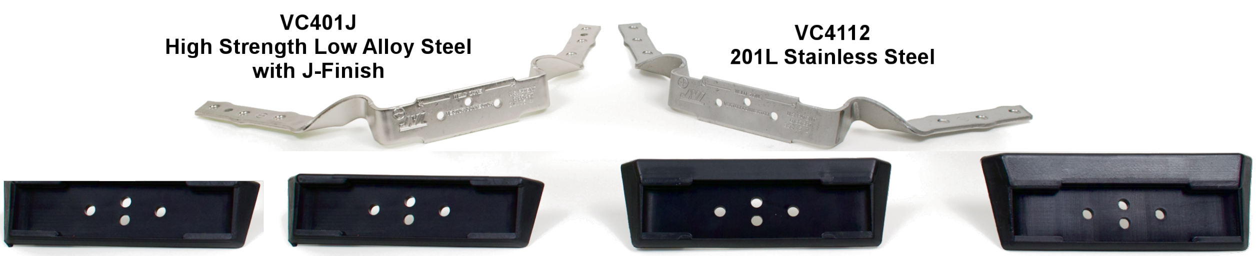
Version 1.0

The JVI VC4 Vector Connector

Compiled Test Reports



Flush Blockout 1/4" Blockout 3/4" Blockout 1" Blockout

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Version 1.0

Introduction

JVI designed the Vector Connector for use as shear and alignment connections between precast concrete elements such as double-tee flanges and wall panels.

Contents

Testing of the JVI Mid V in 4” Slabs (2009)

This report documents the initial testing of a radical vector connector redesign identified as the Mid-V. The Mid-V replaced the VC2 (see Figure 1). The faceplate was reduced from 2” to 1 ½” in total height and the concrete anchorage was changed to strategic deformation along the length of the vector legs in lieu of a 90° hook (See Figure 2).

Figure 1: VC2

Figure 2: Mid-V

This report contains results of load tests on (20) JVI “Mid-V” connectors. The connectors were embedded in 4” thick, 4’ x 4’ concrete slabs. The slabs were not reinforced at the location of the connectors. Tests were conducted using a flat bar 3/8” x 1 ½” x 4” welded with a ¼” x 2.5” long fillet weld passing through the top hole on the faceplate. A36 steel coated with the JVI J-Finish were tested. The Mid-V was detailed with a 1” plastic blockout.

The following was tested.

- (3) Monotonic in-plane tension (flat bar welded top and bottom to prevent weld failure)
- (3) Vertical (out of plane) shear without tension
- (3) In plane monotonic shear without tension
- (4) In plane monotonic shear with tension
- (3) In plane cyclic shear without tension
- (4) In plane cyclic shear with tension

Additional Testing of the JVI Mid V in 4" Slabs (2010)

This report contains results of load tests on (20) JVI "Mid-V" connectors. The connectors were embedded in 4" thick, 4' x 4' concrete slabs. The test slabs were either unreinforced at the connectors or welded wire mesh was included and detailed as either on top of or below the connector. Tests were conducted using a flat bar 3/8" x 1" x 4" welded with a ¼" x 2.5" long fillet weld passing through the top hole on the faceplate. A36 steel coated with the JVI J-Finish were tested. The Mid-V was detailed with both a 1" plastic blockout and a ¾" plastic blockout.

The Vertical (out of plane) shear without tension in test report "Testing of the JVI Mid-V in 4" Slabs (2009)" was deemed insufficient due test variance with location of the top of the vector connector to the top of the slab that was outside of normal tolerances. This test report is considered to characterize the Vertical (out of plane) shear without tension behavior of the connector.

The following loading was tested.

- (20) Vertical (out of plane) shear without tension

Testing of the JVI Vector Connector 4 in 4" Slabs (2012)

The faceplate of the Mid-V was modified and the carbon material changed to SAE J1392 Gr. 045XLF to improve the manufacturing process and the modification was identified as the VC4 (See Figure 3). The VC4 geometry and carbon material is the current manufactured vector connector.

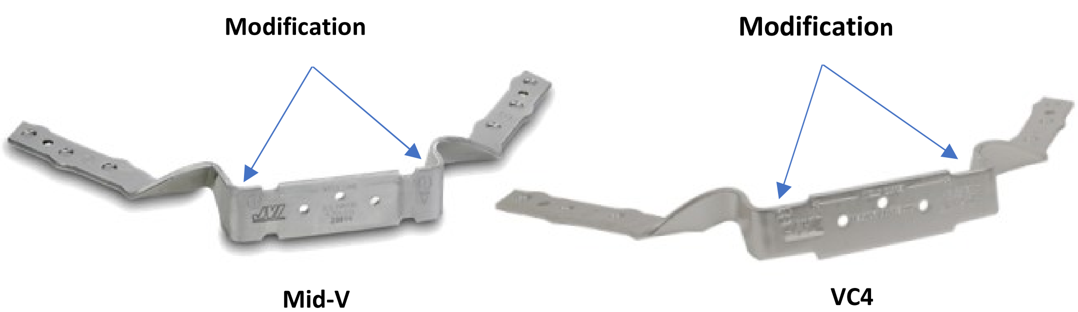

Figure 3: Faceplate Modification Between Mid-V and VC4

This report contains results of load tests on (16) JVI VC4 Connectors. The connectors were embedded in 4" thick, 4' x 4' concrete slabs. The slabs were not reinforced at the location of the connectors. Tests were conducted using a flat bar 3/8" x 1" x 4" welded with a ¼" x 2.5" long fillet weld passing through the top hole on the faceplate. ASTM A240A 240M type 201L annealed stainless steel (UNS S20103) and SAE J1392 Gr. 045 XLF with the JVI J-Finish were tested. The VC4 was detailed with a 1" plastic blockout.

An additional variation was considered in this test regarding a "reinforcing gusset" at the 90° corner of the VC4. This is identified in testing as "with Gusset". The testing indicated that the "gusset" was ineffective and the test results for the VC4 configuration "without Gusset" are the test results considered to characterize the load carrying capacity of the VC4.

The following loading was tested for the relevant "without Gusset" configuration.

- (4) Monotonic shear without tension – Stainless Steel
- (4) Cyclic Shear without tension – Stainless Steel

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Testing of the JVI Mid V in 4" Slabs

Report on the Test Results

by

Al Ghorbanpoor, P.E., Ph.D.
Professor of Structural Engineering, and
Director of the UWM Structures Laboratory

PREFACE

"Mid V" connector embedded in 4" thick concrete slabs. The tests were carried out in the Structural Engineering Laboratory at the University of Wisconsin- Milwaukee (UWM). The test fixtures and instrumentation, and the test protocols were identical to previous JVI "Vector Connector" tests carried out at UWM. The details of those tests are reported in the following two references:

(1)"Shear connector Tests," Test Report No.2, JVI website: www.jvi-inc.com
(2) A. Fattah Shaikh and Eric P. Feile, "Load Testing of a Precast Concrete Double-Tee Flange Connector," PCI Journal 49(3):84-94, May-June 2004.

SPECIMEN DETAILS

The concrete slab specimens for this phase of JVI “Mid V” tests were fabricated by Spancrete, Inc., Waukesha, WI, who also provided field welding of the field connection bars to the “Mid V” face plate and the loading equipment plate.

The following notes pertain to specifics of the test specimens:

Concrete Strengths of 4” x 8” cylinders

Slab #	Poured Date	Break Date	Break Load (lbs.)	Break Pressure (psi)
1 D	07/10/09	07/22/09	70,200	5,586
1 D	07/10/09	07/22/09	77,800	6,191
1 D	07/10/09	07/27/09	78,200	6,223
		Average	75,400	6,000
2 B	07/14/09	07/22/09	74,900	5,960
2 B	07/14/09	07/22/09	73,700	5,865
2 B	07/14/09	07/27/09	79,000	6,287
		Average	75,867	6,037
3 E	07/15/09	07/27/09	70,900	5,642
3 E	07/15/09	07/27/09	69,200	5,507
3 E	07/15/09	07/27/09	72,500	5,769
		Average	70,867	5,639
4 C	07/16/09	07/23/09	65,900	5,244
4 C	07/16/09	07/27/09	75,600	6,016
4 C	07/16/09	07/27/09	76,300	6,072
		Average	72,600	5,777
5 A	07/17/09	07/22/09	71,000	5,650
5 A	07/17/09	07/22/09	68,100	5,419
5 A	07/17/09	07/27/09	77,500	6,167
		Average	72,200	5,745

Reinforcing
Welded Wire Mesh: no welded wire mesh located in the vicinity of the “Mid V” failure zones.
Steel Reinforcing bar: rebar was used only for handling stresses.
See Appendix B for slab details

Flange Connectors
JVI “Mid V” steel: ASTM A36 type steel coated with J-Finish for corrosion protection.

Field Weld Slugs
Weld slugs used: flat bar slug, 3/8” x 1 ½” x 4” long. All welds designed to be ¼” fillet x 2.50” long. Actual sizes as shown below in column “B”. All welds on top of slug, except three (3) tests for tension normal to the faceplate where slugs were welded top and bottom. Every weld passed through the top hole in

the faceplate.

Loading Plates
The test specimens were delivered to the UWM Structures Lab with loading plates welded to the weld slugs which, in turn, were welded to the “Mid V” faceplates.

Test Slab Setup Details

			D	A		B	C	E
Slab #	Slab Thickness	Test #	Distance D -Slab Surface to MidV top edge (in.)	Distance A - Slab surface to weld slug top (in.)	Distance – Mid V top edge to weld slug top (in.)	Vertical Distance B- Fillet Weld Size (in.)	Weld Length C - Top of Slug (in.)	Weld Length E - Bottom of Slug
5 A	4"	1	1.320	1.775	0.455	0.175	2.500	NA
5 A	4"	2	1.280	1.860	0.580	0.248	2.500	NA
5 A	4"	3	1.250	1.820	0.570	0.288	2.500	NA
5 A	4"	4	1.000	1.660	0.660	0.191	2.375	NA
2 B	4"	1	1.506	1.826	0.320	0.238	2.250	NA
2 B	4"	2	1.580	2.028	0.448	0.216	2.500	NA
2 B	4"	3	1.080	1.750	0.670	0.173	2.250	NA
2 B	4"	4	1.000	1.610	0.610	0.190	2.250	NA
4 C	4-1/6"	1	1.203	1.870	0.667	0.221	2.500	NA
4 C	4-1/6"	2	1.516	2.110	0.594	0.210	2.625	NA
4 C	4-1/6"	3	1.514	1.998	0.484	0.211	2.500	NA
4 C	4-1/6"	4	1.314	1.923	0.609	0.200	2.500	NA
1 D	4"	1	1.186	2.051	0.865	0.236	2.500	NA
1 D	4"	2	1.273	1.822	0.549	0.206	2.250	NA
1 D	4"	3	1.055	1.553	0.498	0.175	2.375	NA
1 D	4"	4	0.988	1.603	0.615	0.191	2.750	NA
3 E	4"	1	1.170	1.931	0.761	0.201	2.375	Present
3 E	4"	2	1.140	1.771	0.631	0.180	2.500	Present
3 E	4"	3	1.022	1.561	0.539	0.171	2.750	Present
3 E	4"	4	1.088	1.643	0.555	0.162	2.500	NA

Notes
1 - Specified 1/4" fillet weld x 2-1/2" long
2 - Flat Weld Slug = 1-1/2" x 3/8" x 4" Long
3 - Weld Length on top goes thru center faceplate hole
4 - No mesh used in slab, plain concrete for testing.

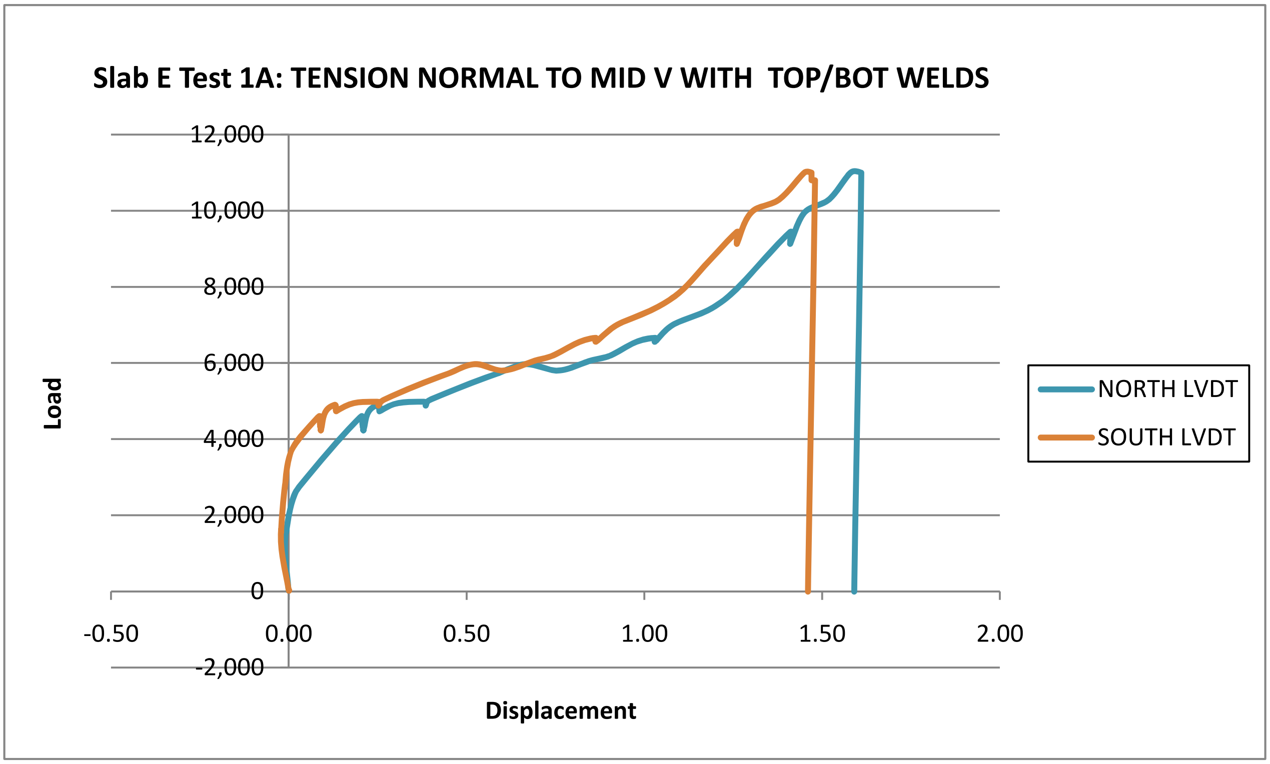
TEST RESULTS
Table 1 gives results of 1st Crack Load, Yield Crack Load, Maximum Load, Displacement at Maximum Load, and the Failure Mode. Load-Displacement curves for the 20 tests are given in Appendix A. Appendix B includes “Mid V” product picture, slab specimen drawings, and photos of each test.

Test #	Test Description	1st Crack Load (lbs.)	Yield Crack Load (lbs.)	Max Load (lbs.)	Displ. @ Max Load (in.)	Failure Mode
E1(A/B)	In Plane Tension w/ Top/Bot. welds	4,500	4,600	11,500	1.745	(S) leg failed @ 1st shear form
E2	In Plane Tension w/ Top/Bot. welds	5,400	5,400	10,800	1.830	(N) leg failed @ 1st shear form
E3	In Plane Tension w/ Top/Bot. welds	5,500	5,500	11,200	1.560	(S) leg failed @ 1st shear form
A3	Out of Plane Shear w/ No Tension	Not Observed	3,850	3,850	0.421	Concrete blowout on bottom
C2	Out of Plane Shear w/ No Tension	Not Observed	3,580	3,580	0.197	Concrete blowout on bottom
E4	Out of Plane Shear w/ No Tension	Not Observed	5,410	5,410	0.468	Concrete blowout on bottom
A1	In Plane Monotonic Shear w/ No Tension	17,000	18,000	18,000	0.731	Concrete @ tension leg side
A2	In Plane Monotonic Shear w/ No Tension	15,000	16,100	19,300	0.121	Concrete @ tension leg side
A4	In Plane Monotonic Shear w/ No Tension	16,300	16,300	16,300	0.137	Concrete @ tension leg side
B1	In Plane Monotonic Shear w/ Tension	8,000	13,000	16,200	1.090	Leg Slippage 1/2" @ tension leg side, possible leg failure
B2	In Plane Monotonic Shear w/ Tension	7,000	14,200	18,300	0.887	Leg Slippage 3/8" @ tension leg side, possible leg failure
B3	In Plane Monotonic Shear w/ Tension	10,000	14,300	16,100	1.150	Steel leg failure @ tension side across 1st shear form
B4	In Plane Monotonic Shear w/ Tension	6,700	16,400	16,400	1.150	Concrete @ tension leg side and steel leg failure @ tension side across 1st shear form
C1	In Plane Cyclic Shear w/ No Tension	15,000	19,500	19,600	0.134	Final Failure steel tear @ face/corner bend; concrete cracks @ Initial & Max loads
C3	In Plane Cyclic Shear w/ No Tension	8,500	15,500	15,500	0.361	Final Failure steel tear @ face/corner bend; concrete cracks @ Initial & Max loads
C4	In Plane Cyclic Shear w/ No Tension	14,500	17,000	17,000	0.287	Final Failure steel tear @ face/corner bend; concrete cracks @ Initial & Max loads
D1	In Plane Cyclic Shear w/ Tension	10,000	14,500	14,500	0.074	Final Failure steel tear @ face/corner bend; concrete cracks @ Initial & Max loads
D2	In Plane Cyclic Shear w/ Tension	8,000	15,200	15,200	0.139	Final Failure steel tear @ face/corner bend; concrete cracks @ Initial & Max loads
D3	In Plane Cyclic Shear w/ Tension	8,000	14,800	14,800	0.194	Final Failure steel tear @ face/corner bend; concrete cracks @ Initial & Max loads
D4	In Plane Cyclic Shear w/ Tension	7,000	13,200	13,200	0.065	Final Failure steel tear @ face/corner bend; concrete cracks @ Initial & Max loads

Table 1: TEST RESULTS SUMMARY

ACKNOWLEDGEMENT
The flange connector is a very important product for the precast/prestressed concrete industry. Test information on its load-displacement behavior is critical in developing and upgrading the design procedures for jointed precast structures, such as parking decks. JVI's participation with precast producers in supporting laboratory testing on the Vector Connector is applauded.

APPENDIX A



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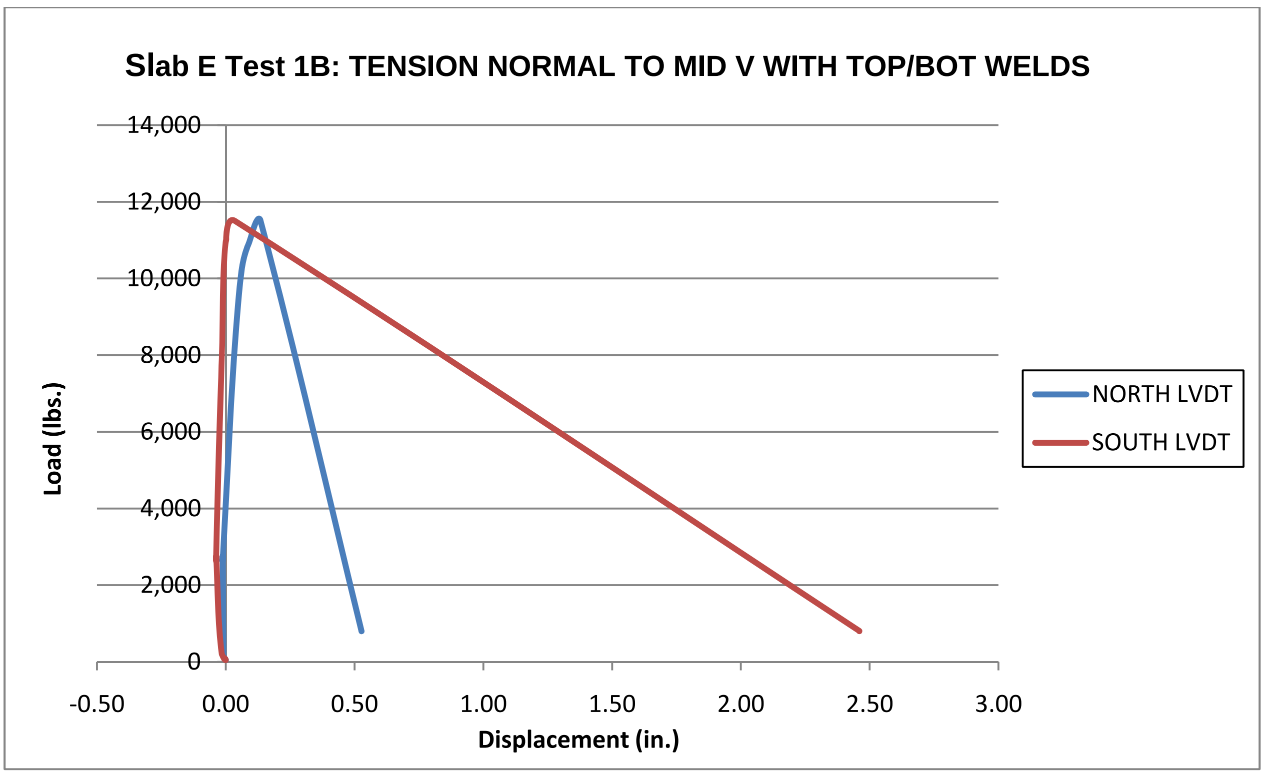
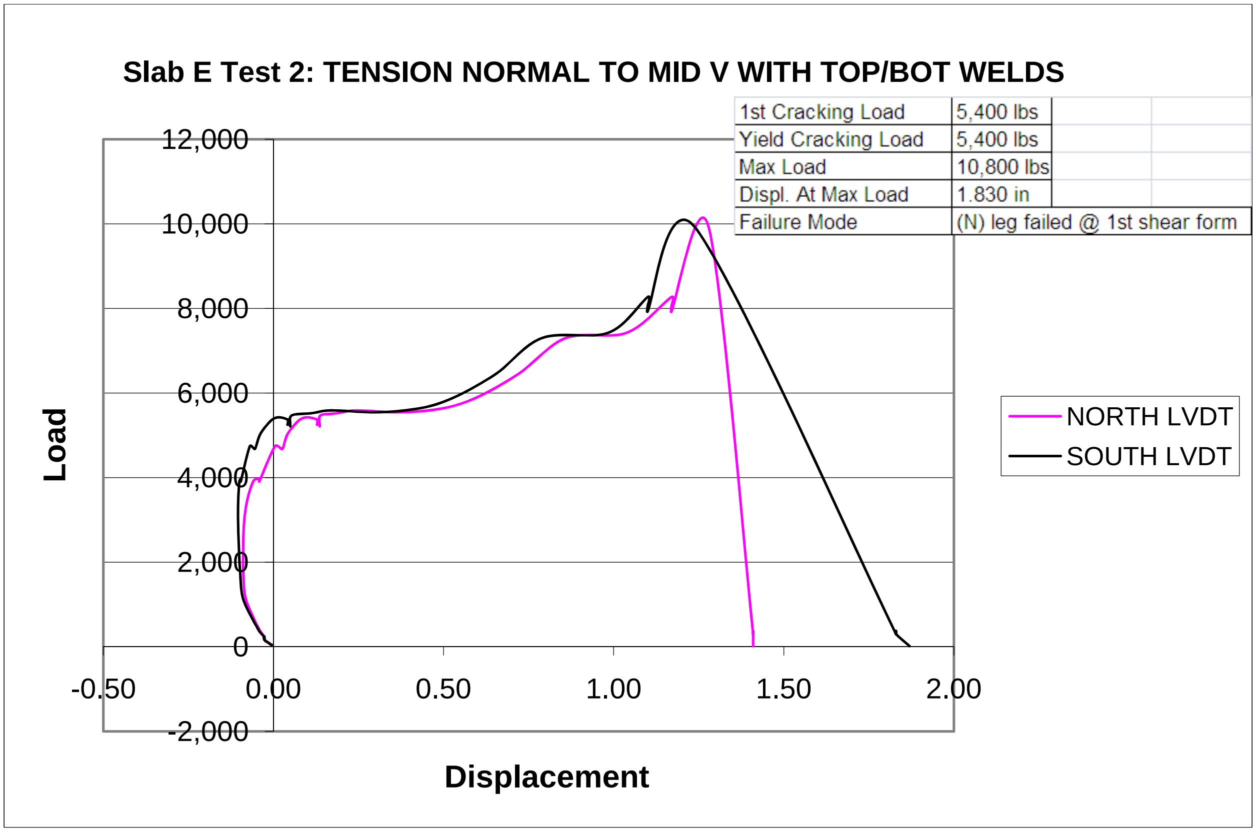
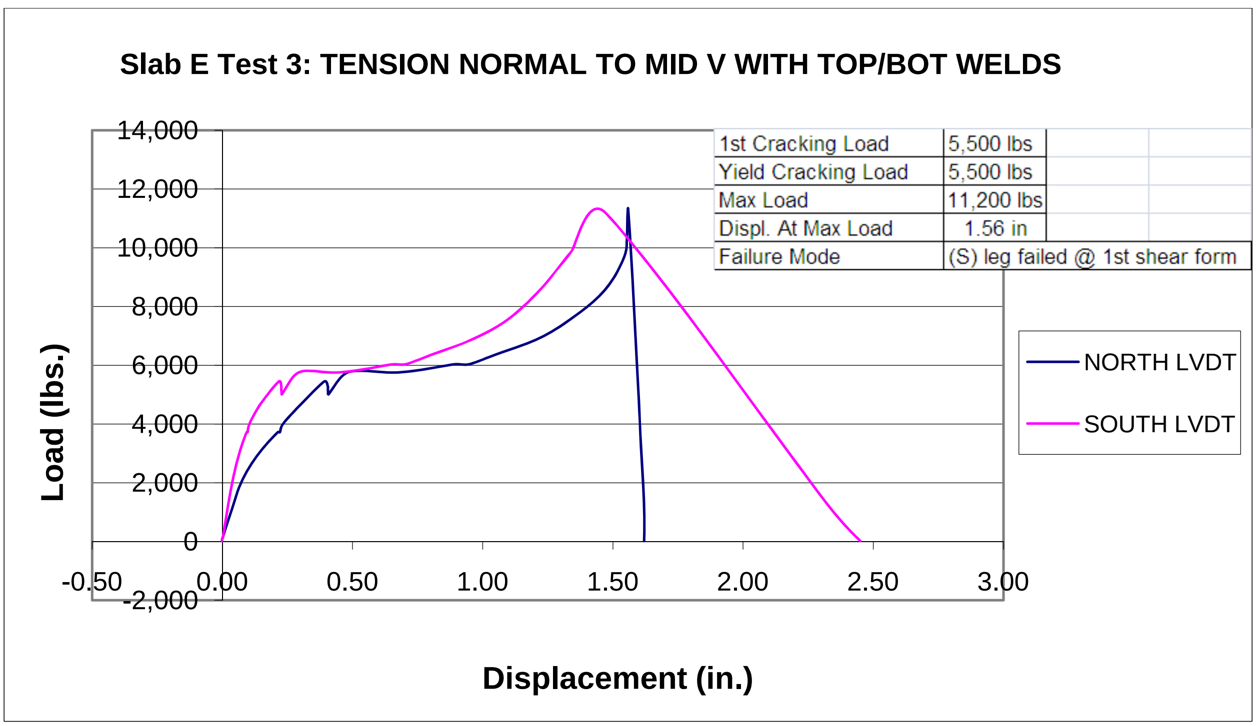
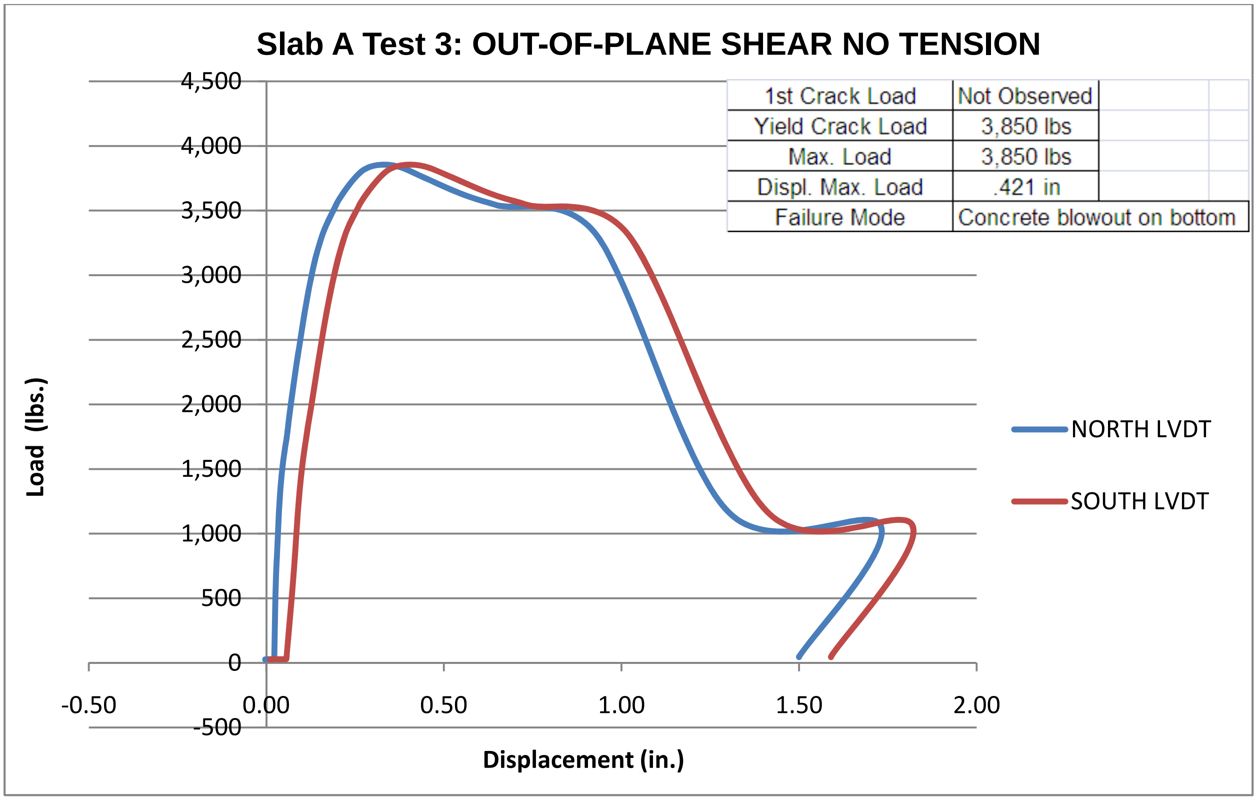


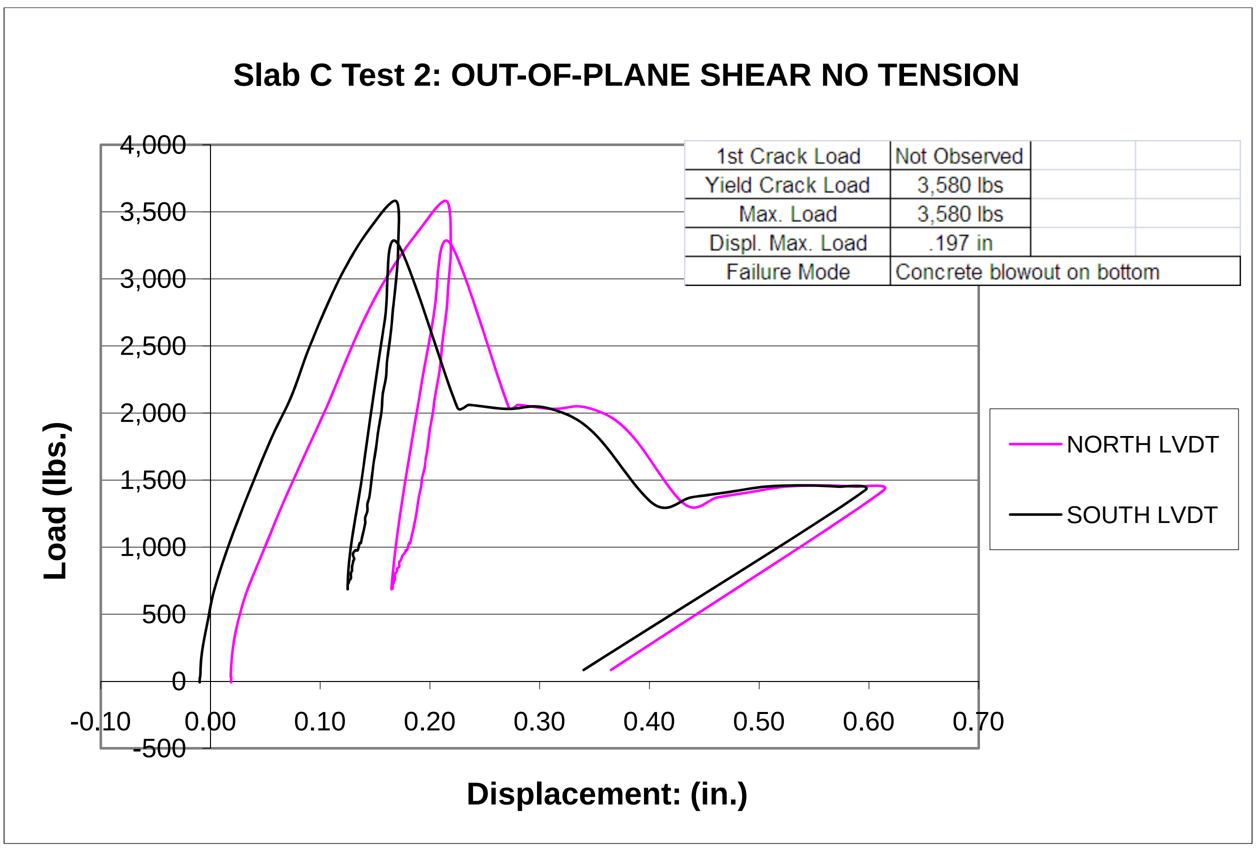
1st Cracking Load	4,500 lbs
Yield Cracking Load	4,600 lbs
Max Load	11,500 lbs
Displ. At Max Load	1.745 in
Failure Mode	(S) leg failed @ 1st shear form


Slab E Test 2: TENSION NORMAL TO MID V WITH TOP/BOT WELDS
1st Cracking Load | 5,400 lbs
Yield Cracking Load | 5,400 lbs
Max Load | 10,800 lbs
Displ. At Max Load | 1.830 in
Failure Mode | (N) leg failed @ 1st shear form
Load
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
-0.50
0.00
0.50
1.00
1.50
2.00
Displacement
NORTH LVDT
SOUTH LVDT

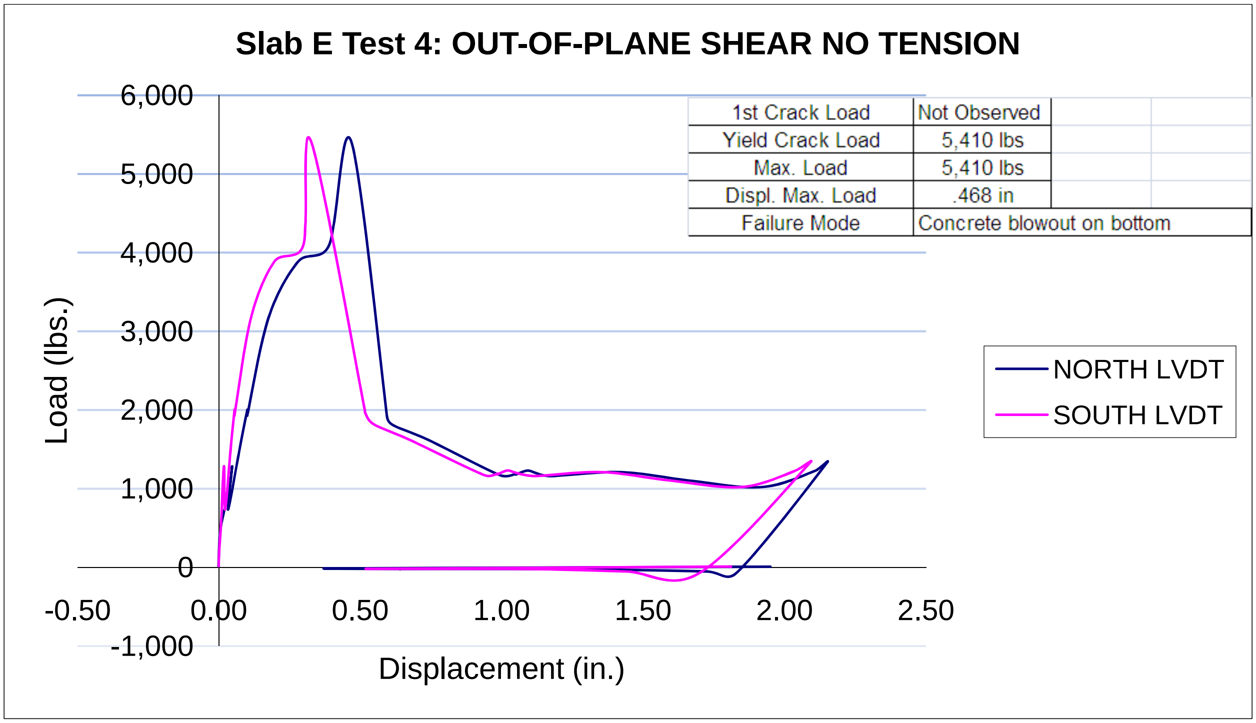

Slab E Test 3: TENSION NORMAL TO MID V WITH TOP/BOT WELDS
1st Cracking Load | 5,500 lbs
Yield Cracking Load | 5,500 lbs
Max Load | 11,200 lbs
Displ. At Max Load | 1.56 in
Failure Mode | (S) leg failed @ 1st shear form
Load (lbs.)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
-0.50
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Displacement (in.)
NORTH LVDT
SOUTH LVDT

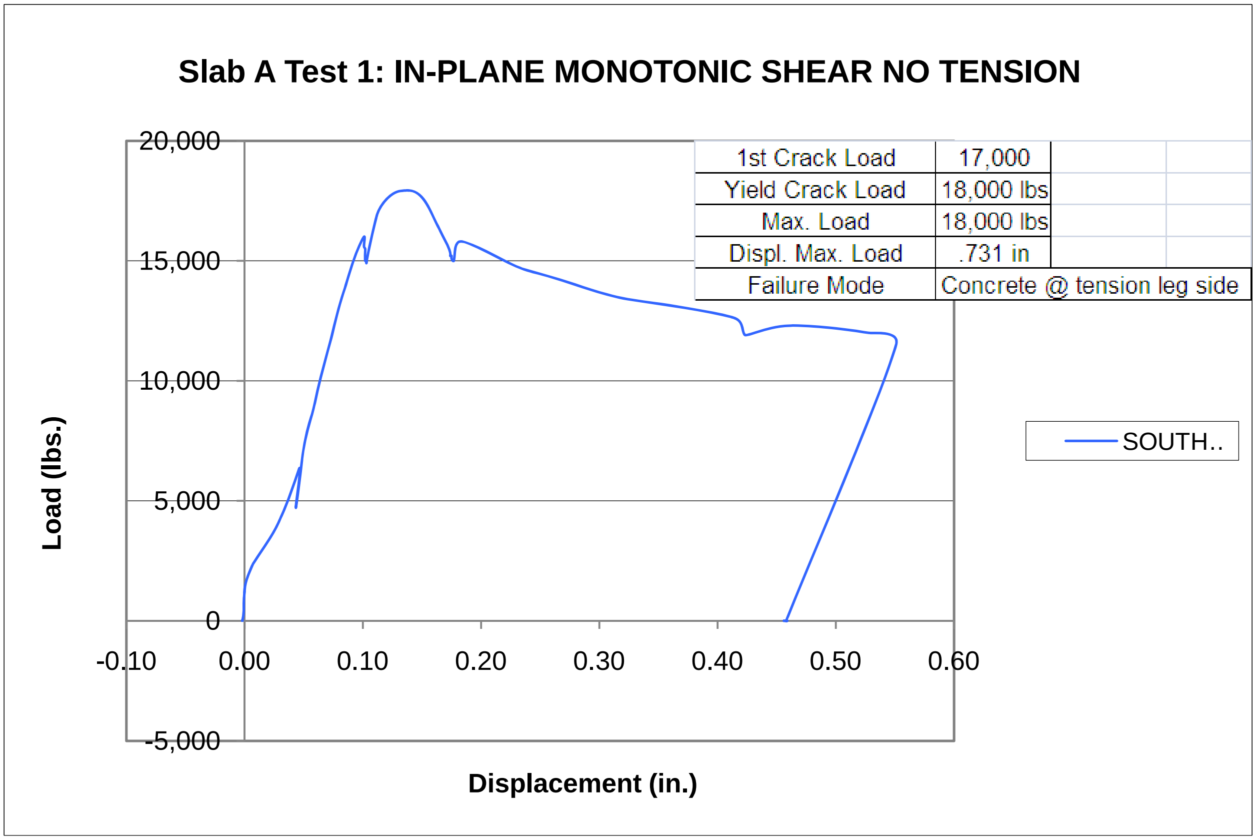


1st Crack Load	Not Observed
Yield Crack Load	3,850 lbs
Max. Load	3,850 lbs
Displ. Max. Load	.421 in
Failure Mode	Concrete blowout on bottom

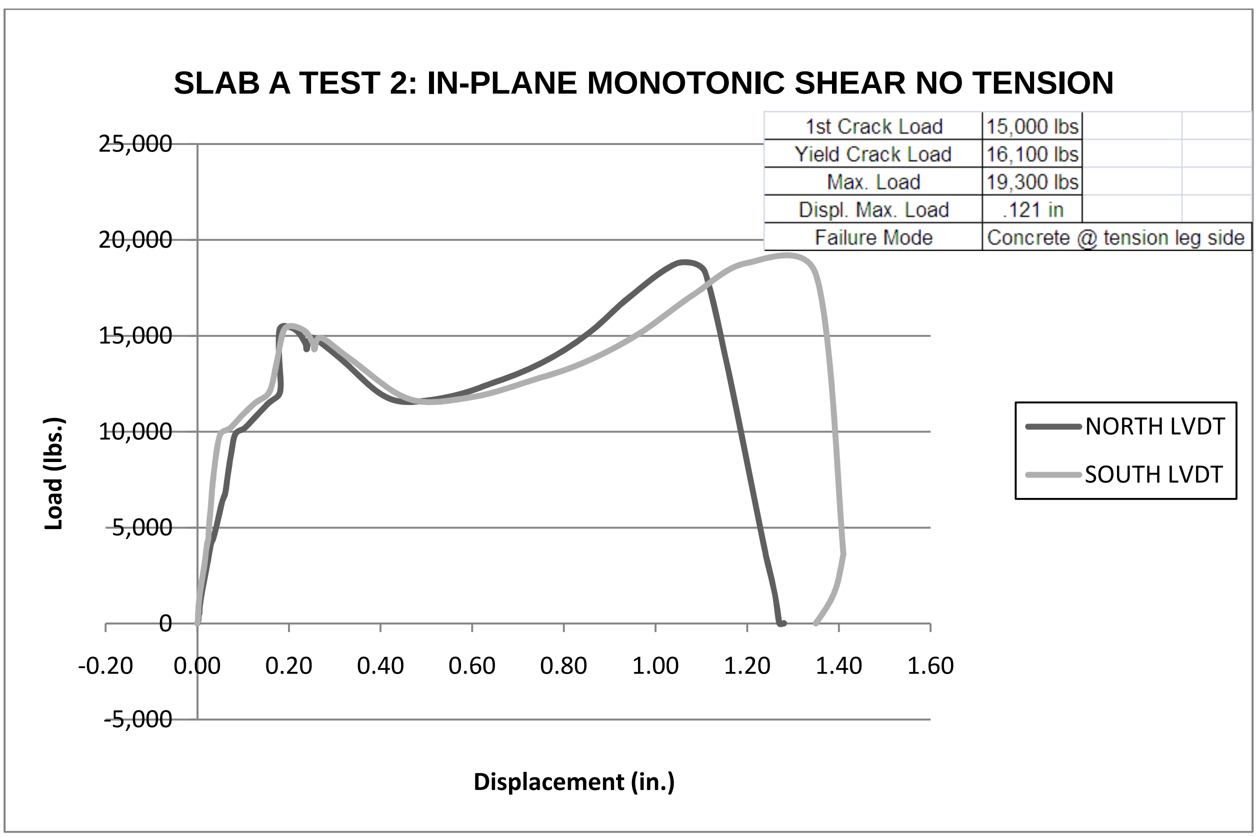


1st Crack Load	Not Observed
Yield Crack Load	3,580 lbs
Max. Load	3,580 lbs
Displ. Max. Load	.197 in
Failure Mode	Concrete blowout on bottom

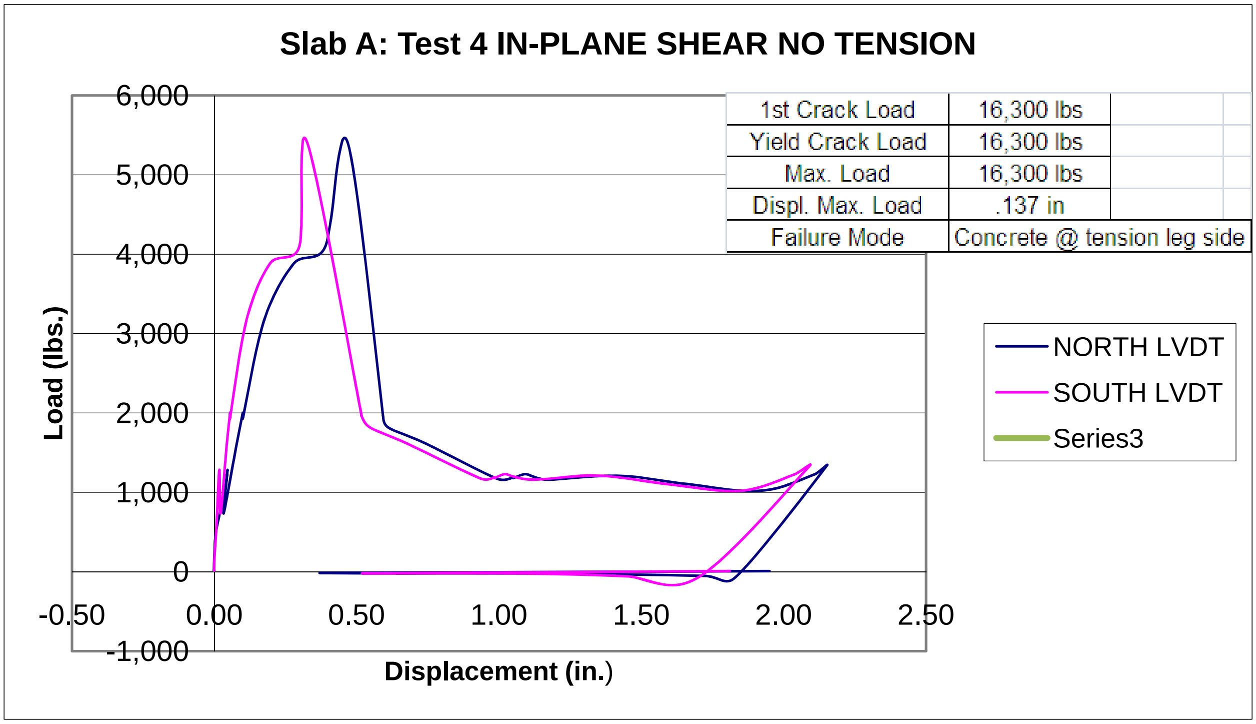

Slab E Test 4: OUT-OF-PLANE SHEAR NO TENSION
1st Crack Load
Not Observed
Yield Crack Load
5,410 lbs
Max. Load
5,410 lbs
Displ. Max. Load
.468 in
Failure Mode
Concrete blowout on bottom
6,000
5,000
4,000
3,000
2,000
1,000
0
-1,000
Load (lbs.)
-0.50
0.00
0.50
1.00
1.50
2.00
2.50
Displacement (in.)
NORTH LVDT
SOUTH LVDT



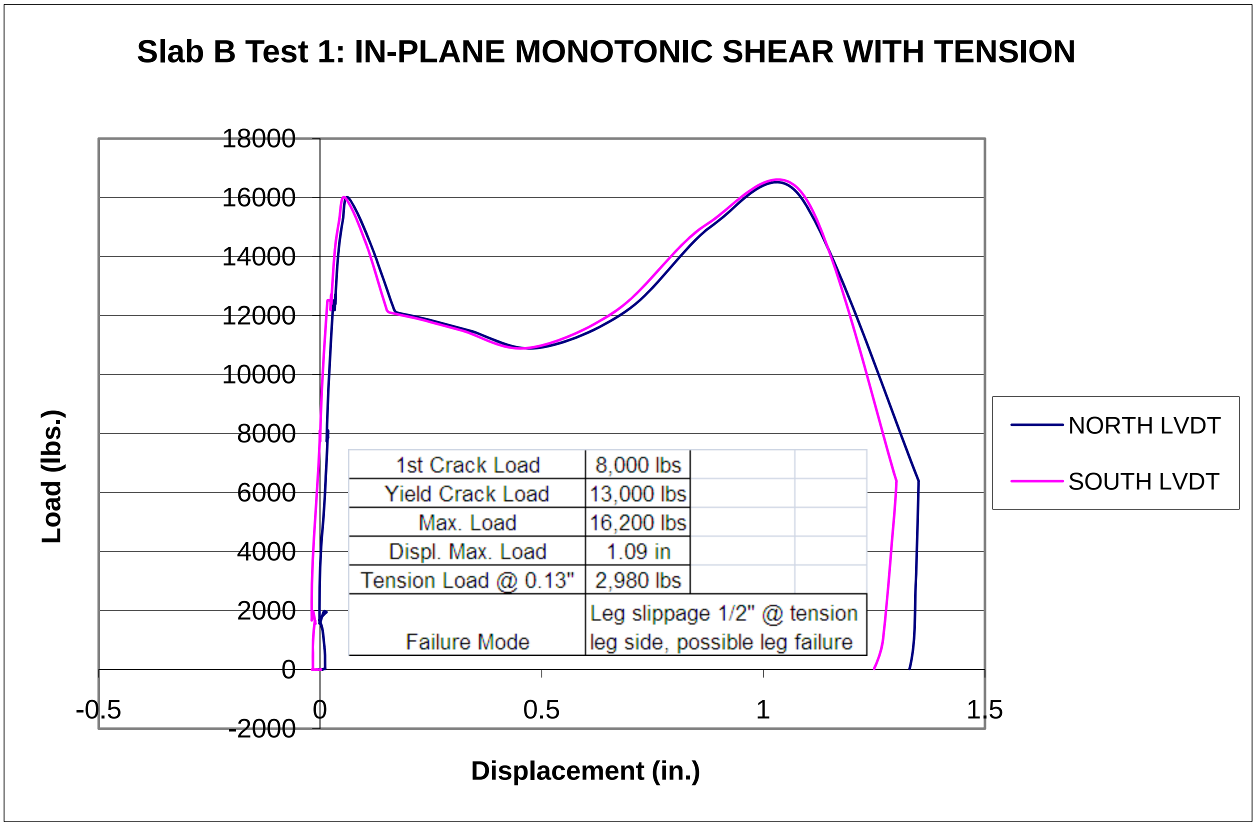
1st Crack Load	17,000
Yield Crack Load	18,000 lbs
Max. Load	18,000 lbs
Displ. Max. Load	.731 in
Failure Mode	Concrete @ tension leg side

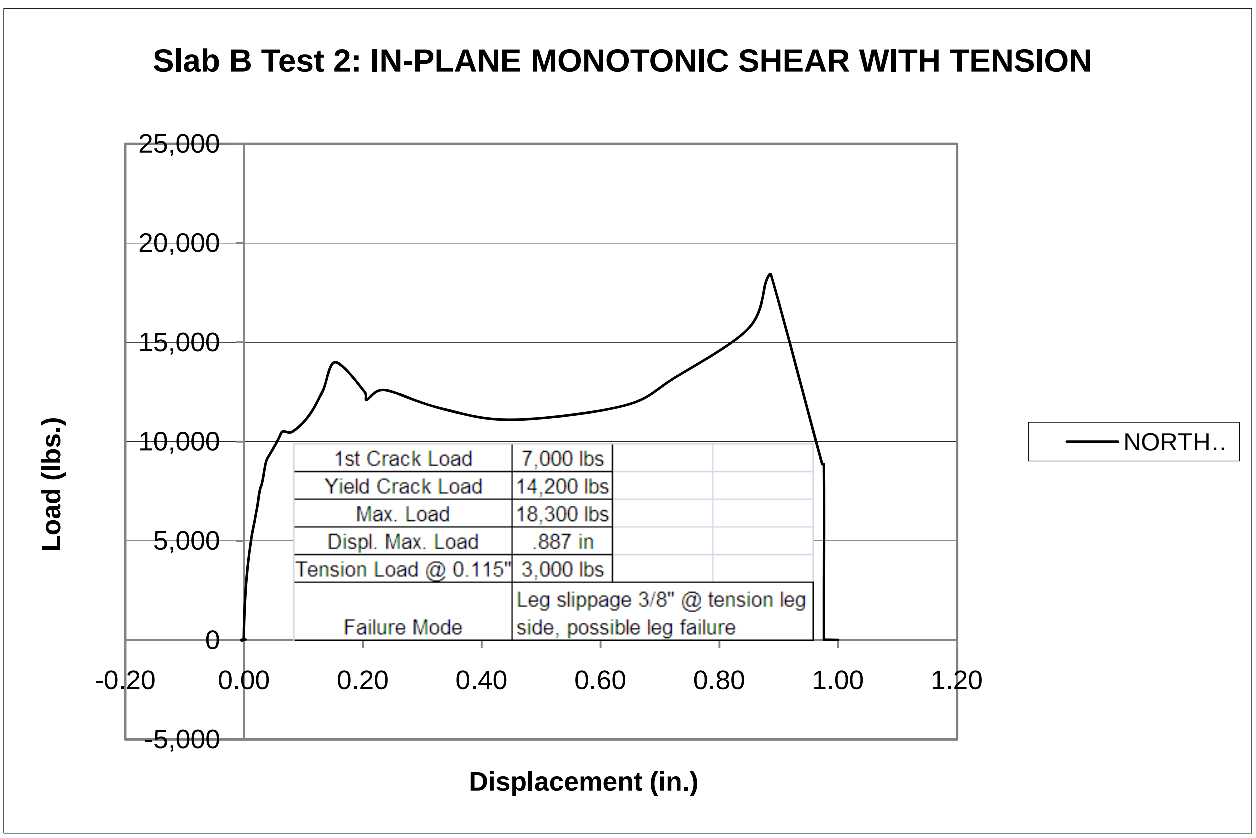


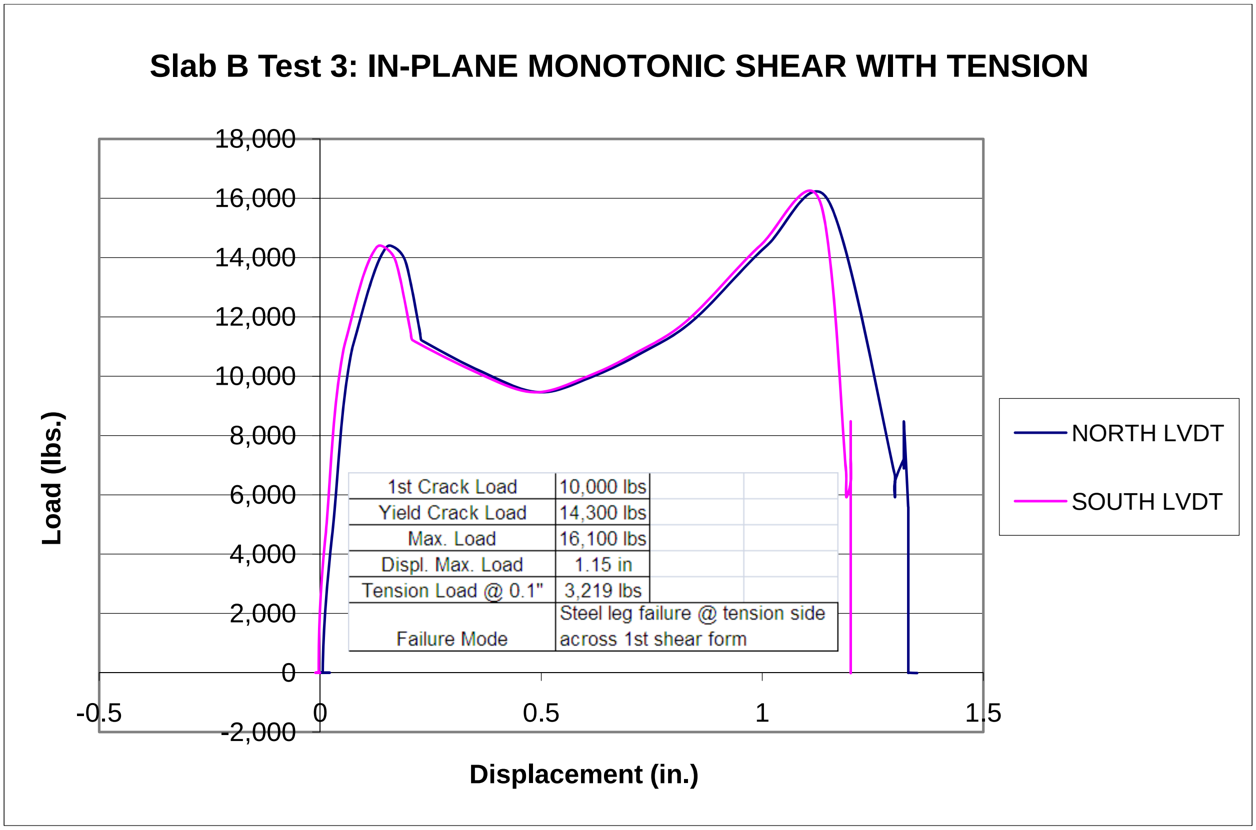
1st Crack Load	15,000 lbs
Yield Crack Load	16,100 lbs
Max. Load	19,300 lbs
Displ. Max. Load	.121 in
Failure Mode	Concrete @ tension leg side

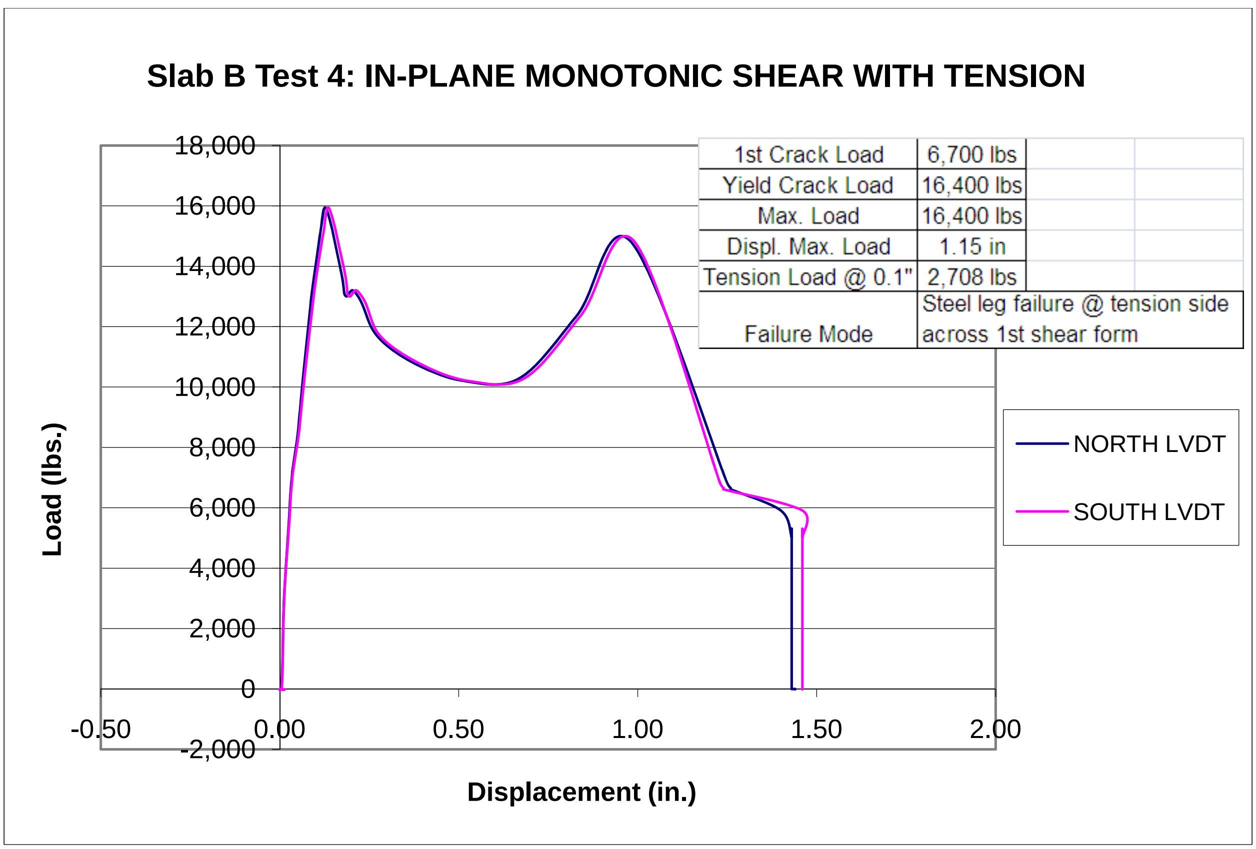


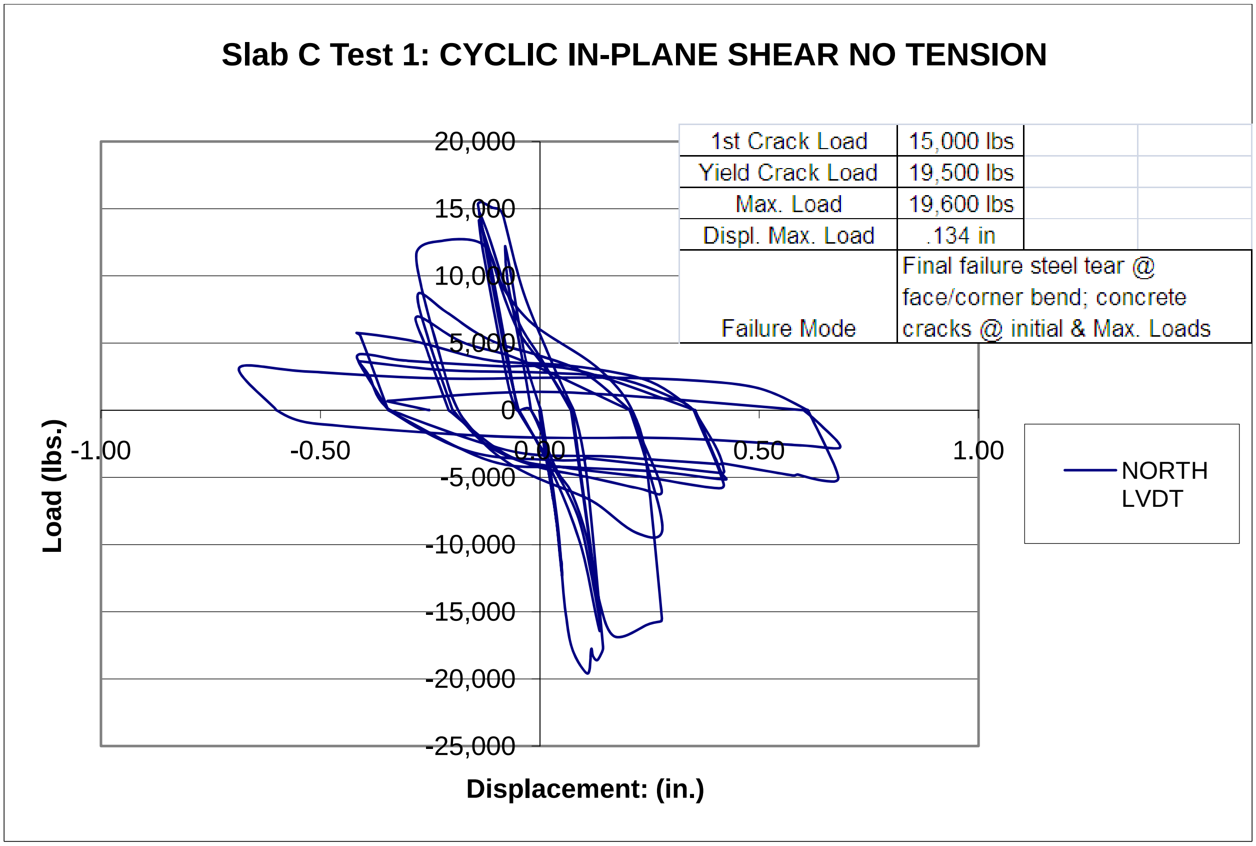
1st Crack Load	16,300 lbs
Yield Crack Load	16,300 lbs
Max. Load	16,300 lbs
Displ. Max. Load	.137 in
Failure Mode	Concrete @ tension leg side


Slab B Test 1: IN-PLANE MONOTONIC SHEAR WITH TENSION
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
-0.5
0
0.5
1
1.5
Load (lbs.)
Displacement (in.)
NORTH LVDT
SOUTH LVDT
1st Crack Load 8,000 lbs
Yield Crack Load 13,000 lbs
Max. Load 16,200 lbs
Displ. Max. Load 1.09 in
Tension Load @ 0.13" 2,980 lbs
Failure Mode Leg slippage 1/2" @ tension leg side, possible leg failure

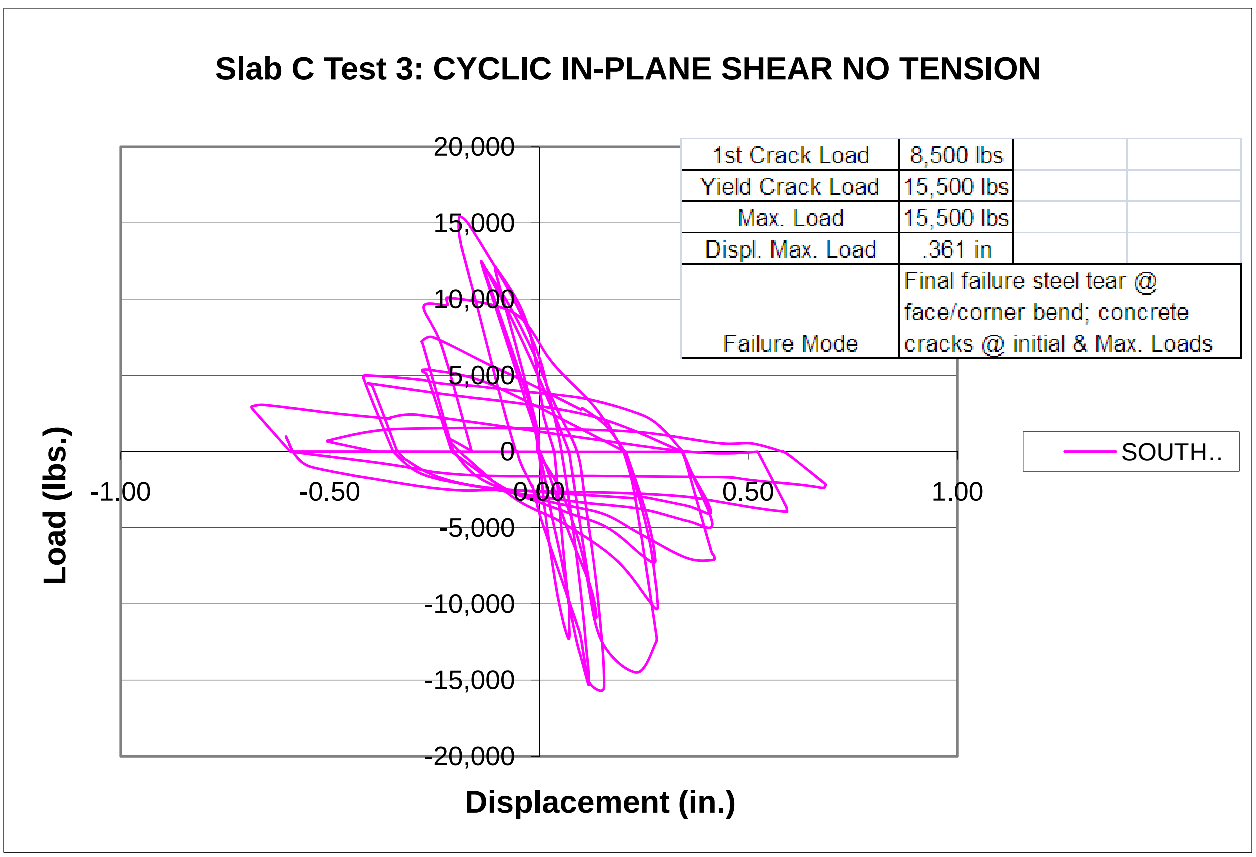

Slab B Test 2: IN-PLANE MONOTONIC SHEAR WITH TENSION
25,000
20,000
15,000
10,000
5,000
0
-5,000
-0.20
0.00
0.20
0.40
0.60
0.80
1.00
1.20
Load (lbs.)
Displacement (in.)
NORTH..
1st Crack Load 7,000 lbs
Yield Crack Load 14,200 lbs
Max. Load 18,300 lbs
Displ. Max. Load .887 in
Tension Load @ 0.115" 3,000 lbs
Failure Mode Leg slippage 3/8" @ tension leg side, possible leg failure


Slab B Test 3: IN-PLANE MONOTONIC SHEAR WITH TENSION
Load (lbs.)
Displacement (in.)
NORTH LVDT
SOUTH LVDT
1st Crack Load 10,000 lbs
Yield Crack Load 14,300 lbs
Max. Load 16,100 lbs
Displ. Max. Load 1.15 in
Tension Load @ 0.1" 3,219 lbs
Failure Mode Steel leg failure @ tension side across 1st shear form

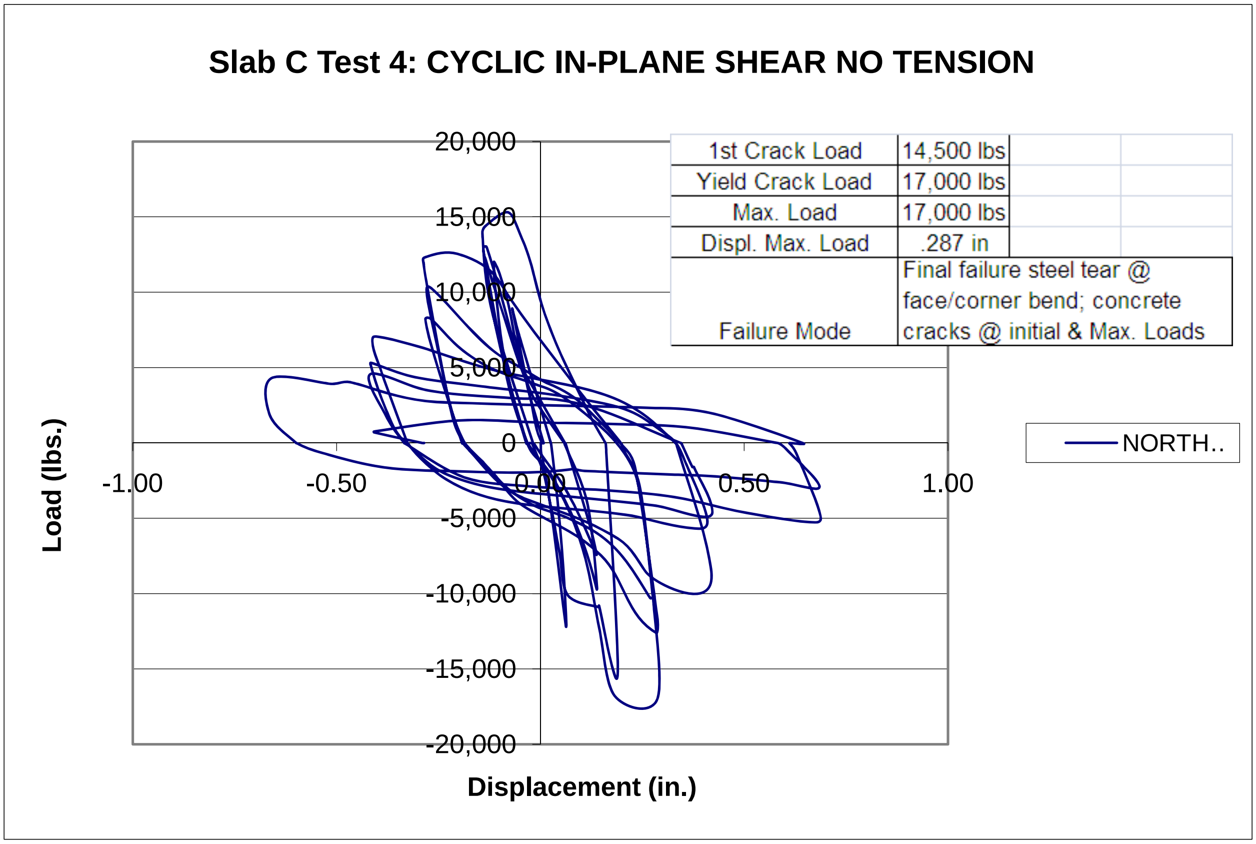

Slab B Test 4: IN-PLANE MONOTONIC SHEAR WITH TENSION
Load (lbs.)
Displacement (in.)
NORTH LVDT
SOUTH LVDT
1st Crack Load 6,700 lbs
Yield Crack Load 16,400 lbs
Max. Load 16,400 lbs
Displ. Max. Load 1.15 in
Tension Load @ 0.1" 2,708 lbs
Failure Mode Steel leg failure @ tension side across 1st shear form

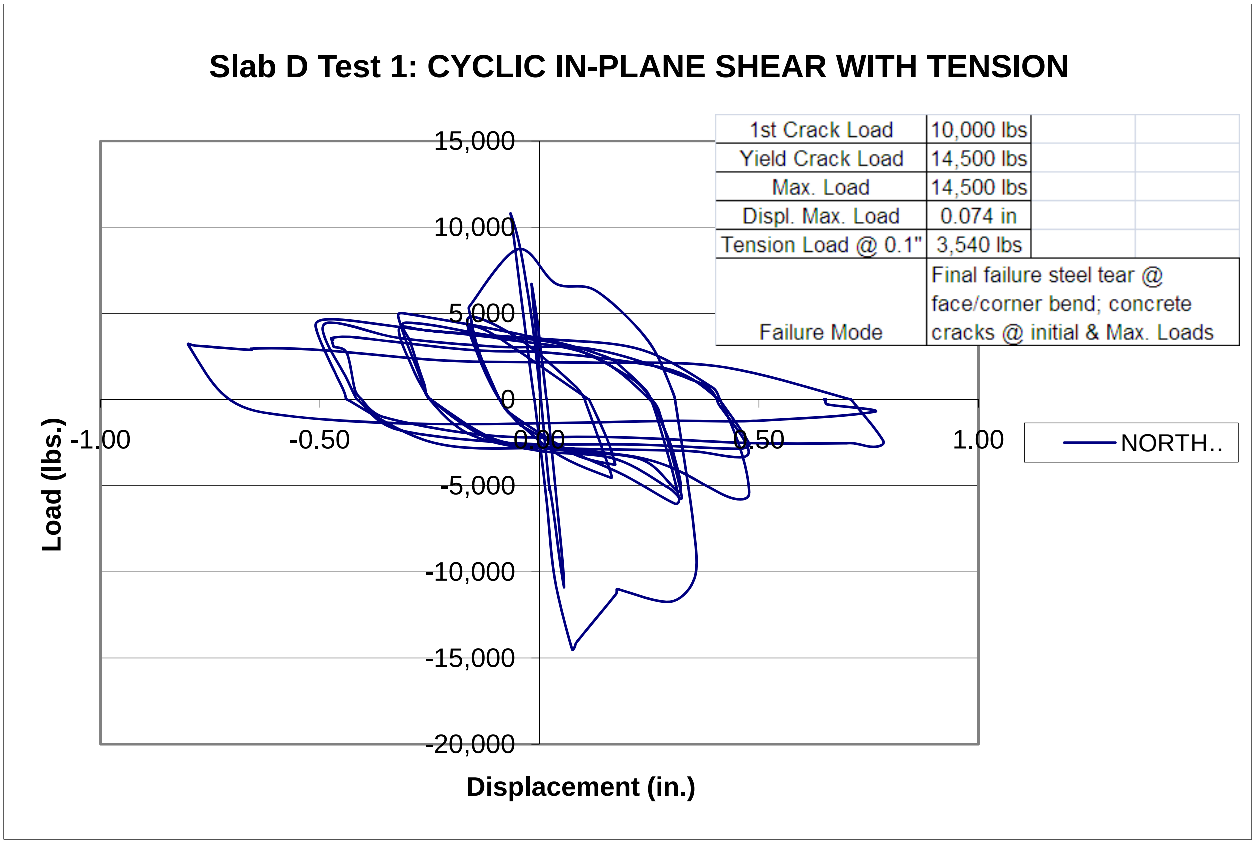


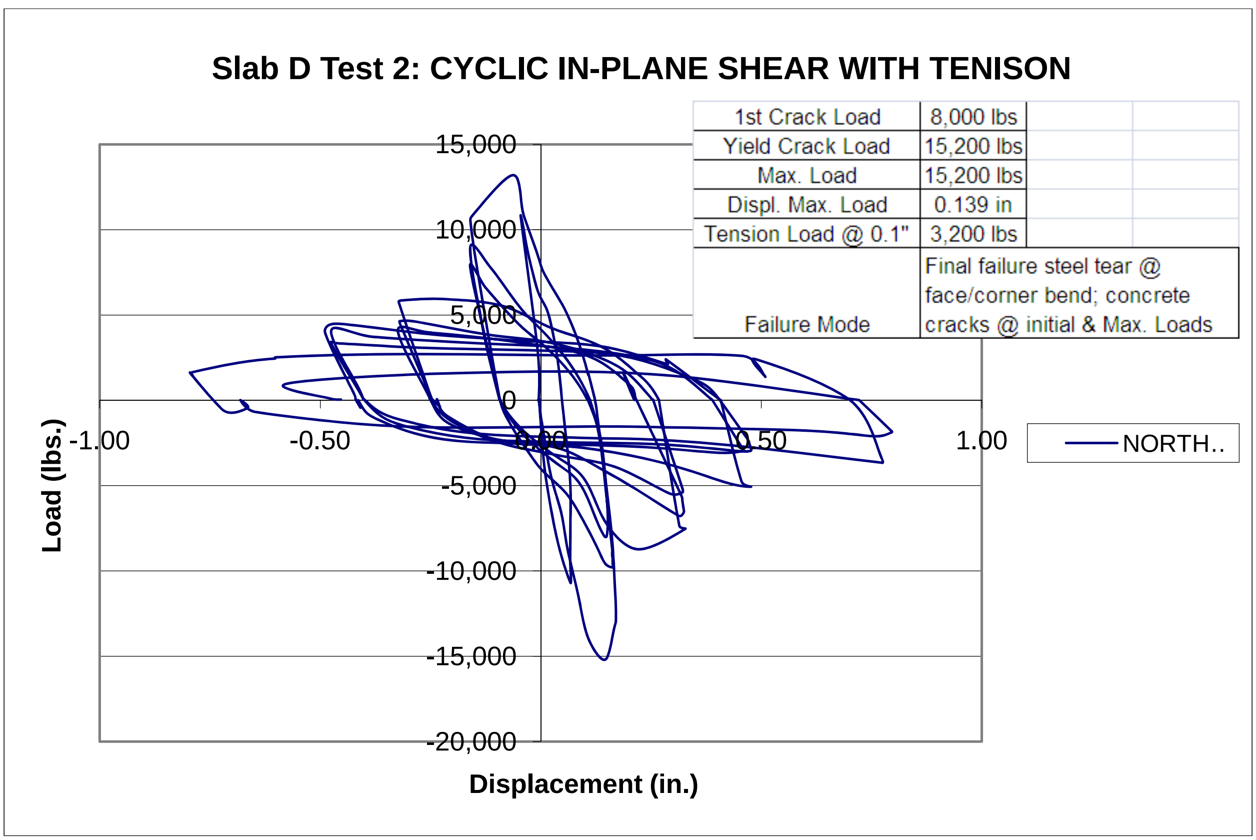
1st Crack Load	15,000 lbs
Yield Crack Load	19,500 lbs
Max. Load	19,600 lbs
Displ. Max. Load	.134 in
Failure Mode	Final failure steel tear @ face/corner bend; concrete cracks @ initial & Max. Loads

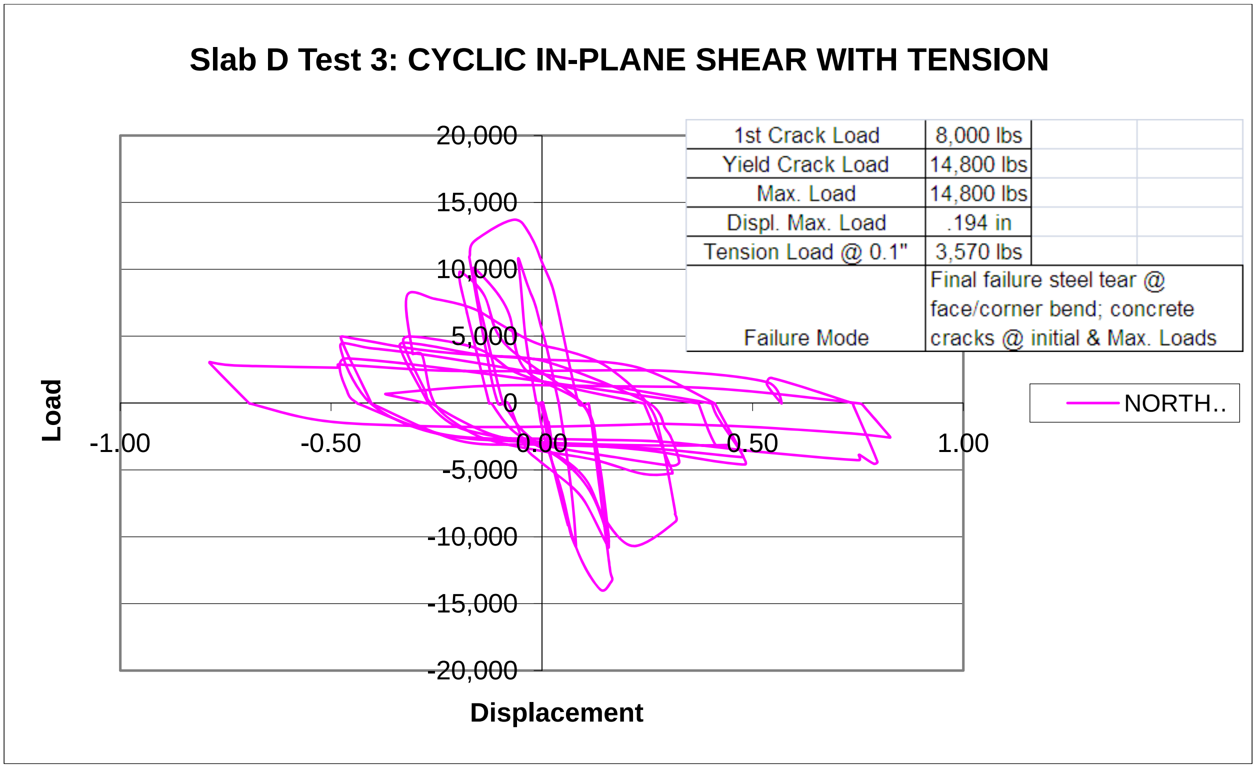


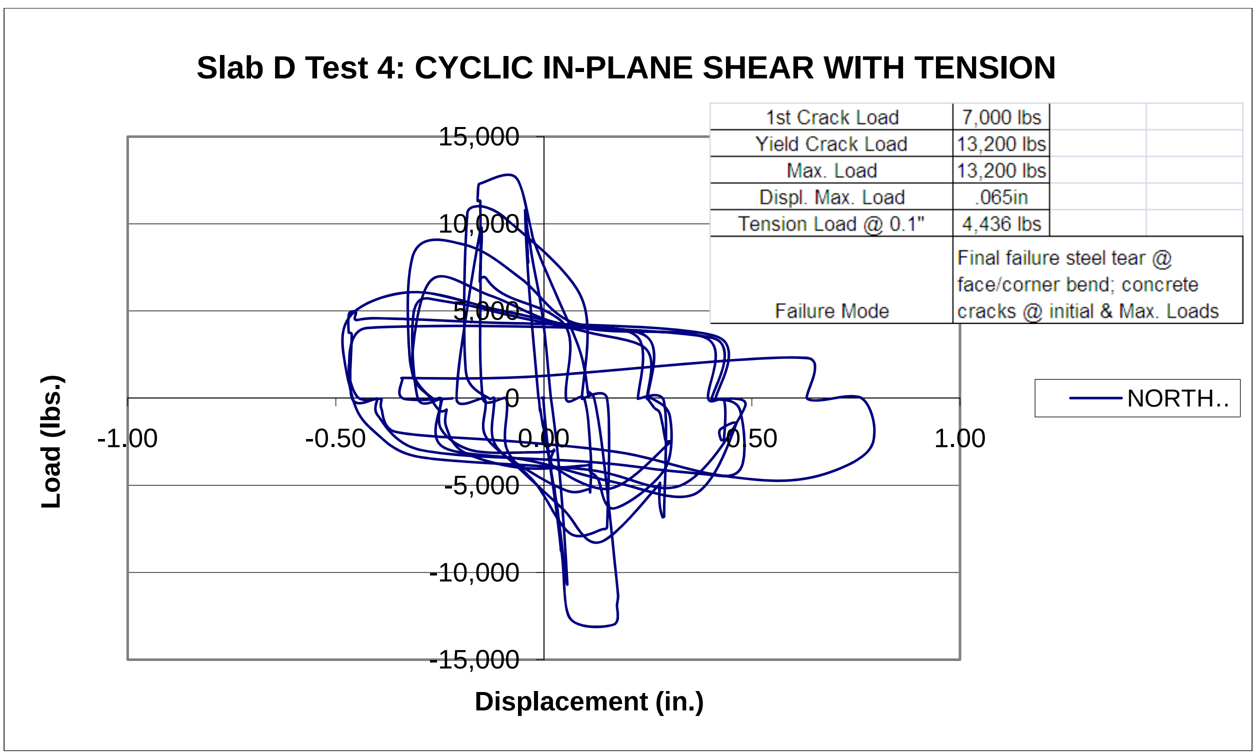
1st Crack Load	8,500 lbs
Yield Crack Load	15,500 lbs
Max. Load	15,500 lbs
Displ. Max. Load	.361 in
Failure Mode	Final failure steel tear @ face/corner bend; concrete cracks @ initial & Max. Loads


Slab C Test 4: CYCLIC IN-PLANE SHEAR NO TENSION
1st Crack Load
14,500 lbs
Yield Crack Load
17,000 lbs
Max. Load
17,000 lbs
Displ. Max. Load
.287 in
Failure Mode
Final failure steel tear @ face/corner bend; concrete cracks @ initial & Max. Loads
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
-1.00
-0.50
0.00
0.50
1.00
Load (lbs.)
Displacement (in.)
NORTH..


Slab D Test 1: CYCLIC IN-PLANE SHEAR WITH TENSION
1st Crack Load | 10,000 lbs
Yield Crack Load | 14,500 lbs
Max. Load | 14,500 lbs
Displ. Max. Load | 0.074 in
Tension Load @ 0.1" | 3,540 lbs
Failure Mode | Final failure steel tear @ face/corner bend; concrete cracks @ initial & Max. Loads
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
-1.00
-0.50
0.00
0.50
1.00
Load (lbs.)
Displacement (in.)
NORTH..


Slab D Test 2: CYCLIC IN-PLANE SHEAR WITH TENISON
1st Crack Load | 8,000 lbs
Yield Crack Load | 15,200 lbs
Max. Load | 15,200 lbs
Displ. Max. Load | 0.139 in
Tension Load @ 0.1" | 3,200 lbs
Failure Mode | Final failure steel tear @ face/corner bend; concrete cracks @ initial & Max. Loads
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
-1.00
-0.50
0.00
0.50
1.00
Load (lbs.)
Displacement (in.)
NORTH..


Slab D Test 3: CYCLIC IN-PLANE SHEAR WITH TENSION
1st Crack Load | 8,000 lbs
Yield Crack Load | 14,800 lbs
Max. Load | 14,800 lbs
Displ. Max. Load | .194 in
Tension Load @ 0.1" | 3,570 lbs
Failure Mode | Final failure steel tear @ face/corner bend; concrete cracks @ initial & Max. Loads
NORTH..
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
-1.00
-0.50
0.00
0.50
1.00
Load
Displacement


Slab D Test 4: CYCLIC IN-PLANE SHEAR WITH TENSION
1st Crack Load | 7,000 lbs
Yield Crack Load | 13,200 lbs
Max. Load | 13,200 lbs
Displ. Max. Load | .065in
Tension Load @ 0.1" | 4,436 lbs
Failure Mode | Final failure steel tear @ face/corner bend; concrete cracks @ initial & Max. Loads
NORTH..
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-1.00
-0.50
0.00
0.50
1.00
Load (lbs.)
Displacement (in.)

APPENDIX B

Figure 1 - Mid V

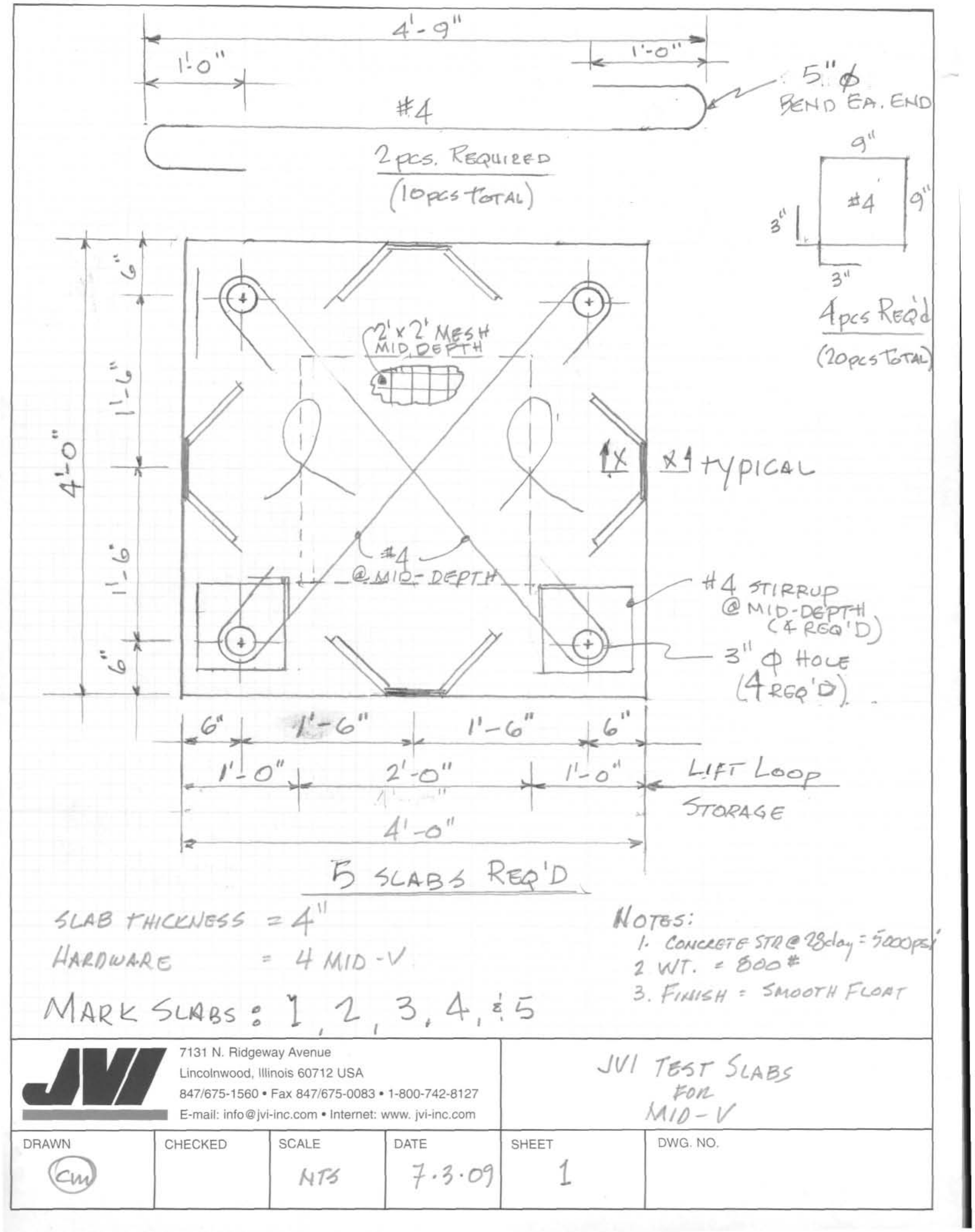


Figure 2 – test slab details and reinforcing

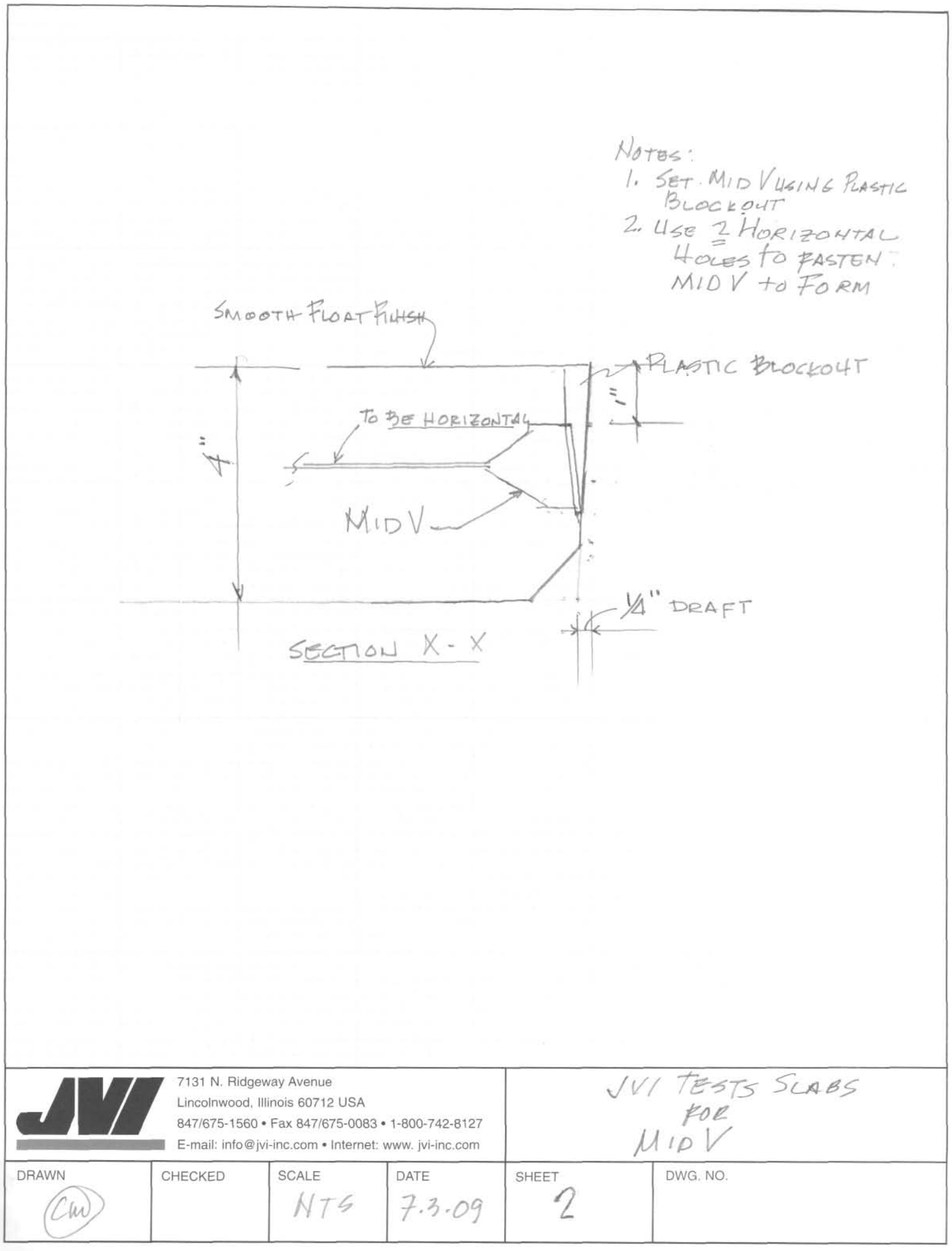


Figure 3 – Section thru Mid V in test slab

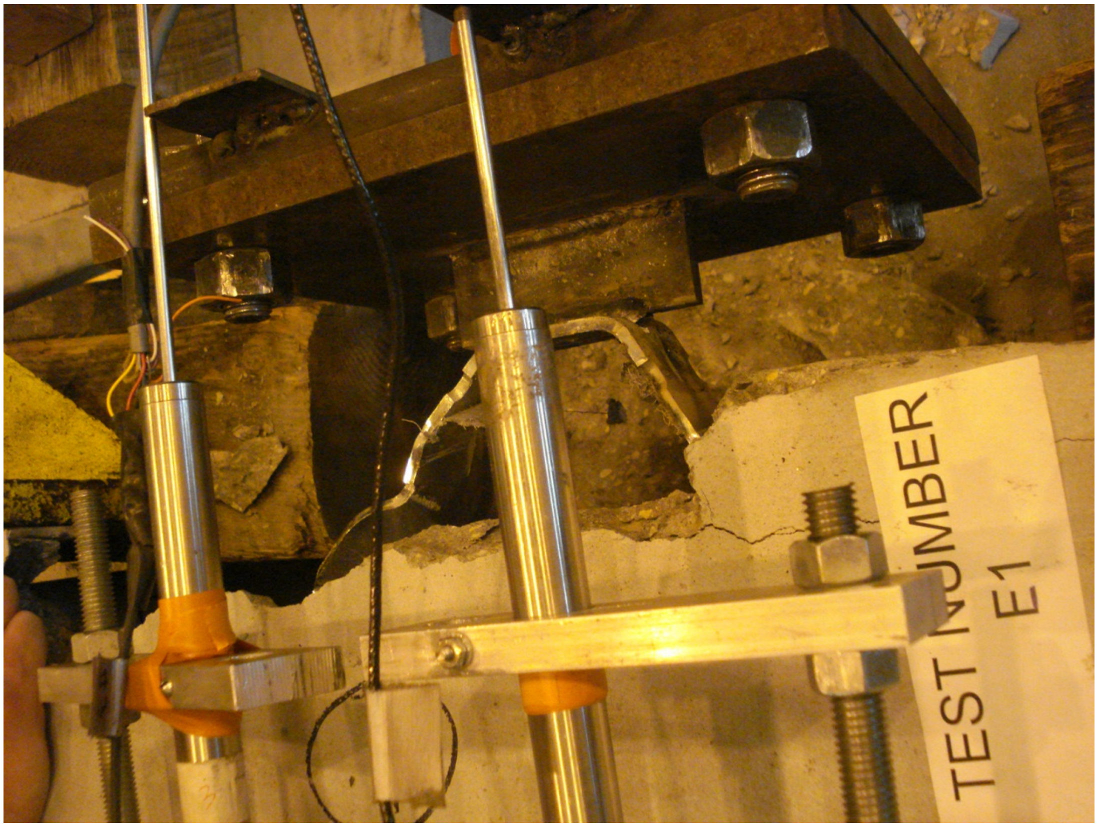


Figure 4 – Test E1A & B: In-Plane Tension

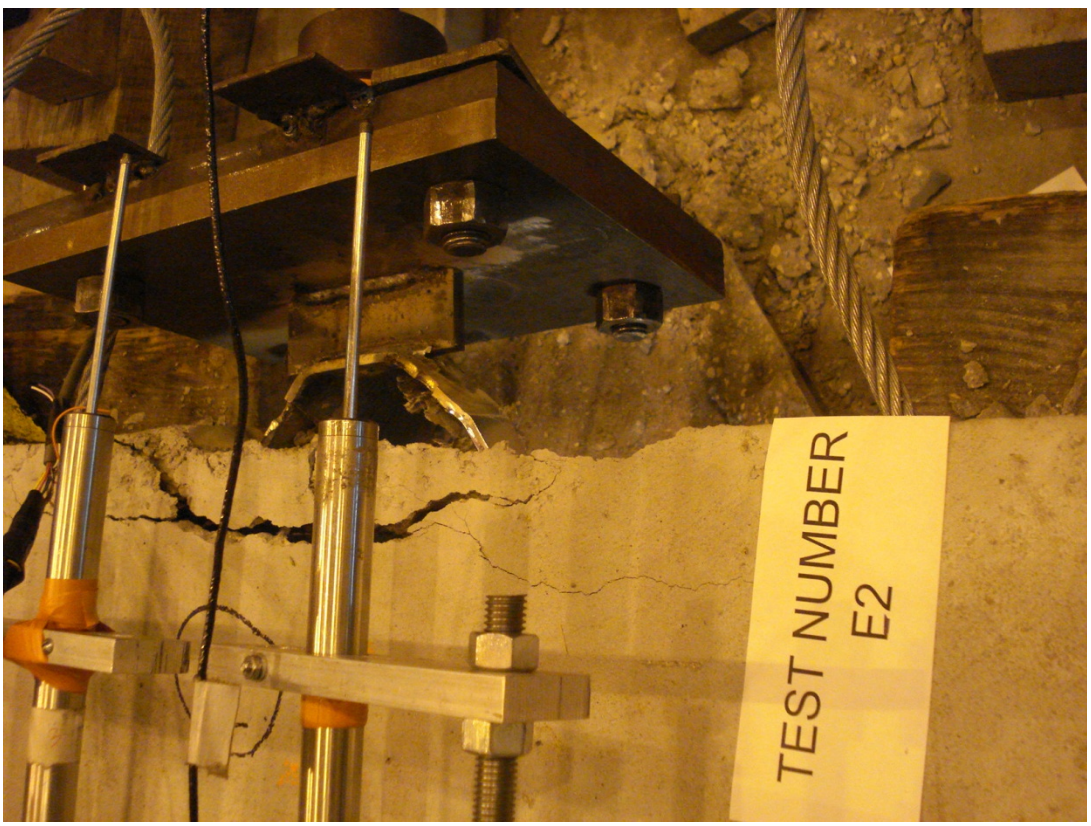


Figure 5 – Test E2: In-Plane Tension

Figure 6 – Test E3: In-Plane Tension

Figure 7 – Test A3: Out of Plane Shear w/ No Tension

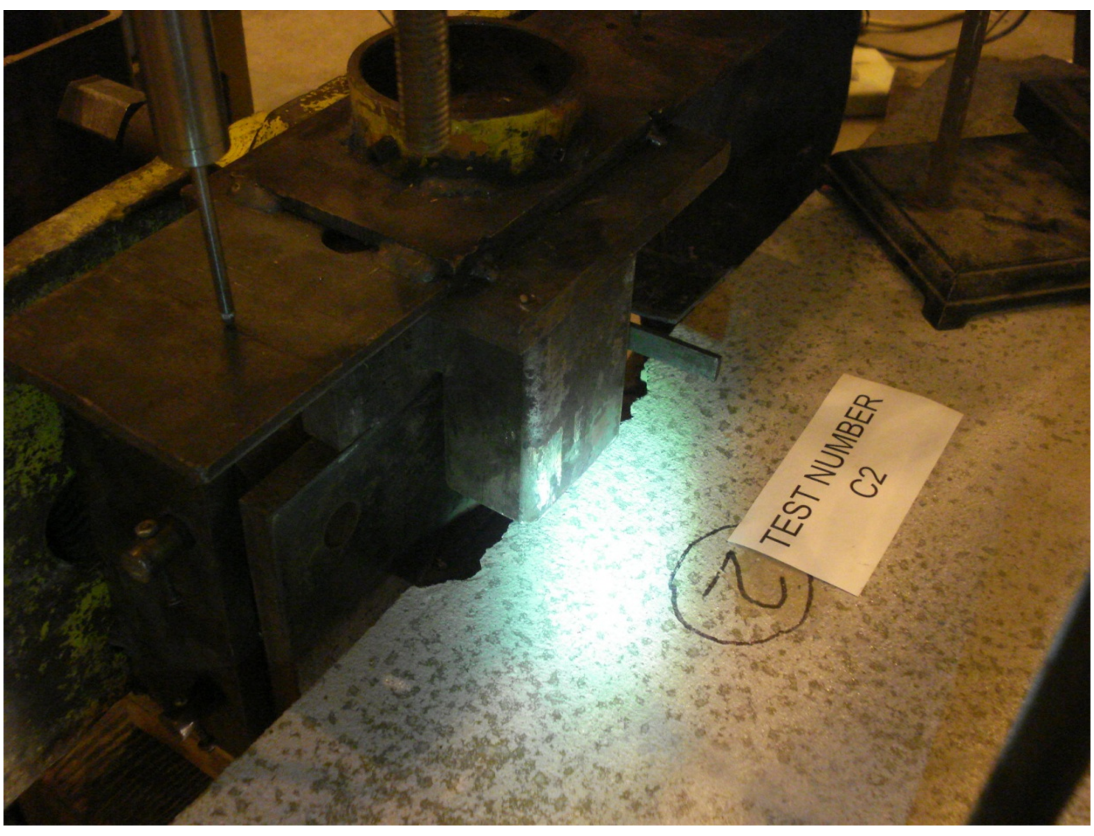


Figure 8 – Test C2: Out of Plane Shear w/ No Tension

Figure 9 – Test E4: Out of Plane Shear w/ No Tension

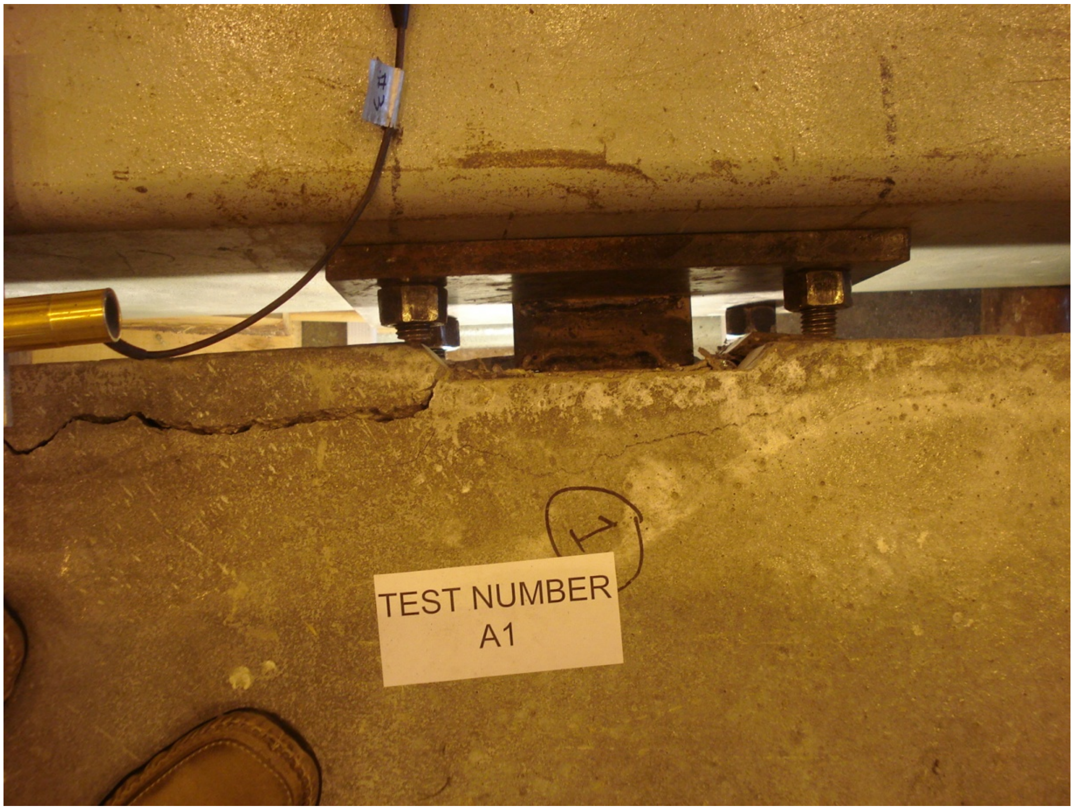


Figure 10 – Test A1: In-Plane Monotonic Shear w/ No Tension

Figure 11 – Test A2: In-Plane Monotonic Shear w/ No Tension

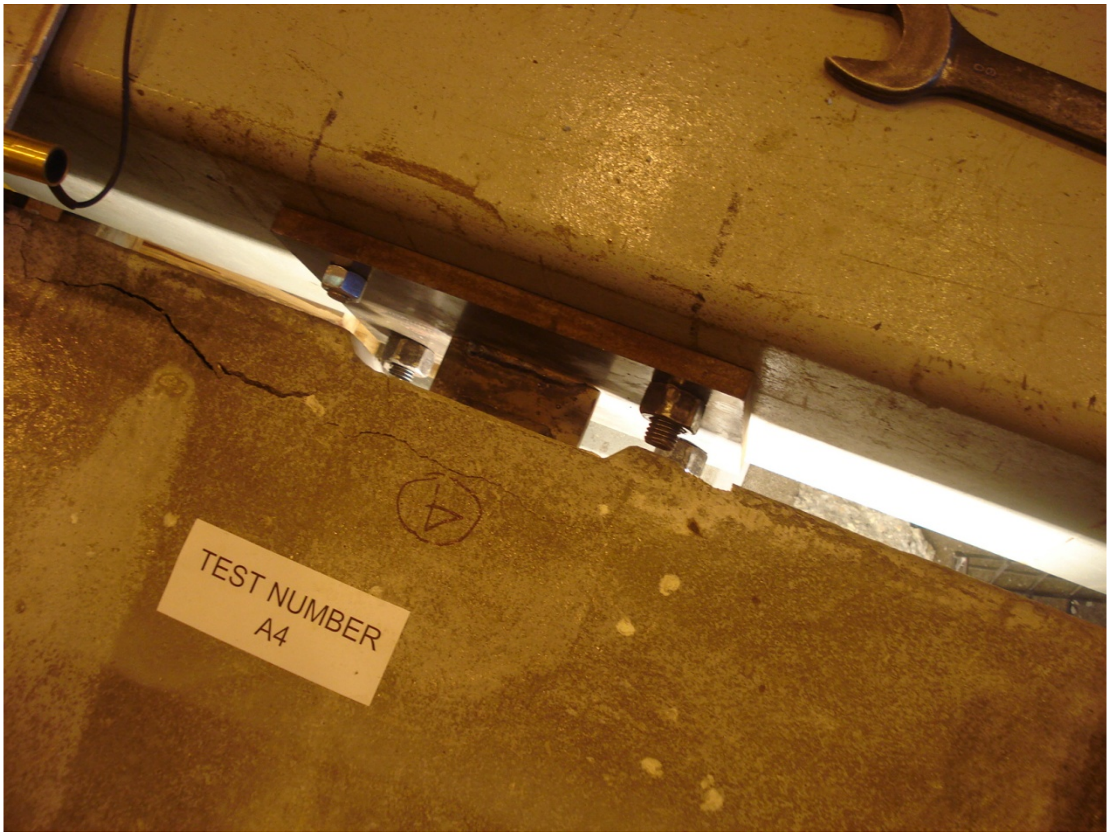


Figure 12 – Test A4: In-Plane Monotonic Shear w/ No Tension

Figure 13 – Test B1: In-Plane Monotonic Shear w/ Tension

Figure 14 –Test B2: In-Plane Monotonic Shear w/ Tension

Figure 15 – Test B3: In-Plane Monotonic Shear w/ Tension

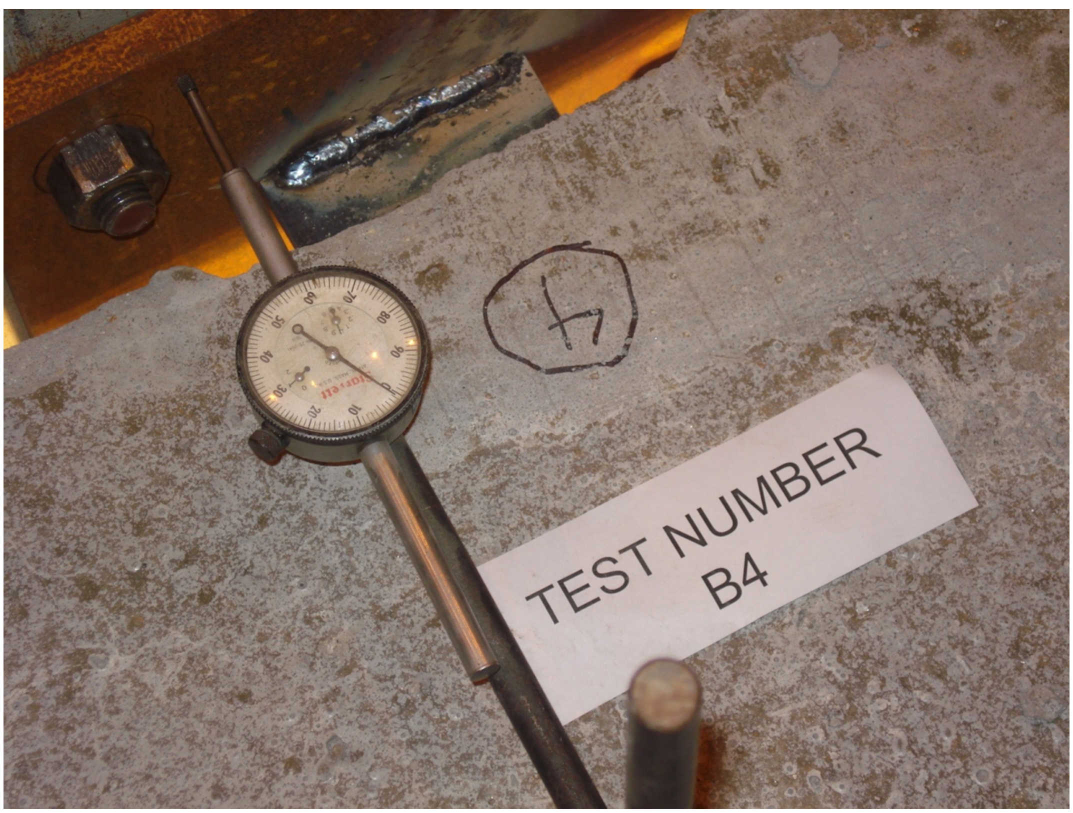


Figure 16 – Test B4: In-Plane Monotonic Shear w/ Tension

Figure 17 – Test C1: In-Plane Cyclic Shear w/ No Tension

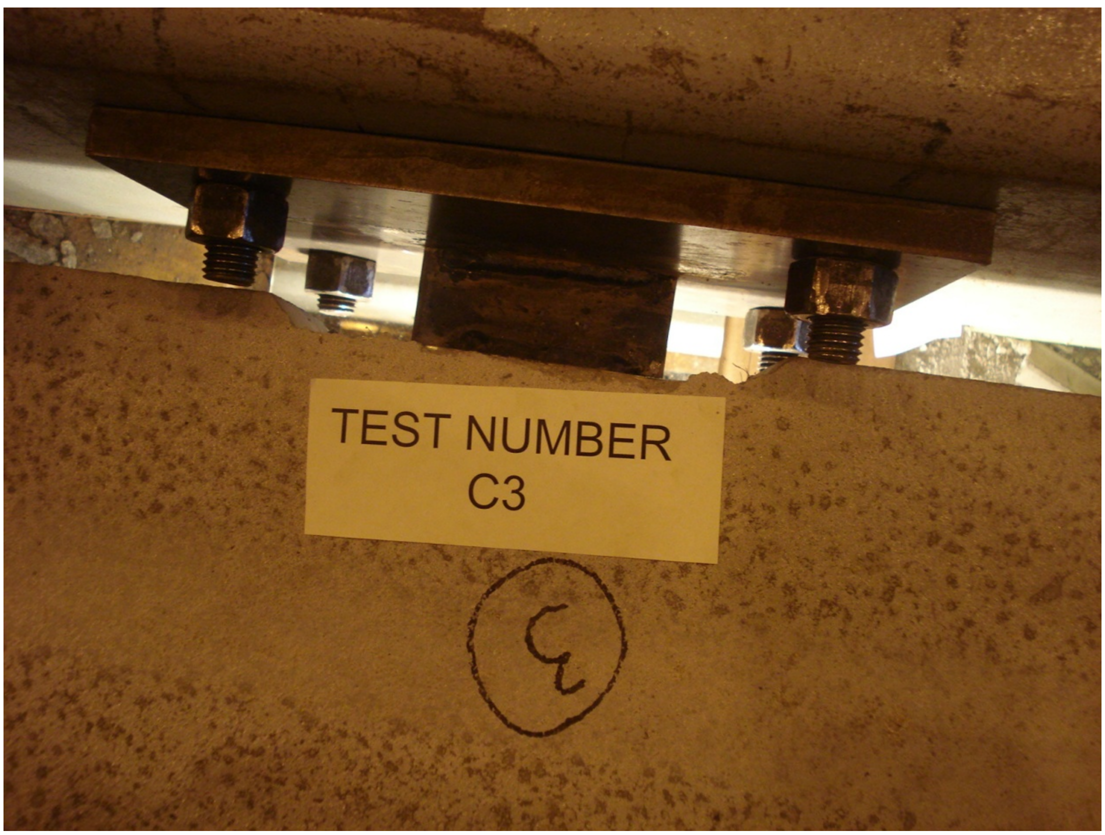


Figure 18 – Test C3: In-Plane Cyclic Shear w/ No Tension

Figure 19 – Test C4: In-Plane Cyclic Shear w/ No Tension

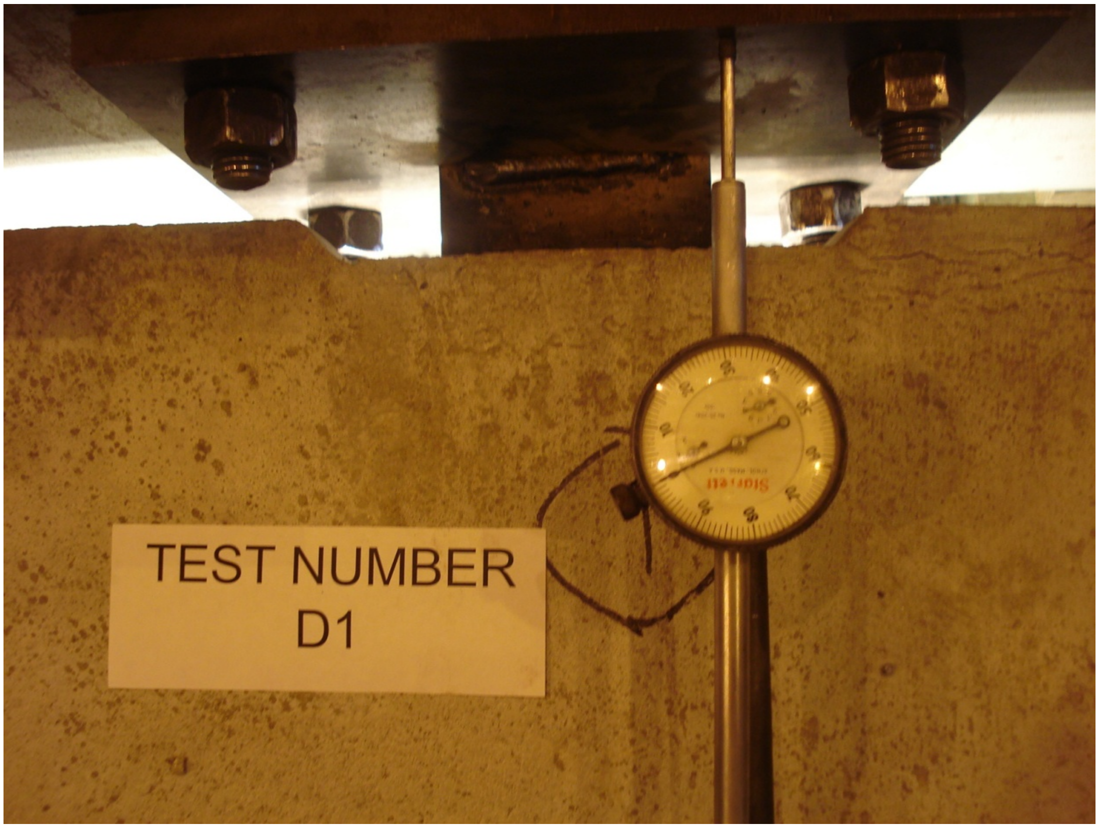


Figure 20 – Test D1: In-Plane Cyclic Shear w/ Tension

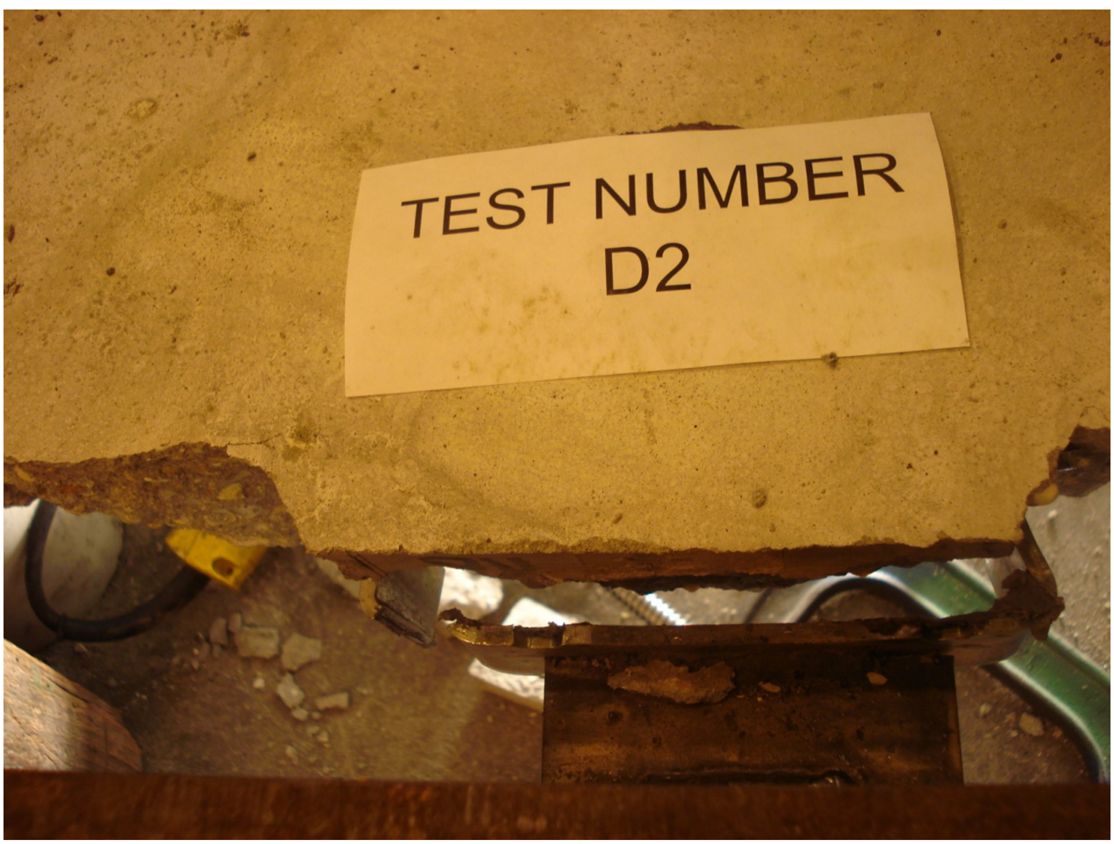


Figure 21 – Test D2: In-Plane Cyclic Shear w/ Tension

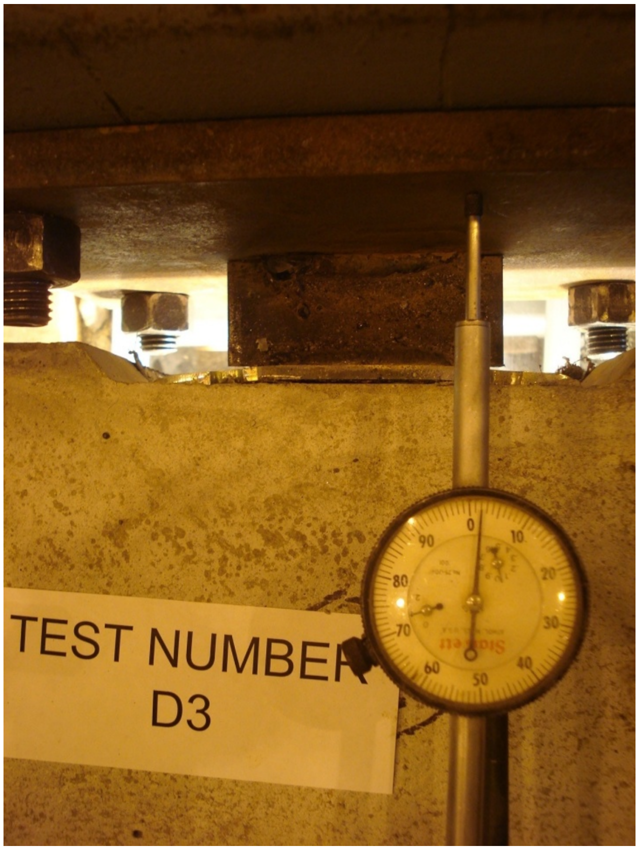


Figure 22 – Test D3: In-Plane Cyclic Shear w/ Tension

Figure 23 – Test D4: In-Plane Cyclic Shear w/ Tension

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Additional Testing of the JVI Mid V in 4" Slabs

Report on the Test Results

by

Al Ghorbanpoor, P.E., Ph.D.
Professor of Structural Engineering, and
Director of the UWM Structures Laboratory

PREFACE

Additional, out of plane shear tests on "Mid V" connector embedded in 4" thick concrete slabs were carried out in the Structural Engineering Laboratory at the University of Wisconsin- Milwaukee (UWM). The test fixture and instrumentation, and the test protocol were identical to previous JVI "Vector Connector" tests carried out at UWM. The details of those tests are reported in the following two references:

(1)"Shear connector Tests," Test Report No.2, JVI website: www.jvi-inc.com
(2) A. Fattah Shaikh and Eric P. Feile, "Load Testing of a Precast Concrete Double-Tee Flange Connector," PCI Journal 49(3):84-94, May-June 2004.

SPECIMEN DETAILS

The concrete slab specimens for this phase of the JVI "Mid V" tests were fabricated by Spancrete, Inc., Waukesha, WI

The following notes pertain to specifics of the test specimens:

Concrete Strengths of 4" x 8" cylinders were made by the Spancrete quality control department and were test in the UWM lab at time of "Mid V" testing. The results were as follows:

Slab #	Poured Date	Break Date	Break Load (lbs)	Pressure (psi)
A1, B	03/15/10	04/07/10	101,500	8,077
A1, B	03/15/10	04/07/10	100,300	7,982
A1, B	03/15/10	04/07/10	102,300	8,141
		Average	101,367	8,067
C, D	03/16/10	04/07/10	99,730	7,936
C, D	03/16/10	04/07/10	100,100	7,966
C, D	03/16/10	04/07/10	102,800	8,181
		Average	100,877	8,028
A2 (white cement)	03/22/10	04/07/10	102,600	8,165
A2 (white cement)	03/22/10	04/07/10	104,500	8,316
		Average	103,550	8,240

Reinforcing
Welded Wire Mesh: see Appendix B, Figures 22 through 29 for details. Tables 1 and 2 gives summary of mesh used in each test slab.
Steel Reinforcing bar: rebar was used only for handling stresses.
See Appendix B for slab details

Flange Connectors
JVI "Mid V" steel: ASTM A36 carbon type steel coated with J-Finish for corrosion protection.

Field Weld Slugs
Weld slugs used: flat bar slug, 3/8" x 1" x 4" long. All welds designed to be ¼" fillet x 2.50" long. The weld slugs were welded to the "Mid V" faceplate, first, and then to the test equipment loading plate. The actual weld sizes were recorded as shown in Table 1, column "C". All welds located on top of slug and each passed through the top hole in the faceplate.

Loading Plates
The equipment loading plates were welded to the "Mid V" after the weld slugs were welded to the "Mid V" faceplate. See Figure 30 for details.

Test Slab Setup Details

						D	A		B	C	E
Slab #	Slab Thickness	Test #	Blockout top edge depth (in.)	Mesh	Load Direction	Distance D - Slab Surface to MidV top edge (in.)	Distance A - Slab surface to weld slug top (in.)	Distance - MidV top edge to weld slug top (in.)	Vertical Distance B- Fillet Weld Size (in.)	Weld Length C - Top of Slug (in.)	Weld Length E - Bottom of Slug
A1	4-1/8"	1	3/4	No	Down	0.850	1.500	0.650	0.170	2.600	NA
A1	4-1/8"	2	3/4	No	Down	0.750	1.400	0.650	0.180	2.600	NA
A1	4-1/8"	3	3/4	No	Down	0.950	1.720	0.770	0.180	2.500	NA
A1	4-1/8"	4	3/4	No	Down	0.830	1.370	0.540	0.190	2.450	NA
A2	4-3/16"	1	3/4	No	Down	0.840	1.410	0.570	0.170	2.600	NA
A2	4-3/16"	2	3/4	No	Upward	0.800	1.350	0.550	0.140	2.500	NA
A2	4-3/16"	3	3/4	No	Upward	0.920	1.440	0.520	0.170	2.600	NA
A2	4-3/16"	4	3/4	No	Upward	0.800	1.440	0.640	0.140	2.800	NA
B	4-1/8"	1	3/4	Yes	Down	0.730	1.310	0.580	0.150	2.700	NA
B	4-1/8"	2	3/4	Yes	Down	0.850	1.440	0.590	0.170	2.800	NA
B	4-1/8"	3	3/4	Yes	Down	0.800	1.400	0.600	0.190	2.700	NA
B	4-1/8"	4	3/4	Yes	Down	0.680	1.240	0.560	0.160	2.900	NA
C	4-1/8"	1	1	No	Down	1.070	1.620	0.550	0.230	2.600	NA
C	4-1/8"	2	1	No	Down	1.240	1.870	0.630	0.210	2.700	NA
C	4-1/8"	3	1	No	Down	1.120	1.680	0.560	0.180	2.800	NA
C	4-1/8"	4	1	No	Down	1.220	1.820	0.600	0.230	2.700	NA
D	4-1/4"	1	1	Yes	Down	1.100	1.670	0.570	0.180	2.600	NA
D	4-1/4"	2	1	Yes	Down	1.250	1.800	0.550	0.180	2.700	NA
D	4-1/4"	3	1	Yes	Down	1.300	1.850	0.550	0.150	2.500	NA
D	4-1/4"	4	1	Yes	Down	1.220	1.800	0.580	0.180	2.600	NA

Notes
1 - Specified 1/4" fillet weld x 2-1/2" long
2 - Flat Weld Slug = 1" x 3/8" x 4" Long
3 - Weld Length on top goes thru center faceplate hole
4 - Certified Welder performed all welds
5 - Welding Machine - Lincoln Power Mig 255
6 - Machine Settings - 18.8 Volts, 270 Wire feed

Table 1: TEST SLABS DETAILS SUMMARY

TEST RESULTS

Table 2 gives results of 1st Crack Load, Yield Crack Load, Maximum Load, Displacement at Maximum Load, and the Failure Mode. Load-Displacement curves for the 20 tests are given in Appendix A. Appendix B includes “Mid V” product picture, slab specimen drawings, and photos of each test

Test #	Test Date	Test Discription	Blockout top edge depth (in.)	Mesh	Load Direction	1st Top Crack Load (lbs.)	Yield Crack Load (lbs.)	Max Load (lbs.)	Displ. @ Max Load (in.)	Existing Concrete Cracks	Failure Mode
A1-1	04/06/10	Vertical SHEAR w/ No Tension	3/4	No	Down	6,230	6,230	6,230	0.399	None	Concrete crack on bottom
A1-2	04/06/10	Vertical SHEAR w/ No Tension	3/4	No	Down	4,700	4,700	5,810	0.426	Bottom	Concrete blowout bottom & sides
A1-3	04/06/10	Vertical SHEAR w/ No Tension	3/4	No	Down	4,300	4,280	5,190	0.121	Bottom	Concrete crack on bottom
A1-4	04/06/10	Vertical SHEAR w/ No Tension	3/4	No	Down	3,400	3,400	6,110	1.090	Bottom	Weld failed at machine plate
A2-1	04/07/10	Vertical SHEAR w/ No Tension	3/4	No	Down	4,360	4,360	5,240	0.107	None	Concrete cracks and spall on bottom
A2-2	04/07/10	Vertical SHEAR w/ No Tension	3/4	No	Upward	3,100	3,100	3,640	0.267	Bottom	Concrete top AND weld failed at machine plate
A2-3	04/07/10	Vertical SHEAR w/ No Tension	3/4	No	Upward	4,090	3,940	4,100	0.233	None	Concrete cracks and spall on top
A2-4	04/07/10	Vertical SHEAR w/ No Tension	3/4	No	Upward	2,000	2,000	4,695	0.277	Top/Bottom	Concrete blowout top & sides
B-1	04/06/10	Vertical SHEAR w/ No Tension	3/4	Yes	Down	4,140	4,140	6,200	0.372	None	Concrete blowout bottom & sides
B-2	04/06/10	Vertical SHEAR w/ No Tension	3/4	Yes	Down	4,100	4,100	5,400	0.334	Bottom	Weld failed at machine plate
B-3	04/06/10	Vertical SHEAR w/ No Tension	3/4	Yes	Down	4,200	4,200	7,070	0.136	Bottom	Concrete blowout bottom & sides
B-4	04/06/10	Vertical SHEAR w/ No Tension	3/4	Yes	Down	4,000	4,000	6,340	0.132	Bottom	Concrete blowout bottom & sides
C-1	04/06/10	Vertical SHEAR w/ No Tension	1	No	Down	4,180	4,180	5,318	0.122	None	Concrete crack on bottom
C-2	04/06/10	Vertical SHEAR w/ No Tension	1	No	Down	3,920	3,740	4,380	0.336	Bottom	Concrete blowout bottom & sides
C-3	04/06/10	Vertical SHEAR w/ No Tension	1	No	Down	4,600	4,600	5,400	0.536	Bottom	Weld failed at machine plate
C-4	04/06/10	Vertical SHEAR w/ No Tension	1	No	Down	3,600	3,600	5,100	0.422	Bottom	Concrete bottom AND weld failed at machine plate
D-1	04/07/10	Vertical SHEAR w/ No Tension	1	Yes	Down	NA	5,000	5,550	0.955	None	Weld failed at machine plate
D-2	04/07/10	Vertical SHEAR w/ No Tension	1	Yes	Down	4,300	4,150	5,450	0.114	Bottom	Concrete blowout bottom & sides
D-3	04/07/10	Vertical SHEAR w/ No Tension	1	Yes	Down	5,000	3,150	5,730	0.050	None	Concrete blowout bottom & sides
D-4	04/07/10	Vertical SHEAR w/ No Tension	1	Yes	Down	4,100	5,300	5,730	0.167	Bottom	Concrete blowout bottom & sides

Table 2: TEST RESULTS SUMMARY

ACKNOWLEDGEMENT
Shear connectors are a very important connection for the precast/prestressed concrete industry. Test information on its load-displacement behavior is critical in developing and upgrading the design procedures for jointed precast structures, such as parking decks. JVI's participation with precast producers in supporting laboratory testing on the Vector Connector is applauded.

APPENDIX A

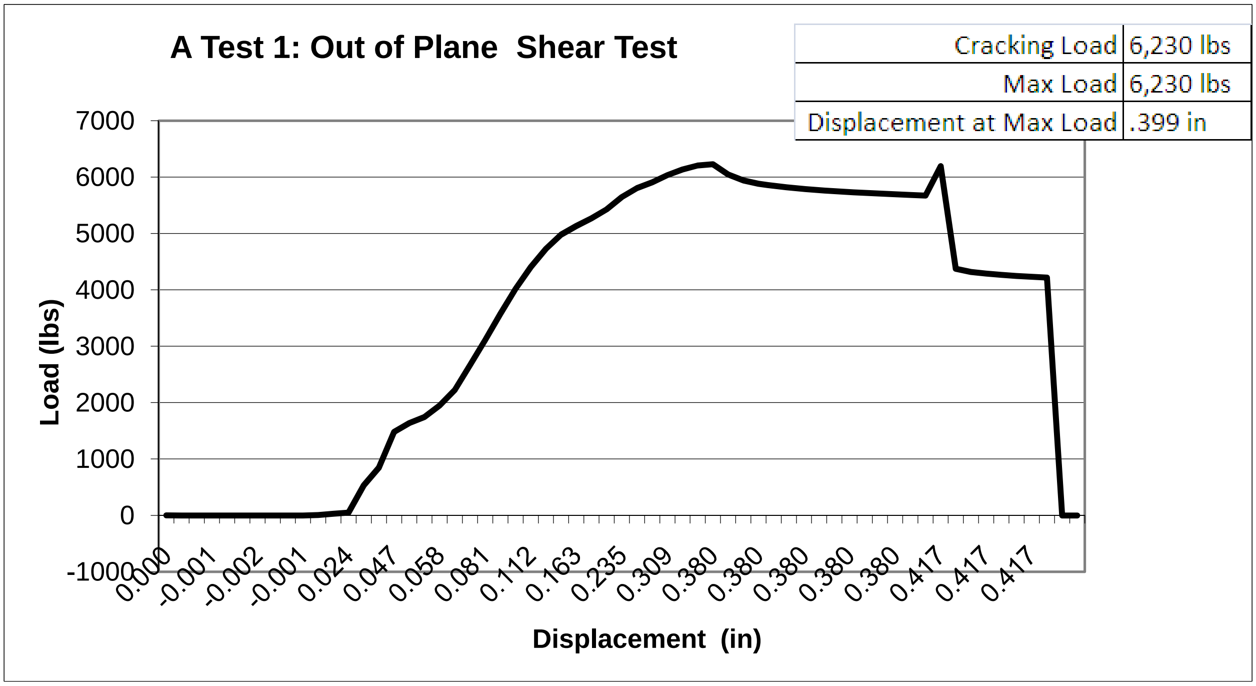


Figure 1

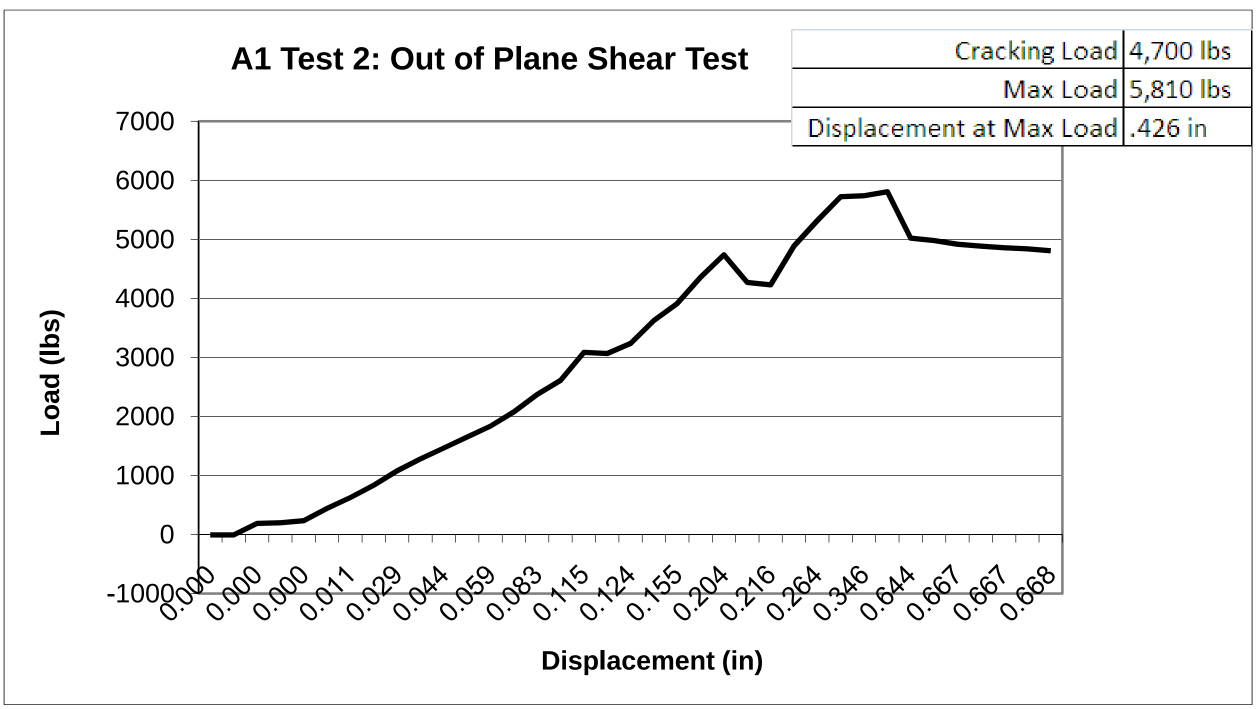
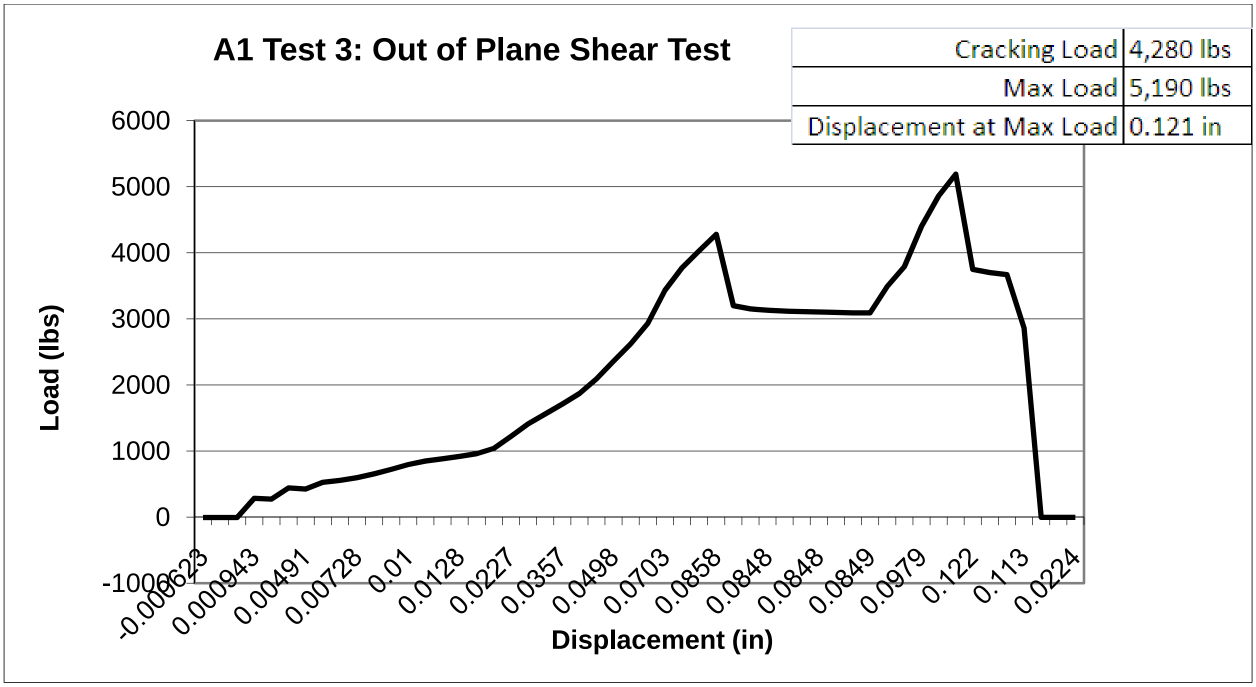


Figure 2



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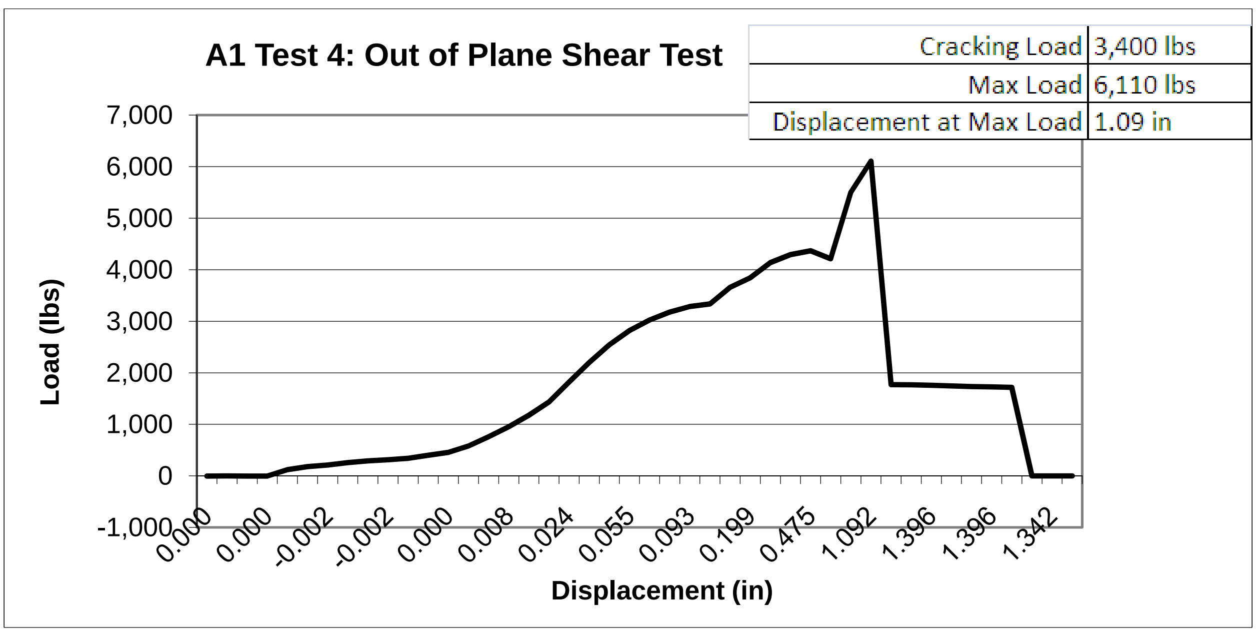
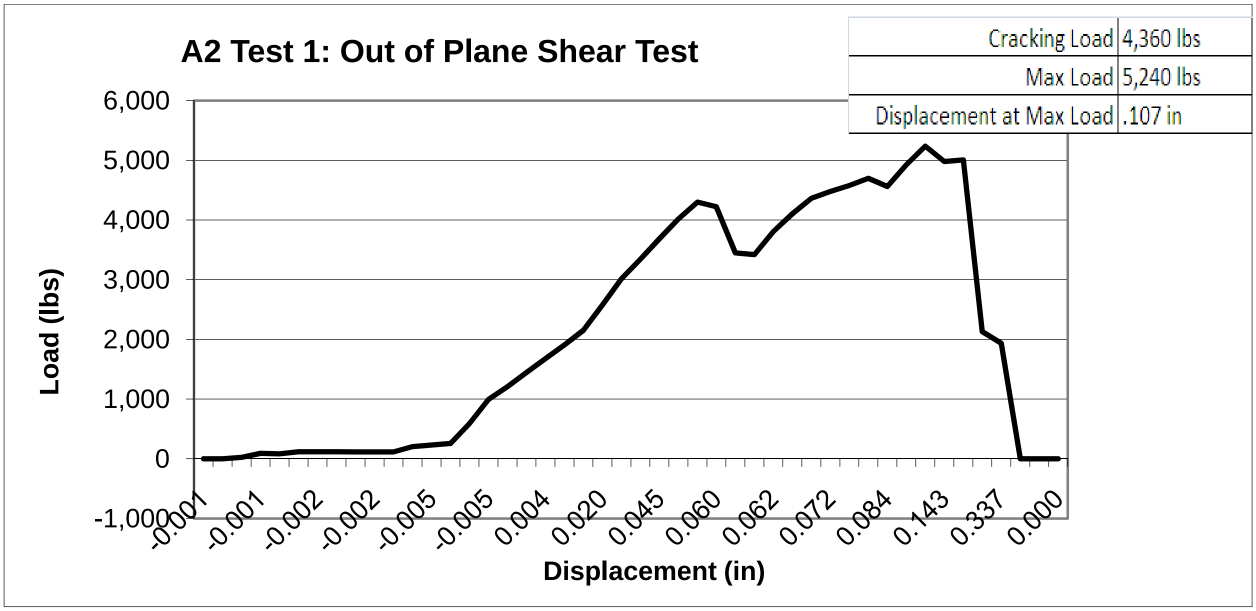


Figure 4



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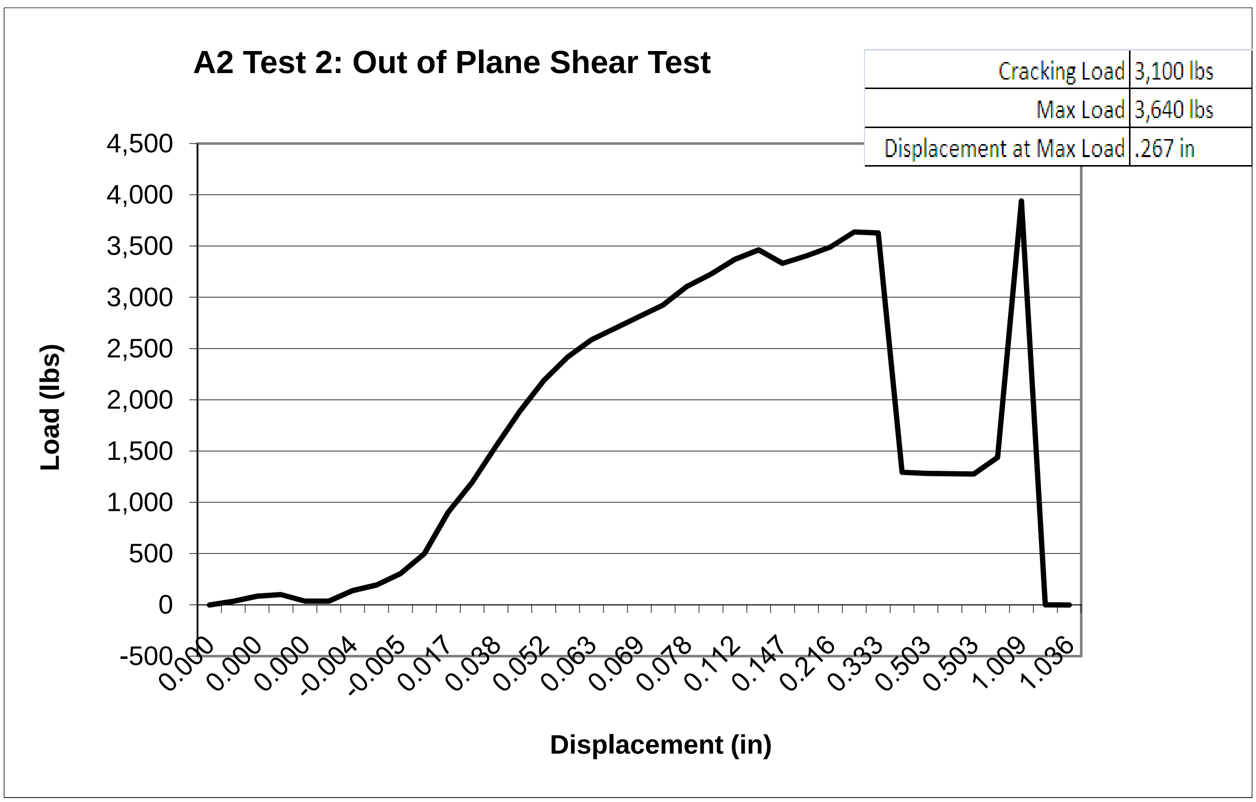

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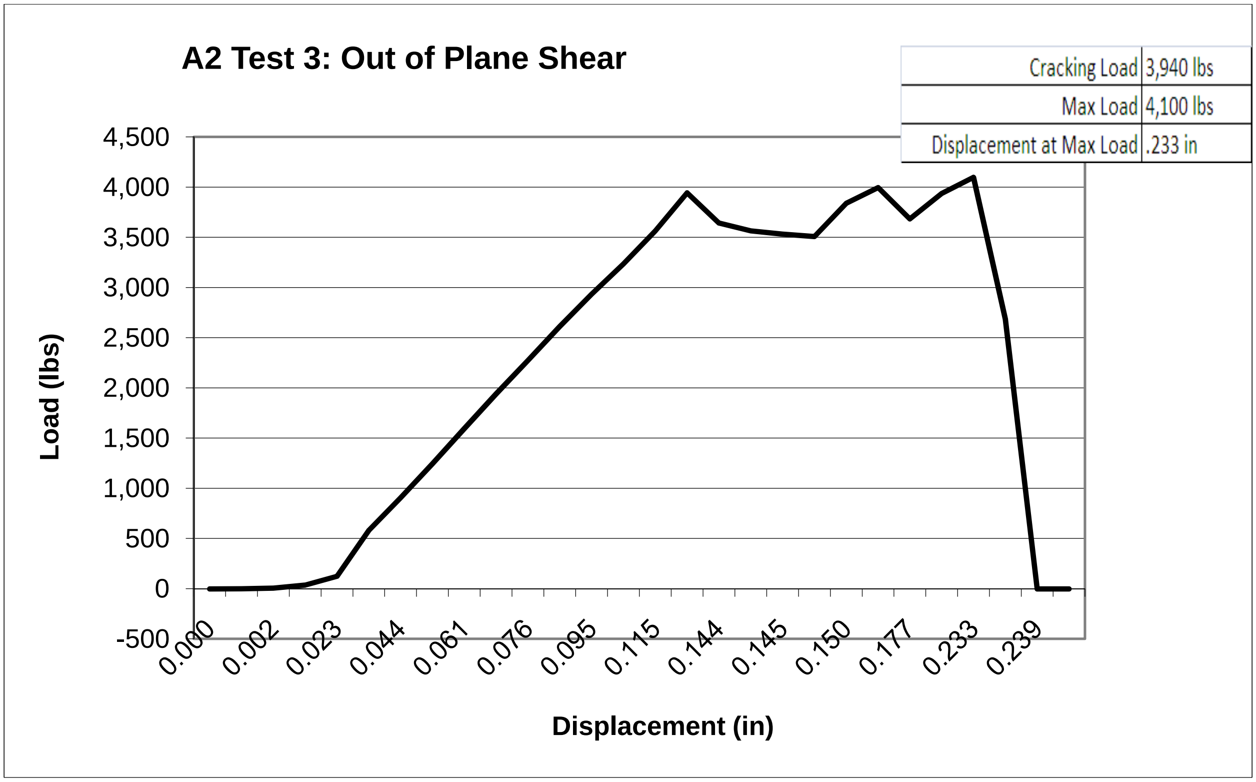
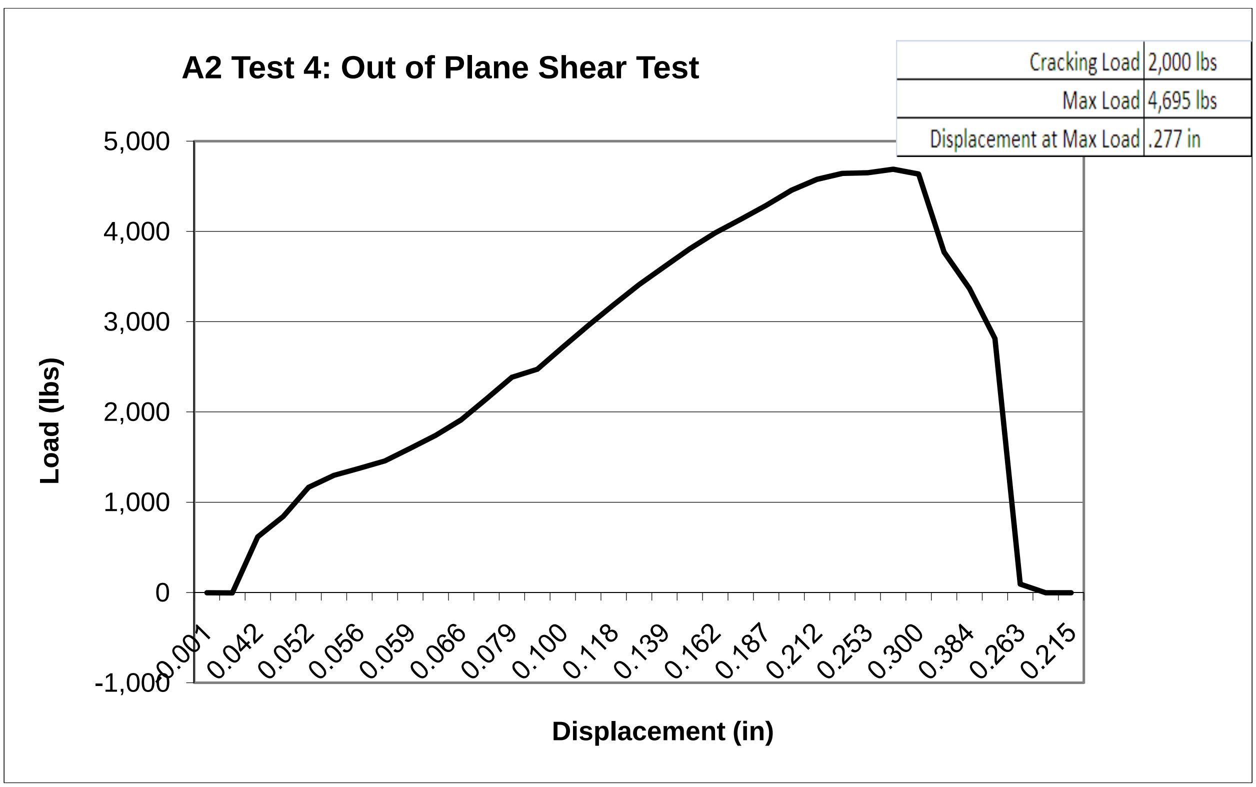


Figure 7



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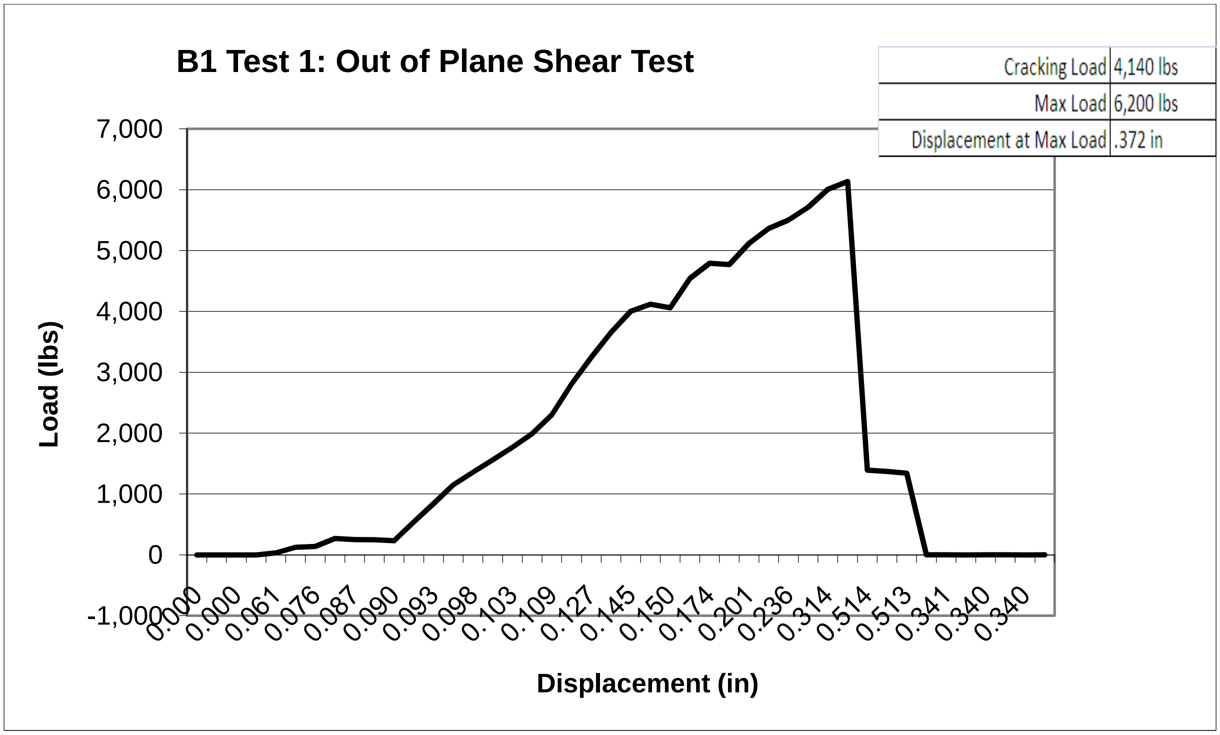

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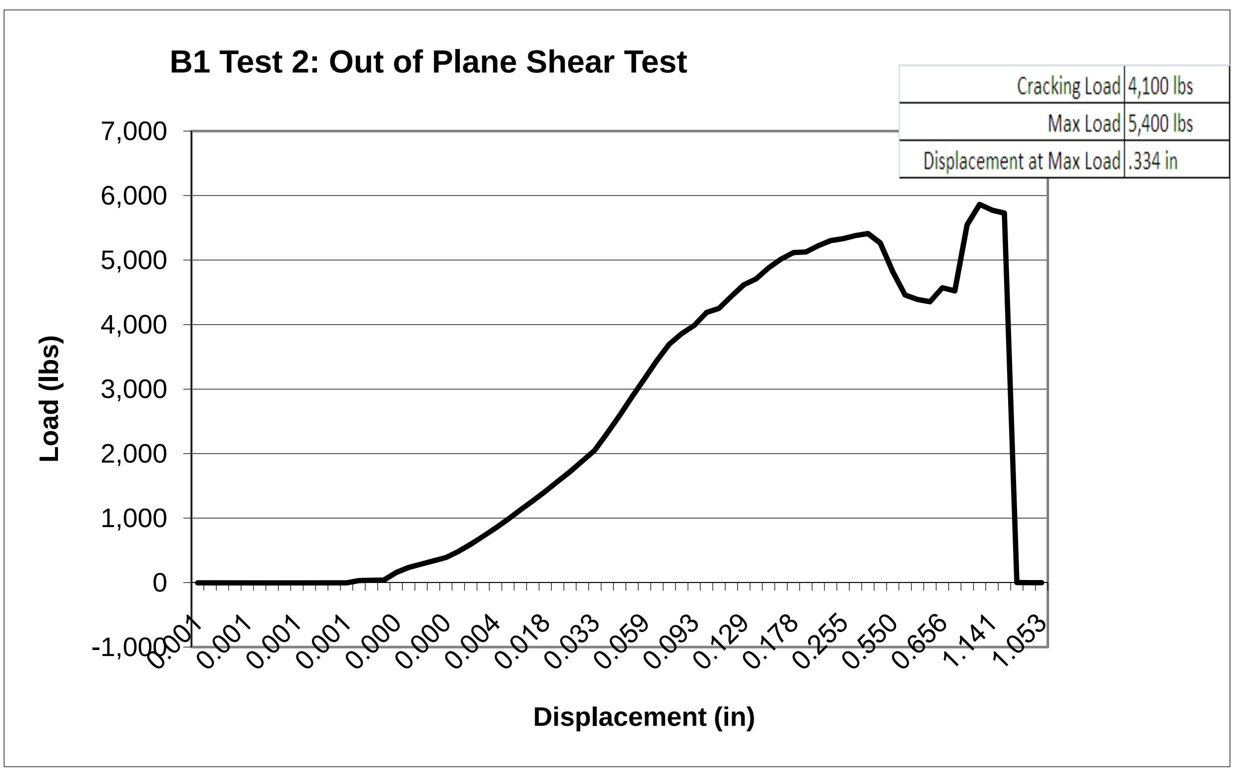

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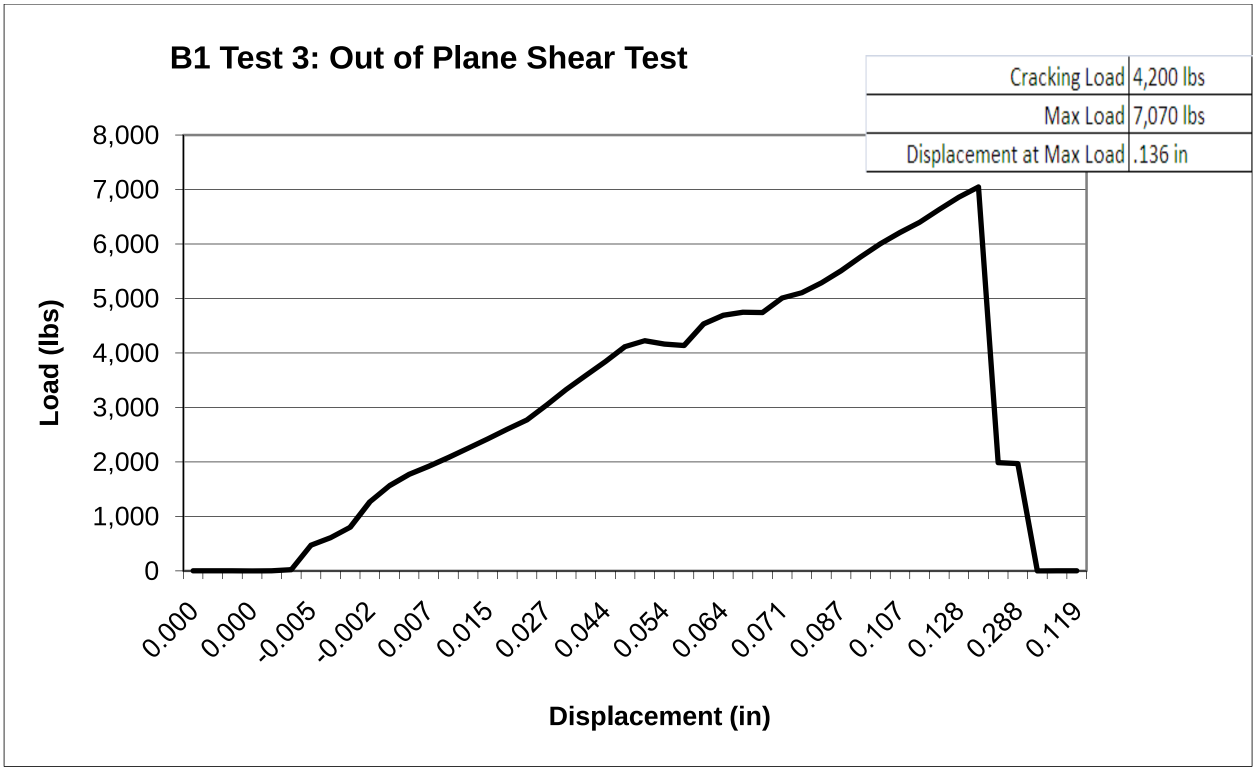

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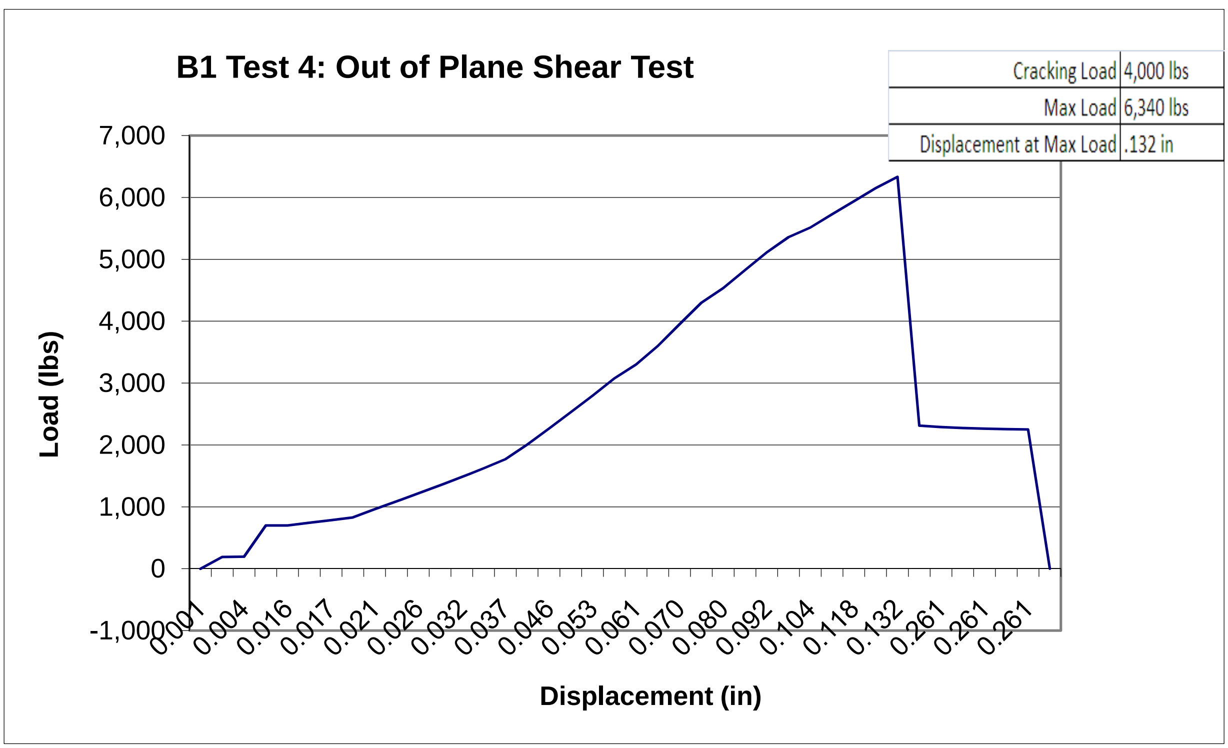


Figure 12

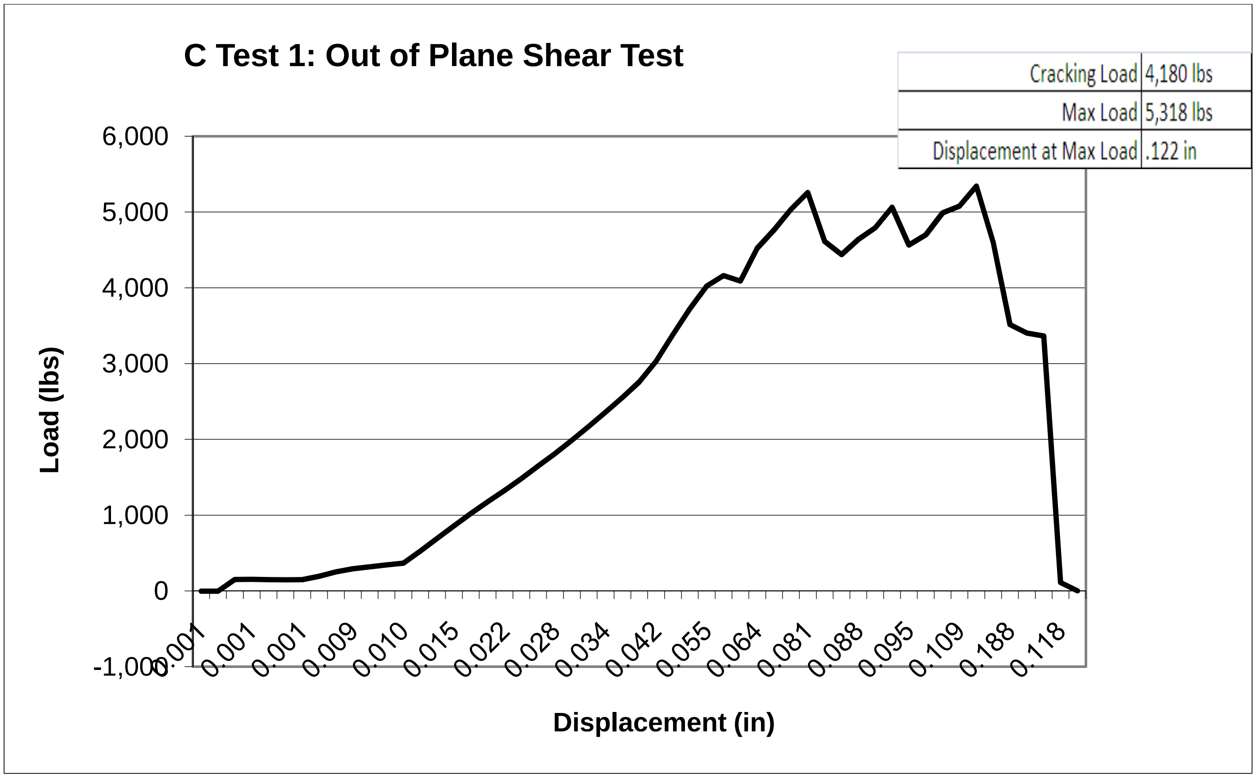
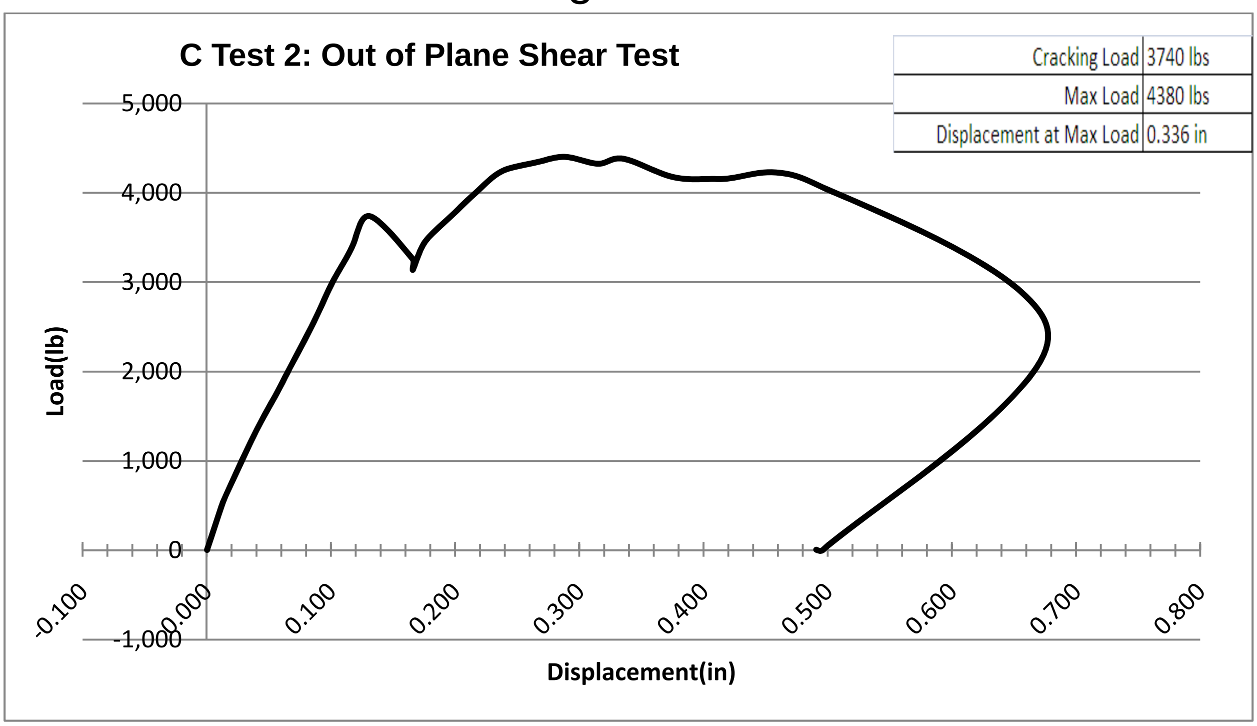


Figure 13



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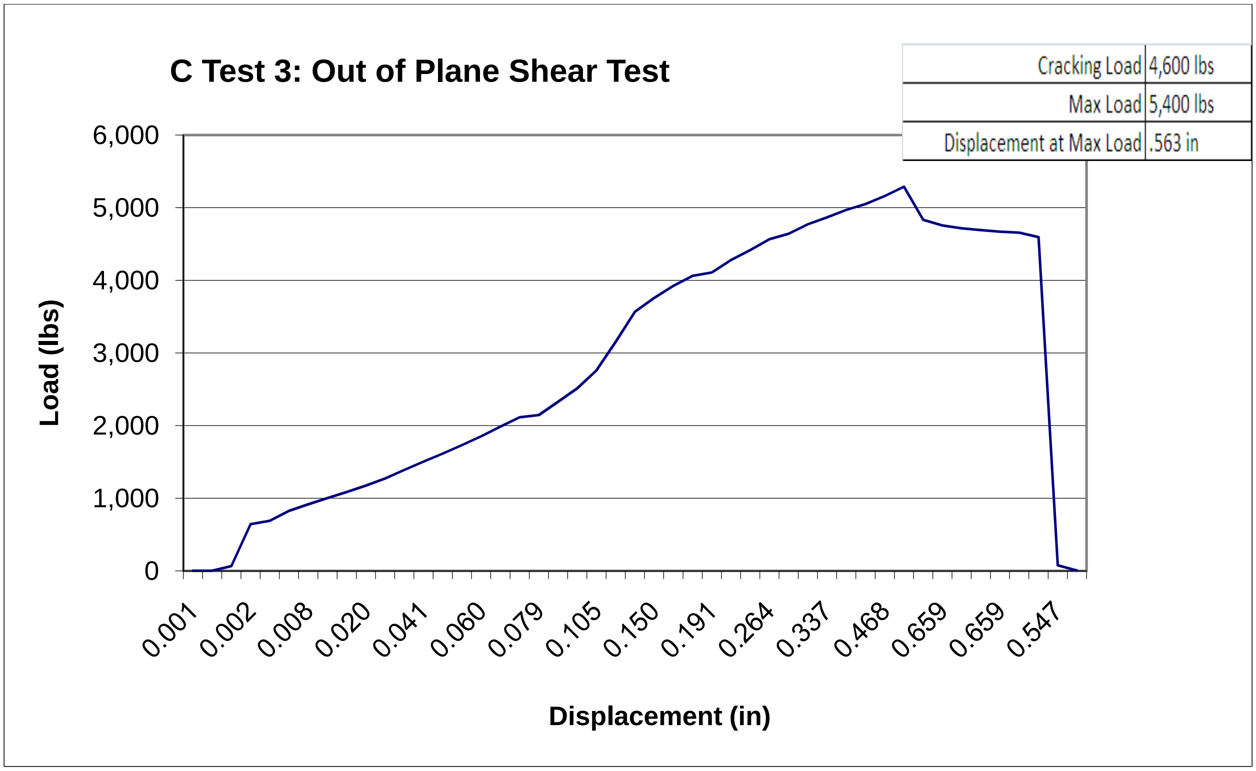

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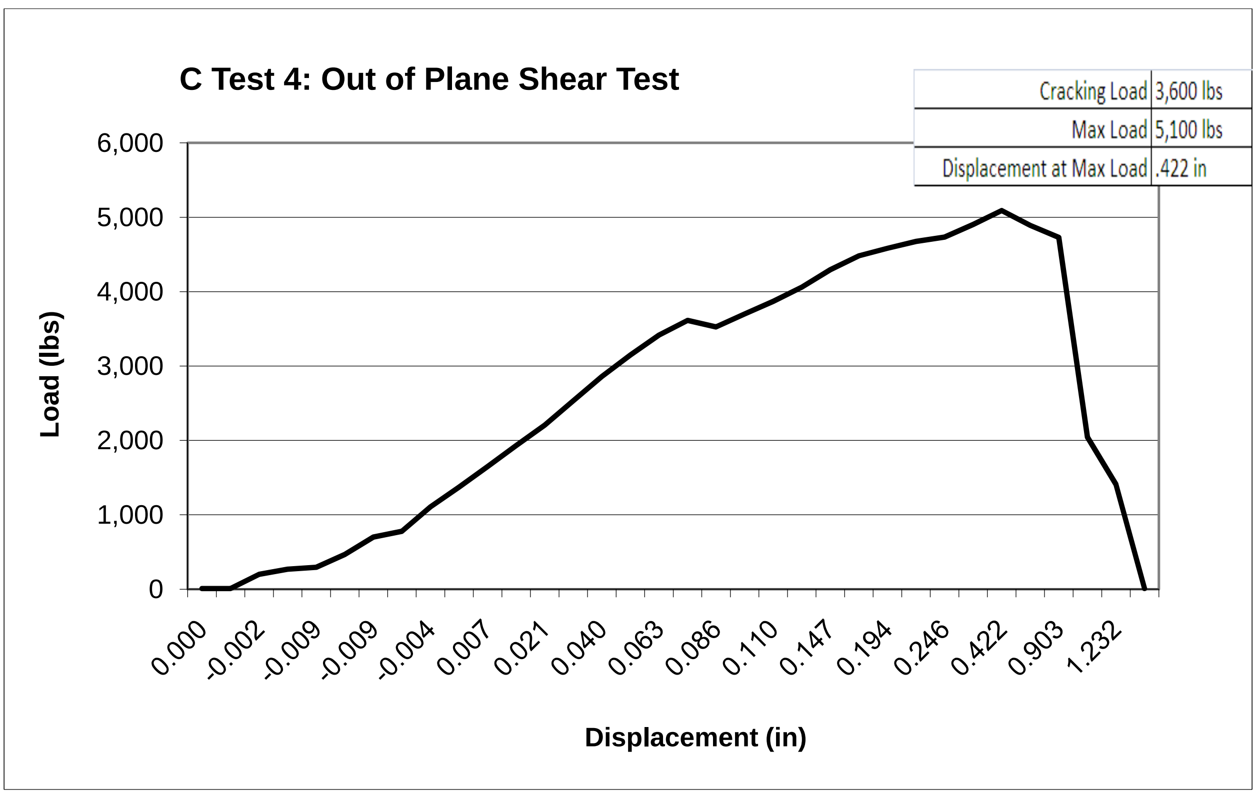
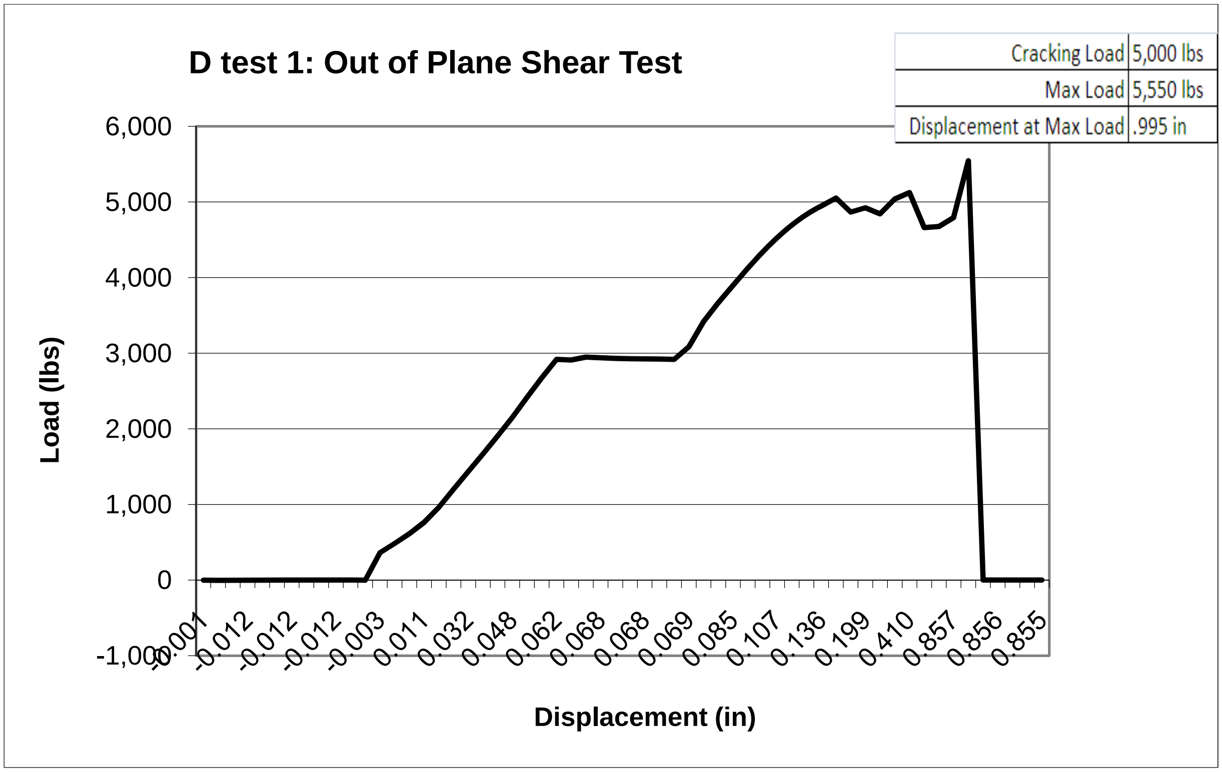


Figure 16



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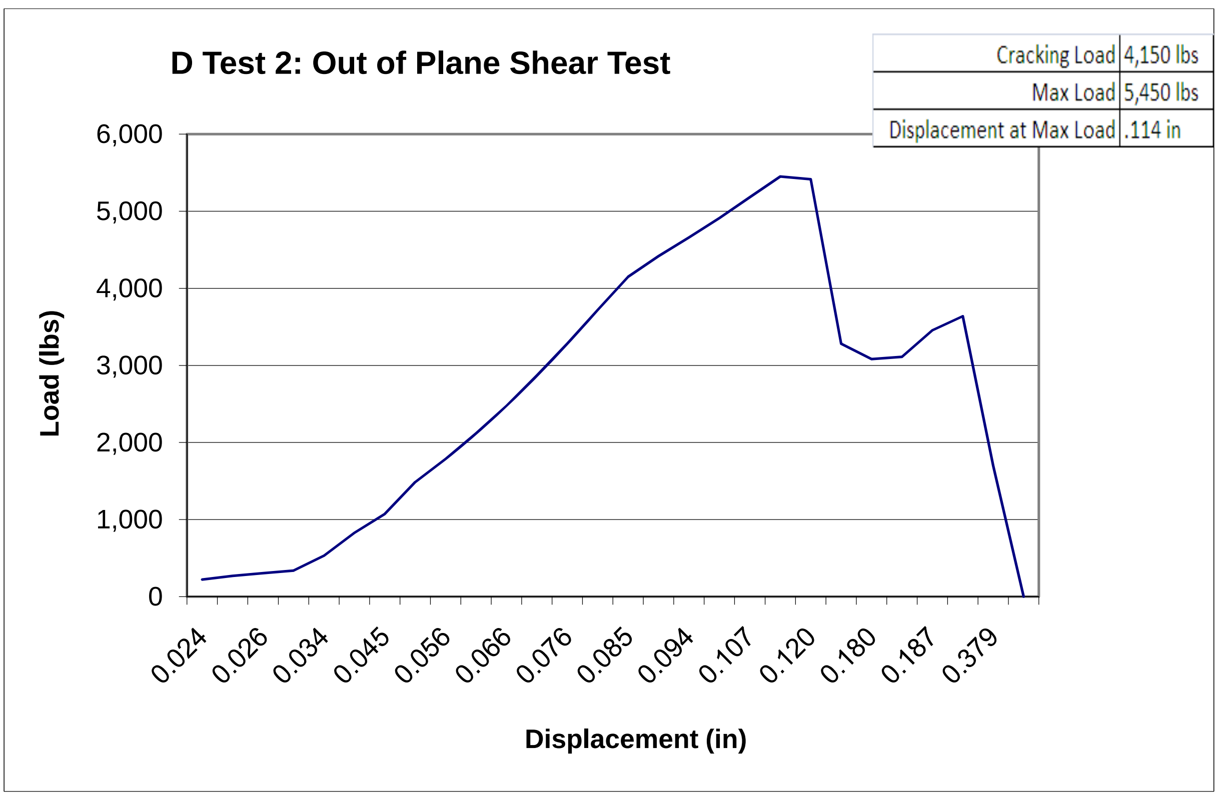

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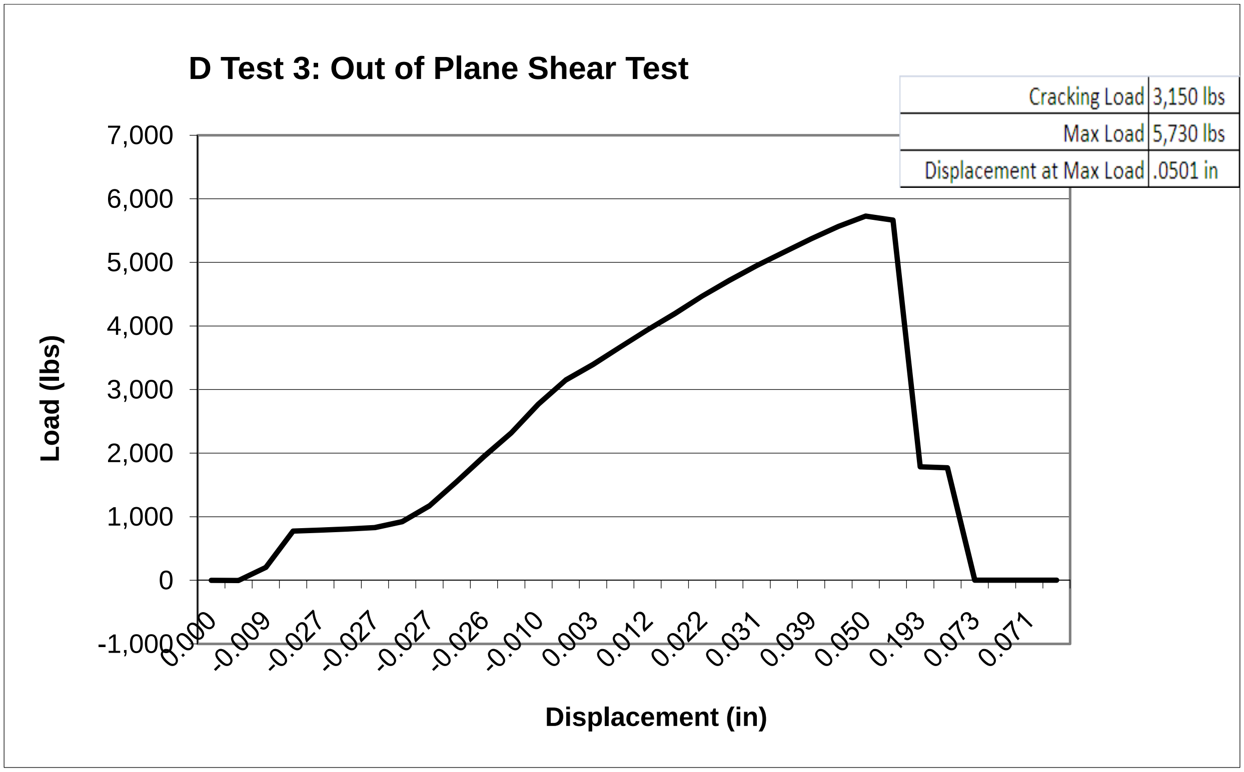

Figure 19

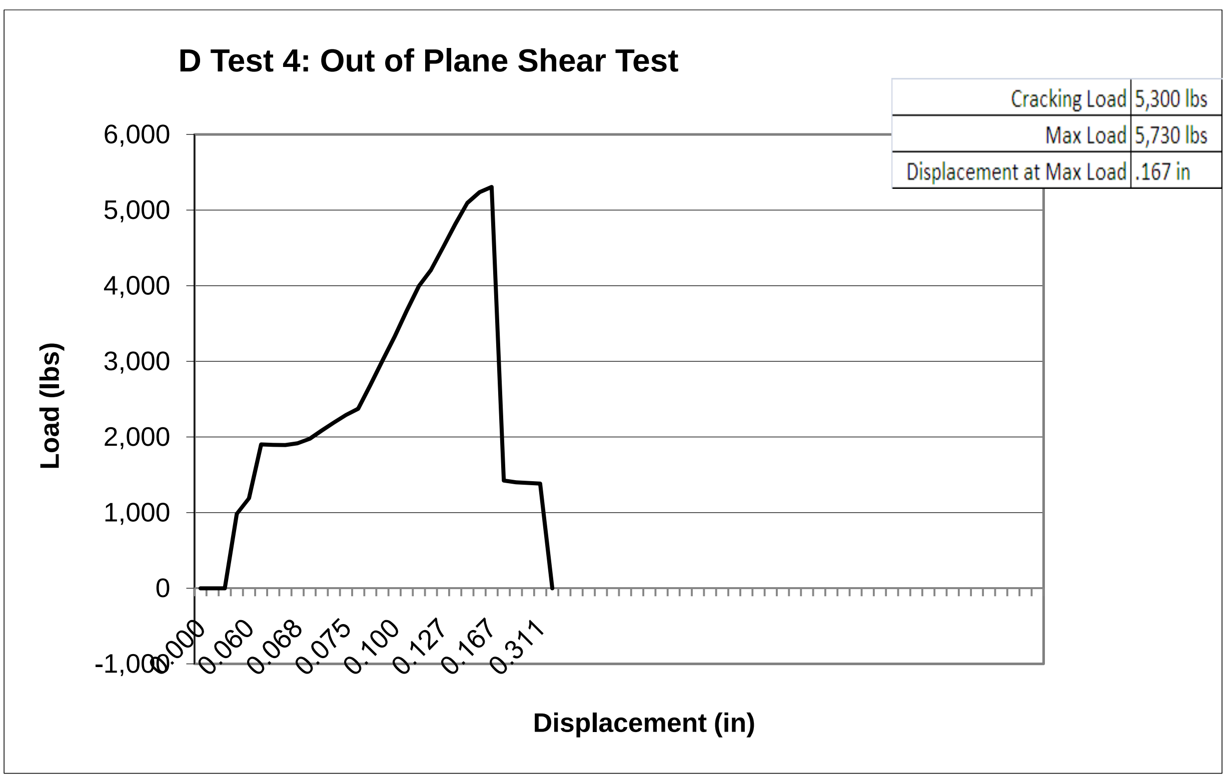

Figure 20

APPENDIX B

Figure 21 - Mid V: Carbon Steel with “J” Finish

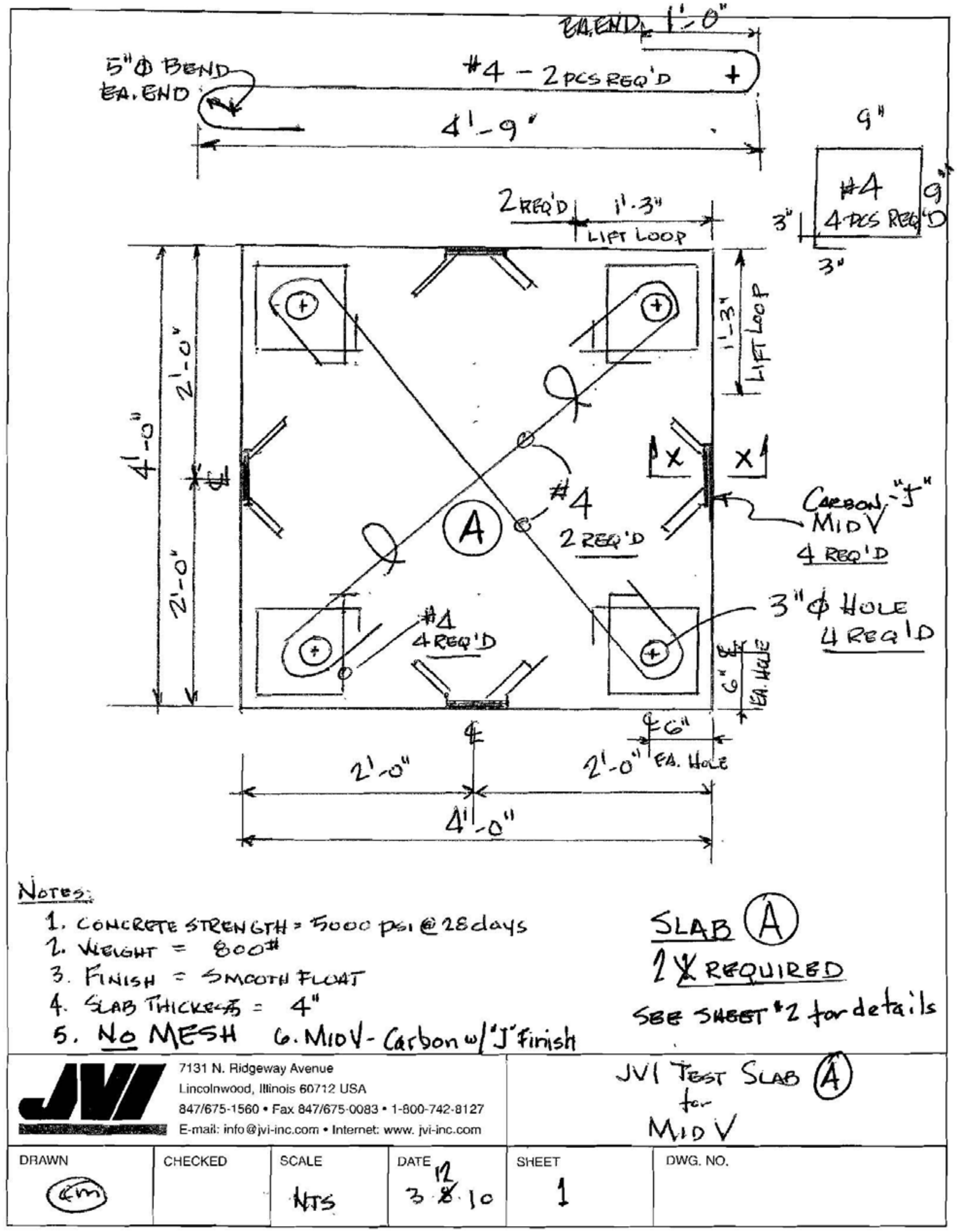

Figure 22 – Test Slab A reinforcing

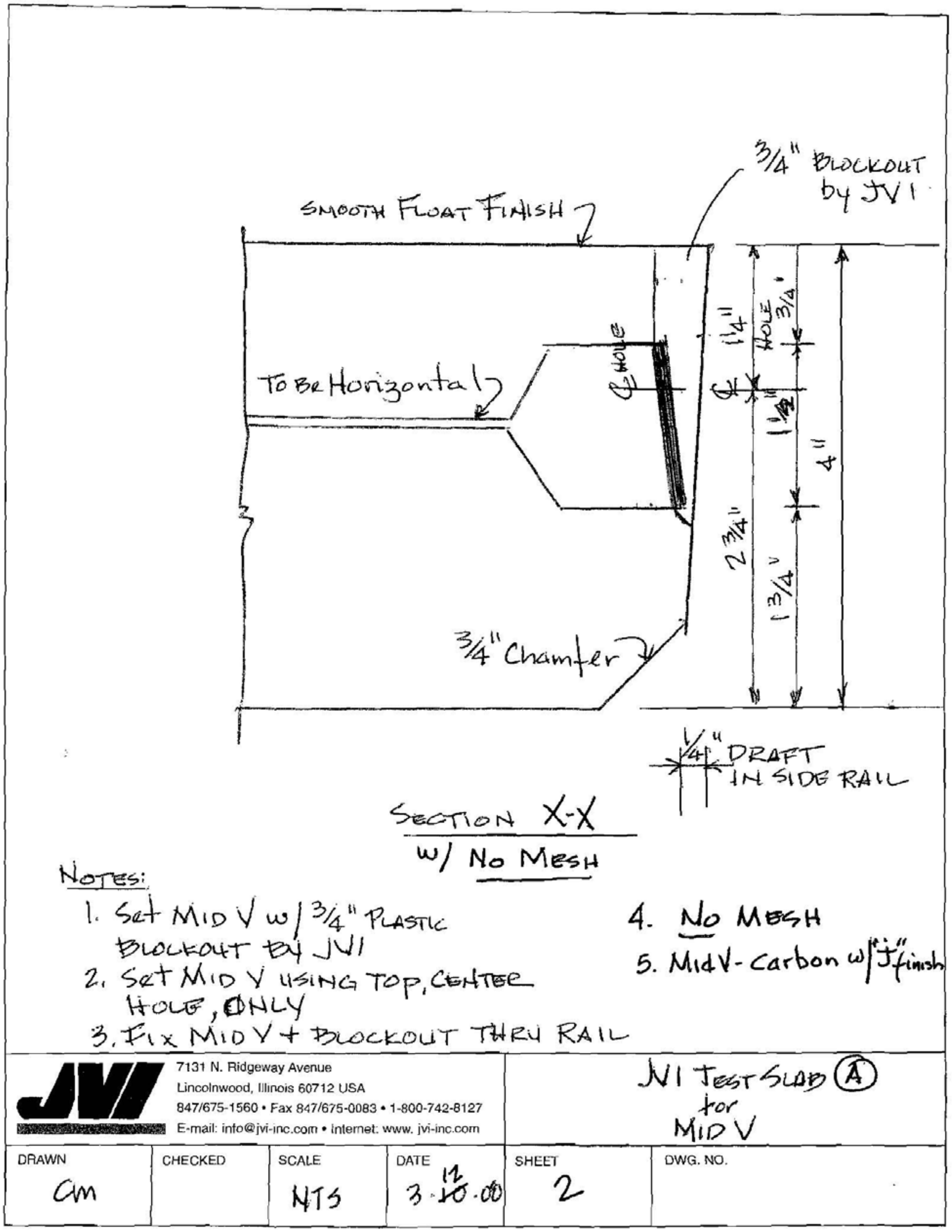

Figure 23 – Test A Details

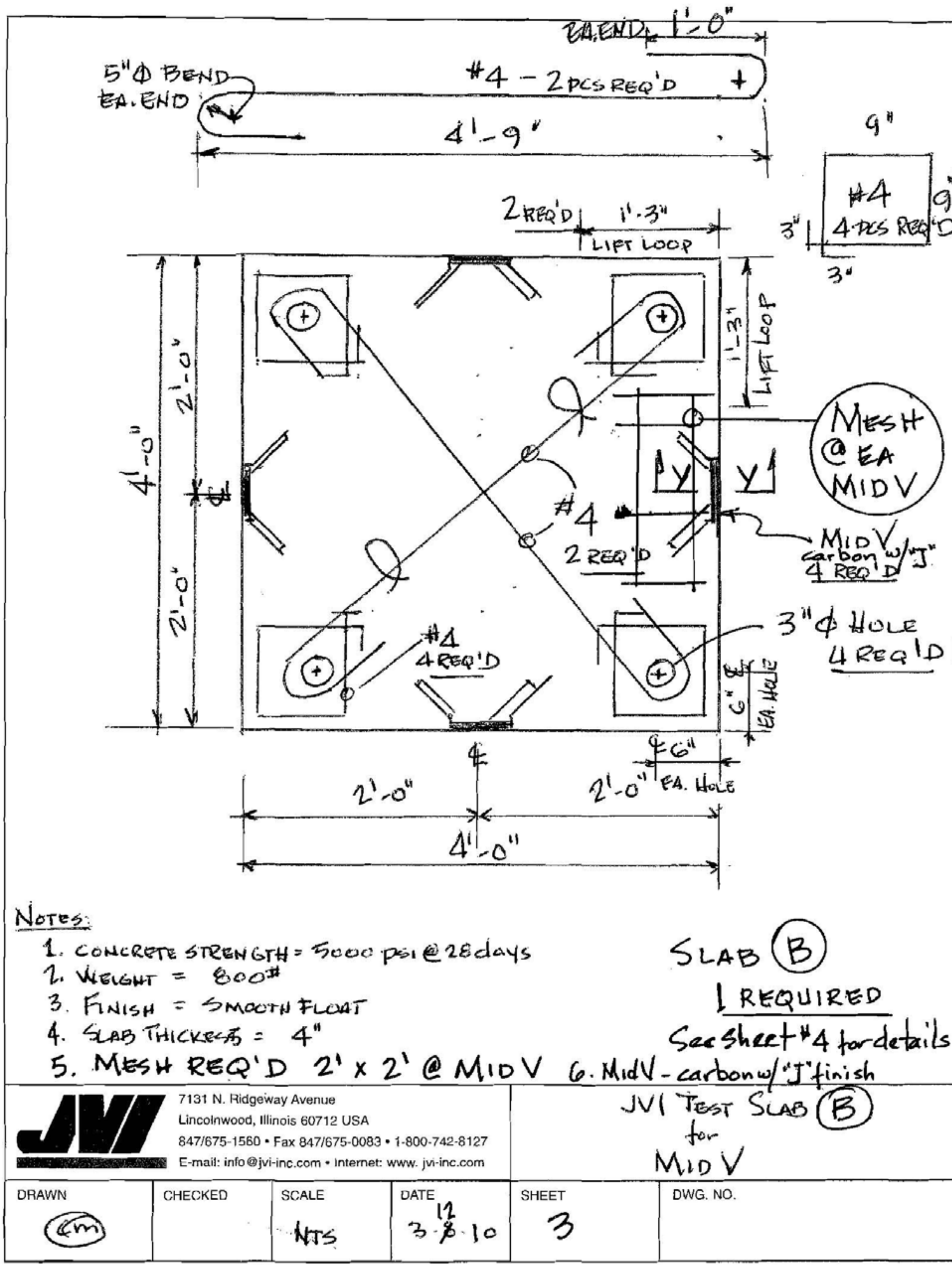

Figure 24 – Test Slab B reinforcing

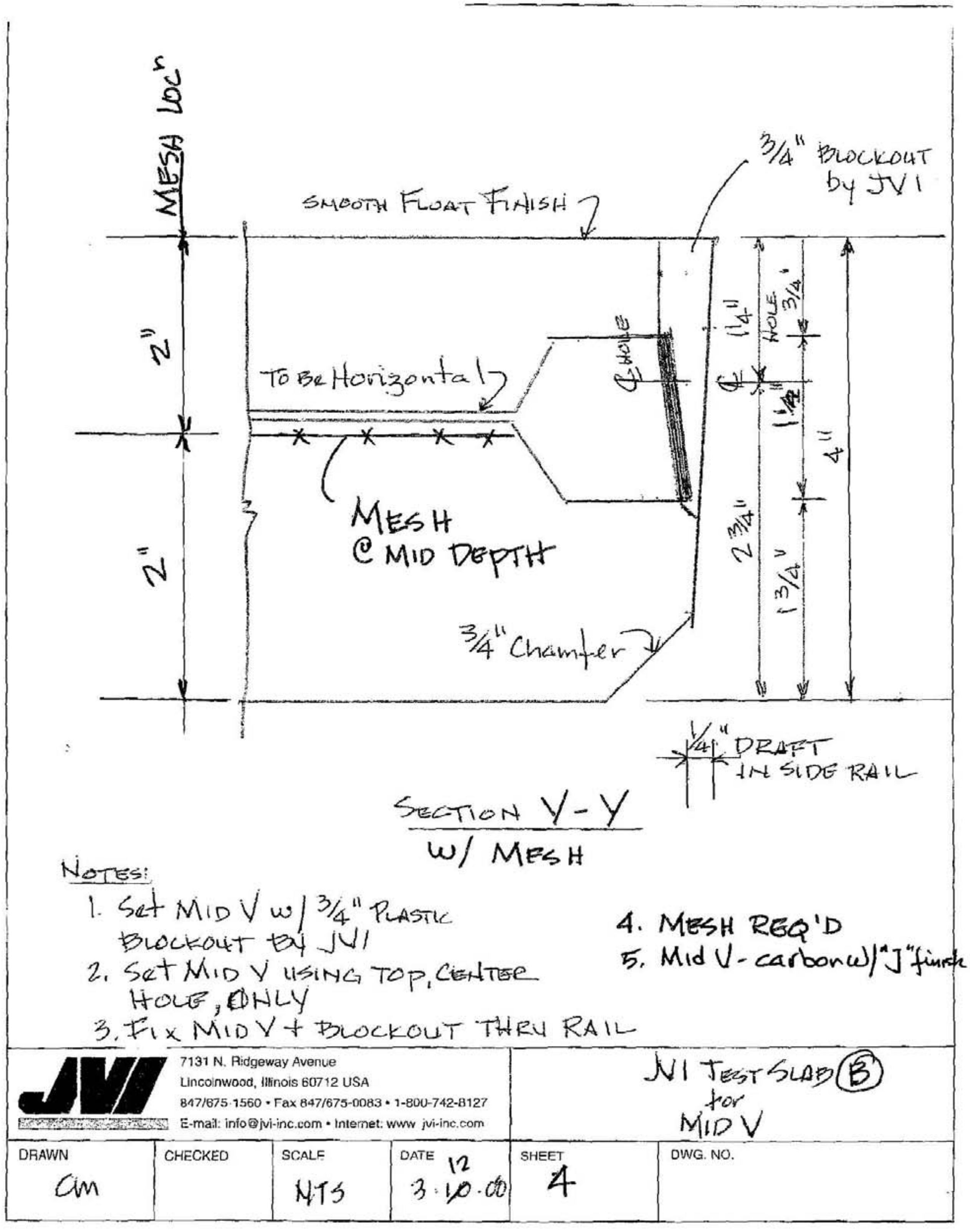

Figure 25 – Test Slab B Details

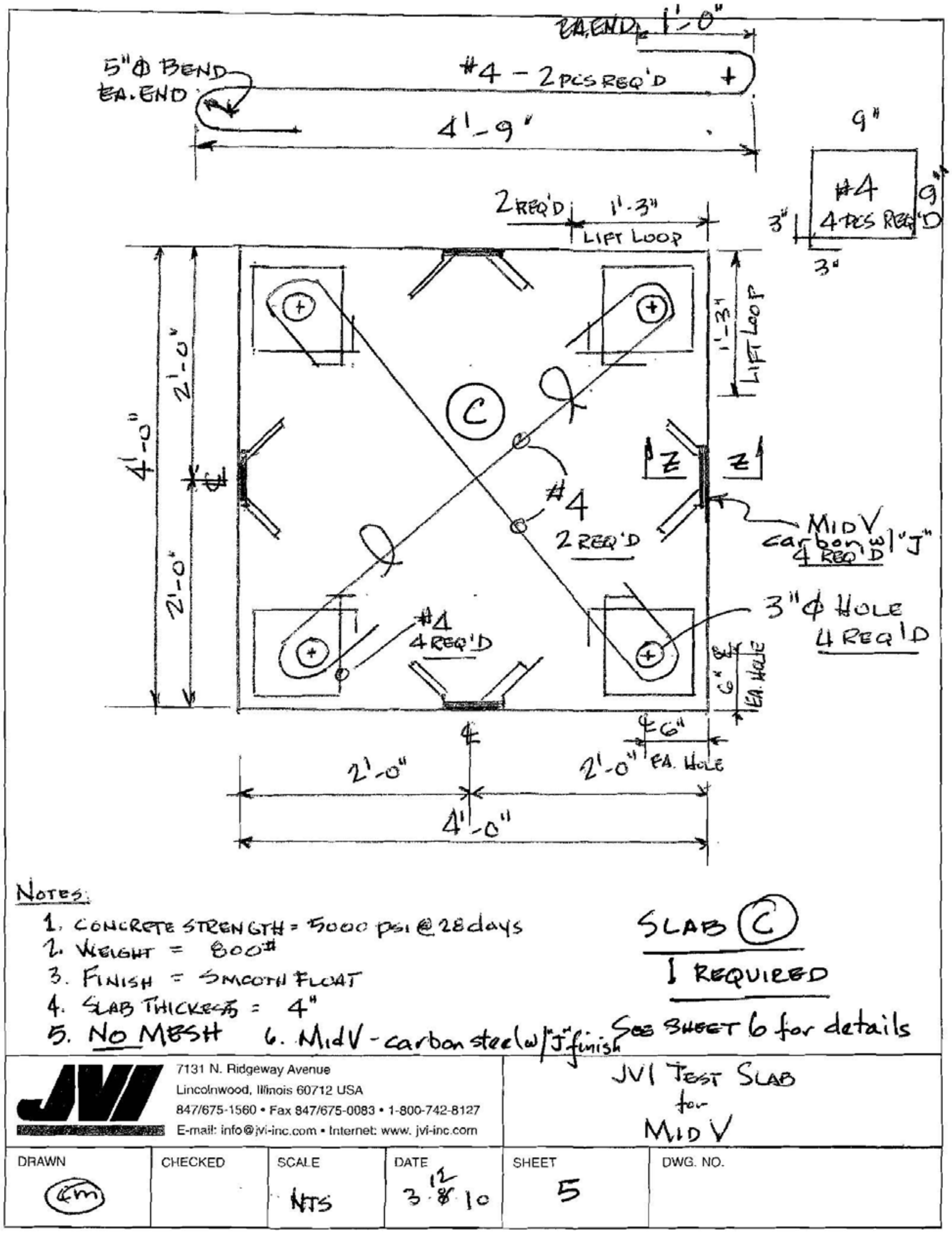

Figure 26 – Test Slab C reinforcing

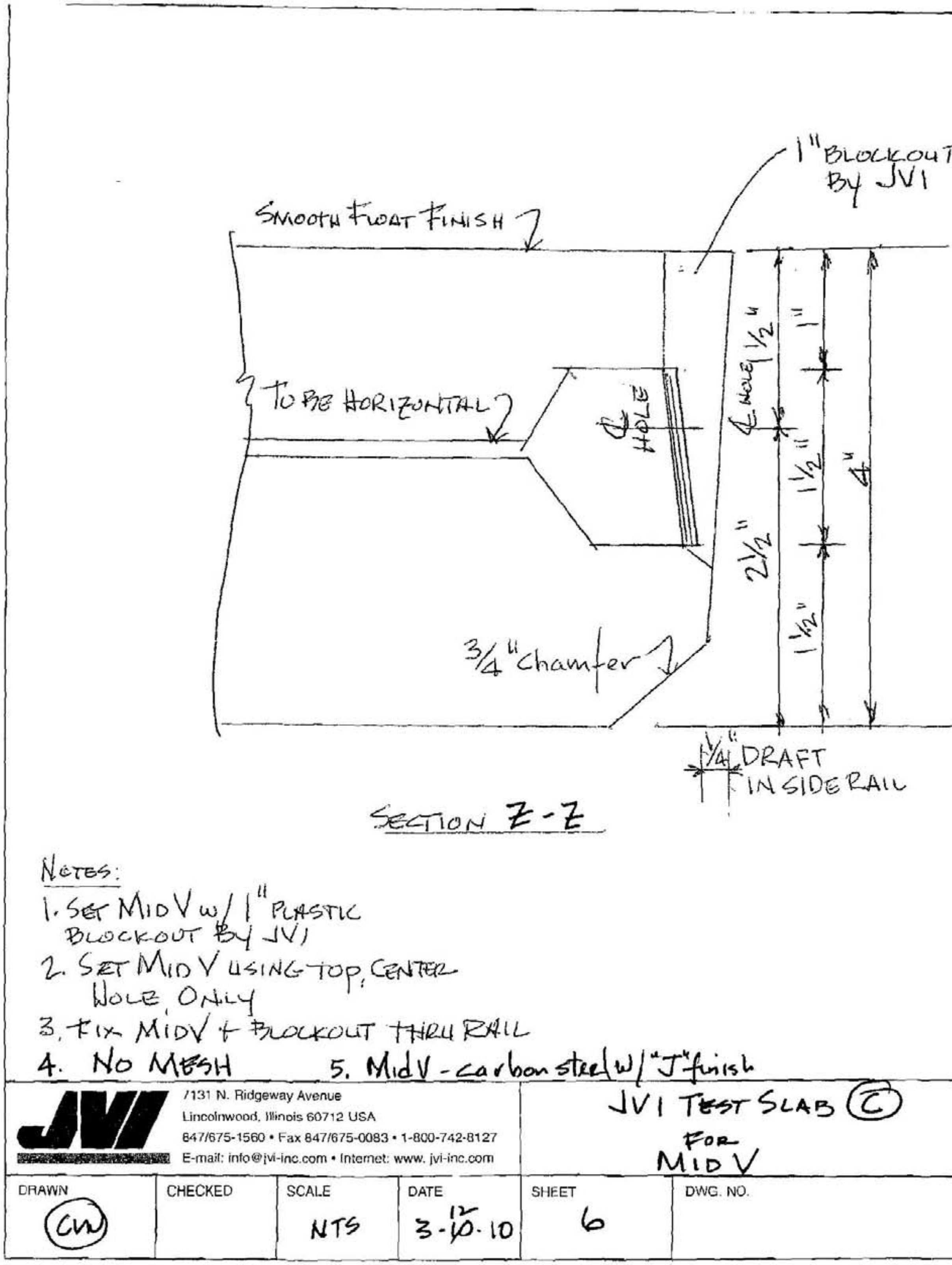

Figure 27 – Test Slab C Details

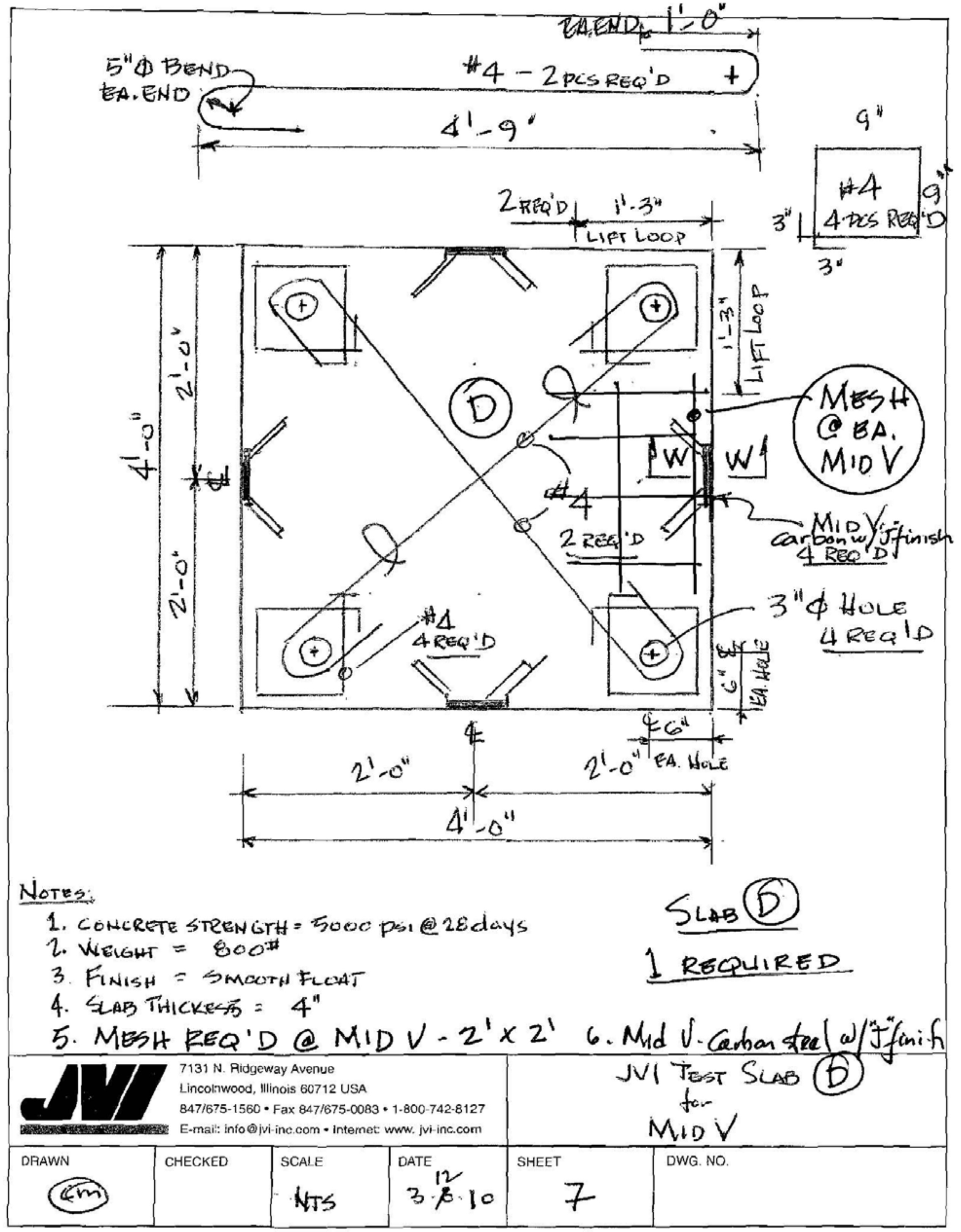

Figure 28 – Test Slab D reinforcing

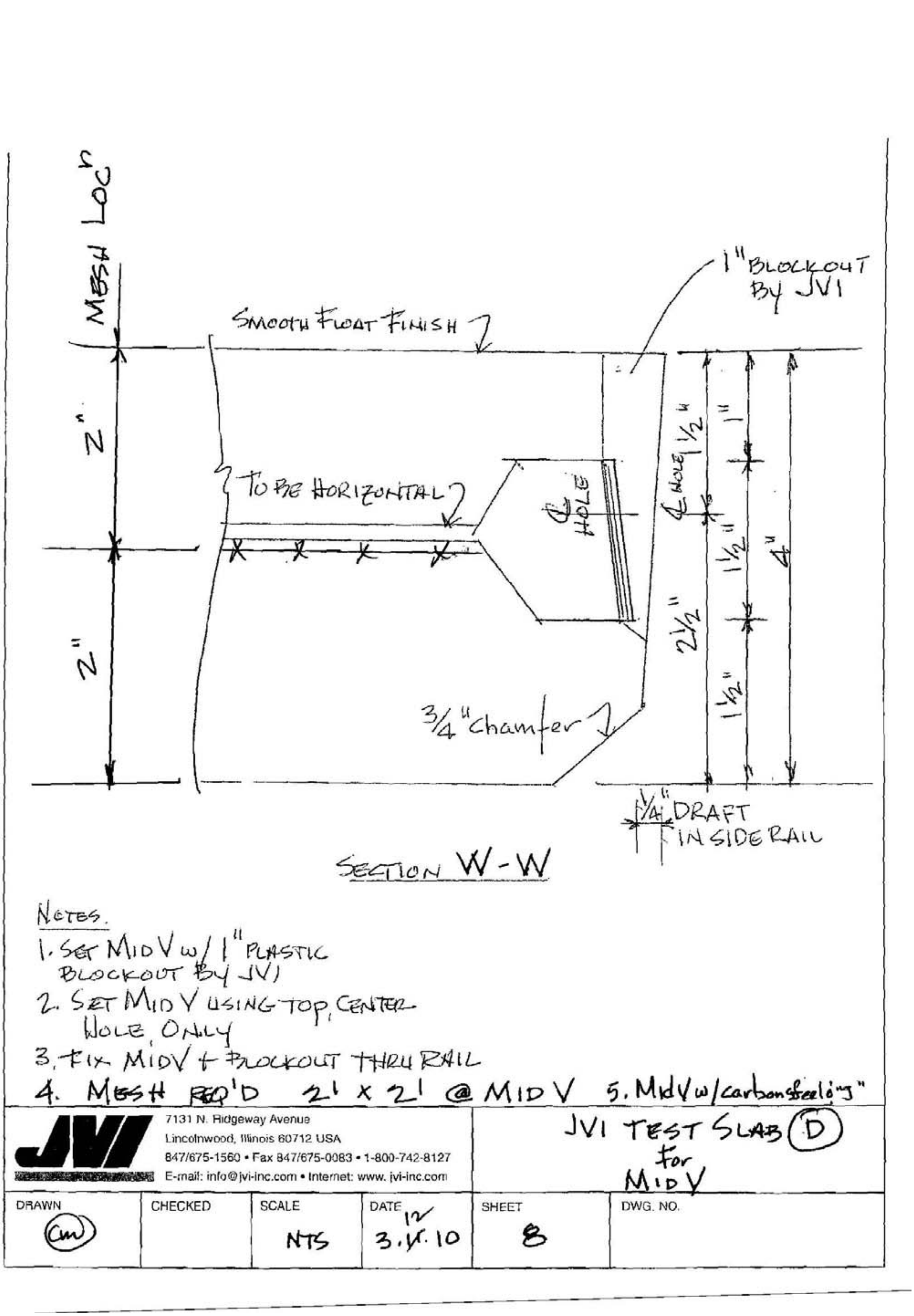

Figure 29 – Test Slab D Details

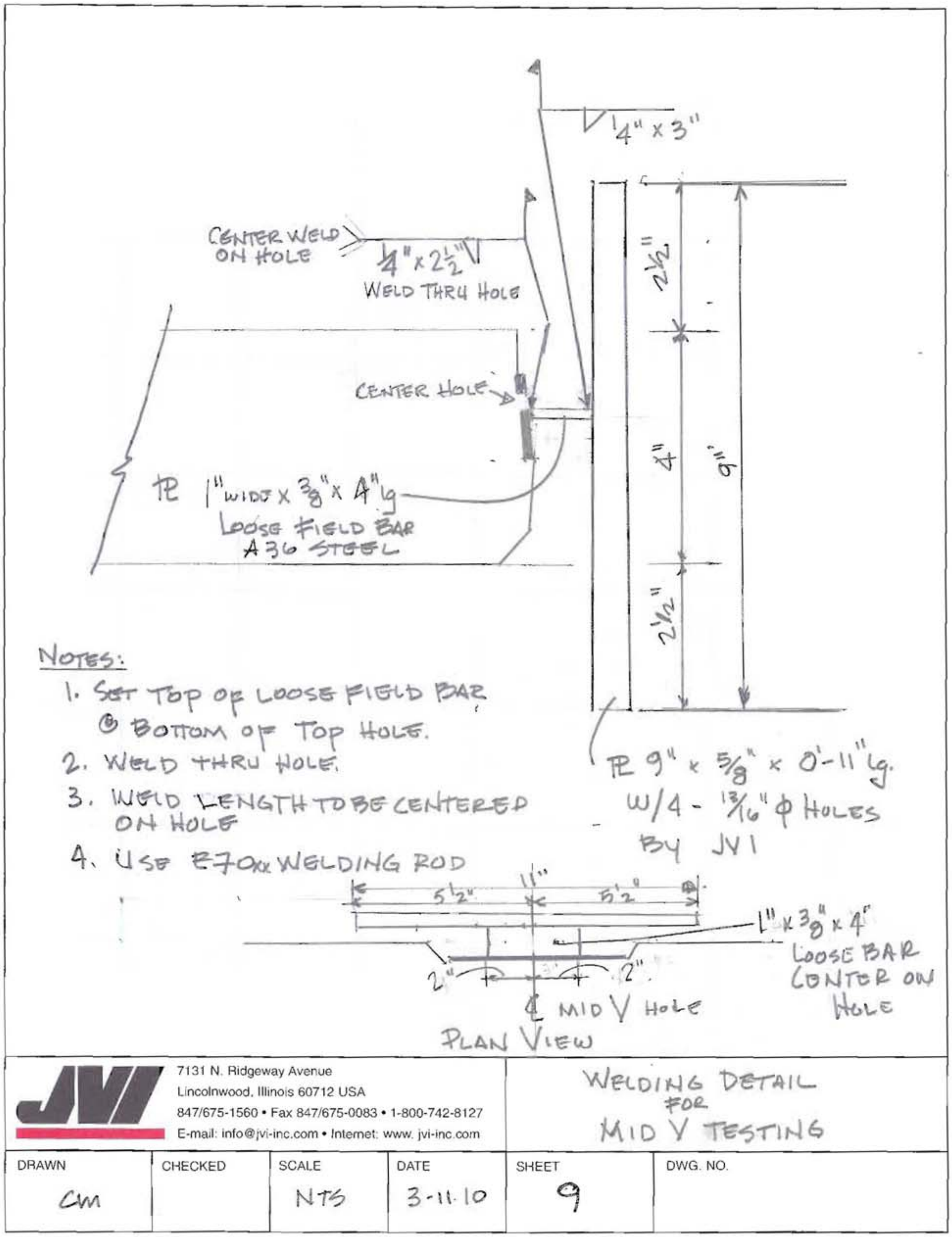

Figure 30 – Welding Detail

Figure 31 – Test A1-1 Failure Mode – top side view

Figure 32 – Test A1-1 Failure Mode – bottom side view

Figure 33 – Test A1-2 Failure Mode – top side view

Figure 34 – Test A1-2 Failure Mode – bottom side view

Figure 35 – Test A1-3 Failure Mode – top side view

Figure 36 – Test A1-3 Failure Mode – bottom side view

Figure 37 – Test A1-4 Failure Mode – top side view

Figure 38 – Test A1-4 Failure Mode – bottom side view

Figure 39 – Test A2-1 Failure Mode – top side view

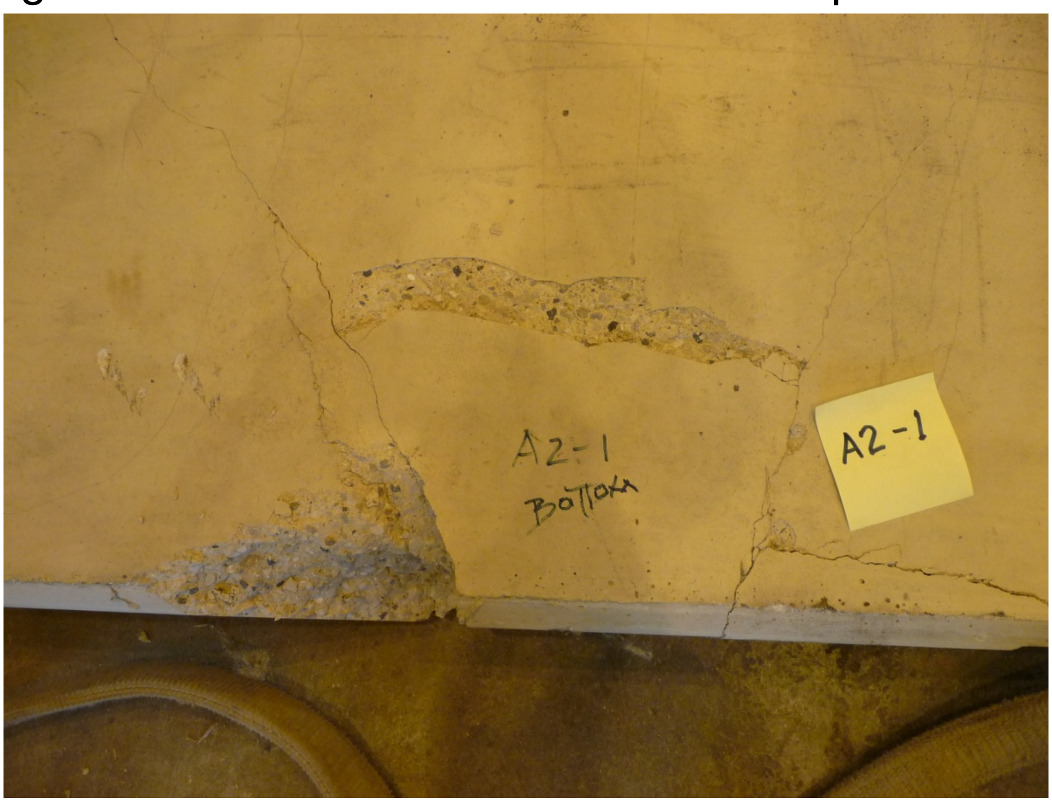

Figure 40 – Test A2-1 Failure Mode – bottom side view

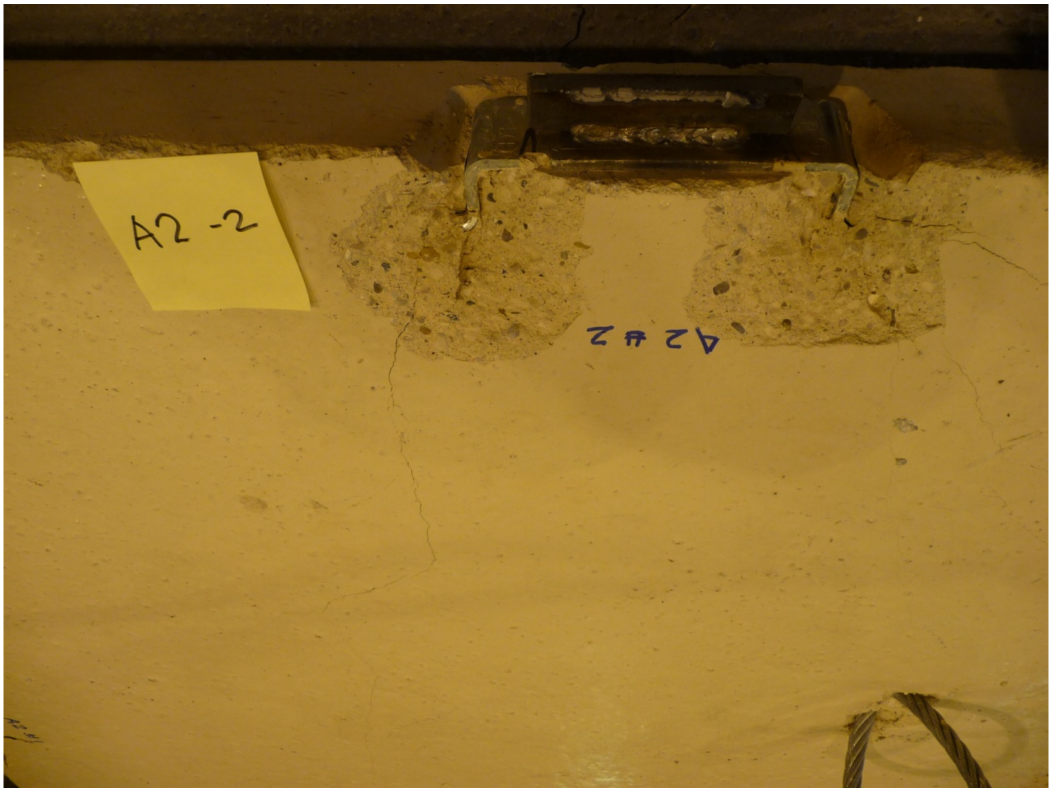

Figure 41 – Test A2-2 Failure Mode – top side view

Figure 42 – Test A2-2 Failure Mode – bottom side view

Figure 43 – Test A2-3 Failure Mode – top side view

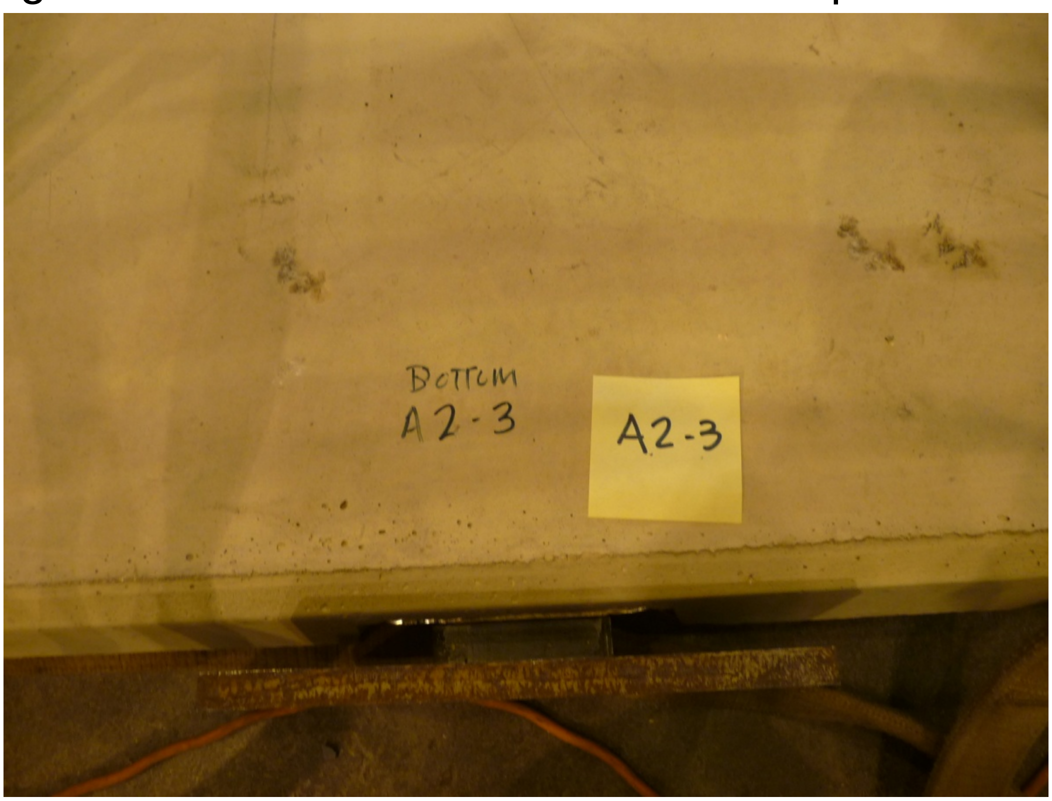

Figure 44 – Test A2-3 Failure Mode – bottom side view

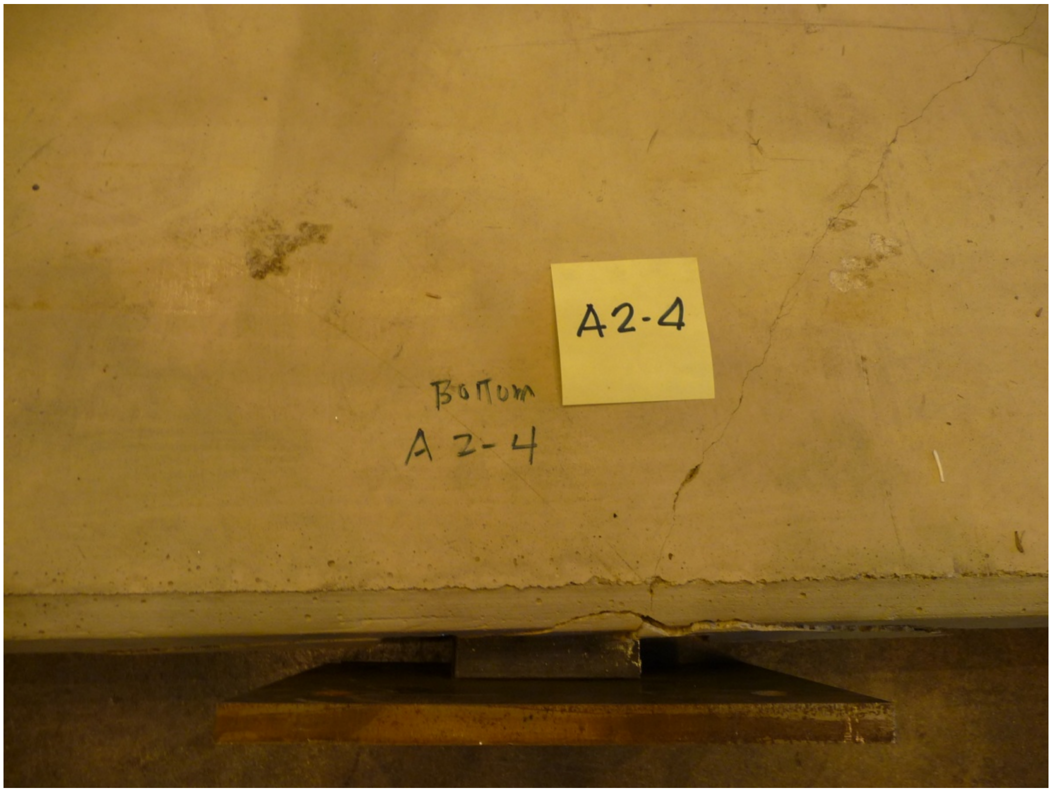

Figure 45 – Test A2-4 Failure Mode – top side view

Figure 46 – Test A2-4 Failure Mode – bottom side view

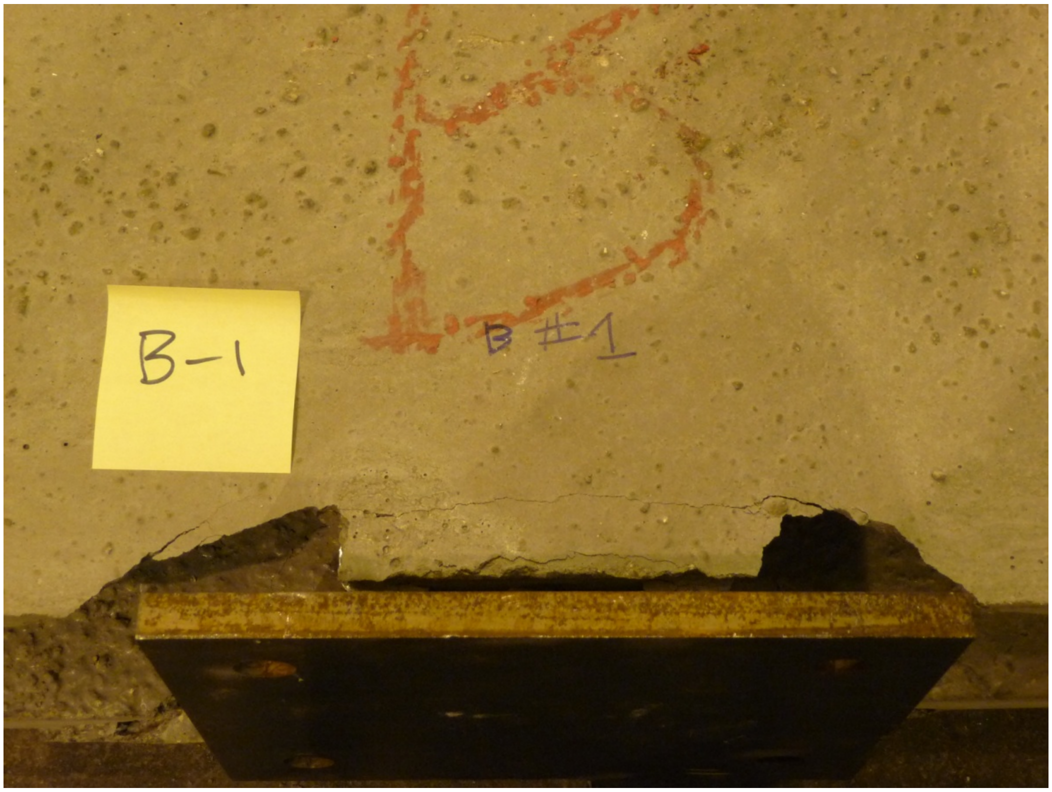

Figure 47 – Test B-1 Failure Mode – top side view

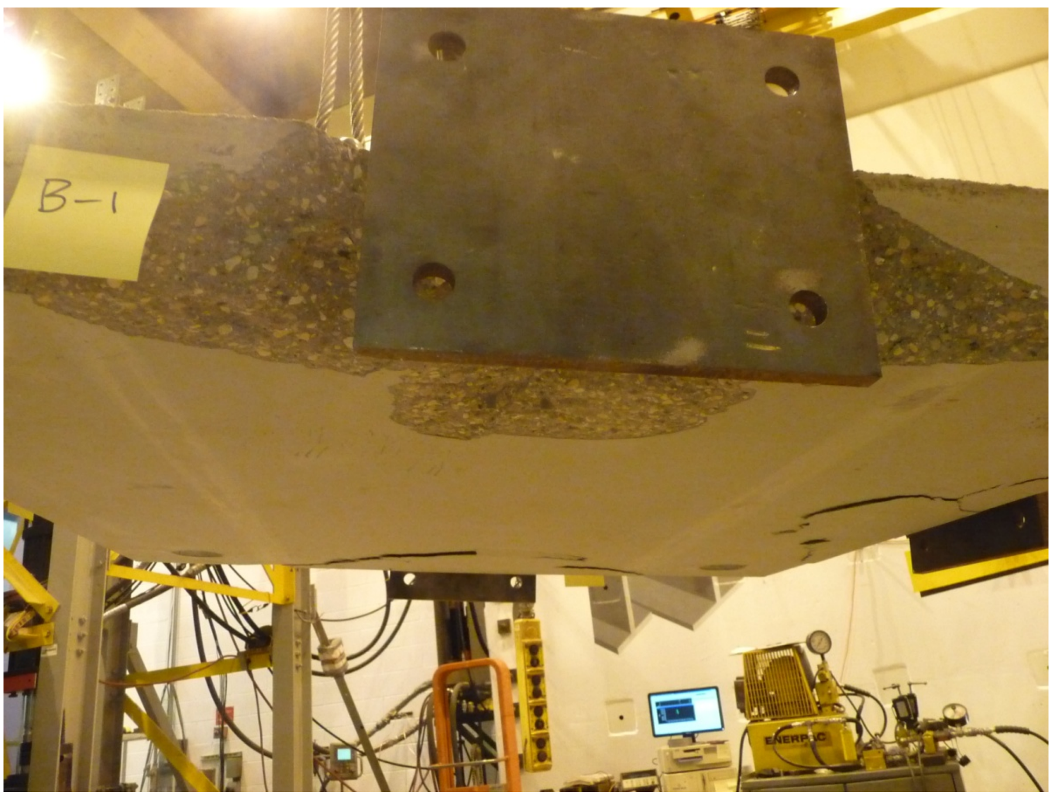

Figure 48 – Test B-1 Failure Mode – bottom side view

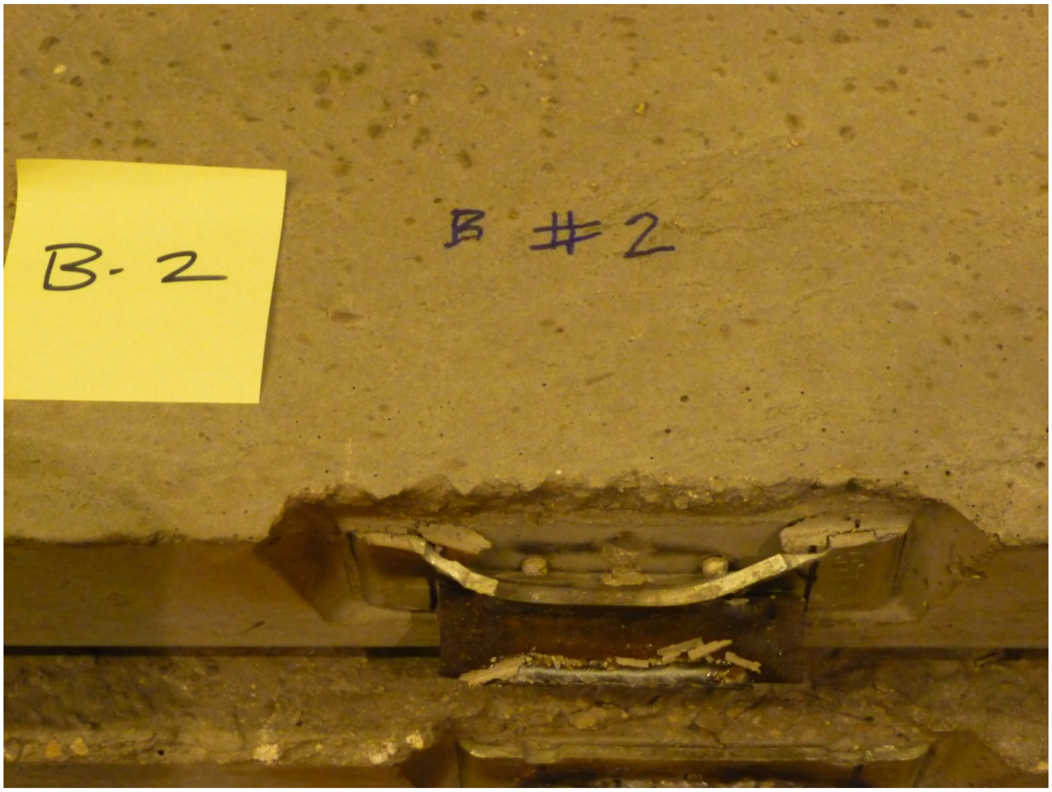

Figure 49 – Test B-2 Failure Mode – top side view

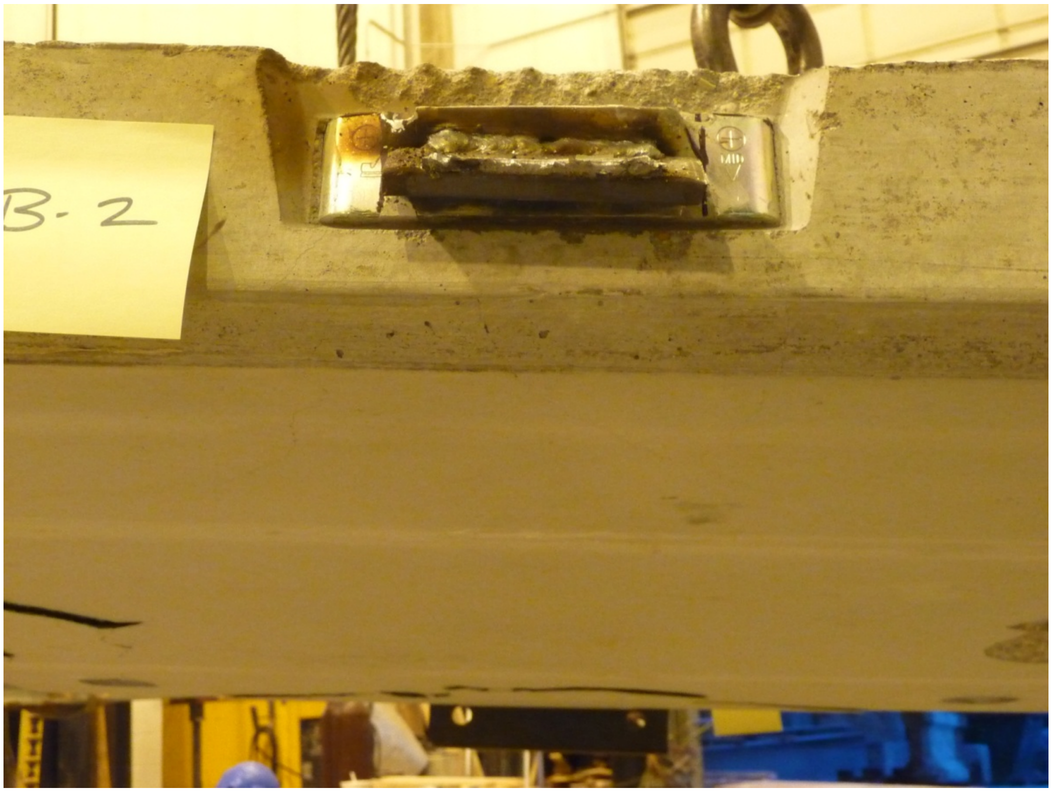

Figure 50 – Test B-2 Failure Mode – bottom side view

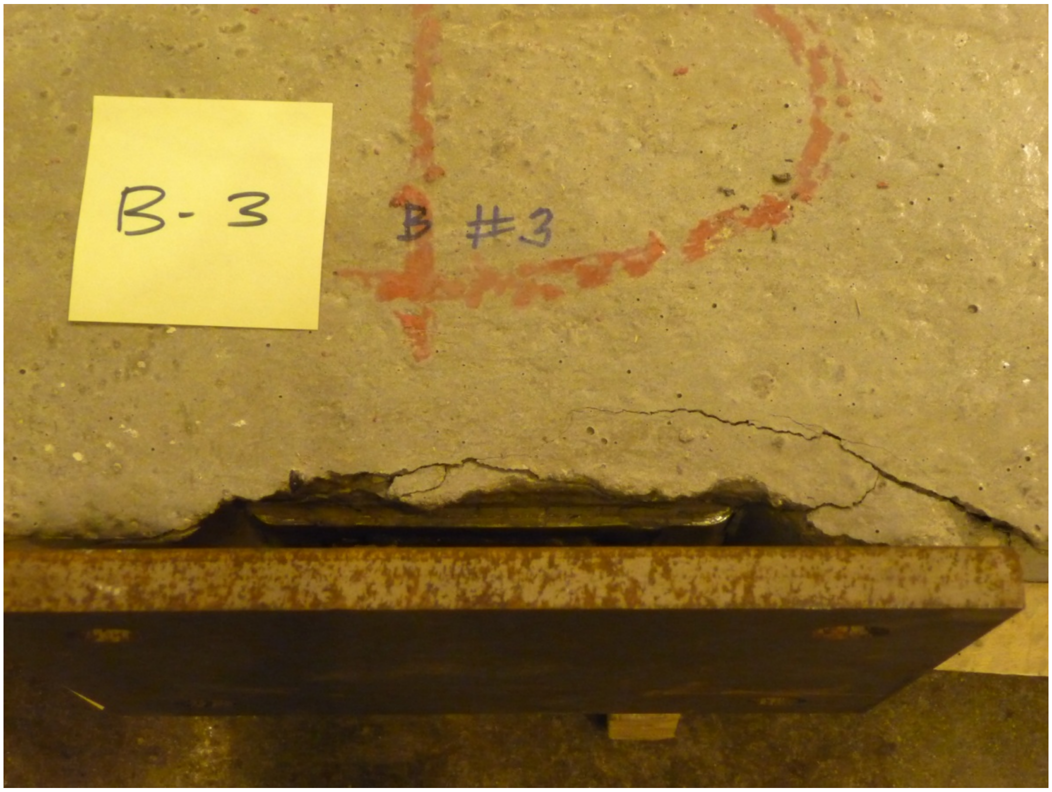

Figure 51 – Test B-3 Failure Mode – top side view

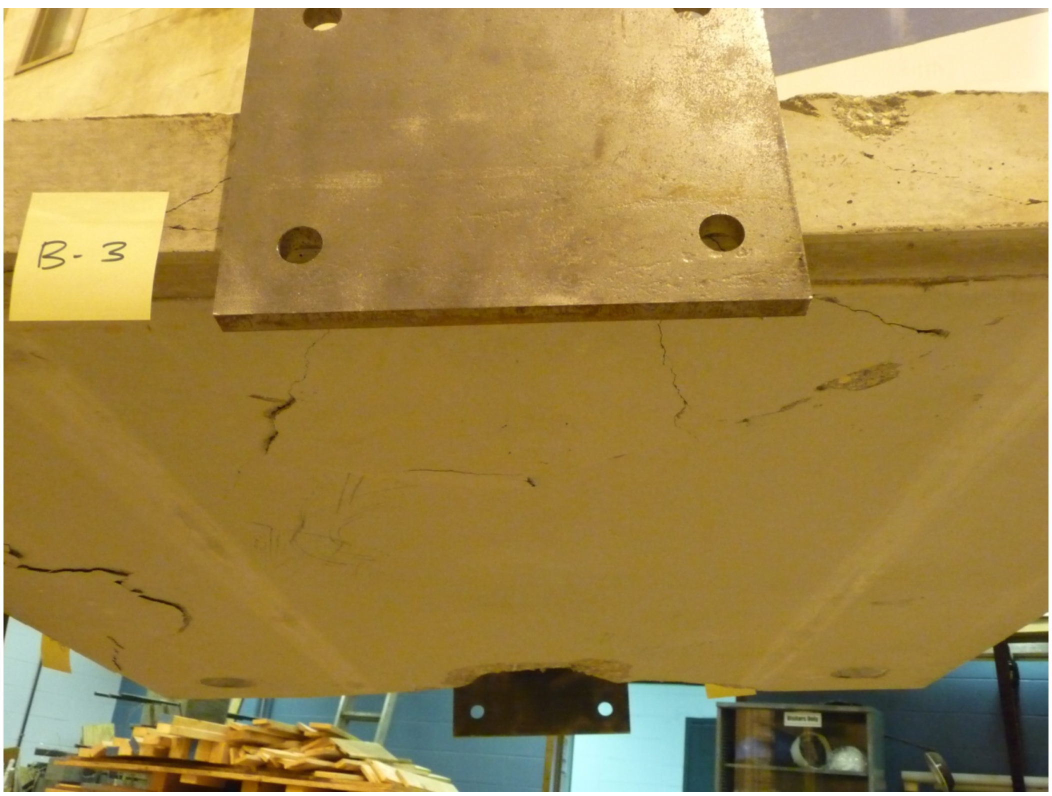

Figure 52 – Test B-3 Failure Mode – bottom side view

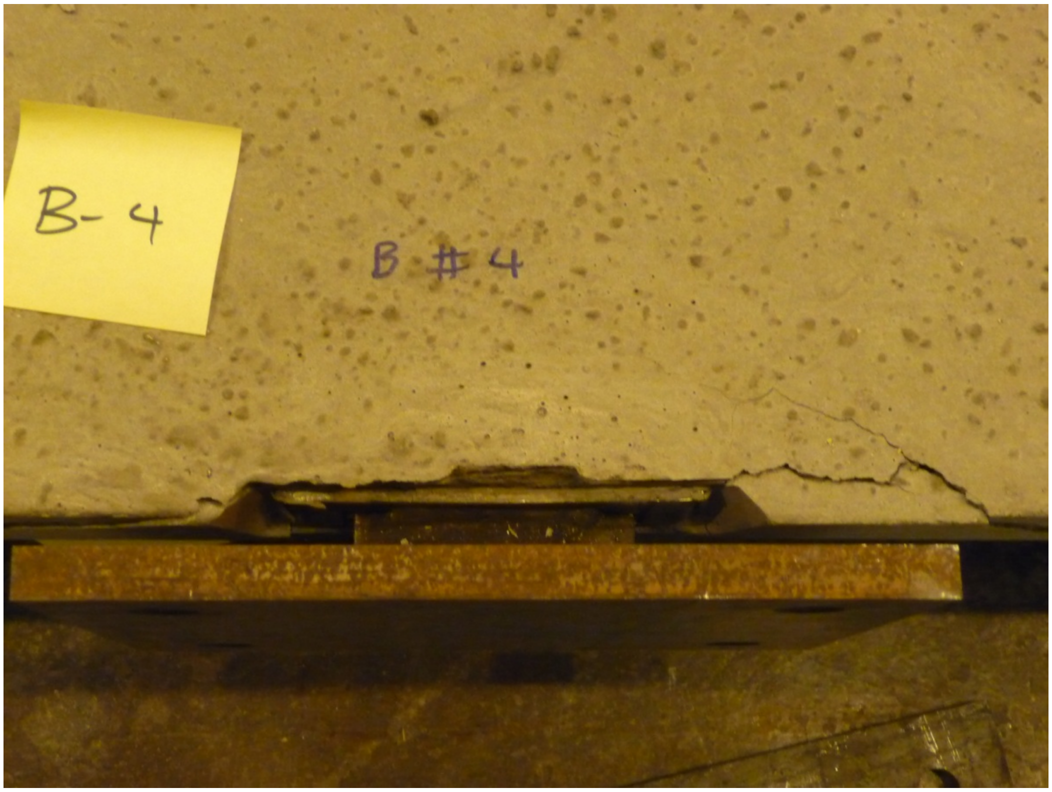

Figure 53 – Test B-4 Failure Mode – top side view

Figure 54 – Test B-4 Failure Mode – bottom side view

Figure 55 – Test C-1 Failure Mode – top side view

Figure 56 – Test C-1 Failure Mode – bottom side view

Figure 57 – Test C-2 Failure Mode – top side view

Figure 58 – Test C-2 Failure Mode – bottom side view

Figure 59 – Test C-3 Failure Mode – top side view

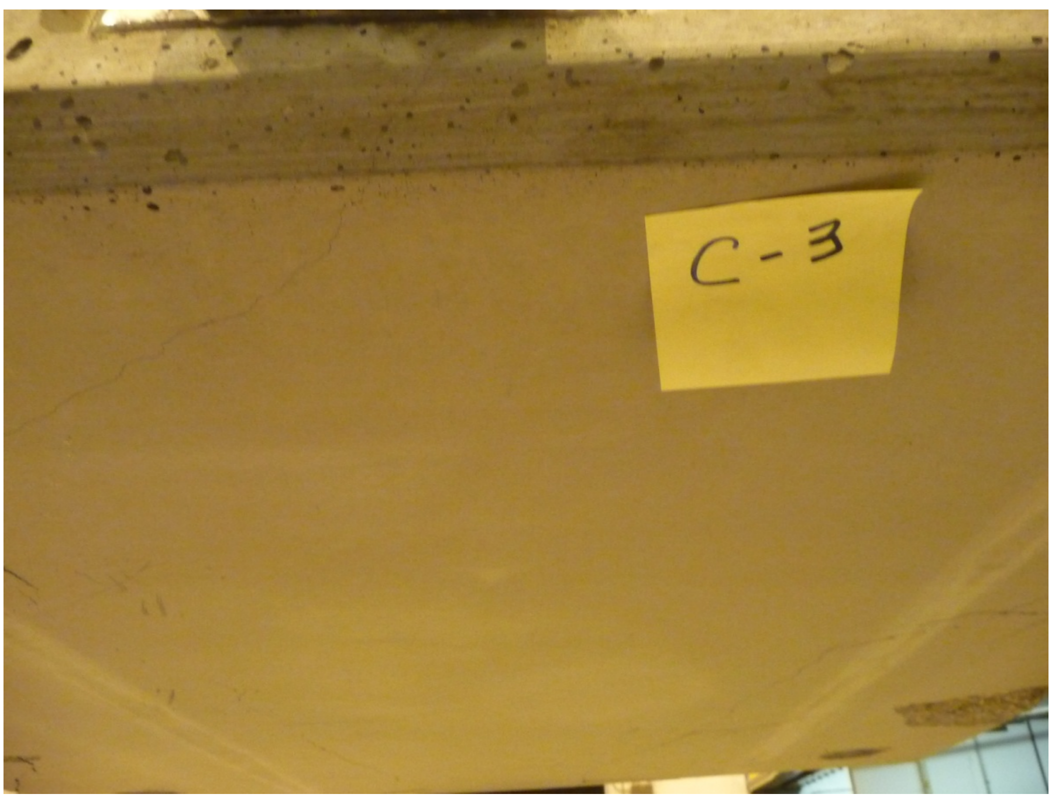

Figure 60 – Test C-3 Failure Mode – bottom side view

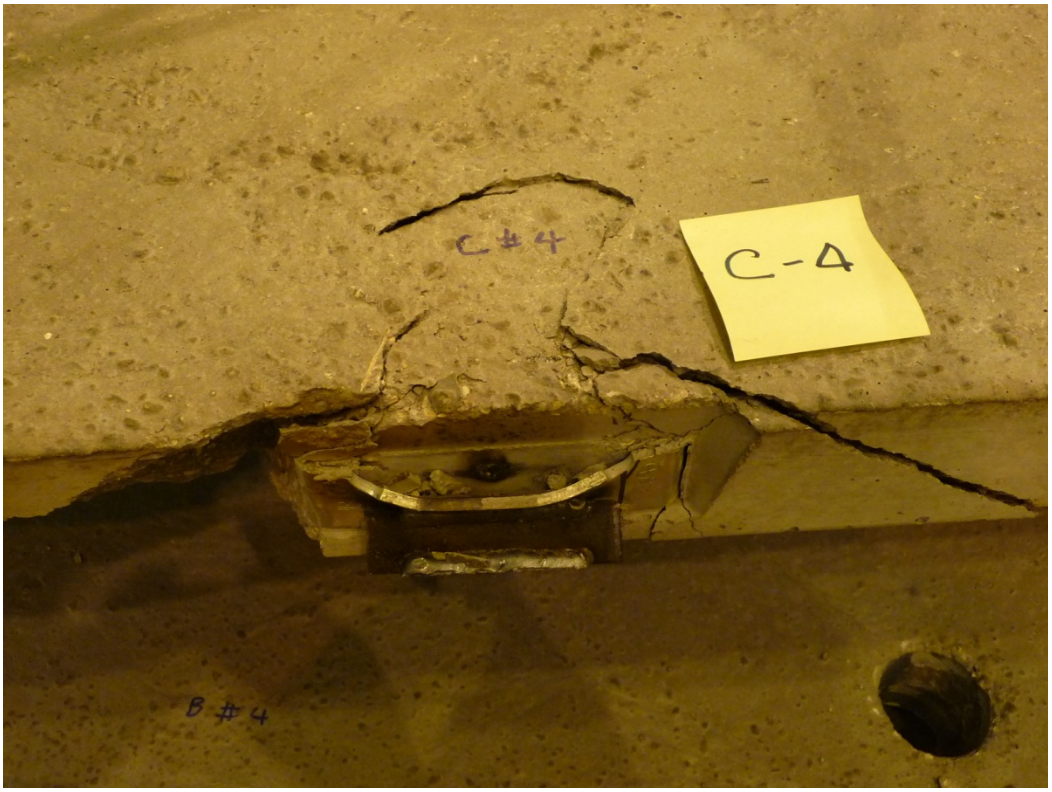

Figure 61 – Test C-4 Failure Mode – top side view

Figure 62 – Test C-4 Failure Mode – bottom side view

Figure 63 – Test D-1 Failure Mode – top side view

Figure 64 – Test D-1 Failure Mode – bottom side view

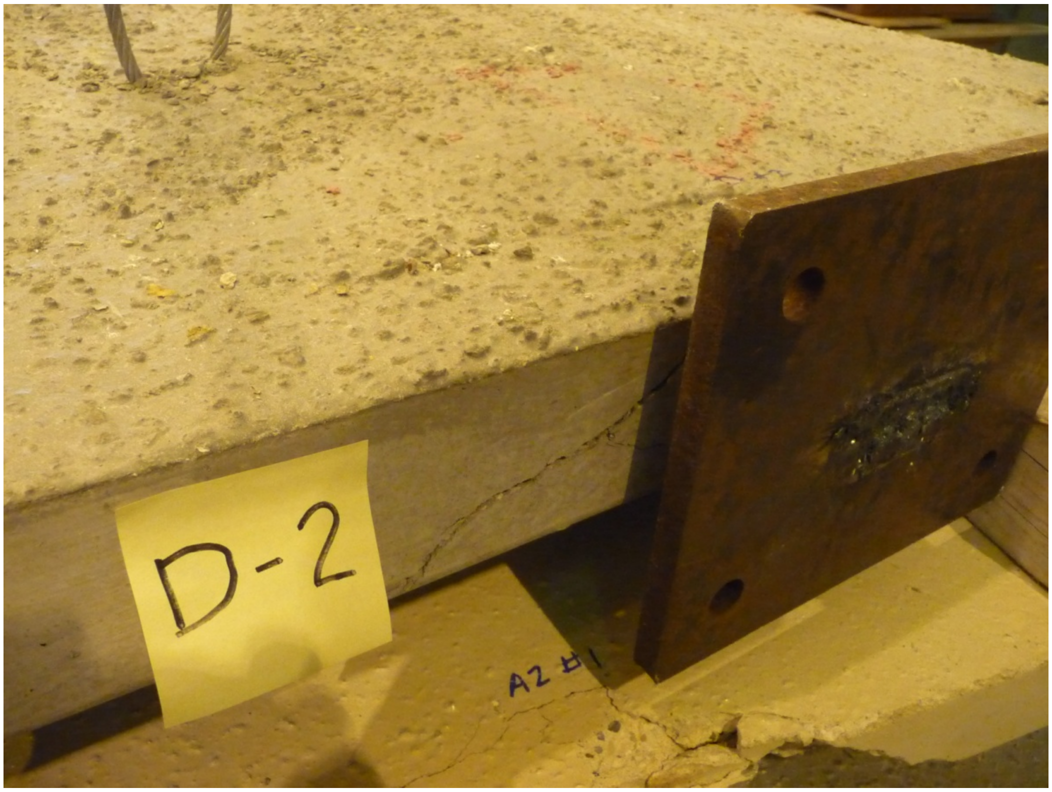

Figure 65 – Test D-2 Failure Mode – top side view

Figure 66 – Test D-2 Failure Mode – bottom side view

Figure 67 – Test D-3 Failure Mode – top side view

Figure 68 – Test D-3 Failure Mode – bottom side view

Figure 69 – Test D-4 Failure Mode – top side view

Figure 70 – Test D-4 Failure Mode – bottom side view

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Testing of the JVI Vector Connector 4 in 4" Slabs

Report No. 113012
January, 2013

by

Al Ghorbanpoor, P.E., Ph.D.
Professor of Structural Engineering, and
Director of the UWM Structures Laboratory

PREFACE

The Vector Connector 4 (VC4) was embedded in 4" thick concrete slabs for the purpose of testing its shear capacity as used in prestressed/precast concrete industry. The VC4 is a modification of the Vector Connector 3 (VC3), formerly called the Mid V. Testing was carried out in the Structural Engineering Laboratory at the University of Wisconsin- Milwaukee (UWM) on November 29, and 30, 2012. The test fixtures, instrumentation, and the test protocols were identical to previous "Vector Connector" tests carried out at UWM. The details of those tests are reported in the following two references:
(1)"Shear connector Tests," Test Report No.2, JVI website: www.jvi-inc.com
(2) A. Fattah Shaikh and Eric P. Feile, "Load Testing of a Precast Concrete Double-Tee Flange Connector," PCI Journal 49(3):84-94, May-June 2004.

TEST SLAB SPECIMEN DETAILS

The concrete slab specimens for the VC4 tests were fabricated by UWM in accordance with Appendix B, figures 2 and 3.

The following notes pertain to specifics of the test slab specimens:

Concrete

Ready mix concrete was used in the fabrication of the test slabs. 4” x 8” concrete cylinders were made and tested by UWM. The concrete cylinder strength results are as follows:

Slab #	Poured Date	Break Date	Break Load (LBS)	Break Pressure (PSI)
None	11/20/12	11/27/12	55600	4425
None	11/20/12	11/28/12	53976	4295
A1 - A4 & B1 - B4	11/20/12	11/29/12	58080	4622
	11/20/12	11/29/12	55306	4401
	11/20/12	11/29/12	55850	4444
		Average	56412	4489
C1 - C4 & D1 - D4	11/20/12	11/30/12	58580	4662
	11/20/12	11/30/12	58210	4632
	11/20/12	11/30/12	56310	4481
		Average	57700	4592

Reinforcing

Welded Wire Mesh: no welded wire mesh located in the vicinity of the VC4 failure zones.

Steel Reinforcing bar: rebar was used only for handling stresses.

See Appendix B, Figure 2 for slab details.

Test Slab Actual Details

Slab #	Slab Thickness	Test #	VC4 Mark #	VC Blockout (BO) Used	Mesh	Distance D -Slab Surface to VC4 top edge (in.)	Distance A - Slab surface to top of weld slug (in.)	Distance - VC4 top edge to top of weld slug (in.)	Distance B - Vert. Fillet Weld Size Height (in.)	Distance C - Weld Length on Top of Slug (in.)
A	4-1/16"	1	A-1	1" Std BO	No	1.140	1.600	0.460	0.250	2.500
A	4-1/16"	2	A-2	1" Std BO	No	1.080	1.500	0.420	0.250	2.500
A	4-1/16"	3	A-3	1" Std BO	No	1.210	1.700	0.490	0.250	2.600
A	4-1/16"	4	A-4	1" Std BO	No	1.150	1.600	0.450	0.220	2.900
B	4-1/16"	1	B-1	1" Std BO	No	1.100	1.510	0.410	0.200	2.600
B	4-1/16"	2	B-2	1" Std BO	No	1.080	1.540	0.460	0.200	2.800
B	4-1/16"	3	B-3	1" Std BO	No	1.280	1.780	0.500	0.200	2.500
B	4-1/16"	4	B-4	1" Std BO	No	1.050	1.600	0.550	0.220	2.300
C	4-1/16"	1	C-1	1" Std BO	No	1.220	1.800	0.580	0.200	2.400
C	4-1/16"	2	C-2	1" Std BO	No	1.080	1.510	0.430	0.200	2.500
C	4-1/16"	3	C-3	1" Std BO	No	1.020	1.500	0.480	0.220	2.300
C	4-1/16"	4	C-4	1" Std BO	No	1.000	1.580	0.580	0.220	2.400
D	4-1/8"	1	D-1	1" Std BO	No	1.080	1.600	0.520	0.200	2.400
D	4-1/8"	2	D-2	1" Std BO	No	1.230	1.640	0.410	0.200	2.600
D	4-1/8"	3	D-3	1" Std BO	No	1.210	1.680	0.470	0.200	2.400
D	4-1/8"	4	D-4	1" Std BO	No	1.220	1.700	0.480	0.230	2.200

Notes
1 - Specified weld between slug and VC4 faceplate is 1/4" fillet x 2-1/2" long
2 - Flat Weld Slug = 1" x 3/8" x 4" Long
3 - Weld Length on top goes thru center faceplate hole
4 - Certified Welder performed all welds
5 - No Reinforcement in area of Vector Connectors
6 - All sides of 4' x 4' test slabs have 1/4" / 4" draft
7 - Specified weld between slug and test fixture is 1/4" fillet x 3" long

Flange Connectors, Vector Connector 4

VC4 materials are ASTM A240/A 240M type 201L annealed stainless steel (UNS Designation S20103), and SAE J1392 Gr. 045 XLF carbon steel with "J Finish" as indicated below. Material certifications are found in Appendix C. Information of each VC4 tested are indicated below.

VC4 Mark #	VC Type	Gusset Stiffener at Corner	Material	VC4 Center Faceplate Height (in.)	VC4 Left Corner Height (in.)	VC4 Right Corner Height (in.)	Loading Method
A-1	VC4 - Opt 3	2nd Ver.	ASTM A240/A 201L SS	1.50	1.158	1.169	Cyclic Shear
A-2	VC4 - Opt 3	2nd Ver.	ASTM A240/A 201L SS	1.50	1.142	1.166	Cyclic Shear
A-3	VC4 - Opt 3	2nd Ver.	ASTM A240/A 201L SS	1.50	1.140	1.131	Cyclic Shear
A-4	VC4 - Opt 3	2nd Ver.	ASTM A240/A 201L SS	1.50	1.120	1.134	Cyclic Shear
B-1	VC4 - Opt 3	2nd Ver.	Grade 045XLF w/ J-Finish	1.50	1.166	1.158	Cyclic Shear
B-2	VC4 - Opt 3	2nd Ver.	Grade 045XLF w/ J-Finish	1.50	1.174	1.178	Cyclic Shear
B-3	VC4 - Opt 3	2nd Ver.	Grade 045XLF w/ J-Finish	1.50	1.170	1.160	Cyclic Shear
B-4	VC4 - Opt 3	2nd Ver.	Grade 045XLF w/ J-Finish	1.50	1.158	1.161	Monotonic Shear
C-1	VC4 - Opt 4	No	ASTM A240/A 201L SS	1.50	1.150	1.170	Cyclic Shear
C-2	VC4 - Opt 4	No	ASTM A240/A 201L SS	1.50	1.194	1.196	Cyclic Shear
C-3	VC4 - Opt 4	No	ASTM A240/A 201L SS	1.50	1.198	1.198	Monotonic Shear
C-4	VC4 - Opt 4	No	ASTM A240/A 201L SS	1.50	1.151	1.143	Monotonic Shear
D-1	VC4 - Opt 4	No	ASTM A240/A 201L SS	1.50	1.160	1.136	Cyclic Shear
D-2	VC4 - Opt 4	No	ASTM A240/A 201L SS	1.50	1.139	1.175	Monotonic Shear
D-3	VC4 - Opt 4	No	ASTM A240/A 201L SS	1.50	1.110	1.136	Cyclic Shear
D-4	VC4 - Opt 4	No	ASTM A240/A 201L SS	1.50	1.171	1.181	Monotonic Shear

Notes

1 - Left & Right Corners of VC4 are from a faceplate front view perspective where markings are visible.

VC4 with Gusset

VC4 with Gusset

VC4 without Gusset

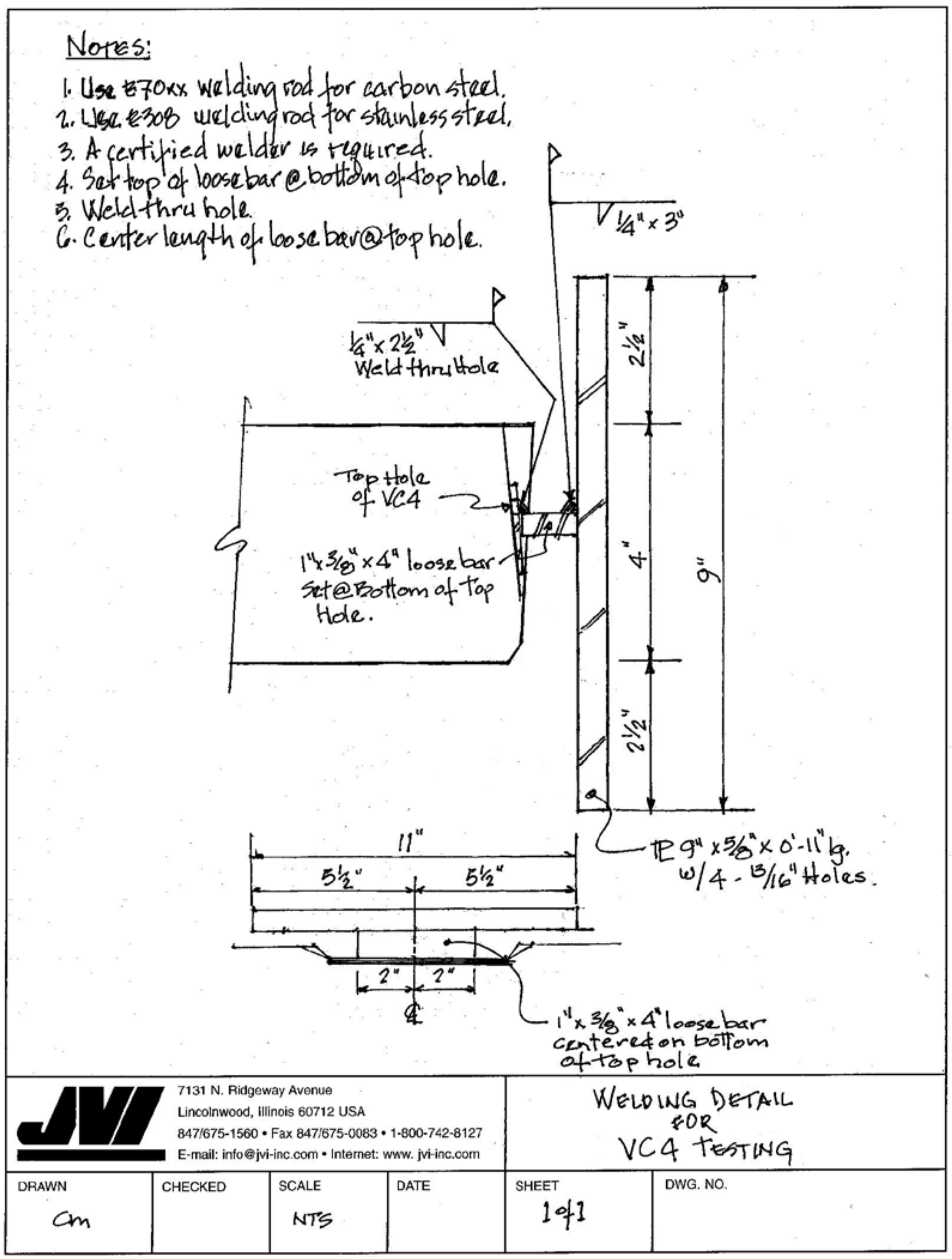
VC4 without Gusset

Field Weld Slugs

The field weld slug materials are ASTM A666, type 304, stainless steel for stainless steel VC4 and ASTM 36 for carbon VC4. Weld slug dimensions are: flat bar slug, 3/8" x 1" x 4" long. All welds from slug to VC4 faceplate designed to be ¼" fillet x 2 ½" long. Actual sizes as shown on page 3, column "Distance –B". All welds were preformed by a certified welder on top of slug. Every weld passed through the top hole in the faceplate.

Loading Plates

The loading plates are welded to the slugs by a certified welder and then bolted to the testing apparatus.



Welding Detail for Field Bar (Slug) to VC4 and Load Plate

Welded Connection – Slug to VC4 faceplate and loading plate

TEST PROCEDURES

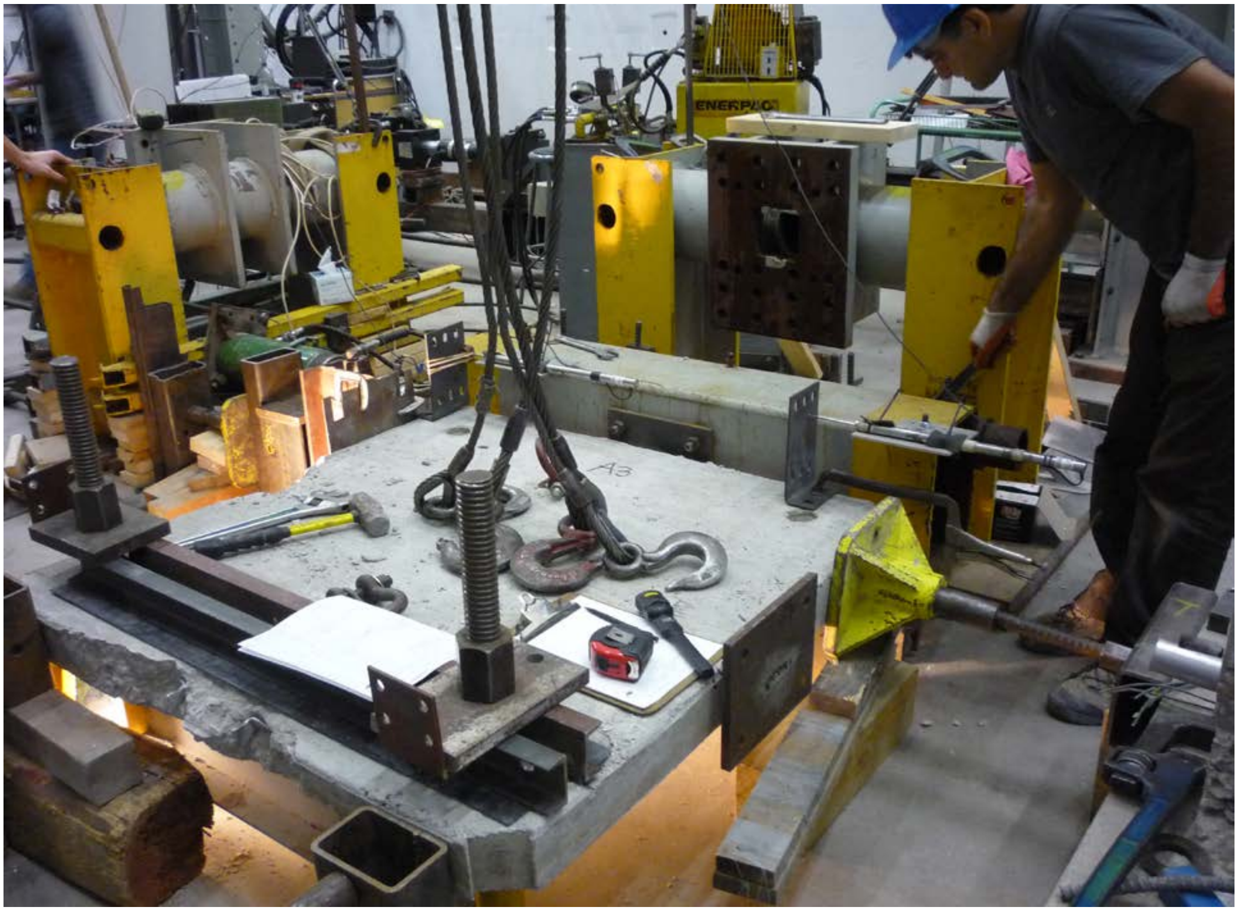
For each of the various types of tests conducted, test procedures were kept similar to allow for true comparison of data between tests. The following description of each of the test procedures gives details of the load application and instrumentation setup; these and other test variables were kept the same to allow for consistency between tests.

Monotonic Horizontal Shear without Tension

For all of the test setups employed, load was applied gradually to allow for data readings to be taken at regular intervals and for specimen inspection while loading was taking place. For all variations of horizontal shear tests, Linear Variable Differential Transducers (LVDTs) were placed on both sides of the slab to read relative slip between the slab and the loading beam. As mentioned previously, two LVDTs were employed for all tests for verification of data. Electronic readings of the load cell and LVDTs were stored for later use in analysis.

Cyclic Horizontal Shear without Tension

The test program utilized for cyclic tests was based on the program developed for the original JVI flange connector testing by Professor Michael Oliva at the University of Wisconsin-Madison. Load application for this test setup was based on the results of the monotonic horizontal shear tests. The yield force and corresponding displacement for each type of steel were estimated and used as a basis for cyclic loading. For cyclic testing, the specimen was first cycled back and forth to a load of 75% of the yield force. Subsequent load cycles were applied in groups of three at displacement levels of 2, 3, 5, 8, and 12 times the yield displacement until connection failure.



Test Setup at University of Wisconsin, Milwaukee

Test Results

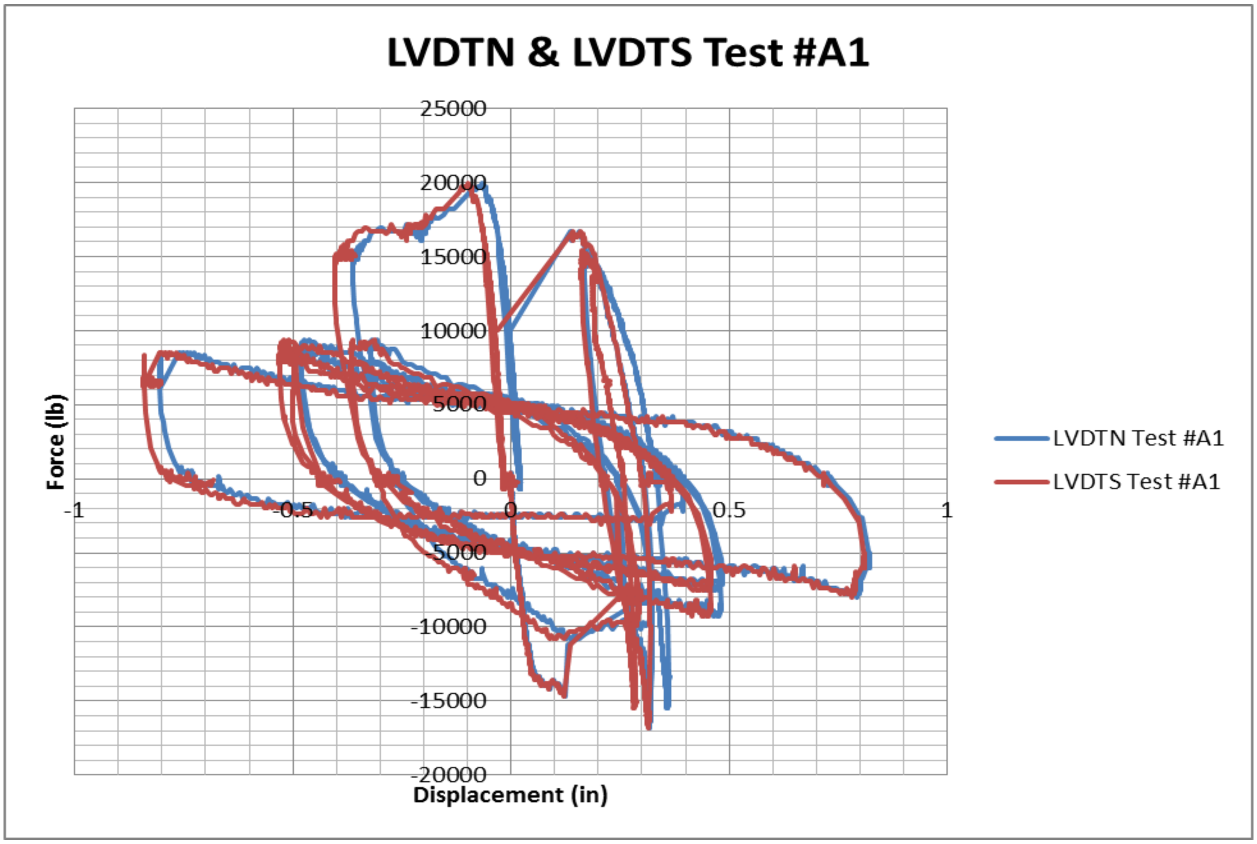
Test #	Test Date	Load Direction	1st Crack Load (lbs.)	Concrete Yield Load (lbs.)	Yield Displacement (in.)	Final Load (lbs.)	Final Displacement	Failure Mode
Monotonic Shear with No Tension, VC4 with Gusset in corner, 1" Blockout, Grade 045 XLF Carbon								
B4	11/29/12	N	15,446	18,454	1.36	6,000	1.760	Conrete failure, leg pullout on tension side
Monotonic Shear with No Tension, VC4 with NO Gusset in corner, 1" Blockout, Type 201L Stainless Steel								
C3	11/30/12	N	18,221	18,651	1.04	5,500	1.540"	Conrete failure, leg pullout on tension side
C4	11/30/12	N	18,420	14,981	1.00	7,400	1.420"	Conrete failure, leg pullout on tension side
D2	11/30/12	N	19,525	20,171	0.90	7,000	1.440"	Conrete failure, leg pullout on tension side
D4	11/30/12	N	20,637	18,702	0.92	8,700	1.520"	Conrete failure, leg pullout on tension side
Cyclic Shear with No Tension, VC4 with Gusset in corner, 1" Blockout, Grade 045 XLF Carbon								
(Load 12,225# N/S, (3) N/S @ 0.137", (3) @ 0.274", (3) @ 0.411", (3) @ 0.685", (3) @ 1.096" until failure)								
B1	11/29/12	N & S	18,771	NA	NA	NA	0.685", N 3rd cycle	Steel failure thru gusset on tension leg
B2	11/29/12	N & S	16,981	NA	NA	NA	1.096", N 1st cycle	Steel failure thru 2nd bend in tension leg
B3	11/29/12	N & S	16,209	NA	NA	NA	1.096", S 1st cycle	Steel failure thru gusset on tension leg
Cyclic Shear with No Tension, VC4 with Gusset in corner, 1" Blockout, Type 201L Stainless Steel								
(Load 15,330# N/S, (3) N/S @ 0.318", (3) @ 0.477", (3) @ 0.795", (3) @ 1.272" until failure)								
A1	11/29/12	N & S	19,946	NA	NA	NA	0.795", N 2nd cycle	Steel failure thru gusset on tension leg
Cyclic Shear with No Tension, VC4 with Gusset in corner, 1" Blockout, Type 201L Stainless Steel								
(Load 12,225# N/S, (3) N/S @ 0.137", (3) @ 0.274", (3) @ 0.411", (3) @ 0.685", (3) @ 1.096" until failure)								
A2	11/29/12	N & S	19,721	NA	NA	NA	0.685", S 2nd cycle	Steel failure thru gusset on tension leg
A3	11/29/12	N & S	17,589	NA	NA	NA	0.685", N 3rd cycle	Steel failure thru gusset on tension leg
A4	11/29/12	N & S	18,472	NA	NA	NA	0.685", S 3rd cycle	Steel failure thru gusset on tension leg
Cyclic Shear with No Tension, VC4 with NO Gusset in corner, 1" Blockout, Type 201L Stainless Steel								
(Load 12,225# N/S, (3) N/S @ 0.137", (3) @ 0.274", (3) @ 0.411", (3) @ 0.685", (3) @ 1.096" until failure)								
C1	11/30/12	N & S	20,065	NA	NA	NA	1.096", N 1st cycle	Steel failure thru 1st faceplate corner bend on tension side
C2	11/30/12	N & S	19,983	NA	NA	NA	0.685", N 1st cycle	Steel failure thru 1st faceplate corner bend on tension side. Failed sooner than test C1 because concrete remained around 2nd leg corner bend which added stiffness to 2nd bend and thus made 1st corner bend work more and take most of the displacement loads.
D1	11/30/12	N & S	19,502	NA	NA	NA	1.096", N 1st cycle	Steel failure thru 1st faceplate corner bend on tension side
D3	11/30/12	N & S	19,218	NA	NA	NA	0.685", S 2nd cycle	Steel failure thru 1st faceplate corner bend on tension side. Similar issues as defined in Test C2 but with a smaller amount of concrete remaining around 2nd bend.
Notes:								
1 - Testing Sequence: 11/29/12 - A1, A2, A3, A4, B1, B2, B3, B4 : 11/30/12 - C1, C2, C3, C4, D2, D4, D1, D3								
2 - Testing Direction: North (N), South (S)								
3 - 1st Crack and Concrete Yield Load values in table above are read directly from computer raw data which created Graphs								
4 - Raw data - (+) Load reading = South Direction, (-) Load reading = North Direction								

Table 1: TEST RESULTS SUMMARY

ACKNOWLEDGEMENT

The flange connector is a very important product for the precast/prestressed concrete industry. Test information on its load-displacement behavior is critical in developing and upgrading the design procedures for jointed precast structures, such as parking decks and wall panels. JVI's participation with precast producers in supporting laboratory testing on the Vector Connector is applauded.

APPENDIX A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20000
15000
10000
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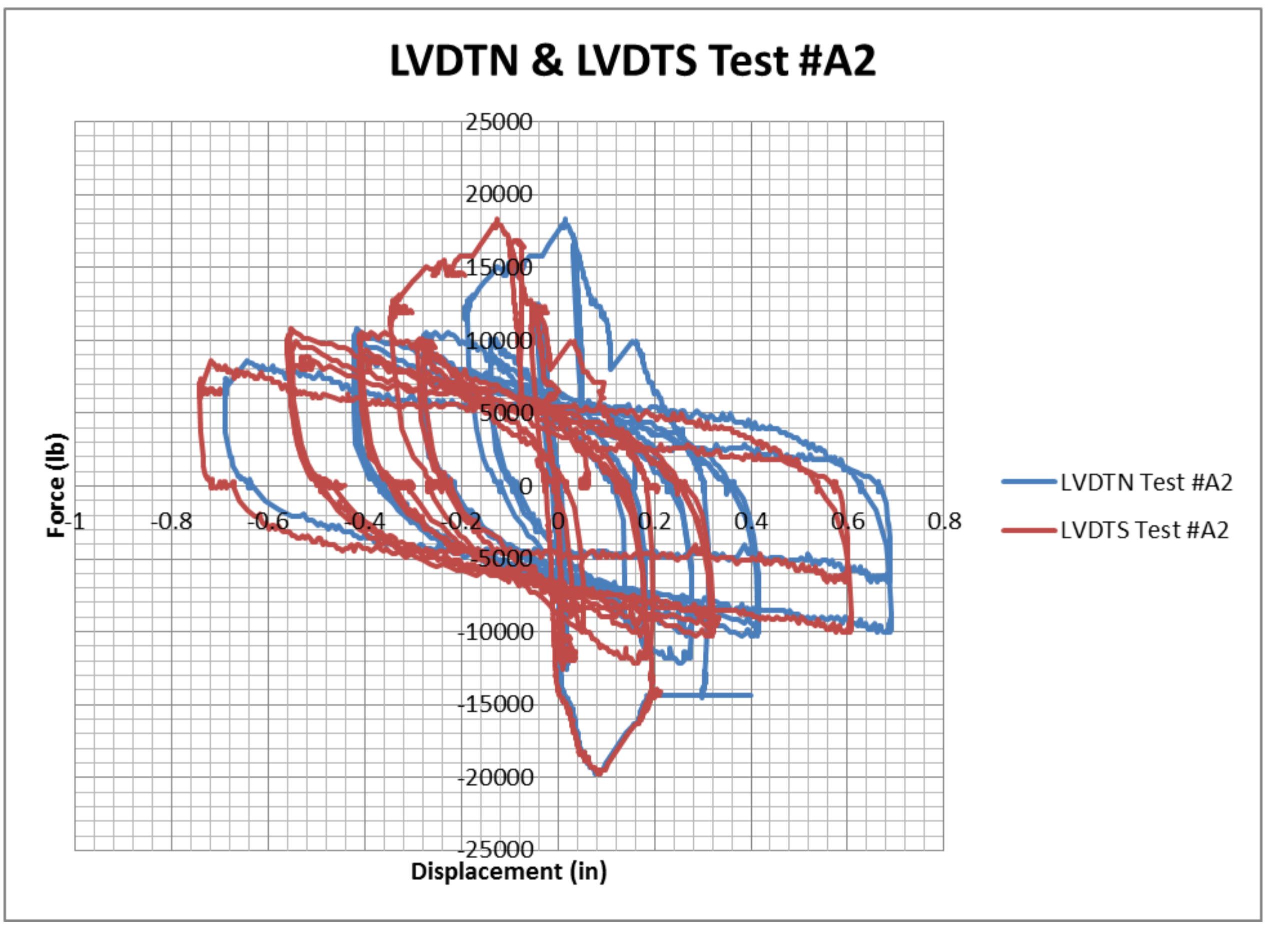
1
Force (lb)
Displacement (in)
LVDTN Test #A1
LVDTS Test #A1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0
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-25000
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-0.8
-0.6
-0.4
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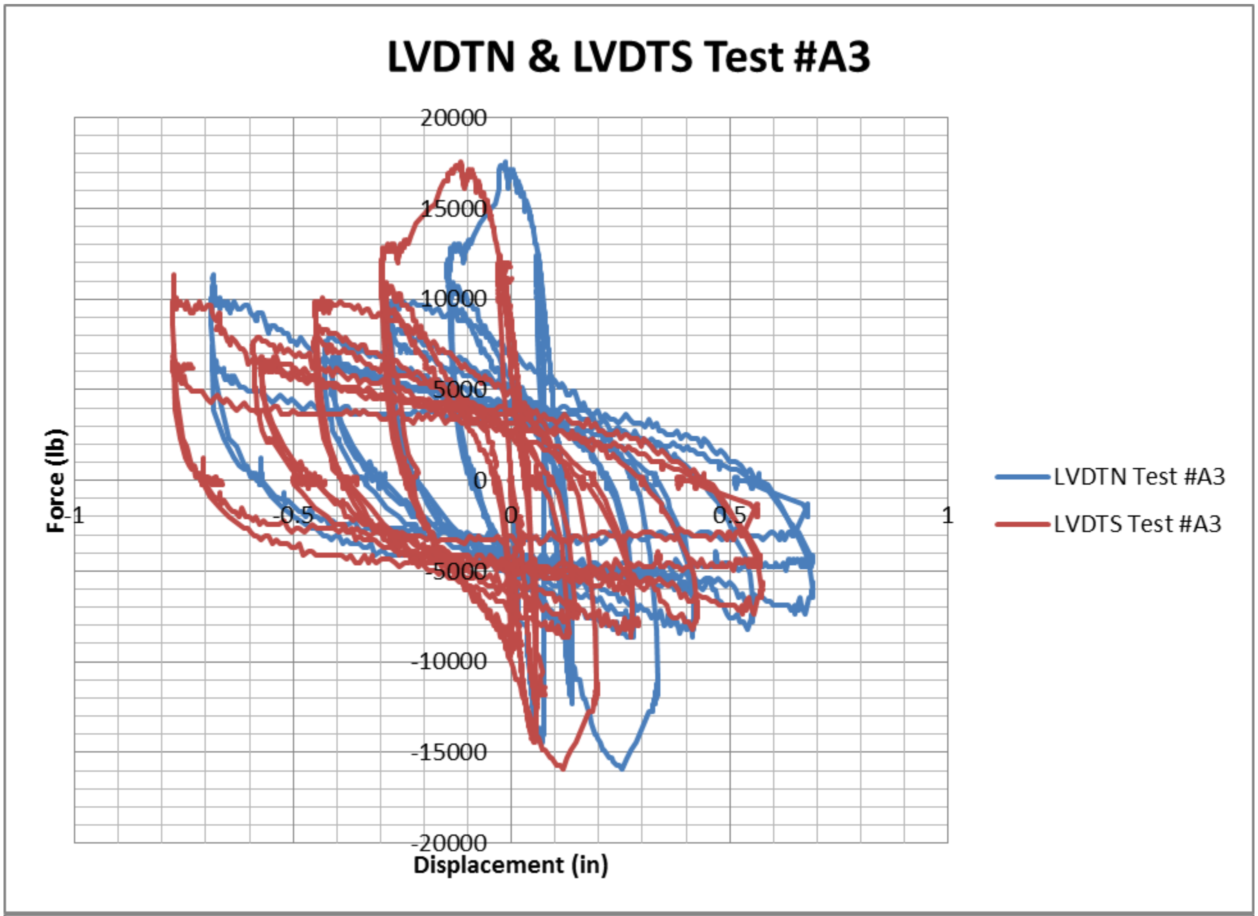
0.4
0.6
0.8
Force (lb)
Displacement (in)
LVDTN Test #A2
LVDTS Test #A2



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-10000
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0.5
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Displacement (in)
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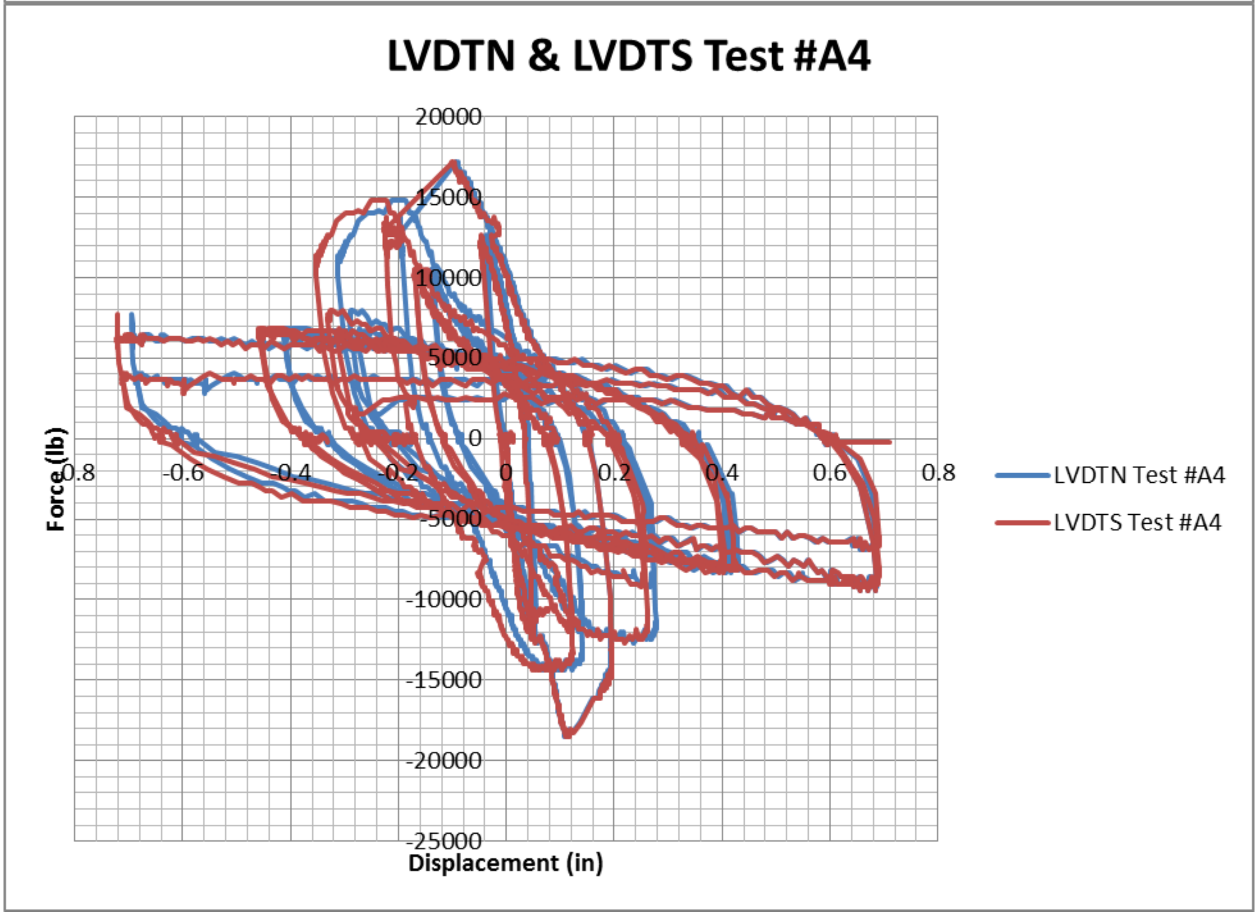

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-0.4
-0.2
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0.2
0.4
0.6
0.8
Force (lb)
Displacement (in)
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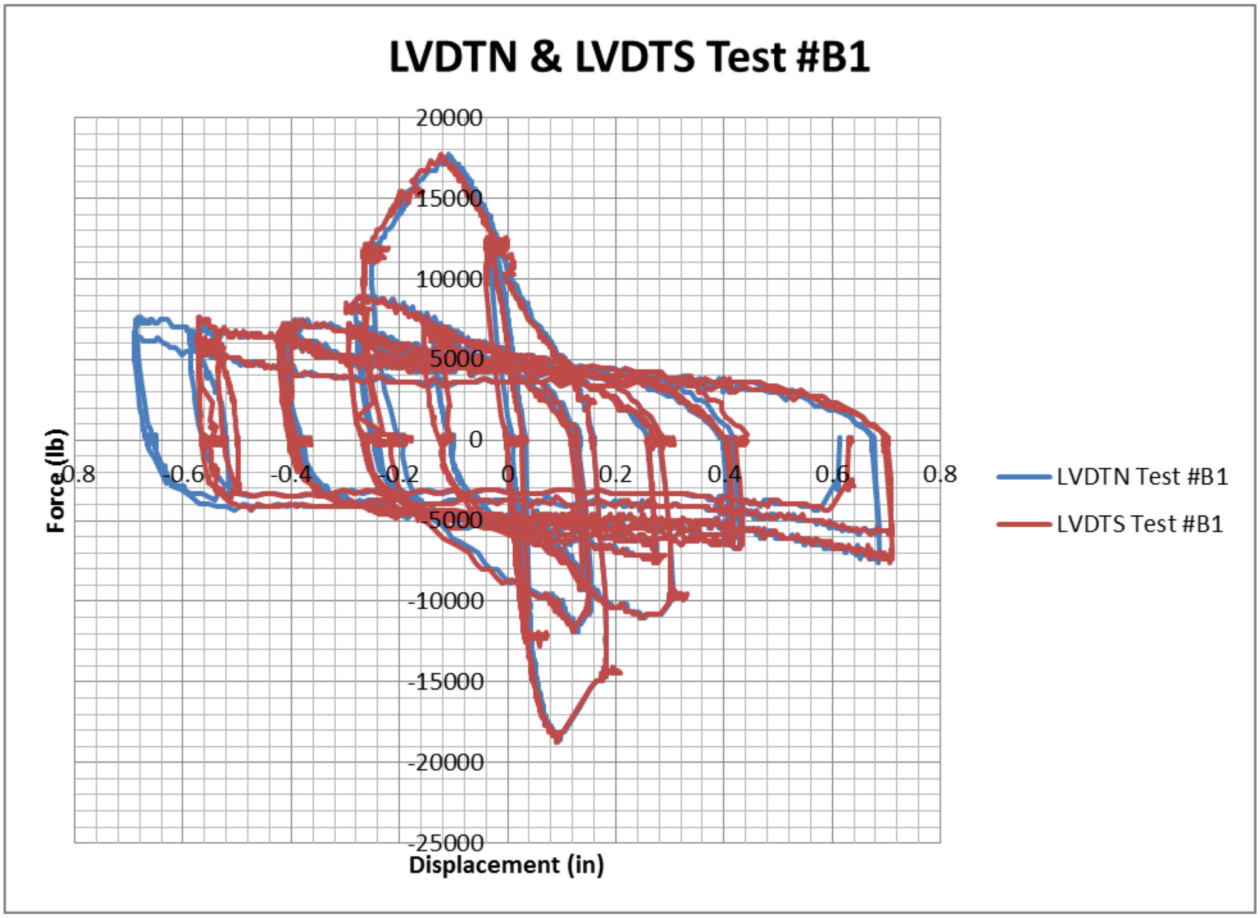
LVDTS Test #A4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Displacement (in)
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-0.2
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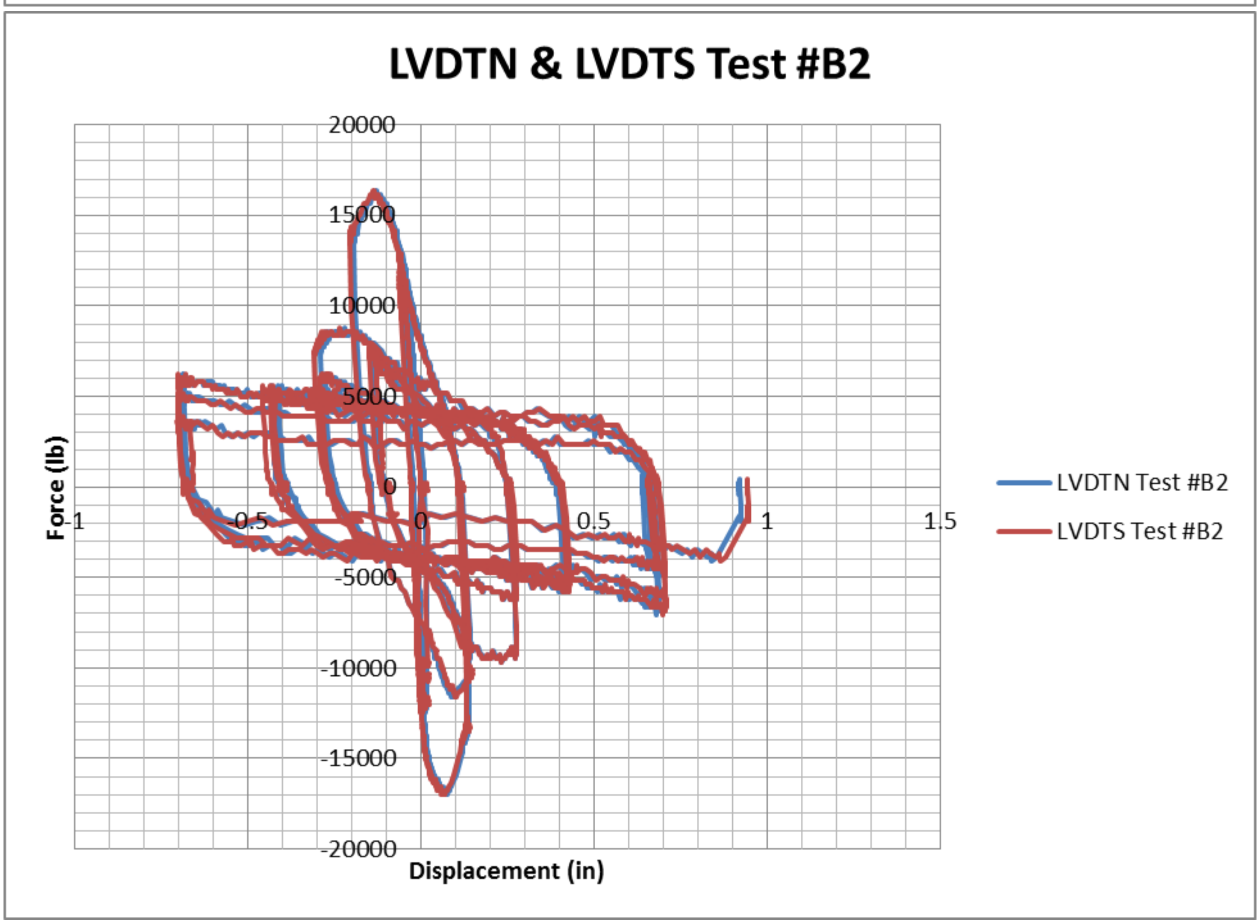
0.2
0.4
0.6
0.8
LVDTN Test #B1
LVDTS Test #B1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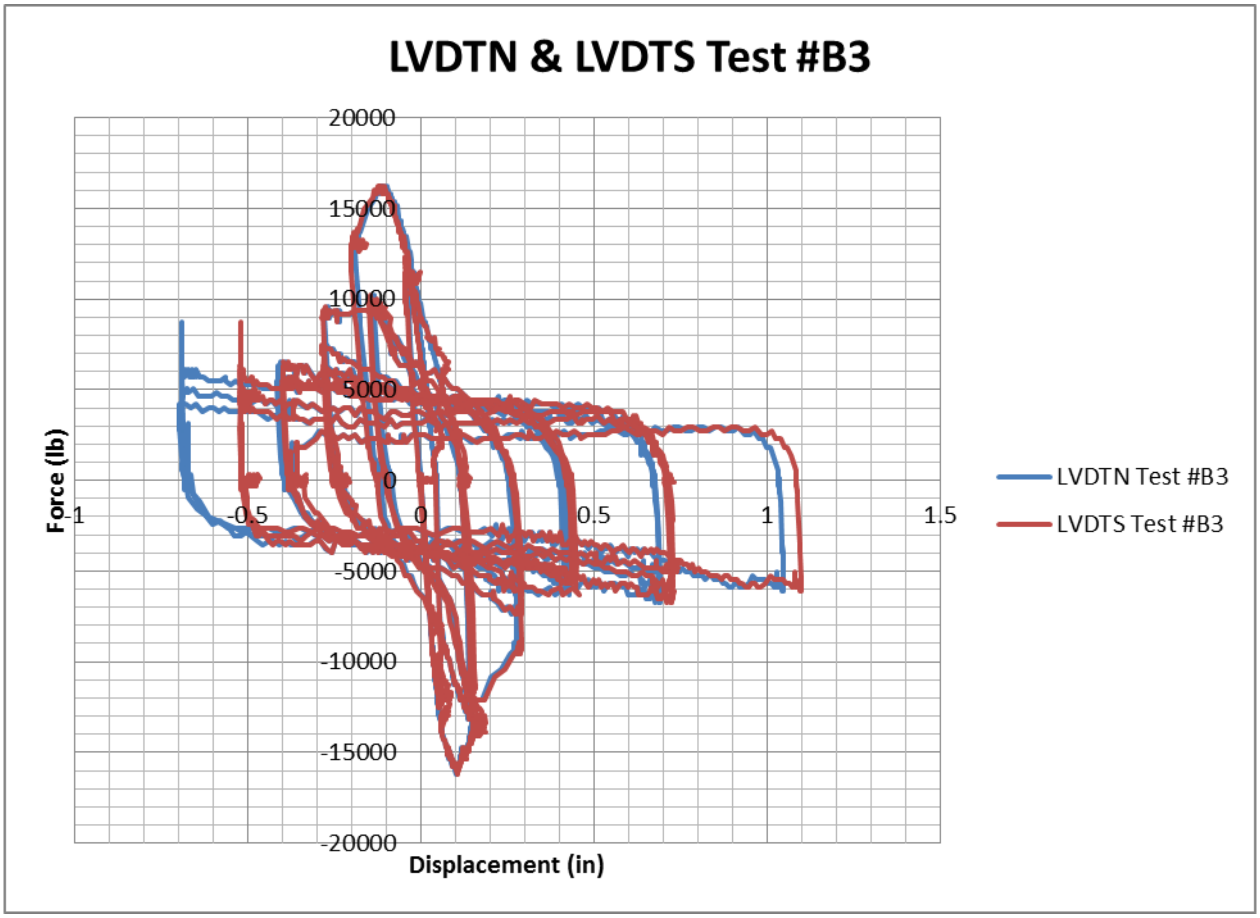
1.5
LVDTN Test #B2
LVDTS Test #B2



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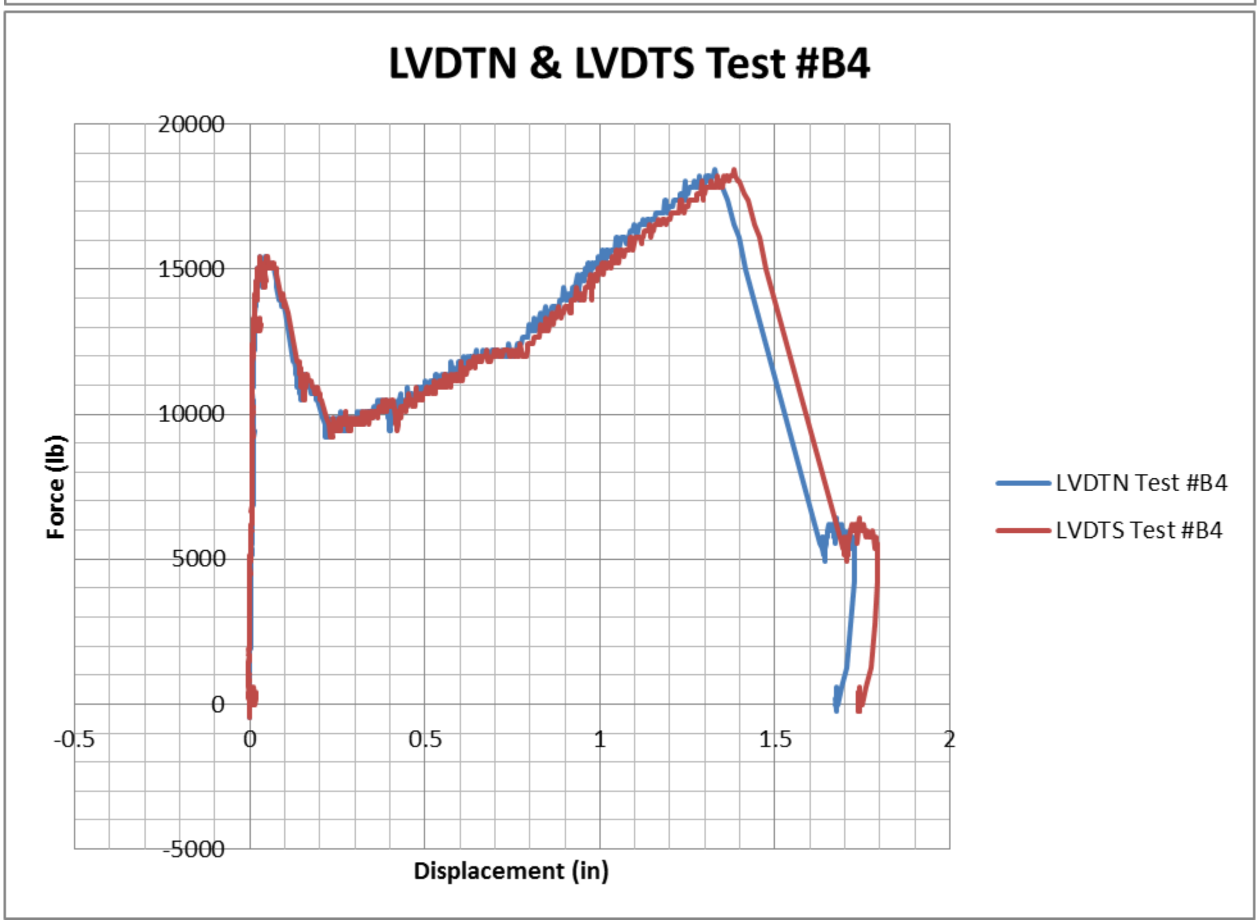
1.5
Displacement (in)
LVDTN Test #B3
LVDTS Test #B3



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0
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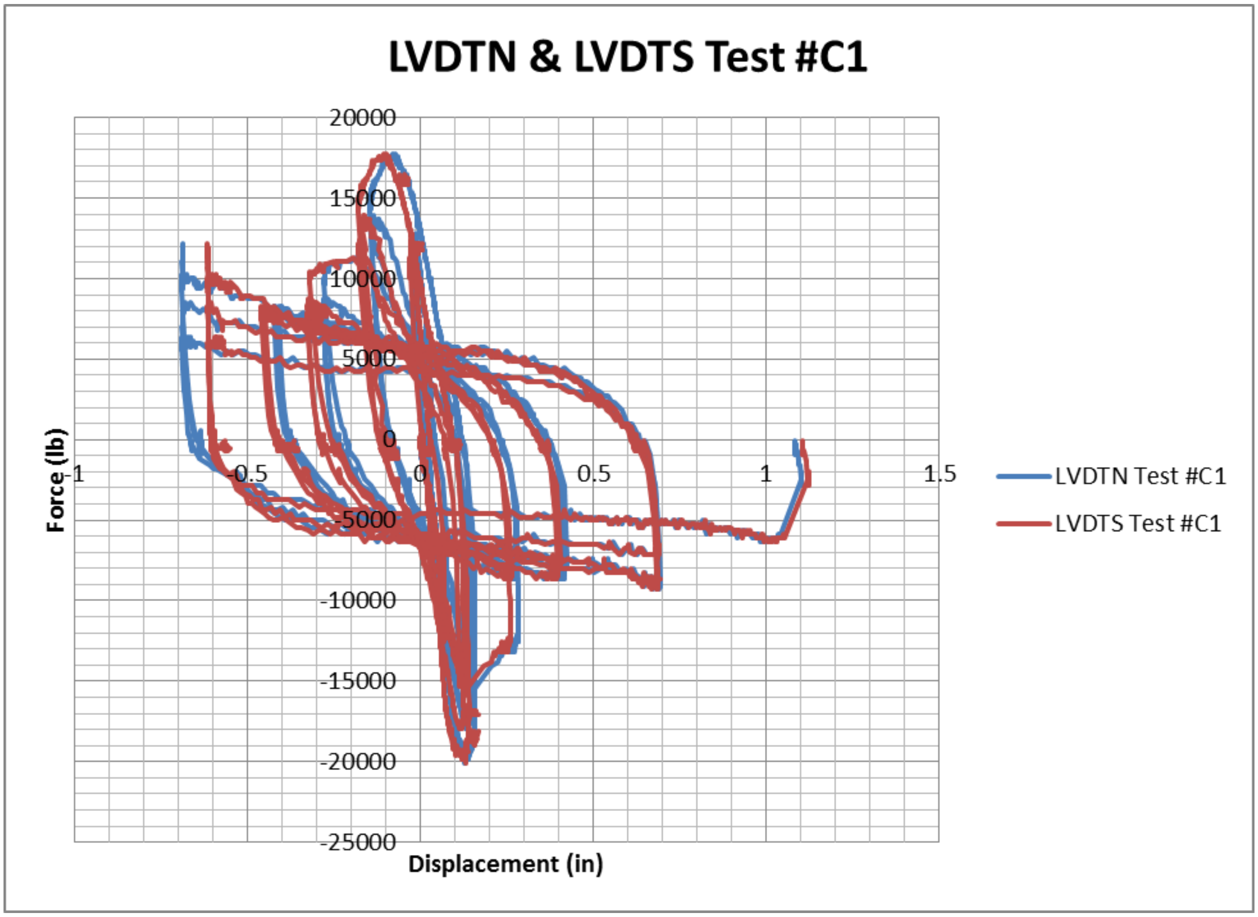
Displacement (in)
LVDTN Test #B4
LVDTS Test #B4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1.5
Force (lb)
Displacement (in)
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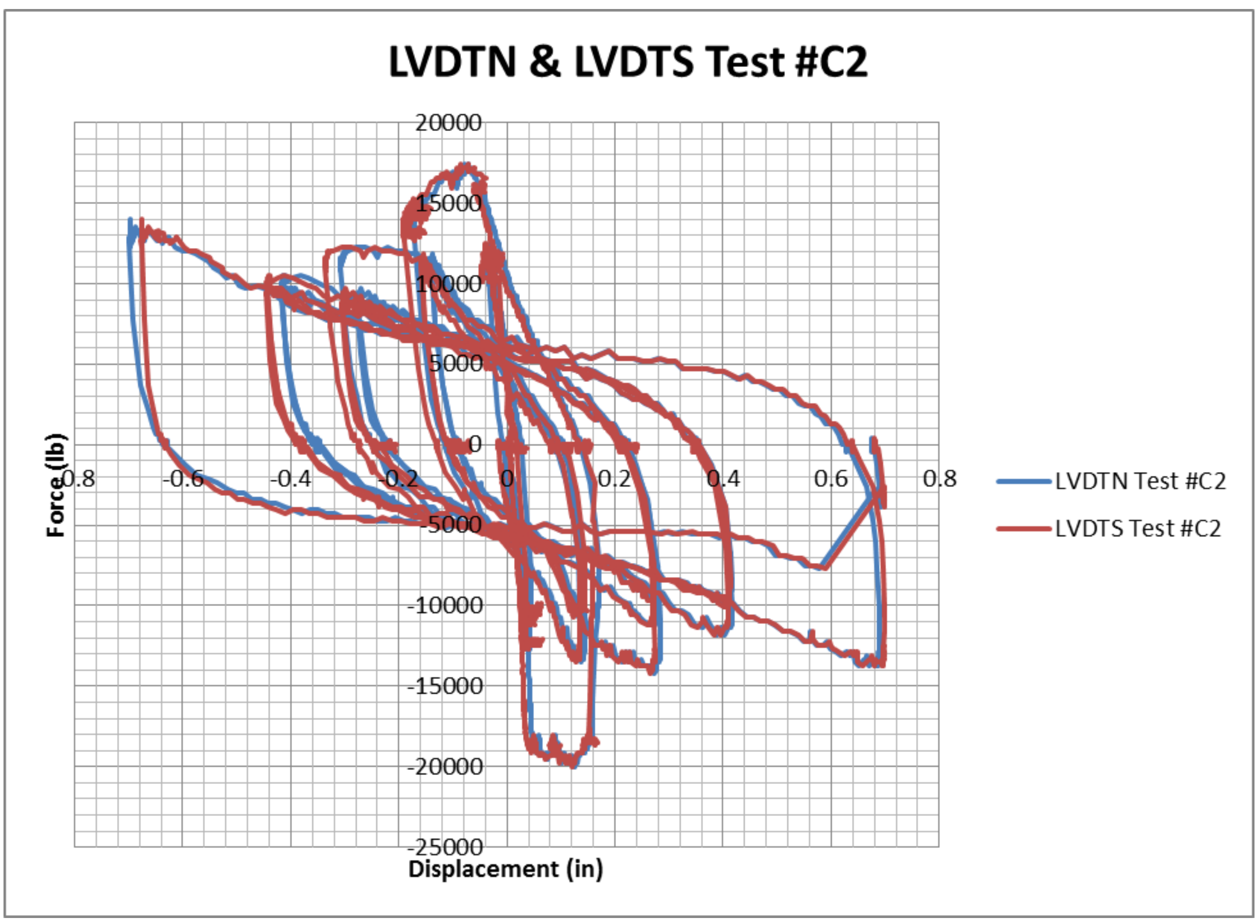
LVDTS Test #C1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-20000
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-0.6
-0.4
-0.2
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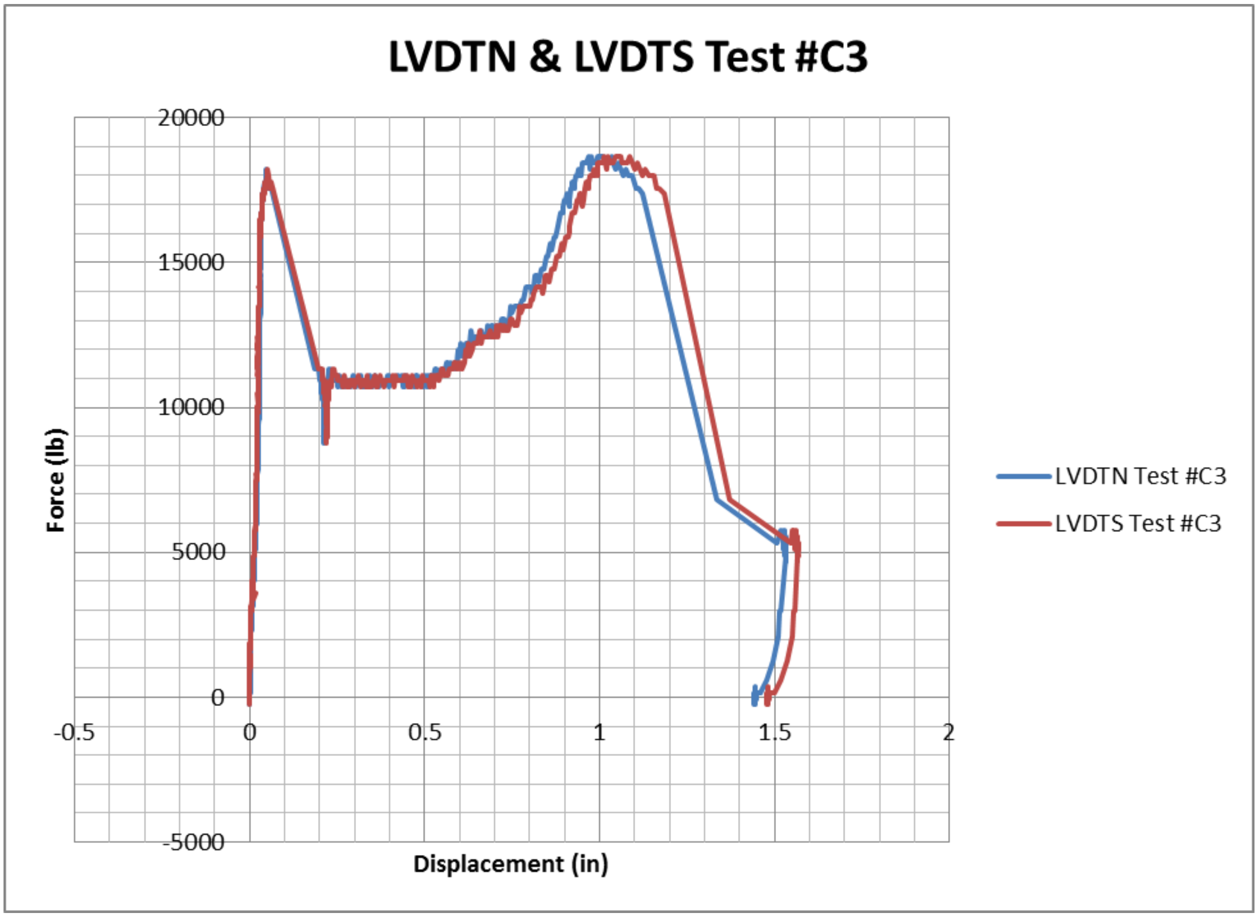
0.2
0.4
0.6
0.8
Force (lb)
Displacement (in)
LVDTN Test #C2
LVDTS Test #C2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1.5
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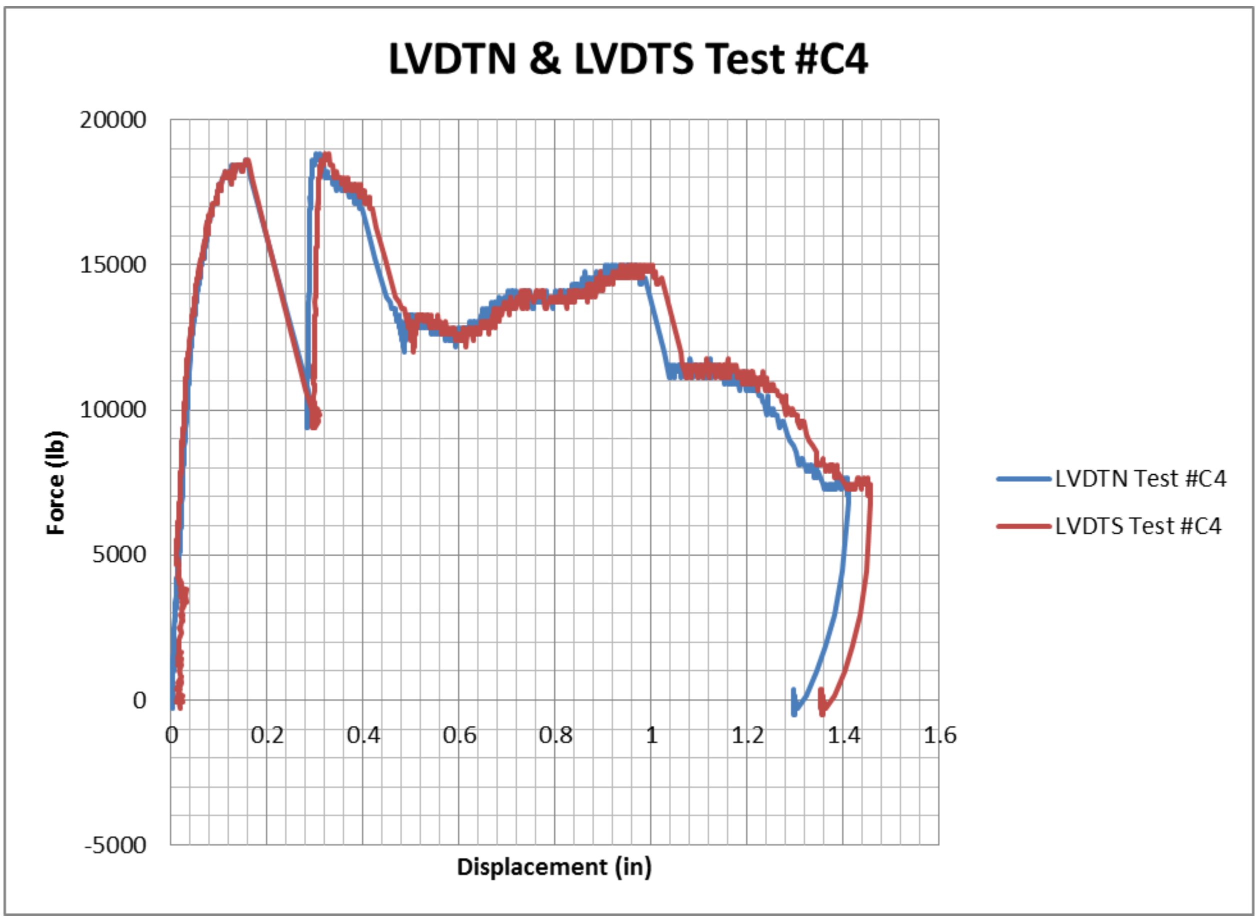
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1.4
1.6
LVDTN Test #C4
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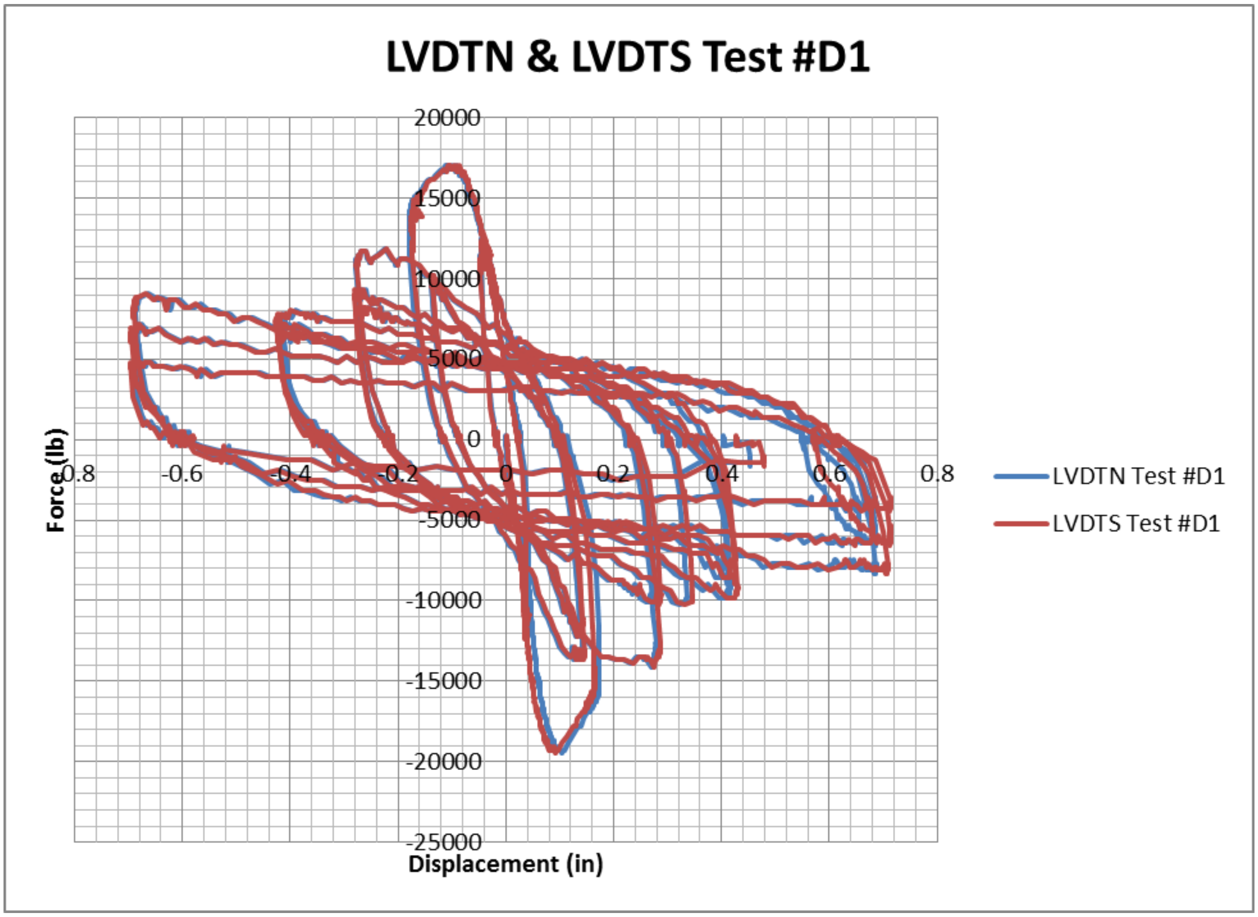
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-15000
-20000
-25000
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-0.6
-0.4
-0.2
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0.2
0.4
0.6
0.8
Force (lb)
Displacement (in)
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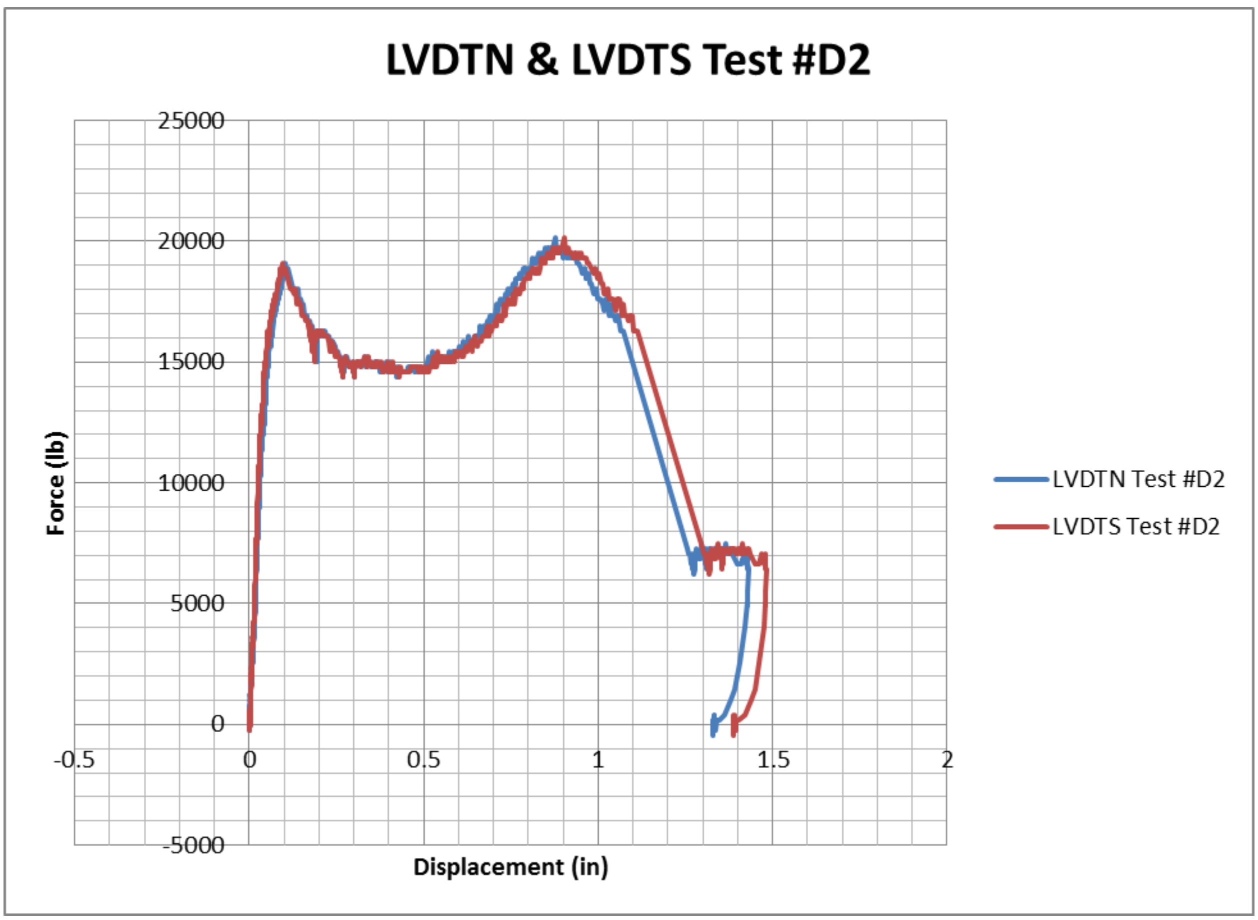
LVDTS Test #D1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Force (lb)
Displacement (in)
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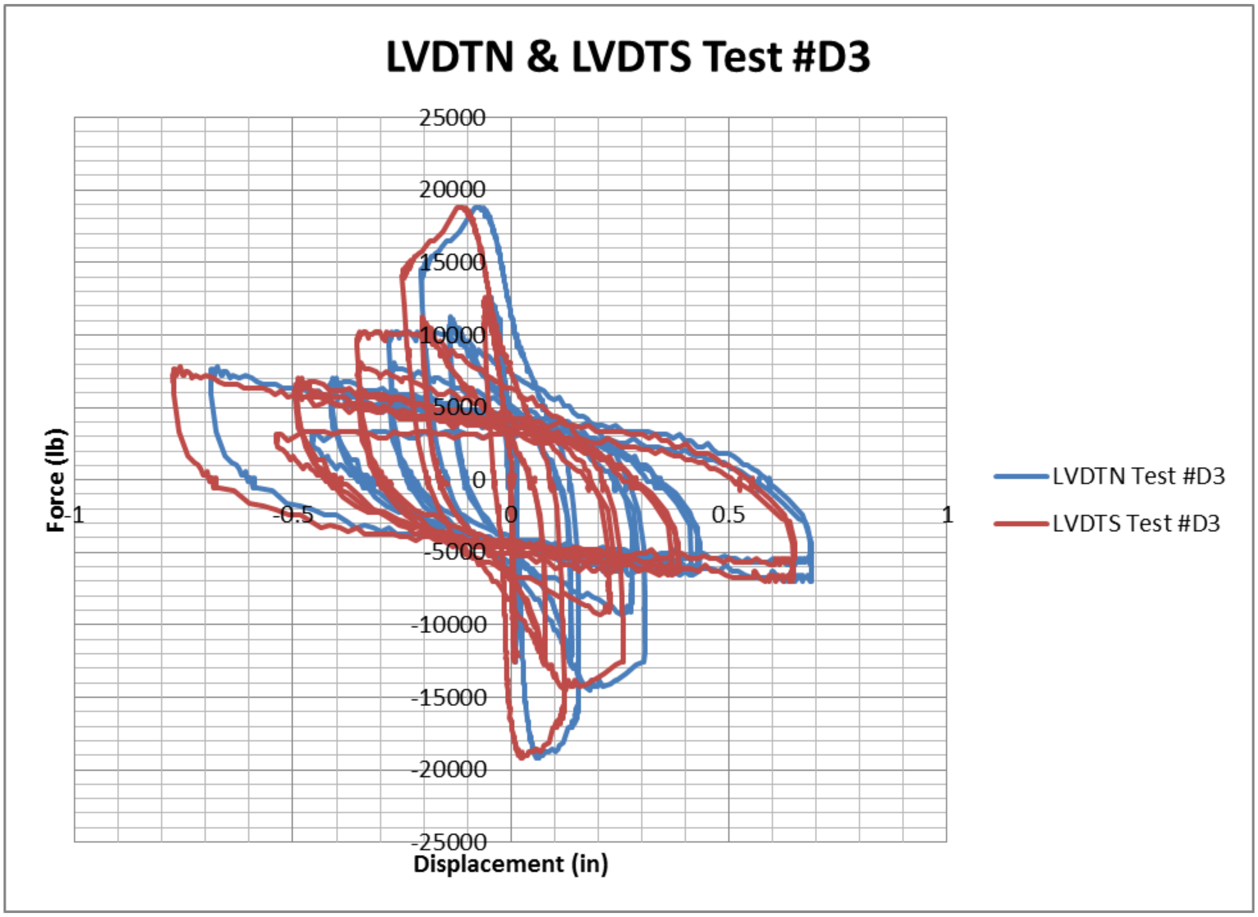
LVDTS Test #D2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-5000
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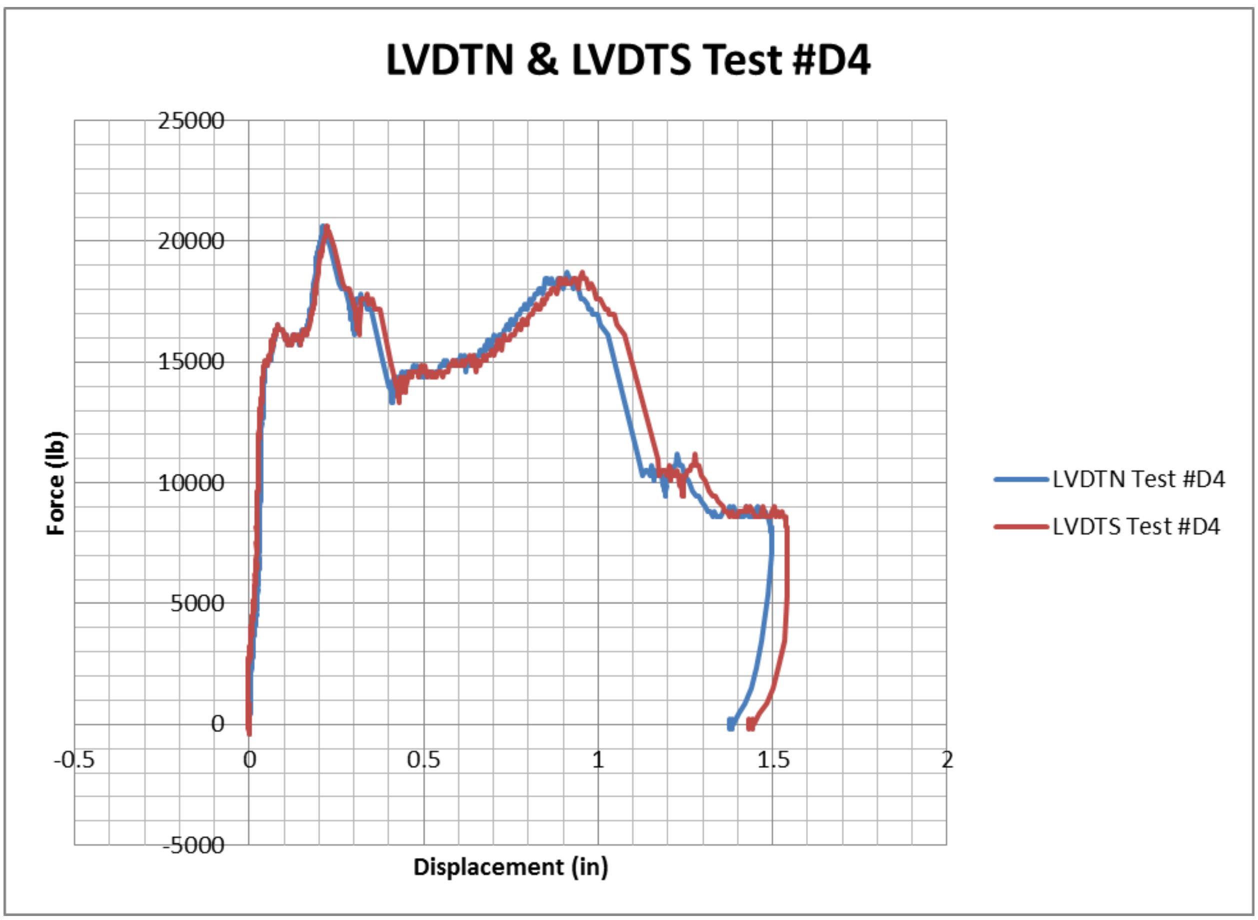
0
0.5
1
Force (lb)
Displacement (in)
LVDTN Test #D3
LVDTS Test #D3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10000
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0
-5000
-0.5
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1.5
2
Force (lb)
Displacement (in)
LVDTN Test #D4
LVDTS Test #D4

APPENDIX B

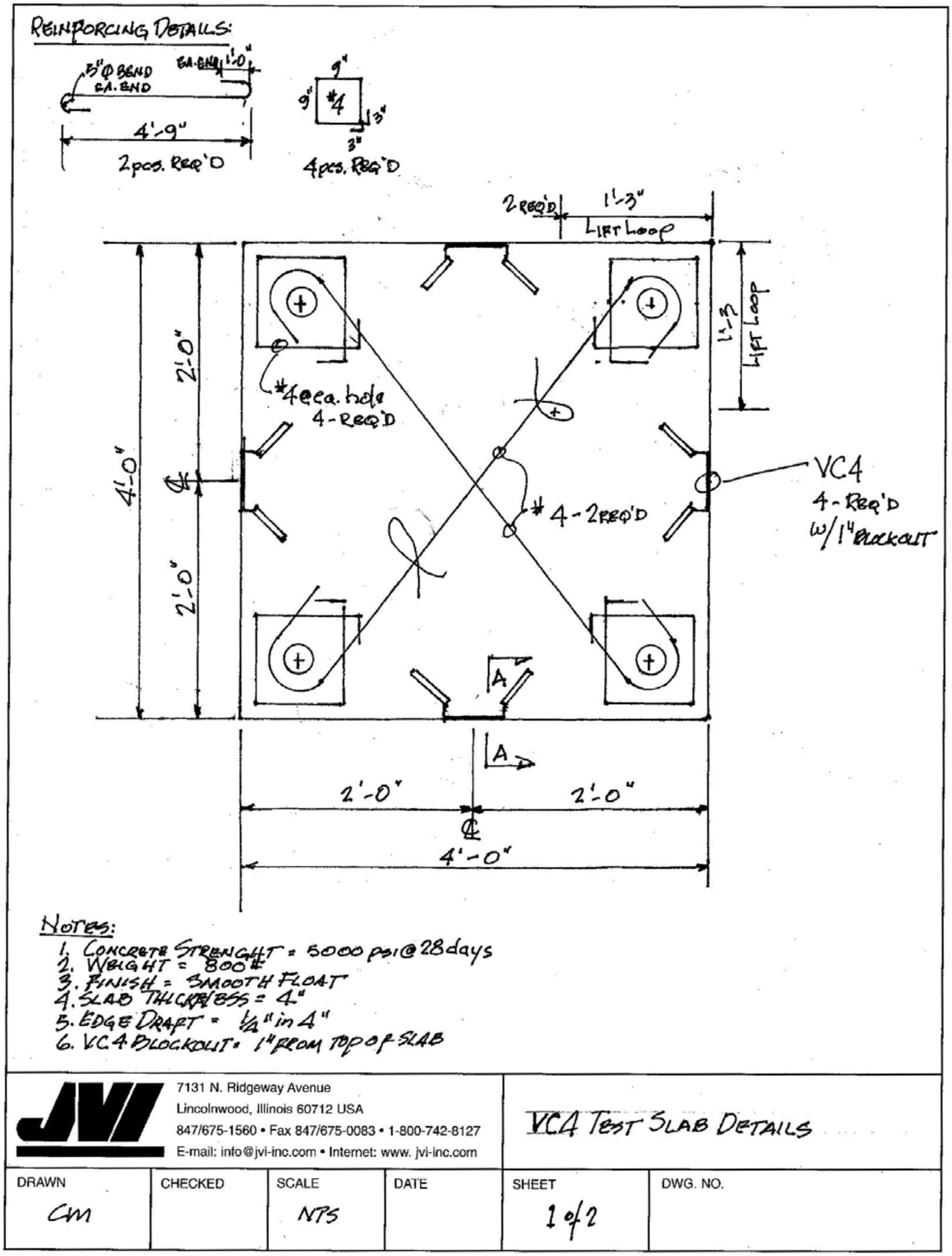
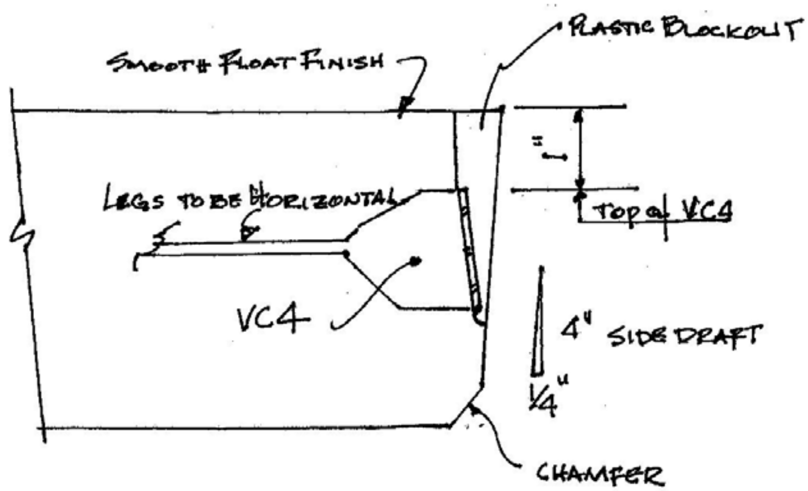


Figure 1 – Test Slab Details and Reinforcing



SECTION A-A
NTS

NOTES:
1. Fix VC4 to side form using 1" plastic blockout.
2. Fasten VC4 & plastic blockout using screws thru the 2 horizontal holes in the VC4 faceplate.

JVI	7131 N. Ridgeway Avenue Lincolnwood, Illinois 60712 USA 847/675-1560 • Fax 847/675-0083 • 1-800-742-8127 E-mail: info@jvi-inc.com • Internet: www. jvi-inc.com			VC4 TEST SLAB DETAILS	
DRAWN cm	CHECKED	SCALE NTS	DATE	SHEET 2 of 2	DWG. NO.

Figure 2 – Section thru VC4 in Test Slab

Figure 3 – Test A-1 Cyclic Shear w/ No Tension

Figure 4 – Test A -2 Cyclic Shear w/ No Tension

Figure 5 – Test A-3 Cyclic Shear w/ No Tension

Figure 6 – Test A-4 Cyclic Shear w/ No Tension

Figure 7 – Test B-1 Cyclic Shear w/ No Tension

Figure 8 – Test B-2 Cyclic Shear w/ No Tension

Figure 9 – Test B-3 Cyclic Shear w/ No Tension

Figure 10 – Test B-4 Monotonic Shear w/ No Tension

Figure 11 – Test C-1 Cyclic Shear w/ No Tension

Figure 12 – Test C-2 Cyclic Shear w/ No Tension

Figure 13 – Test C-3 Monotonic Shear w/ No Tension

Figure 14 – Test C-4 Monotonic Shear w/ No Tension

Figure 15 – Test D-1 Cyclic Shear w/ No Tension

Figure 16 – Test D-2 Monotonic Shear w/ No Tension

Figure 17 – Test D-3 Cyclic Shear w/ No Tension

Figure 18 – Test D-4 Monotonic Shear w/ No Tension

APPENDIX C

WORTHINGTON STEEL
A Worthington Industries Company

100 Worthington Drive
Porter, IN 46304

Ramcel Engineering Company
2926 MacArthur Blvd
Northbrook, IL 60062
US

LOT# 30512

CERTIFICATE OF CHEMICAL ANALYSES AND TESTS

Certificate Number 3379297	Revision No. 0
Customer Order No. 141902-31242	Date 2012-10-22
Sales Order No. 1393582 2.1	Mill Order No.
B/L No. WSC0884420	Weight 46950 lbs
Alloy / Grade 045 XLF	Part No. M-MIDV1J
Specification No. SAE J1392 045XLF, SAE J2340	

Description

Hot Rolled Pickled Temper Rolled
045 XLF
0.1880 in X 21.7100 in X COIL

Heat Number 11010056

Chemical Analysis

C	.070
MN	.580
P	.007
S	.006

Heat Number 11001934

Chemical Analysis

C	.070
MN	.580
P	.013
S	.006

Heat Number	Coil No.
11010056	2979810

Mechanical Analysis

Tensile (KSI)	69.0
Yield (KSI)	52.5
Percent Elongation 2 in	33.6

Heat Number	Coil No.
11001934	2961718

Mechanical Analysis

Tensile (KSI)	67.5
Yield (KSI)	53.5
Percent Elongation 2 in	32.9

THE CHEMICAL DATA REQUIRED ABOVE CONFORM TO AISI SPECIFICATIONS.
THE MECHANICAL PROPERTIES REPORTED ABOVE WERE DETERMINED USING RECOMMENDED ASTM PRACTICES.

Nickolas Sears

Nickolas Sears Metallurgical Engineer

10/22/2012 10:36:28 AM

Carbon Steel Material Mill Certification

NOTICE OF SHIPMENT/ PACKING LIST — ATI Allegheny Ludlum (Allegheny Technologies) — **CERTIFICATE OF TEST** — AL 6168-4 1211

CUST. ORD. NO. & DATE	CUST. CODE	ACCEPTING MILL	SHIPPER NO.	PRODUCT CODE	MILL ORDER NUMBER	DATE SHIPPED
18068 03/06/12	647540	MIDLAND, PA	533430	11020101060000	30-032-145	04/02/12

FORMS DISTRIBUTION: SOLD TO→ 1 SHIP TO→ SPEC→ 1

REPEAT ORDER 99472-0 | DO RATE 22 | PRIORITY | GOVT CONTRACT | MATL. 1170 | SHIPPING LOCATION BROOKFIELD OH | INVOICE 220022 149

PRIME SEC.
DSO DSO
521

SOLD TO
NATIONAL KWIKMETAL SERVICE
560 SANTA ROSA DRIVE
DES PLAINES IL 60018

SHIP TO
NATIONAL KWIKMETAL SERVICE
560 SANTA ROSA DRIVE
DES PLAINES IL 60018

PO# 140201- 30822 4/23/2012

GRADE AND SPECIFICATIONS
CARRIER - CH ROBINSON FLATBED DIV
"ATI 201LN" STAINLESS STEEL SHEET-HOT ROLLED COILS ANNEALED PICKLED 3 EDGE (ASTM-A-240-11B) (ASTM-A-480-11B)
(UNS S20153)

ITEM	PCS	DIMENSIONS W/G/L	HEAT #	LIFT #	TEST #	GROSS	TARE	NET	THEO	TAG #/ CD SKID #
001	1	21.71/.180/705.	979374	03192N872A	M343545	9800		9800		
	1	21.71/.180/705.	979374	03192N872B	M343545	9800		9800		
P CUST IDENTITY 201LN.180X21.710										
2 COILS						19600		19600		

DIST: FAX ACKNOWLEDGEMENT TO ATTN: KEN @847-824-7250

TYPE HEAT/TEST	--C---	--MN--	--P---	--S---	--SI--	--CR--	--NI--	--CU--	--N---
HEAT 979374	.022	6.7	.035	.001	.41	16.4	4.1	.46	.15
TEST LOCATION	MI	MI	MI	MI	MI	MI	MI	MI	MI

ITEM TEST NO	YIELD PSI *	TENSILE PSI	% ELONG IN 2"	% R/A	HARDNESS	BEND		GRAIN SIZE	HARDENABILITY
001 M343545	T 56000.	110000	56.	NR	93.HRBW 94.HRBW	NR	NR	NR	NR
TEST LOCATION	TC	TC	TC		TC				

* Y.S. BY 0.2% OFFSET METHOD

NR = DATA NOT REQUIRED
GRADE VERIFICATION WAS CARRIED OUT SPECTROSCOPICALLY

DIN EN 10204:2005 - 3.1 CERTIFICATE DOES NOT INDICATE PED APPROVAL FOR THIS MATERIAL.

PAGE 01 - CONTINUED ON PAGE 02
04/02/12 13:36:16

The above is a true copy of data on file. The material and test results conform to the sales contract and specification(s) as set forth in Allegheny Ludlum's Order Acknowledgement.
Stephen Wolff - Director, Corporate Quality Assurance

NOTICE OF SHIPMENT/ PACKING LIST — ATI Allegheny Ludlum (Allegheny Technologies) — **CERTIFICATE OF TEST** — AL 6168-4 1211

CUST. ORD. NO. & DATE	CUST. CODE	ACCEPTING MILL	SHIPPER NO.	PRODUCT CODE	MILL ORDER NUMBER	DATE SHIPPED
18068 03/06/12	647540	MIDLAND, PA	533430	11020101060000	30-032-145	04/02/12

FORMS DISTRIBUTION: SOLD TO→ 1 SHIP TO→ SPEC→ 1

REPEAT ORDER 99472-0 | DO RATE 22 | PRIORITY | GOVT CONTRACT | MATL. 1170 | SHIPPING LOCATION BROOKFIELD OH | INVOICE 220022 149

PRIME SEC.
DSO DSO
521

SOLD TO
NATIONAL KWIKMETAL SERVICE
560 SANTA ROSA DRIVE
DES PLAINES IL 60018

SHIP TO
NATIONAL KWIKMETAL SERVICE
560 SANTA ROSA DRIVE
DES PLAINES IL 60018

GRADE AND SPECIFICATIONS
CARRIER - CH ROBINSON FLATBED DIV
"ATI 201LN" STAINLESS STEEL SHEET-HOT ROLLED COILS ANNEALED PICKLED 3 EDGE (ASTM-A-240-11B) (ASTM-A-480-11B)
(UNS S20153)

THIS DIN EN 10204:2005 - 3.1 CERTIFICATE OF TEST SHALL NOT BE REPRODUCED EXCEPT IN FULL. FEDERAL LAW PROHIBITS THE RECORDING OF FALSE, FICTITIOUS, OR FRAUDULENT STATEMENTS OR ENTRIES ON THE CERTIFICATE AND MAY BE PUNISHABLE AS A FELONY UNDER FEDERAL LAW. ATI AL HOLDS SEVERAL QUALITY CERTIFICATIONS THAT INCLUDE ISO 9001, AS9100, NADCAP, AND ISO/IEC 17025. MATERIAL WAS MANUFACTURED IN ACCORDANCE WITH THE ATI AL QUALITY MANUAL REVISION 20 DATED 02/24/2012.

ATI ALLEGHENY LUDLUM PERFORMS CHEMICAL ANALYSIS BY THE FOLLOWING TECHNIQUES:
C, S BY COMBUSTION/INFRARED
N, O, H BY INERT FUSION/THERMAL CONDUCTIVITY
MN, P, SI, CR, NI, MO, CU, CB, CO, V BY WDXRF
B BY OES
AL AND TI (>=0.10%) BY WDXRF, OTHERWISE BY OES
PB, BI, AG BY GFAA

TESTING WAS PERFORMED AT THE FOLLOWING LOCATIONS:
MI = ATI-ALLEGHENY LUDLUM; 950 TENTH STREET; MIDLAND, PA 15059
TC = ATI-ALLEGHENY LUDLUM; 1300 PACIFIC AVENUE; NATRONA HEIGHTS, PA 15065

<<<<<<<< FOR ACCESS TO ONLINE CERTIFICATES OF TEST >>>>>>>>
<<<<<<<< REGISTER AT WWW.ALCEXTRA.COM >>>>>>>>

PAGE 02 - FINAL PAGE.
04/02/12 13:36:16

The above is a true copy of data on file. The material and test results conform to the sales contract and specification(s) as set forth in Allegheny Ludlum's Order Acknowledgement.
Stephen Wolff - Director, Corporate Quality Assurance

Stainless Steel Material Mill Certification