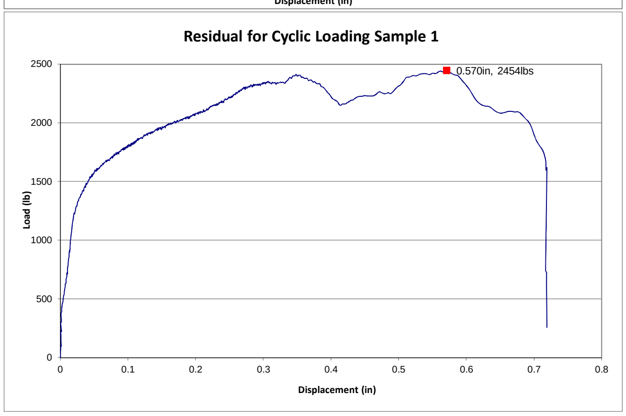


AISI Project-Cyclic Test Load Graphs							**7/16/13-7/17/13**
TEST PARAMETERS				Track Length (ft)	4	Nominal Embedment	1.00"
Test Series	**7**	Min. Yield Strength (50 KSI)	50	PAF Spacing (in)	12	Teflon used?	Yes
Track Thick. (mils)	33	Track width (3-5/8 or 6 in.)	3-5/8"	No. of PAF	4	Avg. concrete strgth. (psi)	2,550
Track Ga.	20	Loading protocol	cyclic	PAF dia. (in)	0.118	Cyclic frequency (Hz)	0.1
5 ea.cyclic loads @ approx. 67, 75, 85, 95, 100, 110% of 948lbs							

Sample 1:







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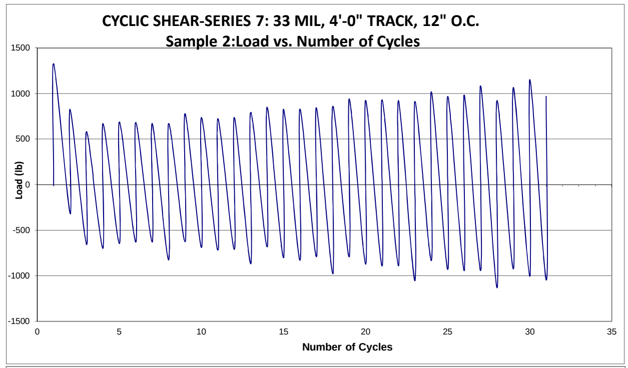
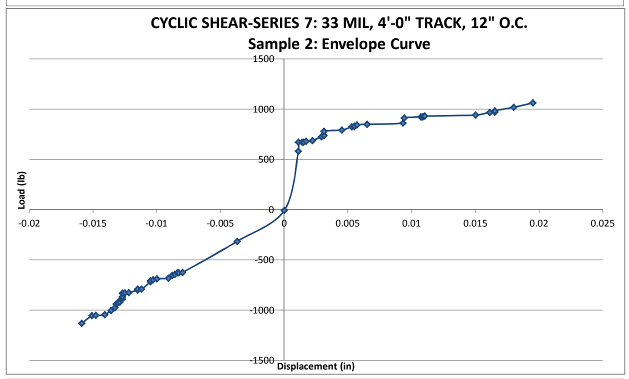
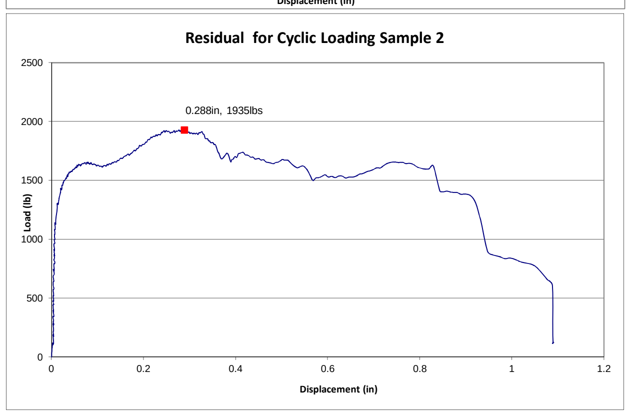
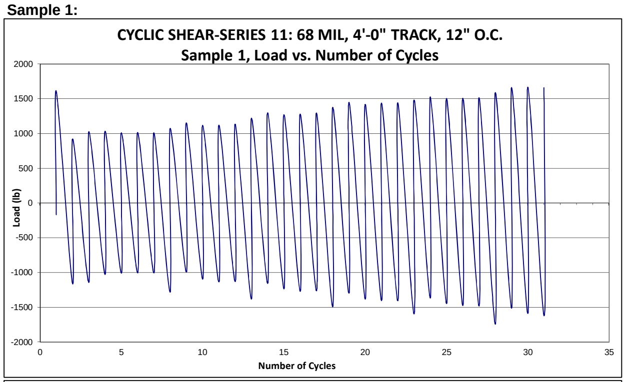






AISI Project-Cyclic Test Load Graphs							8/20/13-8/21/13
TEST PARAMETERS				Track Length (ft)	4	Nominal Embedment	1"
Test Series	11	Min. Yield Strength (50 KSI)	50	PAF Spacing (in)	12	Teflon used?	Yes
Track Thick. (mils)	68	Track width (3-5/8 or 6 in.)	6	No. of PAF	4	Avg. concrete strgth. (psi)	2,550
Track Ga.	14	Loading protocol	cyclic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1
5 ea.cyclic loads @ approx. 67, 75, 85, 95, 100, 110% of 1485lbs							

Sample 1:



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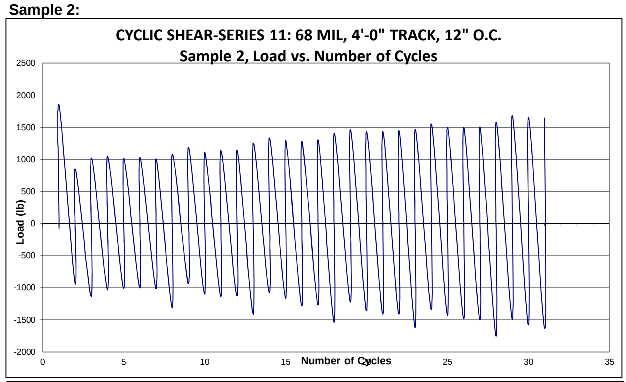
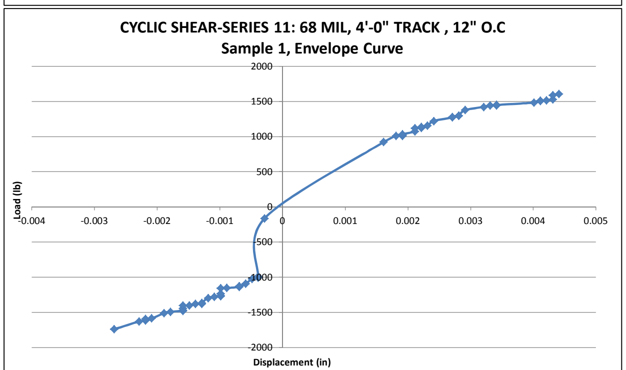
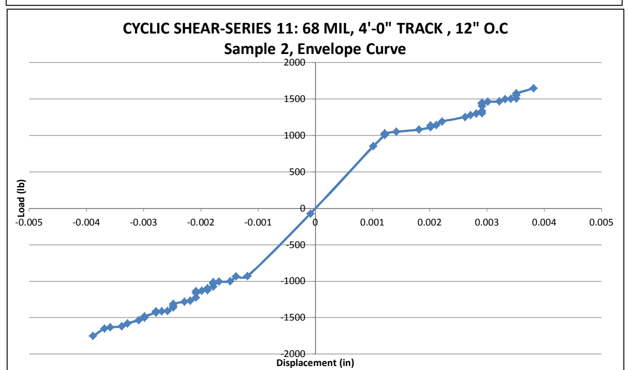
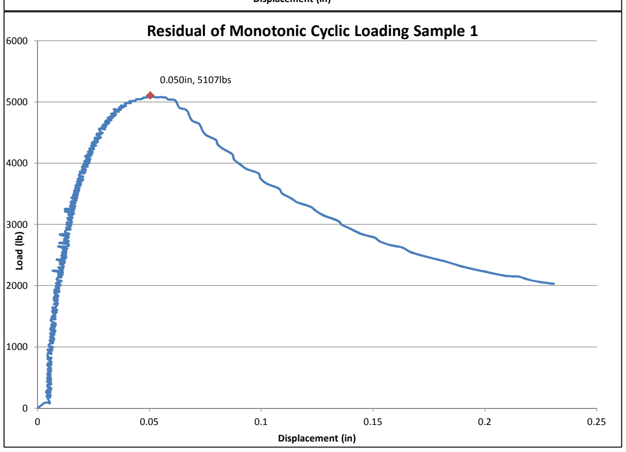
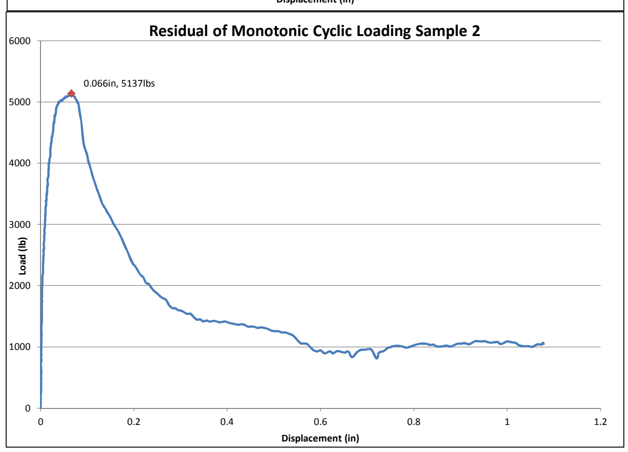




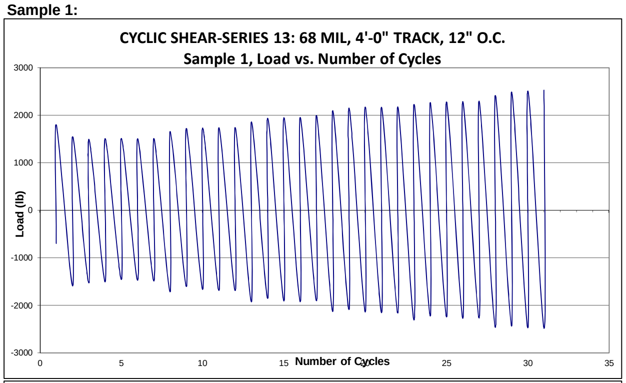






AISI Project-Cyclic Test Load Graphs							8/19/13-8/20/13
TEST PARAMETERS				Track Length (ft)	4	Nominal Embedment	1.25"
Test Series	**13**	Min. Yield Strength (50 KSI)	50	PAF Spacing (in)	12	Teflon used?	Yes
Track Thick. (mils)	68	Track width (3-5/8 or 6 in.)	6"	No. of PAF	4	Avg. concrete strgth. (psi)	2,550
Track Ga.	14	Loading protocol	cyclic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1
5 ea.cyclic loads @ approx. 67, 75, 85, 95, 100, 110% of 1991lbs							

Sample 1:



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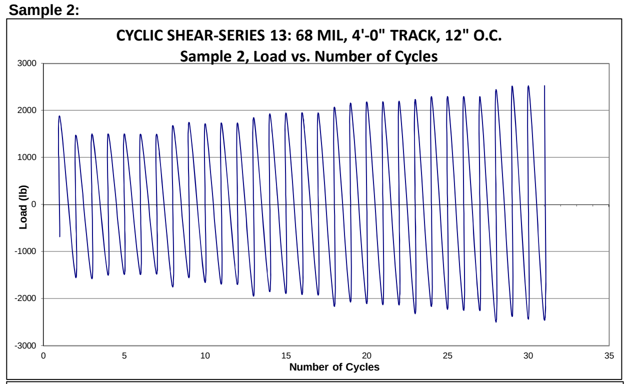
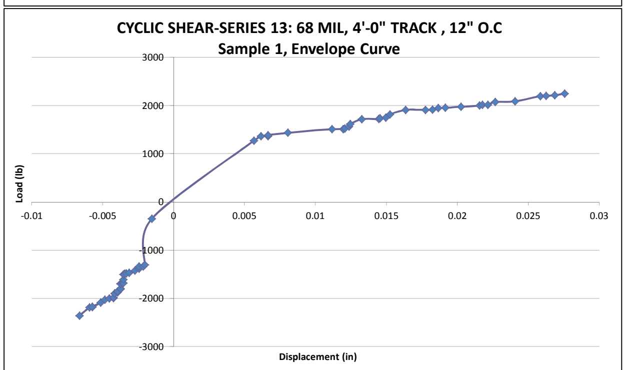
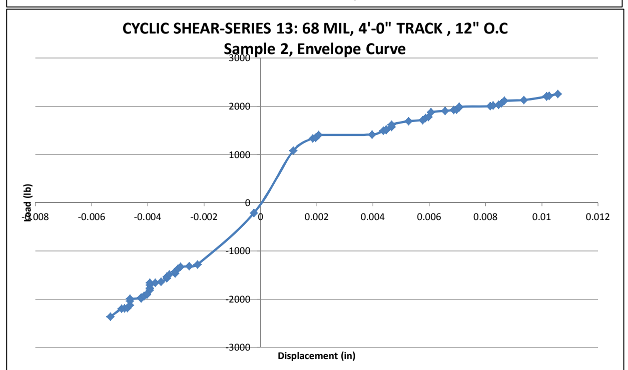
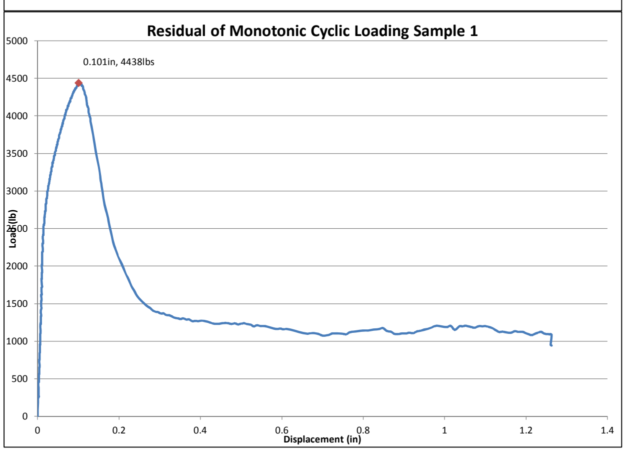
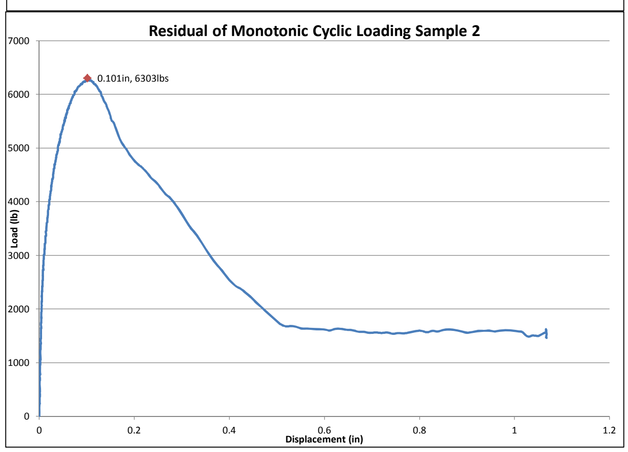




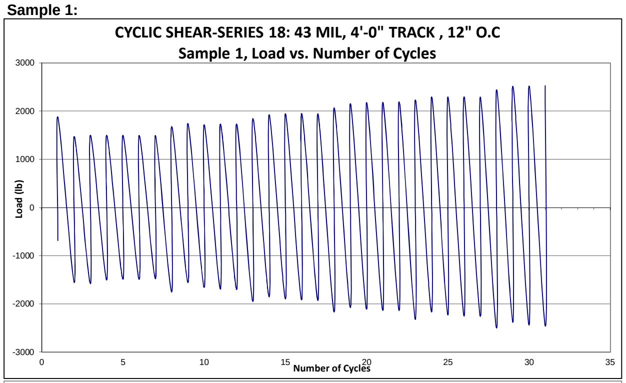






AISI Project-Cyclic Test Load Graphs							8/19/2013
TEST PARAMETERS				Track Length (ft)	4	Nominal Embedment	1.25"
Test Series	**18**	Min. Yield Strength (50 KSI)	50	PAF Spacing (in)	12	Teflon used?	Yes
Track Thick. (mils)	43	Track width (3-5/8 or 6 in.)	3-5/8"	No. of PAF	4	Avg. concrete strgth. (psi)	2,550
Track Ga.	18	Loading protocol	cyclic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1
5 ea.cyclic loads @ approx. 67, 75, 85, 95, 100, 110% of 2267lbs							

Sample 1:



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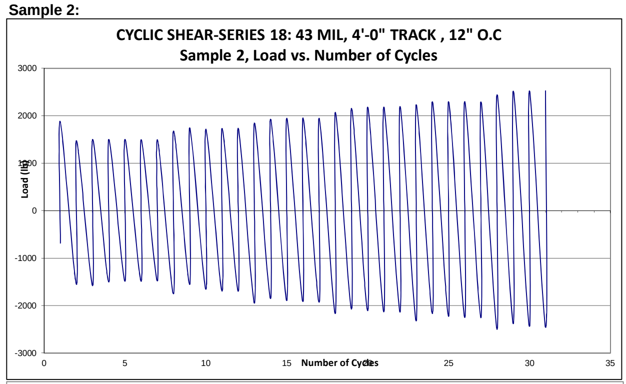
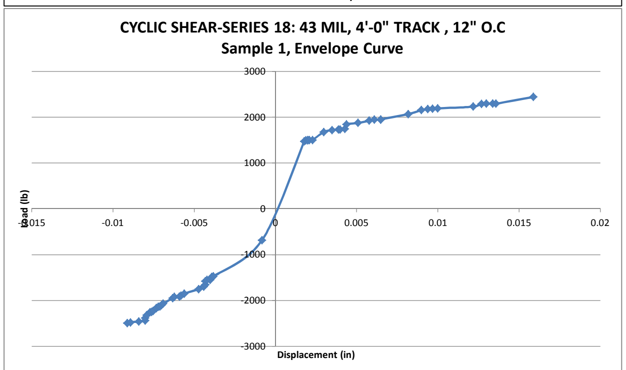
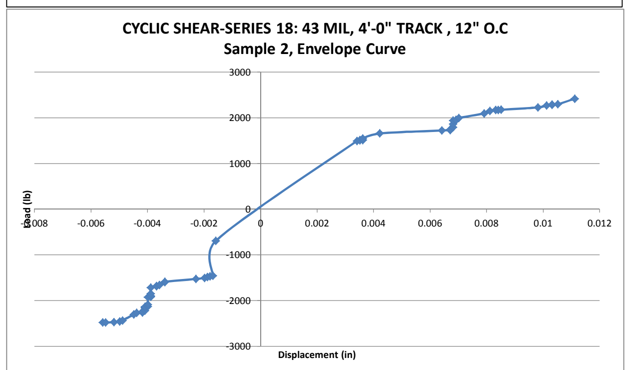
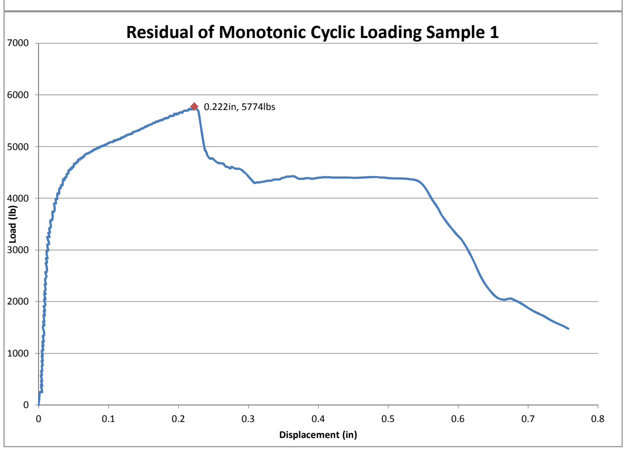
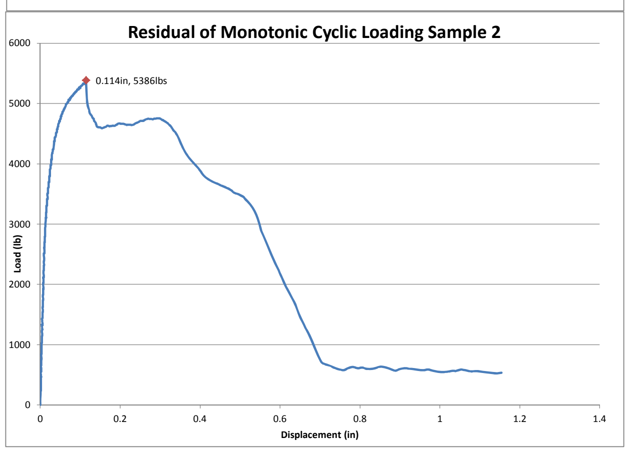




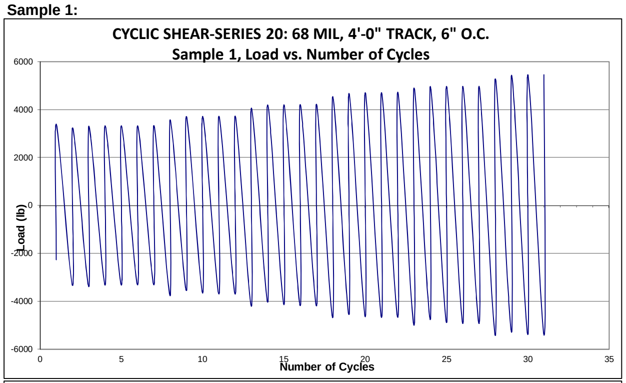






AISI Project-Cyclic Test Load Graphs							8/21/2013
TEST PARAMETERS				Track Length (ft)	4	Nominal Embedment	1.25"
Test Series	**20**	Min. Yield Strength (50 KSI)	50	PAF Spacing (in)	6	Teflon used?	Yes
Track Thick. (mils)	68	Track width (3-5/8 or 6 in.)	6"	No. of PAF	8	Avg. concrete strgth. (psi)	2,550
Track Ga.	14	Loading protocol	cyclic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1
5 ea.cyclic loads @ approx. 67, 75, 85, 95, 100, 110% of 4950lbs							

Sample 1:



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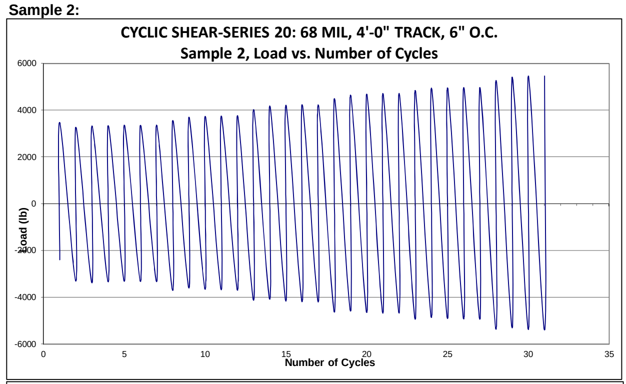
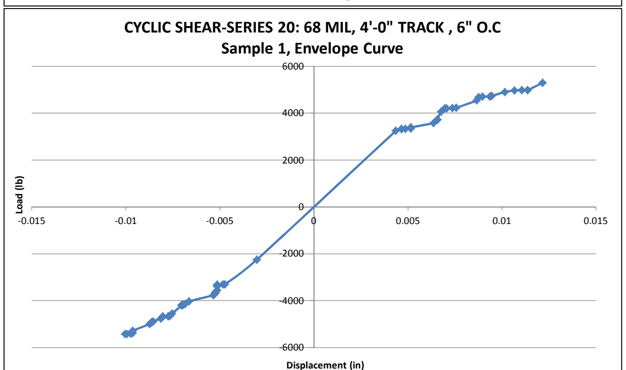
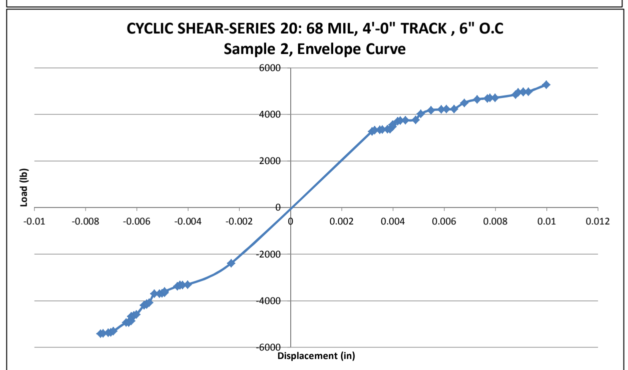
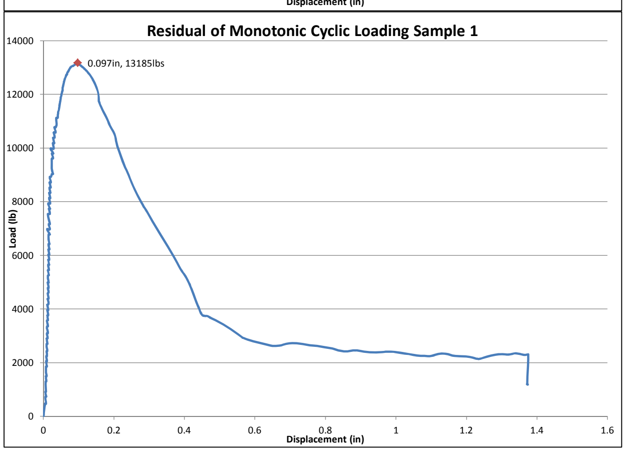
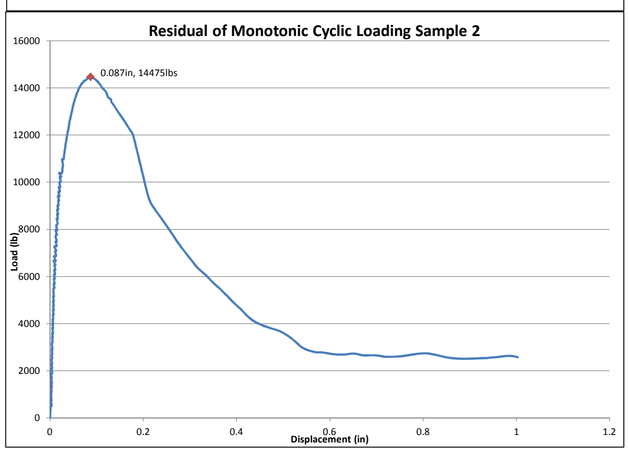




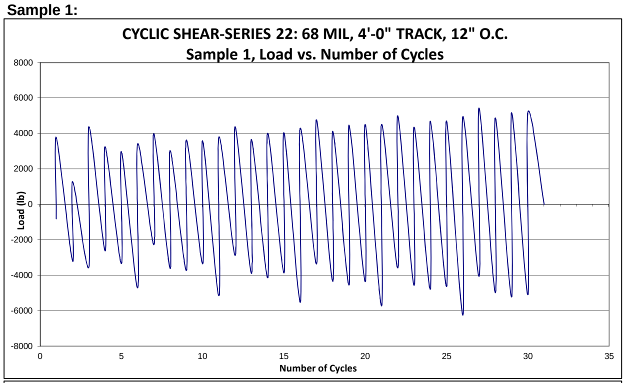






AISI Project-Cyclic Test Load Graphs							8/22/2013
TEST PARAMETERS				Track Length (ft)	4	Nominal Embedment	0.625"
Test Series	**22**	Min. Yield Strength (50 KSI)	50	PAF Spacing (in)	12	Teflon used?	Yes
Track Thick. (mils)	68	Track width (3-5/8 or 6 in.)	6"	No. of PAF	4	Avg. concrete strgth. (psi)	2,550
Track Ga.	14	Loading protocol	cyclic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1
5 ea.cyclic loads @ approx. 67, 75, 85, 95, 100, 110% of 4649bs							

Sample 1:



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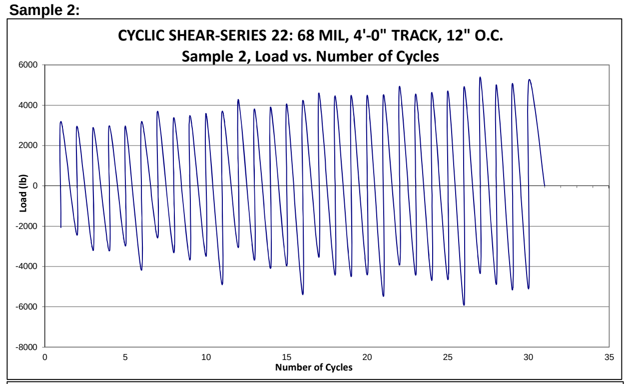
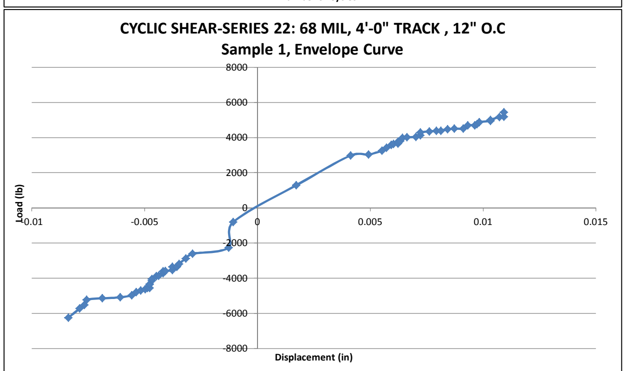
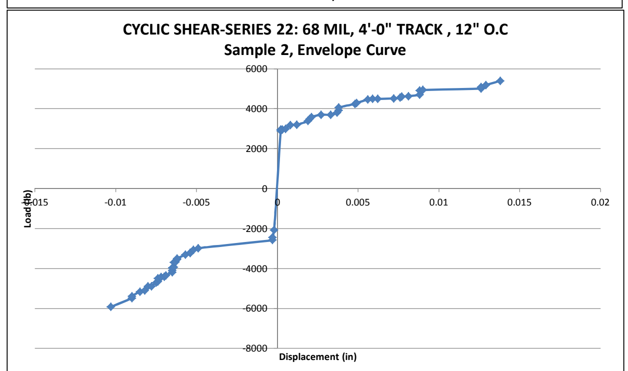
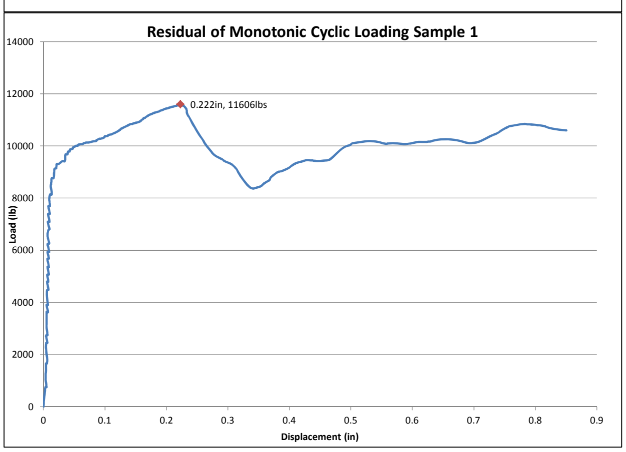
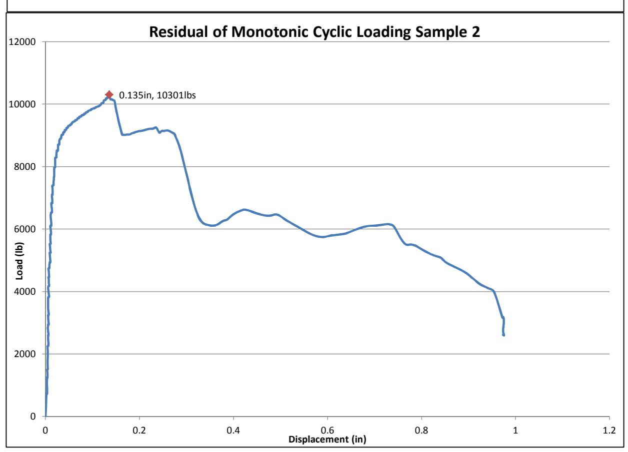




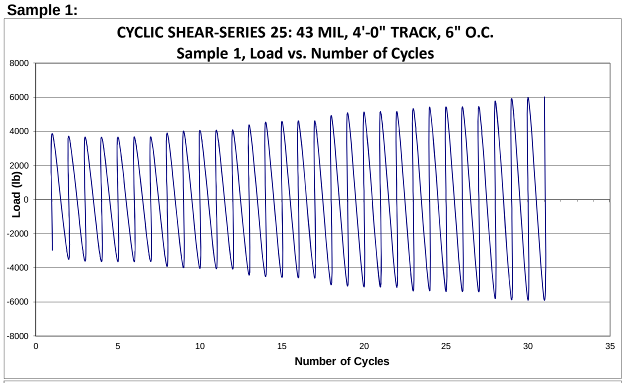






AISI Project-Cyclic Test Load Graphs							8/27/2013
TEST PARAMETERS				Track Length (ft)	4	Nominal Embedment	1.25"
Test Series	**25**	Min. Yield Strength (50 KSI)	50	PAF Spacing (in)	6	Teflon used?	Yes
Track Thick. (mils)	43	Track width (3-5/8 or 6 in.)	3-5/8"	No. of PAF	8	Avg. concrete strgth. (psi)	2,550
Track Ga.	18	Loading protocol	cyclic	PAF dia. (in)	0.157	Cyclic frequency (Hz)	0.1
5 ea.cyclic loads @ approx. 67, 75, 85, 95, 100, 110% of 5413lbs							

Sample 1:



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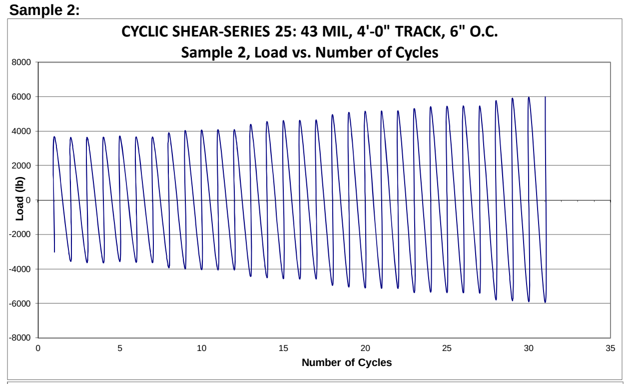
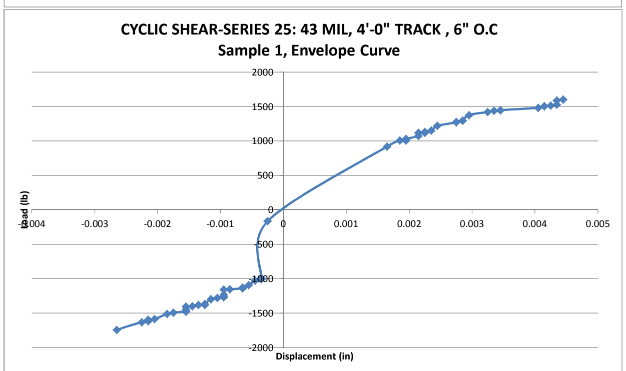
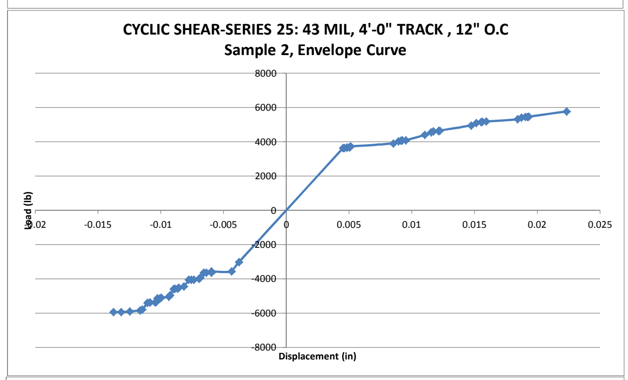
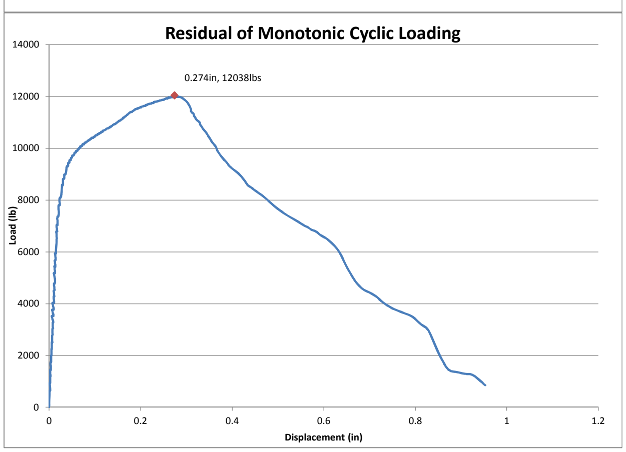
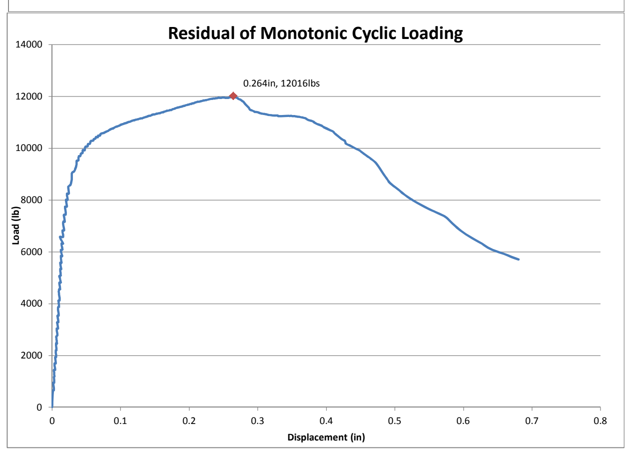










Appendix E - Material Properties

Concrete
Steel Plate
CFS Track
Fasteners

STANDARD TESTING AND ENGINEERING COMPANY
Since 1951

902 Trails West Loop
202 SE J Avenue
3400 N. Lincoln Blvd.

Standard Testing - Tulsa Office
10816 E. Newton St., Suite 110
Tulsa, OK 74116 (918) 439-9539

Area Offices
Enid, OK 73703 (580) 237-3130
Lawton, OK 73501 (580) 353-0872
Oklahoma City, OK 73105 (405) 528-0541

Report On: Compressive Strength of 4x8 Cylindrical Concrete Speciments

Lab No: 33876
Report No: 33876
Page 1 of 1

File No: 2120-0024 **Acct ID:** 2120HIL20

Client: Hilti, Inc.
Christopher Gamache
P.O. Box 21148
Tulsa, OK 74121

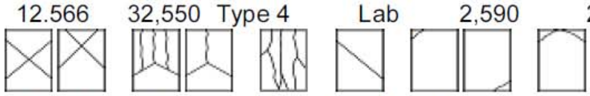
Project: Drill Bit and Anchor Testing

Report Date: 06/21/2013 **Revised Test Report**
Prev. Rpt. Date: 02/27/2013
Sample Date: 07/10/2012
Sampled By: Hamilton, Mike

Location: 7x9 112-412

Material: Not Stated

Spec Nbr	Age Tested (date : days)	Diameter (in)	Area (in²)	Maximum Load (lbs)	Break Type	Cure	Compressive Strength (PSI)	Average Strength (PSI)	Comments
1	07/17/12 : 7	4.00	12.566	25,240	Type 5	Lab	2,010		
2	07/17/12 : 7	4.00	12.566	26,530	Type 5	Lab	2,110	2,060	
3	02/14/13 : 219	4.00	12.566	30,800	Type 4	Lab	2,450		
4	02/14/13 : 219	4.00	12.566	30,810	Type 1	Lab	2,450		
5	02/14/13 : 219	4.00	12.566	28,740	Type 1	Lab	2,290	2,400	
6	06/21/13 : 346	4.00	12.566	31,550	Type 5	Lab	2,510		
7	06/21/13 : 346	4.00	12.566	32,210	Type 4	Lab	2,560		
8	06/21/13 : 346	4.00	12.566	32,550	Type 4	Lab	2,590	2,550	



Date Received: 07/11/2012
Curing Method: Standard
Time Sampled: 11:15 am
Temp.: Ambient: 90ºF
Mix: 90ºF
Slump: 5.5 Inches
Air Content: 1.9%

Transported By:
Source/Sampled At:
Plant:
Truck No:
Mix Code:
Ticket No:

Quantity Represented:
Remarks: 4 x 8 Cylinders
Test Method (As Applicable): ASTM C31, C39, C138, C143, C172, C231, C1064, C1231; AASHTO T22, T23, T119, T121, T141, T152, T309

AASHTO R18 IAS ACCREDITED

Respectfully Submitted,
Standard Testing and Engineering Company

Farid Ahmad, P.E.
CA #77 Exp. 6/30/2015

SHERRY LABORATORIES
An Element Materials Technology Company

TESTING TODAY, PROTECTING TOMORROW
WWW.SHERRYLABS.COM

Western Materials, SEG, & Nonmetallics
3100 North Hemlock Circle
Broken Arrow, OK 74012-1115

Tel: 918-258-6066
800-982-8378
Fax: 918-258-1154

LABORATORY REPORT

Attn: Dillan Carney

HILTI, INC.
c/o Standard Testing & Engineering
10816 E. Newton St., Suite 110
Tulsa, OK 74116

Report No: B13080713
Date Reported: 8/19/2013
P.O. No: Credit Card

Material: Steel

Specification: ASTM A36-08/ASME SA-36 (2011a)

Description: (1) 3/8" Thick Test Plate, Material: A36

Room Temperature Tensile Testing - ASTM E8/E8M-11, Parallel to Length of the Specimen, As Received

Thickness, Initial, in	Width, Initial, in	Tensile Strength, ksi	Yield (0.2% Offset), ksi	Elongation (4W), %	Location of Fracture
0.375	0.499	65	40	37	No closer then 25% of the gage length from either gage mark
ASTM A36-08/ASME SA-36 (2011a)	Not Specified	58 - 80	36 Min.	23 Min.	--

These test results CONFORM to ASTM A36-08/ASME SA-36 (2011a).

Room Temperature Tensile Testing - ASTM E8/E8M-11, Parallel to Length of the Specimen, As Received

Thickness, Initial, in	Width, Initial, in	Tensile Strength, ksi	Yield (0.2% Offset), ksi	Elongation (4W), %	Location of Fracture
0.375	0.500	65	40	38	No closer then 25% of the gage length from either gage mark
ASTM A36-08/ASME SA-36 (2011a)	Not Specified	58 - 80	36 Min.	23 Min.	--

These test results CONFORM to ASTM A36-08/ASME SA-36 (2011a).

Room Temperature Tensile Testing - ASTM E8/E8M-11, Parallel to Length of the Specimen, As Received

Thickness, Initial, in	Width, Initial, in	Tensile Strength, ksi	Yield (0.2% Offset), ksi	Elongation (4W), %	Location of Fracture
0.374	0.500	65	39	35	No closer then 25% of the gage length from either gage mark
ASTM A36-08/ASME SA-36 (2011a)	Not Specified	58 - 80	36 Min.	23 Min.	--

These test results CONFORM to ASTM A36-08/ASME SA-36 (2011a).

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LABORATORY REPORT

Attn: Dillan Carney

HILTI, INC.
c/o Standard Testing & Engineering
10816 E. Newton St., Suite 110
Tulsa, OK 74116

Report No: B13080713
Date Reported: 8/19/2013
P.O. No: Credit Card

Approved by:

Doug Kooken
Operations Manager

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LABORATORY REPORT

Attn: Dillan Carney

Standard Testing & Eng. - Tulsa
10816 E. Newton Street
Suite 110
Tulsa, OK 74116 United States

Report No: B13070647
Date Reported: 7/17/2013
P.O. No: Credit Card

Material: Steel

Description: (4) 2' Galv Track Sections

Room Temperature Tensile Testing ASTM E8/E8M-11, Parallel to Length of the Specimen, As Received

Sample ID	Width, Initial, in	Thickness, Initial, in	Tensile Strength, psi	Yield (0.2% Offset), psi	Elongation (4W), %	Location of Fracture
20ga Galv Track	0.500	0.020	101900	99800	4	Outside Middle Half of Gage

Room Temperature Tensile Testing ASTM E8/E8M-11, Parallel to Length of the Specimen, As Received

Sample ID	Width, Initial, in	Thickness, Initial, in	Tensile Strength, psi	Yield (0.2% Offset), psi	Elongation (4W), %	Location of Fracture
18ga Galv Track	0.500	0.046	59700	47400	34	Inside Middle Half of Gage

Room Temperature Tensile Testing ASTM E8/E8M-11, Parallel to Length of the Specimen, As Received

Sample ID	Width, Initial, in	Thickness, Initial, in	Tensile Strength, psi	Yield (0.2% Offset), psi	Elongation (4W), %	Location of Fracture
16ga Galv Track	0.500	0.059	84400	69600	21	Inside Middle Half of Gage

Room Temperature Tensile Testing ASTM E8/E8M-11, Parallel to Length of the Specimen, As Received

Sample ID	Width, Initial, in	Thickness, Initial, in	Tensile Strength, psi	Yield (0.2% Offset), psi	Elongation (4W), %	Location of Fracture
14ga Galv Track	0.500	0.069	79600	57200	29	Inside Middle Half of Gage

Approved by:

Doug Kooken
Operations Manager

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LABORATORY REPORT

Attn: Dillan Carney
Standard Testing & Eng. - Tulsa
10816 E. Newton Street
Suite 110
Tulsa, OK 74116 United States

Report No: B13071455
Date Reported: 8/1/2013
P.O. No: Credit Card

Material: Steel

Description: (4) 2' Galv Track Sections
Reference: Sherry Job No.: B13070647 - Additional Testing

Room Temperature Tensile Testing ASTM E8/E8M-11, Parallel to Length of the Specimen, As Received

Sample ID	Width, Initial, in	Thickness, Initial, in	Tensile Strength, psi	Yield (0.2% Offset), psi	Elongation (4W), %	Location of Fracture
20ga Galv Track	0.500	0.020	102500	100800	3	No closer then 25% of the gage length from either gage mark

Room Temperature Tensile Testing ASTM E8/E8M-11, Parallel to Length of the Specimen, As Received

Sample ID	Width, Initial, in	Thickness, Initial, in	Tensile Strength, psi	Yield (0.2% Offset), psi	Elongation (4W), %	Location of Fracture
20ga Galv Track	0.500	0.019	103000	100800	3	Outside Middle Half of Gage

Room Temperature Tensile Testing ASTM E8/E8M-11, Parallel to Length of the Specimen, As Received

Sample ID	Width, Initial, in	Thickness, Initial, in	Tensile Strength, psi	Yield (0.2% Offset), psi	Elongation (4W), %	Location of Fracture
18ga Galv Track	0.501	0.044	61400	49000	31	Inside Middle Half of Gage

Room Temperature Tensile Testing ASTM E8/E8M-11, Parallel to Length of the Specimen, As Received

Sample ID	Width, Initial, in	Thickness, Initial, in	Tensile Strength, psi	Yield (0.2% Offset), psi	Elongation (4W), %	Location of Fracture
18ga Galv Track	0.501	0.045	60500	48200	32	Inside Middle Half of Gage

Room Temperature Tensile Testing ASTM E8/E8M-11, Parallel to Length of the Specimen, As Received

Sample ID	Width, Initial, in	Thickness, Initial, in	Tensile Strength, psi	Yield (0.2% Offset), psi	Elongation (4W), %	Location of Fracture
16ga Galv Track	0.501	0.059	84500	70000	20	Outside Middle Half of Gage

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LABORATORY REPORT

Attn: Dillan Carney

Standard Testing & Eng. - Tulsa
10816 E. Newton Street
Suite 110
Tulsa, OK 74116 United States

Report No: B13071455
Date Reported: 8/1/2013
P.O. No: Credit Card

Room Temperature Tensile Testing ASTM E8/E8M-11, Parallel to Length of the Specimen, As Received

Sample ID	Width, Initial, in	Thickness, Initial, in	Tensile Strength, psi	Yield (0.2% Offset), psi	Elongation (4W), %	Location of Fracture
16ga Galv Track	0.502	0.059	84800	69800	20	Inside Middle Half of Gage

Room Temperature Tensile Testing ASTM E8/E8M-11, Parallel to Length of the Specimen, As Received

Sample ID	Width, Initial, in	Thickness, Initial, in	Tensile Strength, psi	Yield (0.2% Offset), psi	Elongation (4W), %	Location of Fracture
14ga Galv Track	0.502	0.069	79500	58600	26	Inside Middle Half of Gage

Room Temperature Tensile Testing ASTM E8/E8M-11, Parallel to Length of the Specimen, As Received

Sample ID	Width, Initial, in	Thickness, Initial, in	Tensile Strength, psi	Yield (0.2% Offset), psi	Elongation (4W), %	Location of Fracture
14ga Galv Track	0.502	0.069	79600	58300	28	Inside Middle Half of Gage

Approved by:

Doug Kooken
Operations Manager

SPECIALIZED TESTING
10600 Pioneer Boulevard, Suite G • Santa Fe Springs, California 90670 • (562) 903-0032 • Fax (562) 903-3534
IAS ACCREDITED

5/21/2012

Dillan Carney
Standard Testing and Engineering Company
10816 East Newton Street – Suite 110
Tulsa, OK 74116

Reference: Dimensional Tests of Hilti X-U 27 P8 Power-driven Fasteners
Specialized Testing Report Number STQA50424B

Dear Mr. Carney:

Pursuant to the your request, on 3/22/2012 Specialized Testing performed dimensional tests of five representative samples from the 20 samples of Hilti X-U 27 P8 Power-driven fasteners (lot number 11911226) that Standard Testing and Engineering Company sampled on 1/30/2012 and sent to our laboratory. The fasteners were received and logged into our incoming materials inventory (Log No. 497) on 2/6/2012.

The specified dimensional tests included head diameter, shank diameter and overall length. The dimensional tests were performed in-house by Specialized Testing. The dimensional test report is presented in Attachment 1.

Please let us know if you have any questions or comments.

Respectfully submitted,

REGISTERED PROFESSIONAL ENGINEER
TIM FOSTER
NO. C 056556
Exp. 6/2013
CIVIL
STATE OF CALIFORNIA

Tim Foster, P.E.
Spec Testing, Inc.
dba Specialized Testing

attachment

SPECIALIZED TESTING • 10600 Pioneer Boulevard, Suite G • Santa Fe Springs, California 90670 • (562)903-0032 Fax (562)903-3534

ATTACHMENT 1 – HILTI X-U 27 P8 DIMENSIONAL TEST REPORT
STQA50424B

SPECIALIZED TESTING • 10600 Pioneer Boulevard, Suite G • Santa Fe Springs, California 90670 • (562)903-0032 Fax (562)903-3534

DIMENSIONAL MEASUREMENT REPORT
HILTI, INC. X-U 27 P8 POWER-DRIVEN FASTENER

Date of Test	3/22/2012
Client Name	Hilti, Inc.
Work Order Number	STQA50424 (Log Number 497)
Product Name	Hilti X-U 27 P8 Power-driven Fastener (Lot Number 11911226)
Technicians Name	TF
Test Equipment	Calipers (SN 07148578)
Test Standards	ICC-ES AC 70

Dimensions	SN 1	SN 2	SN 3	SN 4	SN 5	Avg.	Tolerance
1 - Head Diameter	8.24	8.38	8.26	8.22	8.20	8.3	8.0 - 8.5
2 - Overall Length	30.28	29.92	29.50	30.09	29.93	29.9	28.9 - 30.9
3 - Shank Dia	4.00	3.98	3.99	3.99	4.03	4.00	3.95 - 4.10

Notes:

All readings in millimeters

The five sample average of the three measured dimensions comply with Hilti's specifications
(Hilti document no. 381182 / 08 / 521108)

SPECIALIZED TESTING
ACCREDITED
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8/7/2013

Dillan Carney
Standard Testing and Engineering Company
10816 East Newton Street – Suite 110
Tulsa, OK 74146

Reference: Dimensional Tests of Hilti X-U 32 P8 Power-driven Fasteners
Specialized Testing Report Number STQA50482B

Dear Mr. Carney:

Pursuant to your request, on 8/2/2013 Specialized Testing performed dimensional tests of five representative samples from the 20 samples of Hilti X-U 32 P8 Power-driven fasteners (lot number 12310035) that Standard Testing and Engineering Company sampled on 6/26/2013 and sent to our laboratory. The fasteners were received and logged into our incoming materials inventory (Log No. 652) on 7/11/2013.

The specified dimensional tests included head diameter, shank diameter and overall length. The dimensional tests were performed in-house by Specialized Testing. The dimensional test report is presented in Attachment 1. The dimensional test results comply with Hilti's specifications.

Please let us know if you have any questions or comments.

Respectfully submitted,

REGISTERED PROFESSIONAL ENGINEER
TIM FOSTER
NO. C 056556
Exp.
CIVIL
STATE OF CALIFORNIA

Tim Foster, P.E.
Specialized Testing, Inc.
dba Specialized Testing

attachment

ATTACHMENT 1 – HILTI X-U 32 P8 DIMENSIONAL TEST REPORT
STQA50482B

DIMENSIONAL MEASUREMENT REPORT
HILTI, INC. X-U 32 P8 POWER-DRIVEN FASTENER

Date of Test	8/2/2013
Client Name	Hilti, Inc.
Work Order Number	STQA50482 (Log Number 652)
Product Name	Hilti X-U 32 P8 Power-driven Fastener (Lot Number 12310035)
Technicians Name	TF
Test Equipment	Calipers (SN 03258526)
Test Standards	ICC-ES AC 70

Dimensions	SN 1	SN 2	SN 3	SN 4	SN 5	Avg.	Hilti Specified Tolerance
1 - Head Diameter	8.33	8.36	8.41	8.42	8.24	8.4	8.0 - 8.5
2 - Overall Length	34.52	34.67	34.46	34.73	34.81	34.6	33.9 - 35.9
3 - Shank Diameter	4.00	4.01	4.00	4.00	4.01	4.01	3.95 - 4.10

Notes:

All readings in millimeters

The five sample average of the three measured dimensions comply with Hilti's specifications

SPECIALIZED TESTING

10600 Pioneer Boulevard, Suite G • Santa Fe Springs, California 90670 • (562) 903-0032 • Fax (562) 903-3534

IAS ACCREDITED

1/6/2012

Dillan Carney
Standard Testing and Engineering Company
10816 East Newton Street – Suite 110
Tulsa, OK 74116

Reference: Core Hardness Tests of Hilti X-GN27 MX Power-driven Fasteners
Specialized Testing Report Number STQA50414H

Dear Mr. Carney:

Pursuant to the your request, on 11/10/2011 Specialized Testing coordinated Rockwell Core Hardness tests of five representative samples from the 20 samples of Hilti X-GN27 MX Power-driven fasteners that Standard Testing and Engineering Company sampled on 10/24/2011 and sent to our laboratory. The fasteners were received and logged into our incoming materials inventory (Log No. 467) on 11/1/2011.

The core hardness tests were performed by Atlas Testing Laboratories (an A2LA accredited Metallurgical Test Laboratory). Specialized Testing facilitated the tests by transferring samples to Atlas Testing Laboratories with a purchase order and test instructions. The Atlas Testing Laboratories core hardness test report is presented in Attachment 1. The average core hardness value for the X-GN27 MX fastener was 53 HRC.

Please let us know if you have any questions or comments.

Respectfully submitted,

REGISTERED PROFESSIONAL ENGINEER
TIM FOSTER
NO. C 056556
Exp. 6/2013
CIVIL
STATE OF CALIFORNIA

Tim Foster, P.E.
Spec Testing, Inc.
dba Specialized Testing

attachment

ATTACHMENT 1 – HILTI X-GN27 MX CORE HARDNESS TEST REPORT
STQA50414H

ample (s): Customer Supplied"

TEST REPORT

ATLAS TESTING LABORATORIES, INC.

9820 6th Street, Rancho Cucamonga, CA 91730 909-373-4130 FAX 909-373-4132

WF

PO#/WO#: 2084/STQA50414

DATE: 11/21/11
ATL# 151294

CLIENT: SPECIALIZED TESTING
ATTN: TIM FOSTER
10600 S. PIONEER BLVD. STE# G
SANTA FE SPRINGS, CA 90670

LOG# LN467 LINE# 1
CUST: HILTI X-GN27 MX FASTENERS
ITEM# 226934

ALLOY: STEEL

METALLURGICAL EVALUATION: (FIVE SAMPLES)

The samples were prepared per ASTM-E3/11. Tested with HV 1000g load.
Examined at 500x magnification.

Core	Hardness
1	53 HRC (553 HV 1000)
2	53 HRC (555 HV 1000)
3	52 HRC (551 HV 1000)
4	52 HRC (548 HV 1000)
5	53 HRC (553 HV 1000)

REMARKS: Results provided for information only.

Respectfully Submitted: [signature]

Date: 11/21/11 Sharon A. Norton
Quality Assurance

Page 1 of 1

SPECIALIZED TESTING

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IAS ACCREDITED

1/6/2012

Dillan Carney
Standard Testing and Engineering Company
10816 East Newton Street – Suite 110
Tulsa, OK 74116

Reference: Dimensional Tests of Hilti X-GN27 MX Power-driven Fasteners
Specialized Testing Report Number STQA50414D

Dear Mr. Carney:

Pursuant to the your request, on 12/12/2011 Specialized Testing performed dimensional tests of five representative samples from the 20 samples of Hilti X-GN27 MX Power-driven fasteners that Standard Testing and Engineering Company sampled on 10/24/2011 and sent to our laboratory. The fasteners were received and logged into our incoming materials inventory (Log No. 467) on 11/1/2011.

The specified dimensional tests included head diameter, shank diameter and overall length. The dimensional tests were performed in-house by Specialized Testing. The dimensional test report is presented in Attachment 1.

Please let us know if you have any questions or comments.

Respectfully submitted,

REGISTERED PROFESSIONAL ENGINEER
TIM FOSTER
NO. C 056556
Exp. 6/2013
CIVIL
STATE OF CALIFORNIA

Tim Foster, P.E.
Spec Testing, Inc.
dba Specialized Testing

attachment

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ATTACHMENT 1 – HILTI X-GN27 MX DIMENSIONAL TEST REPORT
STQA50414D

SPECIALIZED TESTING • 10600 Pioneer Boulevard, Suite G • Santa Fe Springs, California 90670 • (562) 903-0032 Fax (562) 903-3534

DIMENSIONAL MEASUREMENT REPORT
HILTI, INC. - X-GN27 MX POWER-DRIVEN FASTENER

Date of Test	12/12/2011
Client Name	Hilti, inc
Work Order Number	STQA50414D (Log Number 467)
Product Name	Hilti X-GN27 MX Power-driven Fastener
Technicians Name	TF
Test Equipment	Calipers (SN 07188578)
Test Standards	ICC-ES AC 70

Dimensions	SN 1	SN 2	SN 3	SN 4	SN 5	Avg.	Tolerance
X-GN27 MX							
1 - Head Diameter (1)	6.63 / 6.67	6.79 / 6.85	6.77 / 6.86	6.65 / 6.71	6.59 / 6.74	6.69 / 6.74	6.50 - 7.00
2 - Shank Diameter	2.98	2.96	2.97	2.94	2.94	2.96	2.95 - 3.10
3 - Overall Length (2)	29.50	29.19	29.39	29.42	29.48	29.40	27.7 - 30.1

Notes:
All readings in millimeters
(1) Minimum / Maximum diameter reported
(2) Tolerance based on L2 tolerance noted on the Hilti drawing (+/- 1mm)

The five sample average of the three measured dimensions comply with Hilti's specifications (Hilti document no. 321634 / 09 / 521108) for the X-GN27 MX fastener.

Appendix F – AISI S100-12 Appendix F Safety Factor Calculation

Number of Tests: 10
Design Type: LRFD or ASD

Results	
Test Series 11:	1277
	1284
Test Series 13:	1110
	1576
Test Series 18:	1444
	1346
Test Series 20:	1648
	1809
Test Series 25:	1505
	1502

Standard Deviation = 203.750092
R_n = 1450.1
Coefficient of Variation = 0.14050761

C_F=	1.6
M_m=	1.1
F_m=	0.9
P_m=	1
e=	2.718
b_o=	3.5
V_M=	0.1
V_F=	0.1
C_P=	1.41428571
V_P=	0.14050761
V_Q=	0.25

ϕ = 0.50

Ω = 3.23

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Research Report RP-13-3