

## Testing of the JVI Mid V in 4" Slabs

### Report on the Test Results

by

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### 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](http://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 1<sup>st</sup> 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**

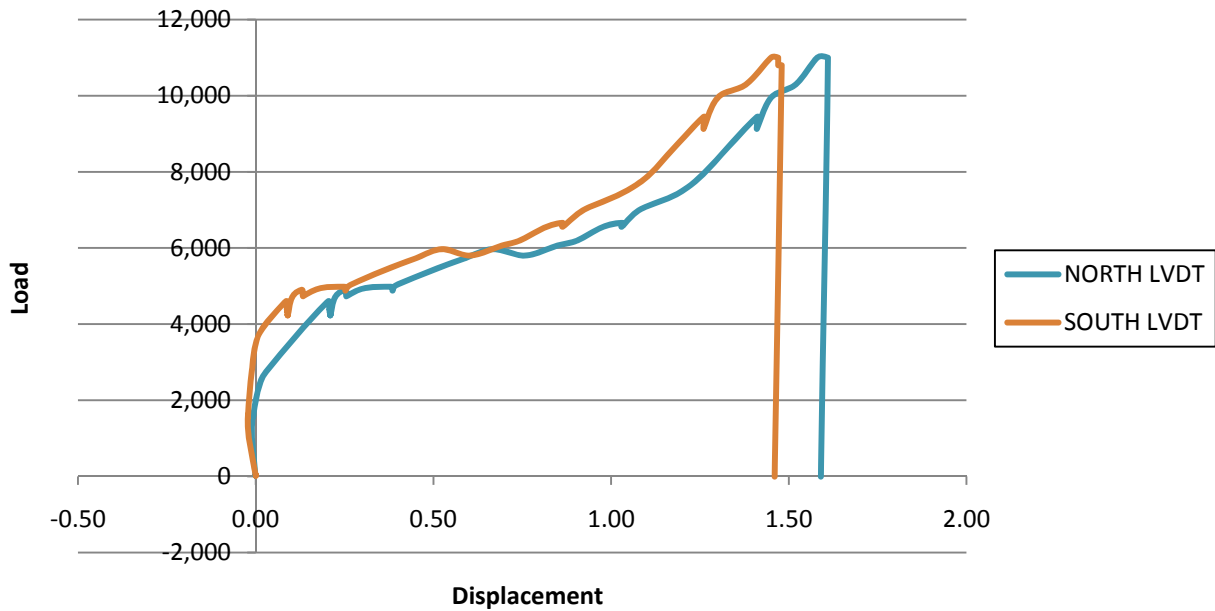


**ACKNOWLEDGEMENT**

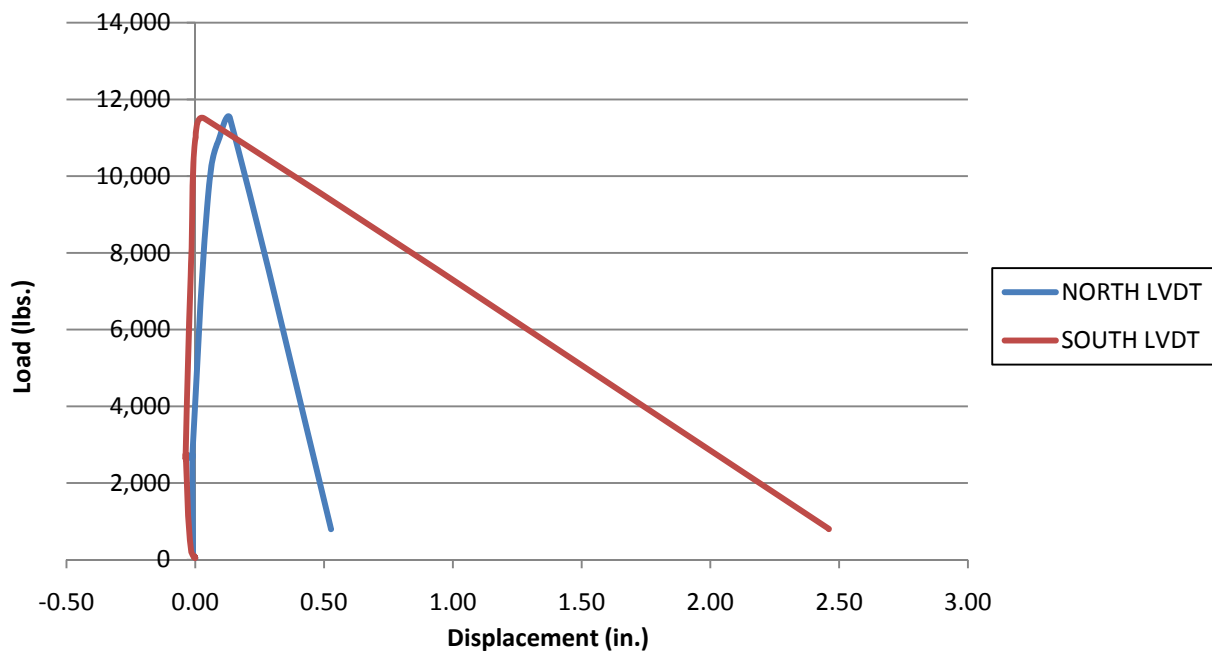
The flange connector is a very important product for the precast/prestressed concrete industry. Test information on its load-displacement behavior is critical in developing and upgrading the design procedures for jointed precast structures, such as parking decks. JVI's participation with precast producers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

# **APPENDIX A**

### Slab E Test 1A: TENSION NORMAL TO MID V WITH TOP/BOT WELDS

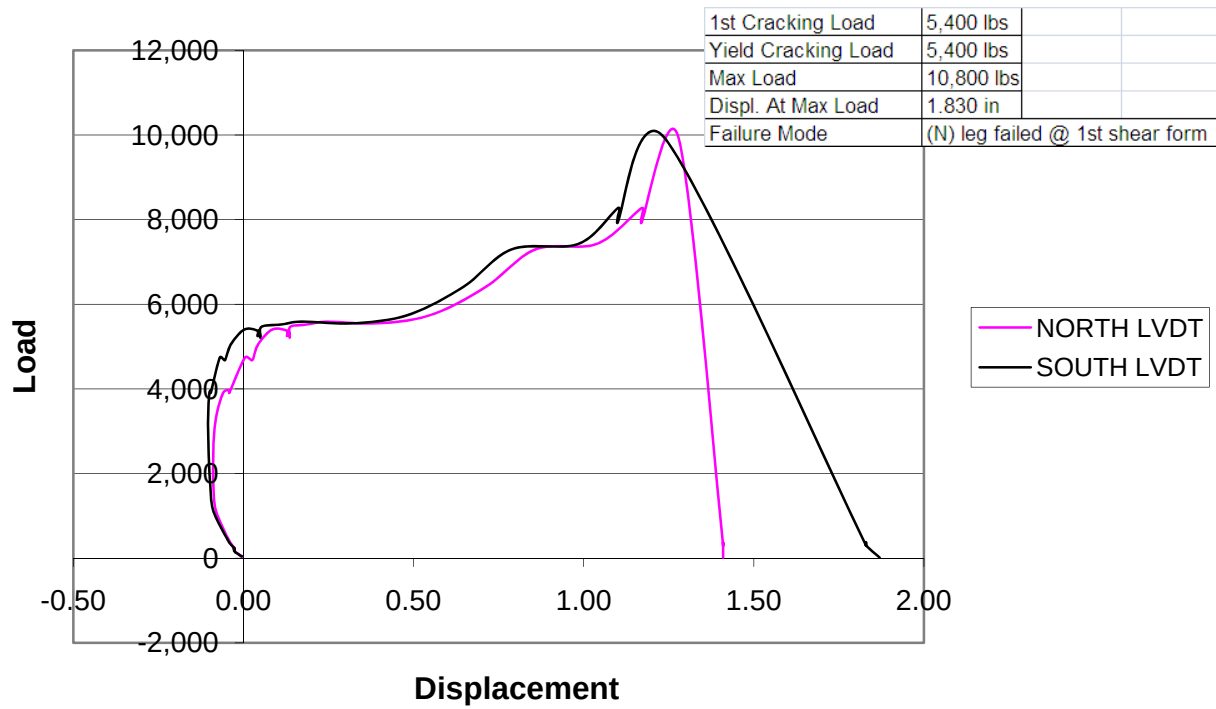


### Slab E Test 1B: TENSION NORMAL TO MID V WITH TOP/BOT WELDS

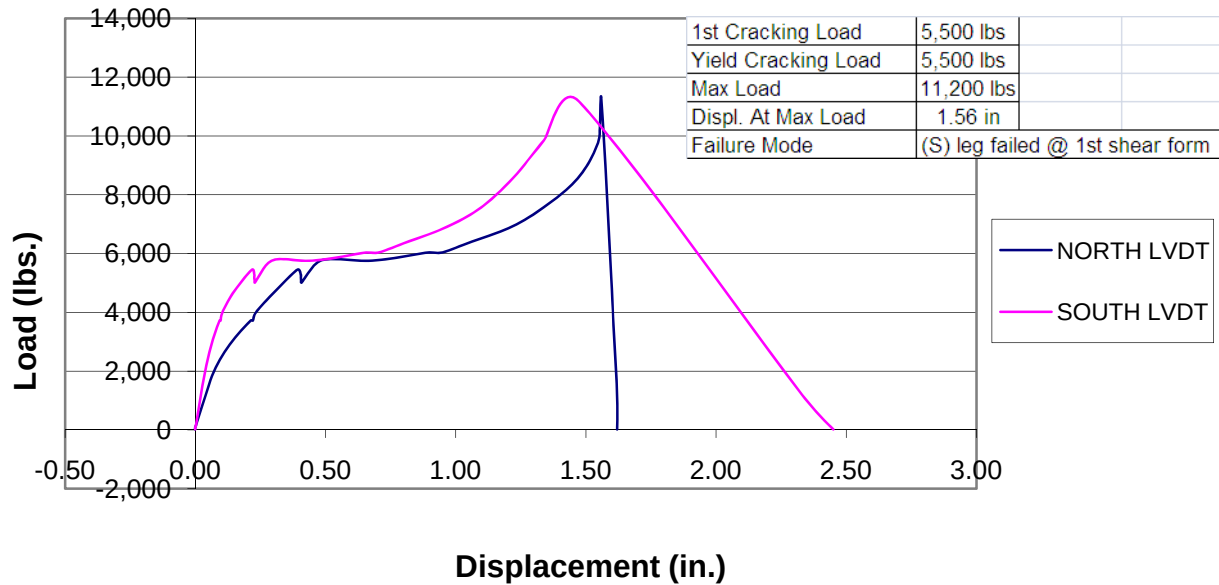


|                     |                                 |
|---------------------|---------------------------------|
| 1st Cracking Load   | 4,500 lbs                       |
| Yield Cracking Load | 4,600 lbs                       |
| Max Load            | 11,500 lbs                      |
| Displ. At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

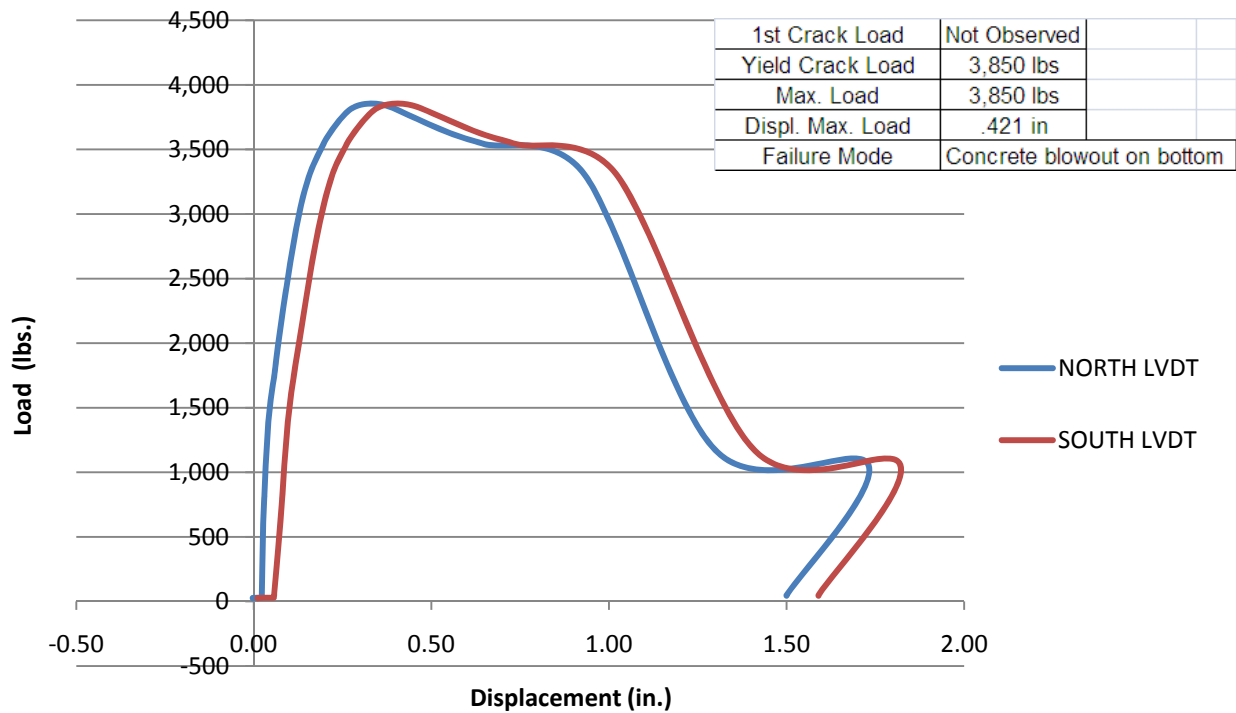
### Slab E Test 2: TENSION NORMAL TO MID V WITH TOP/BOT WELDS



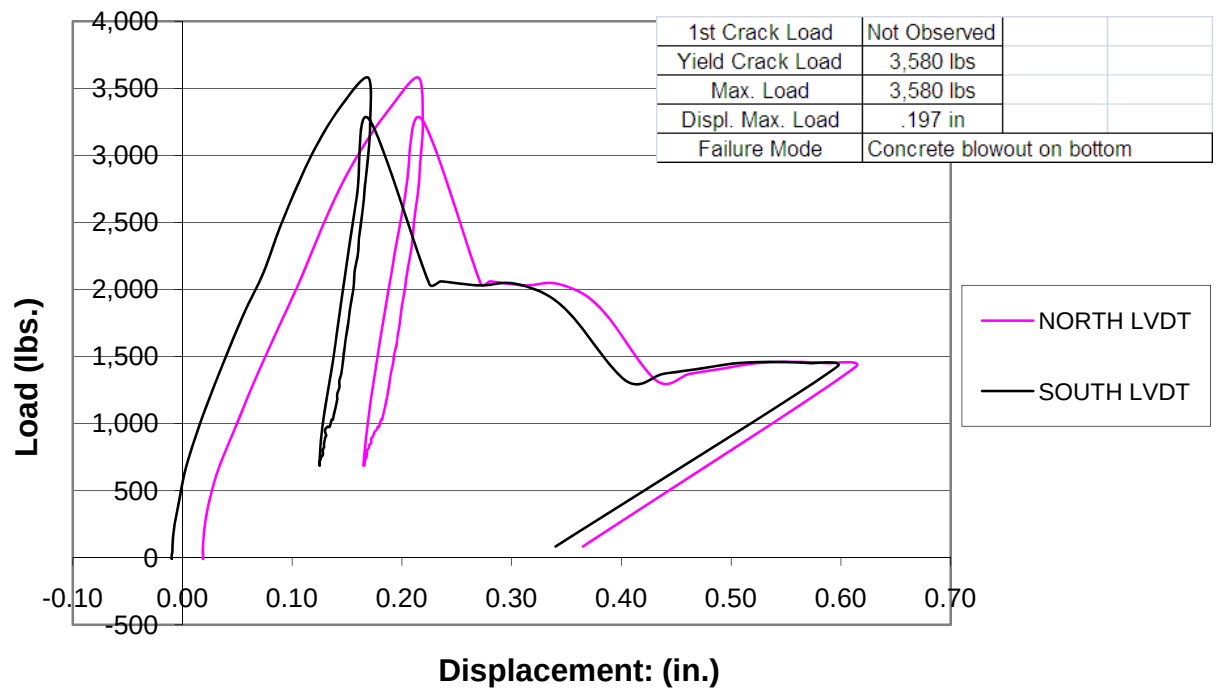
### Slab E Test 3: TENSION NORMAL TO MID V WITH TOP/BOT WELDS



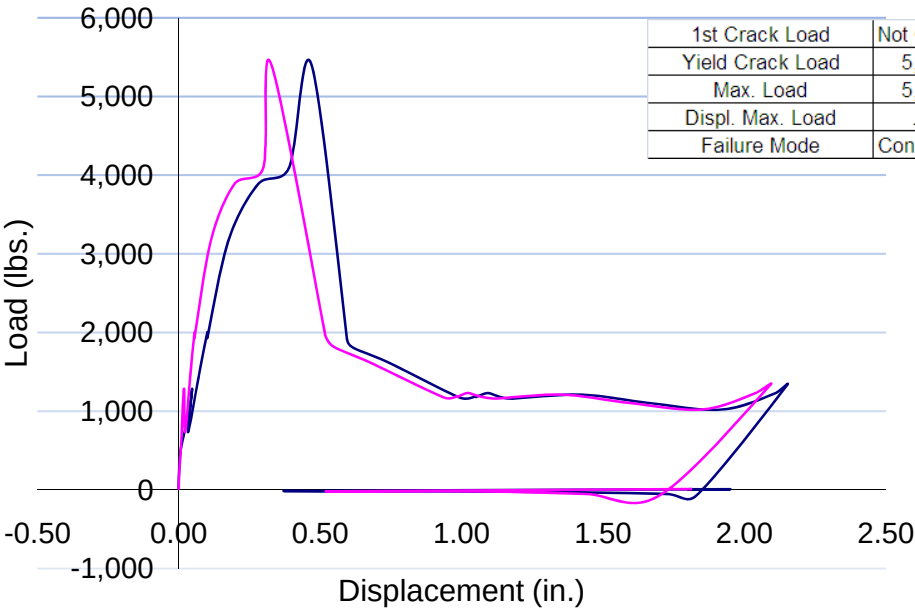
### Slab A Test 3: OUT-OF-PLANE SHEAR NO TENSION



### Slab C Test 2: OUT-OF-PLANE SHEAR NO TENSION

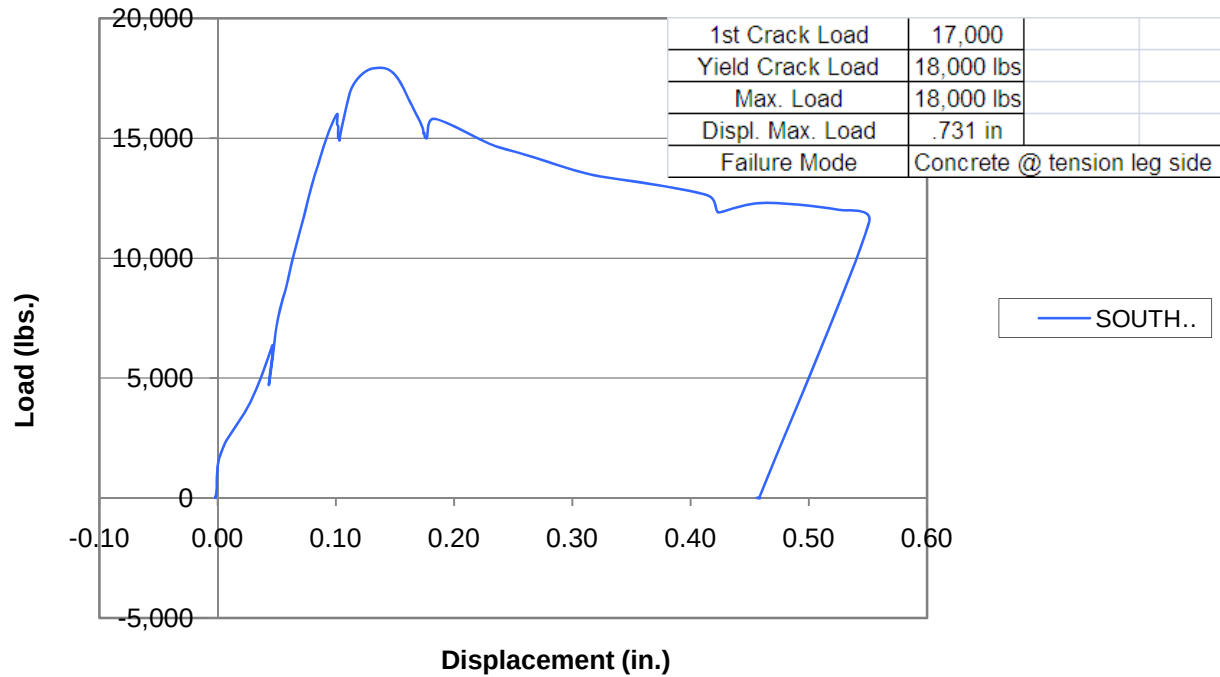


Slab E Test 4: OUT-OF-PLANE SHEAR NO TENSION

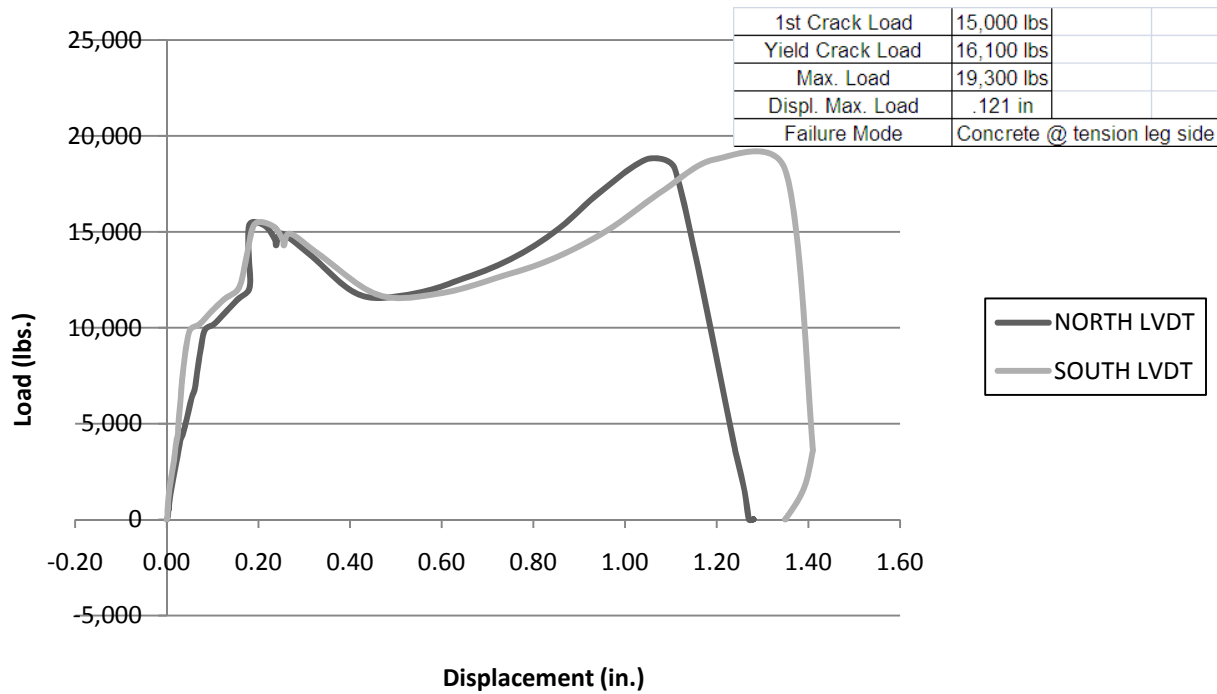


|                  |                            |  |  |
|------------------|----------------------------|--|--|
| 1st Crack Load   | Not Observed               |  |  |
| Yield Crack Load | 5,410 lbs                  |  |  |
| Max. Load        | 5,410 lbs                  |  |  |
| Displ. Max. Load | .468 in                    |  |  |
| Failure Mode     | Concrete blowout on bottom |  |  |

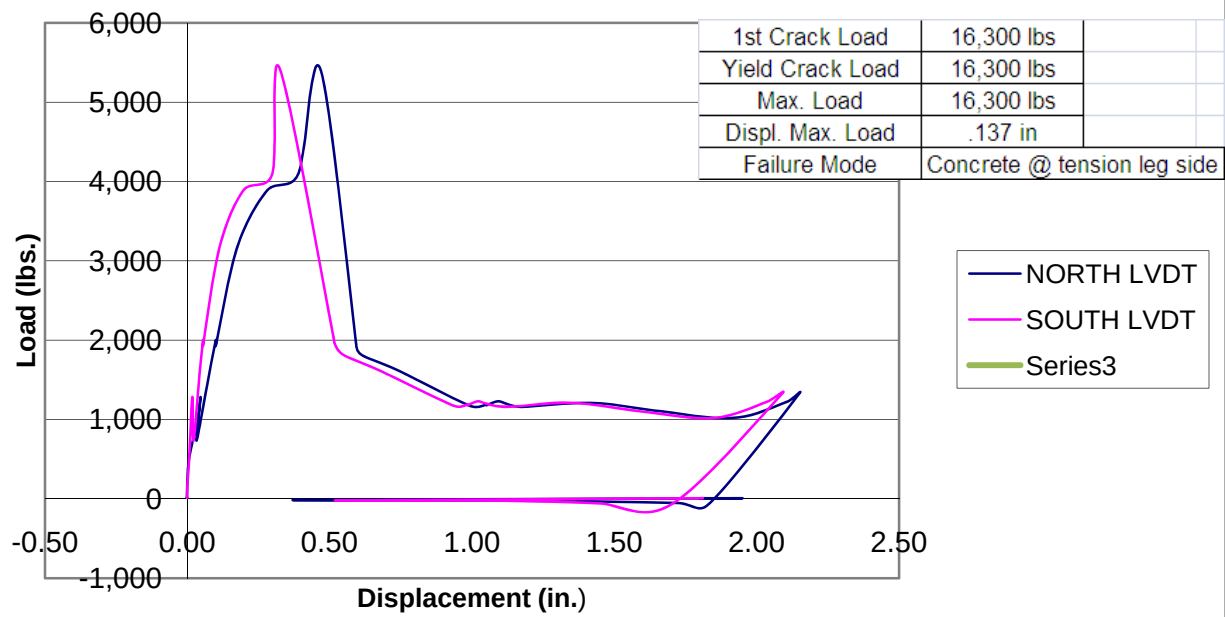
### Slab A Test 1: IN-PLANE MONOTONIC SHEAR NO TENSION



### SLAB A TEST 2: IN-PLANE MONOTONIC SHEAR NO TENSION

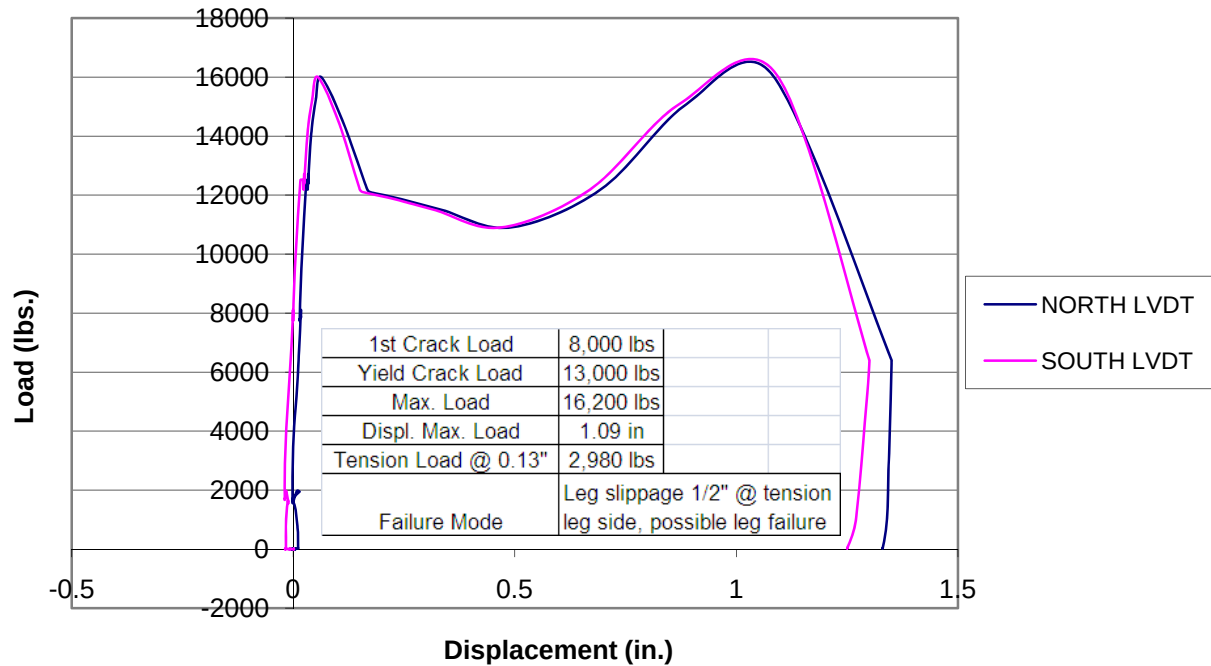


Slab A: Test 4 IN-PLANE SHEAR NO TENSION

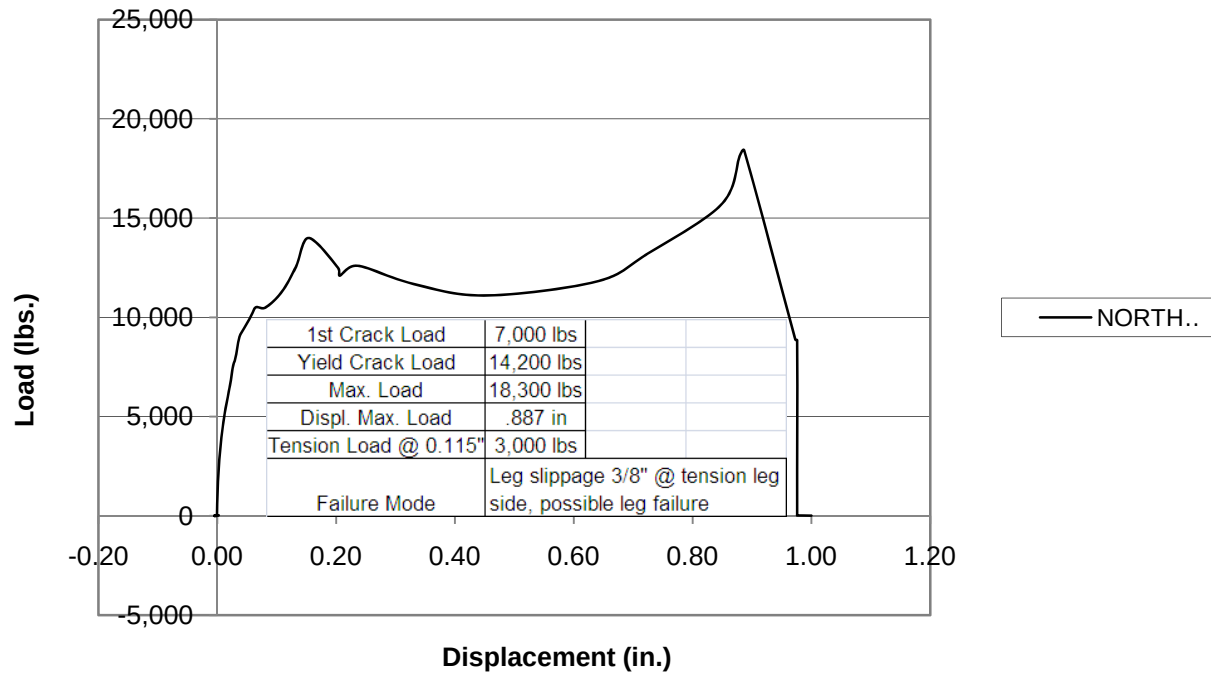




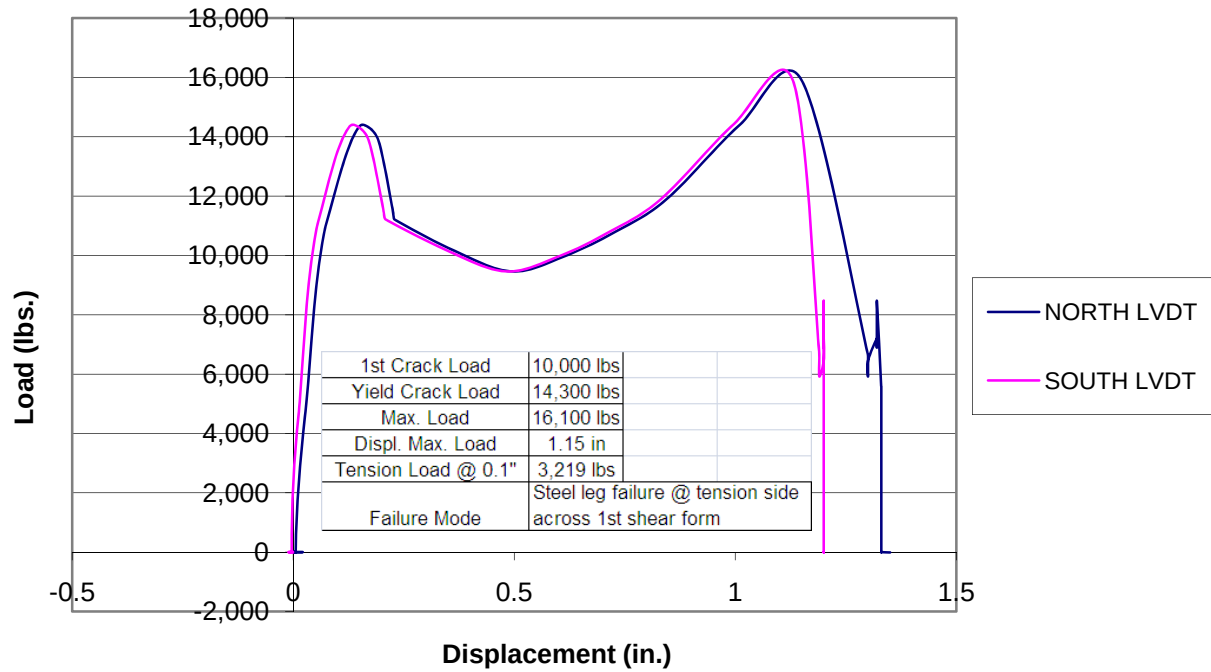
### Slab B Test 1: IN-PLANE MONOTONIC SHEAR WITH TENSION



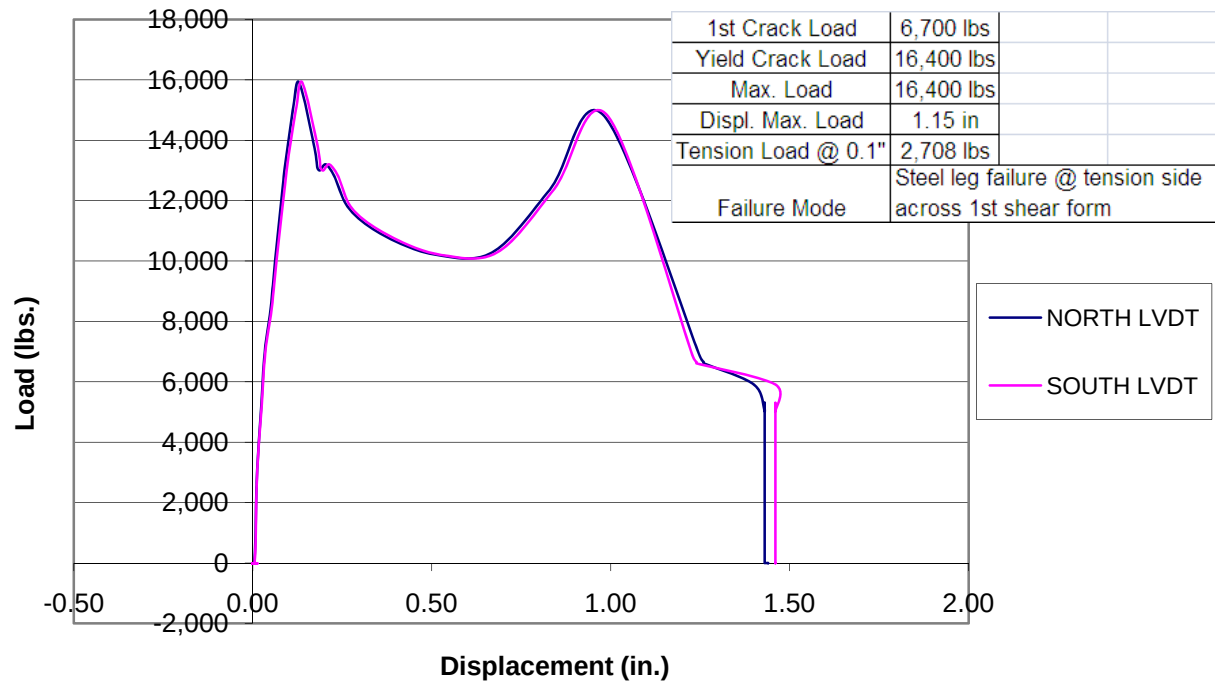
### Slab B Test 2: IN-PLANE MONOTONIC SHEAR WITH TENSION



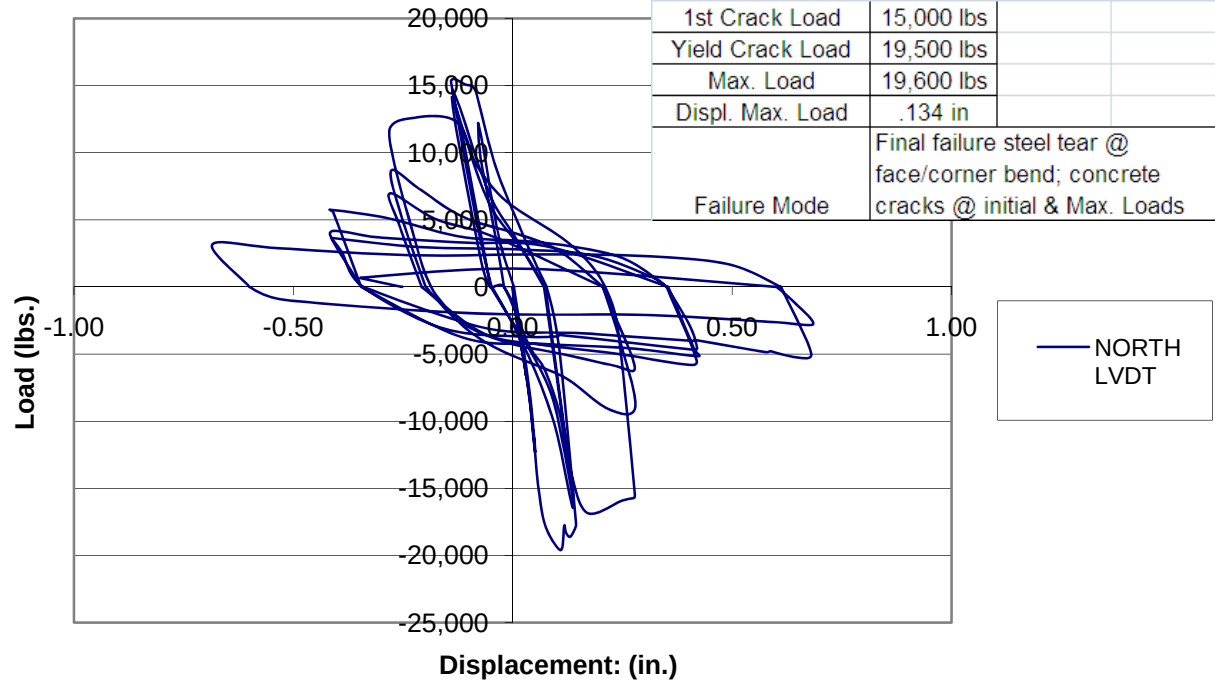
### Slab B Test 3: IN-PLANE MONOTONIC SHEAR WITH TENSION



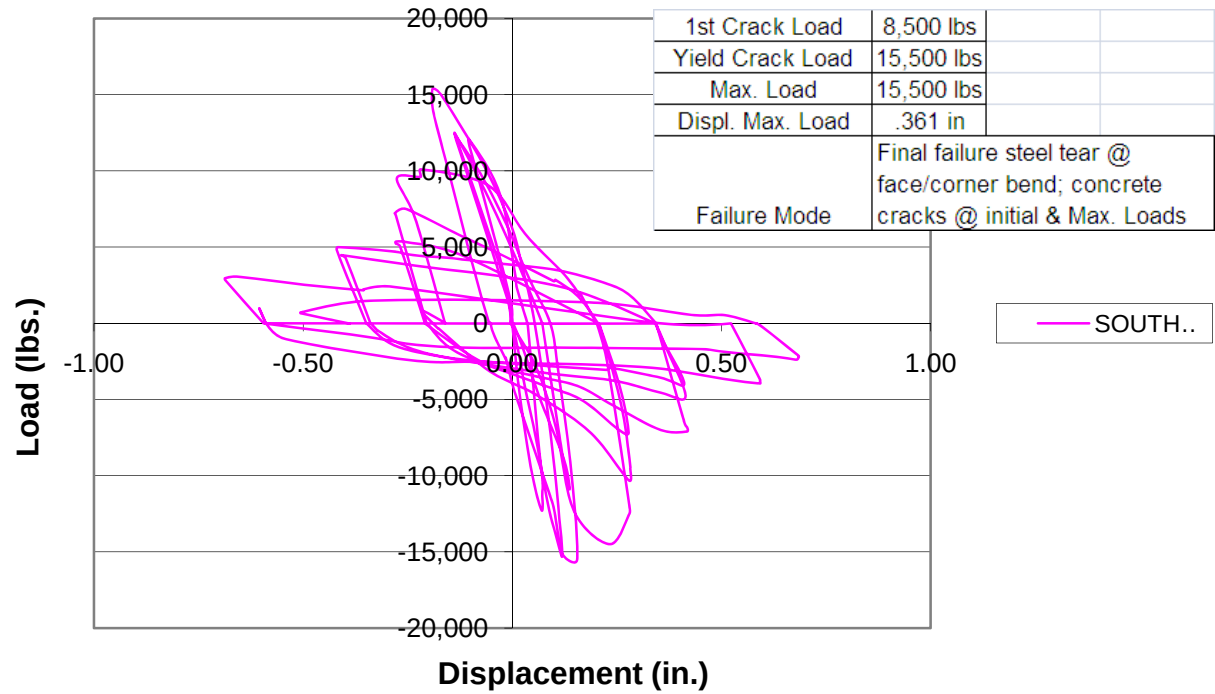
### Slab B Test 4: IN-PLANE MONOTONIC SHEAR WITH TENSION



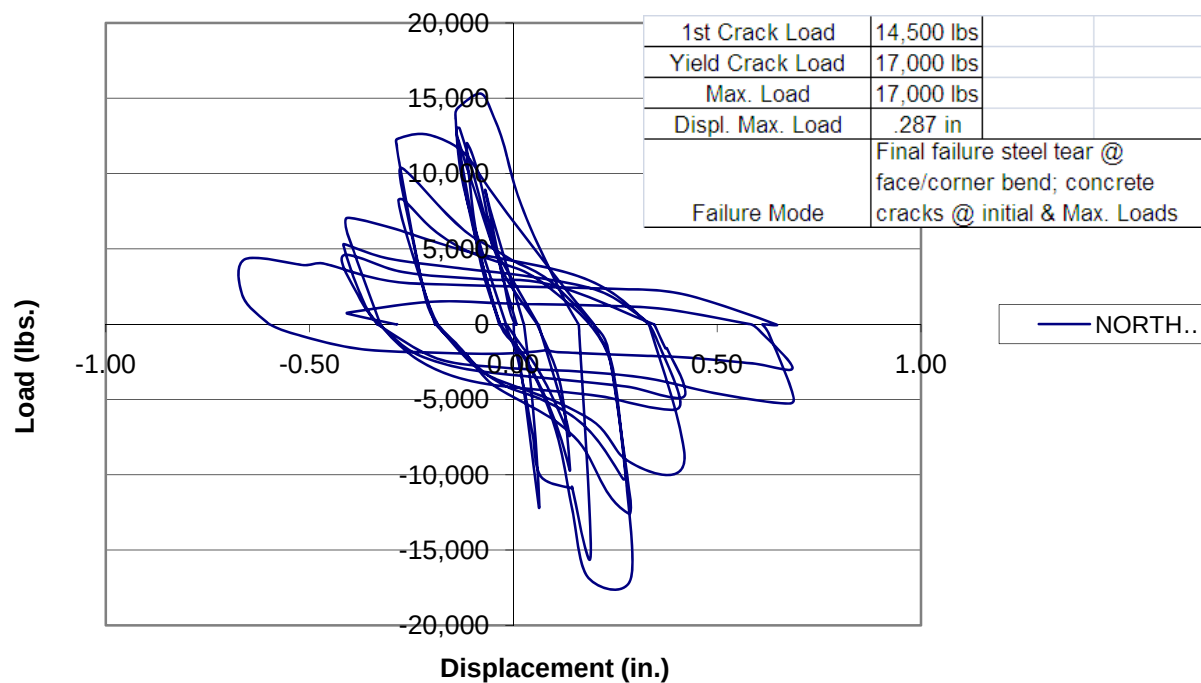
### Slab C Test 1: CYCLIC IN-PLANE SHEAR NO TENSION



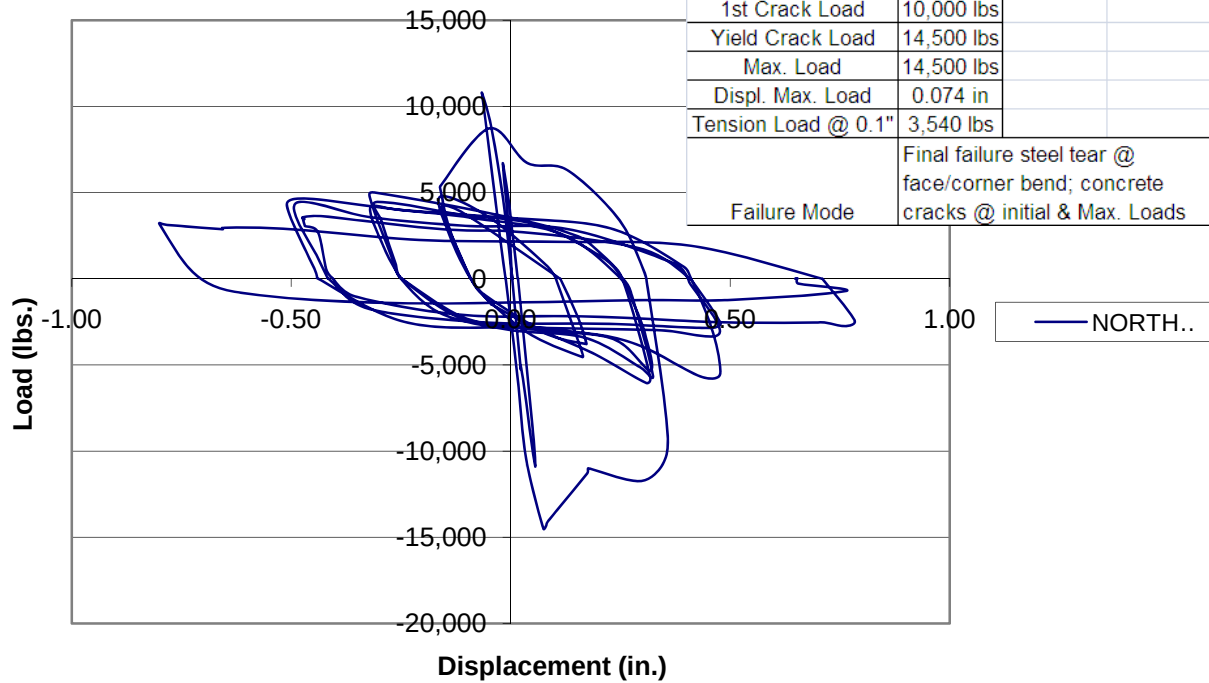
### Slab C Test 3: CYCLIC IN-PLANE SHEAR NO TENSION



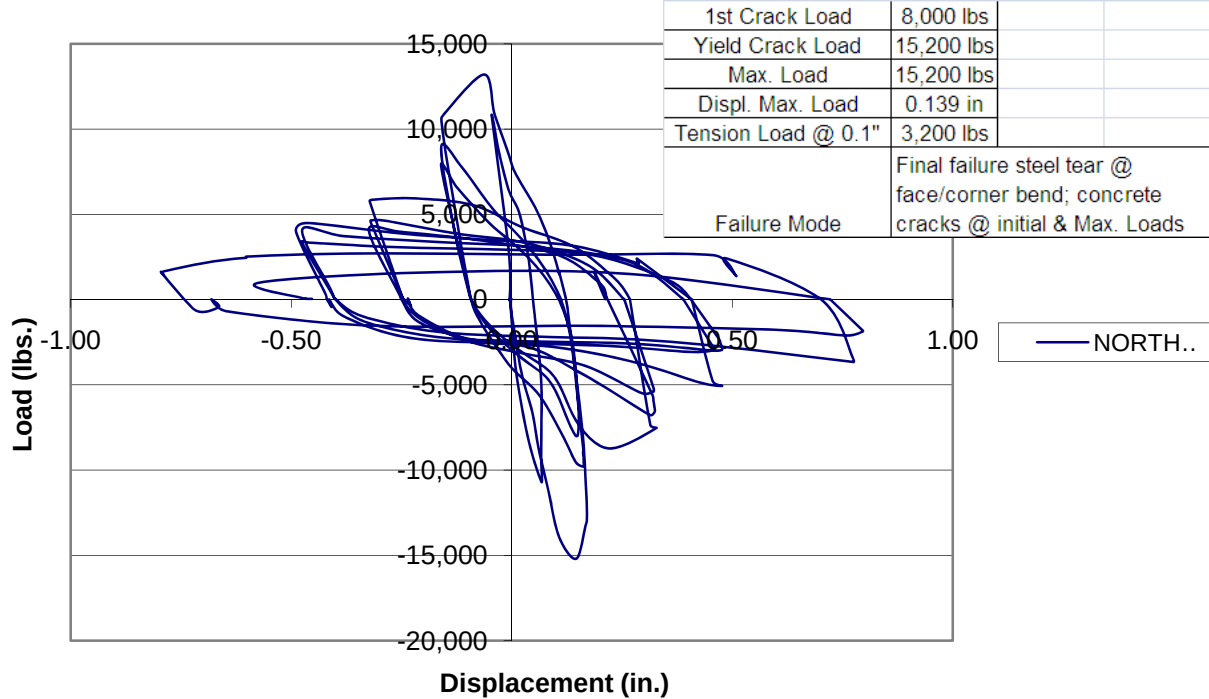
### Slab C Test 4: CYCLIC IN-PLANE SHEAR NO TENSION



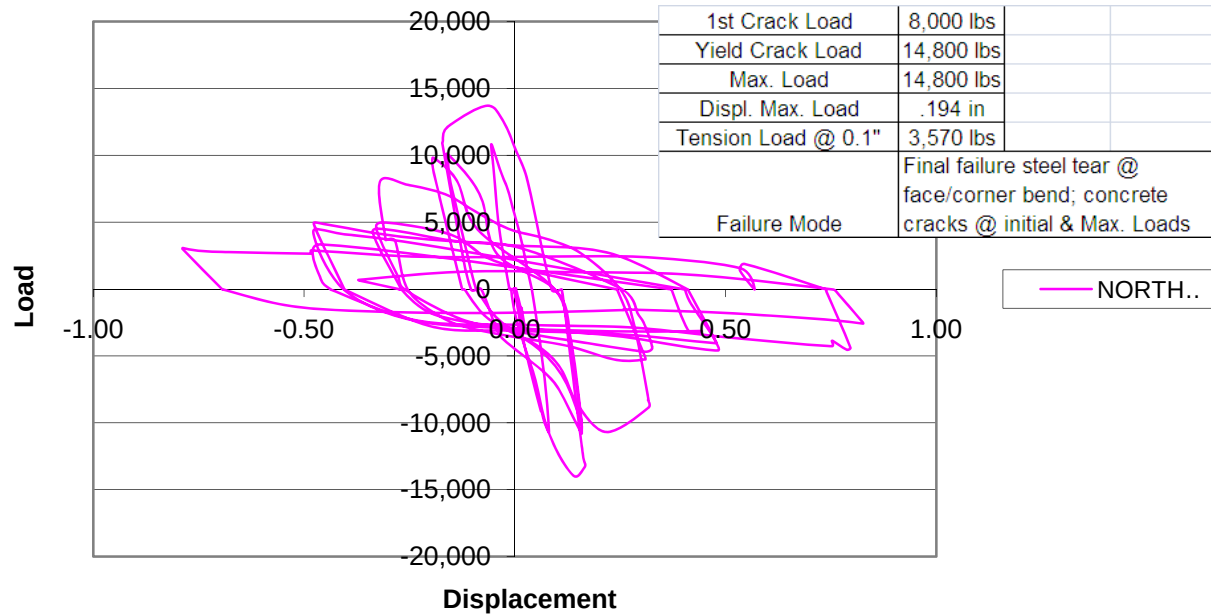
### Slab D Test 1: CYCLIC IN-PLANE SHEAR WITH TENSION



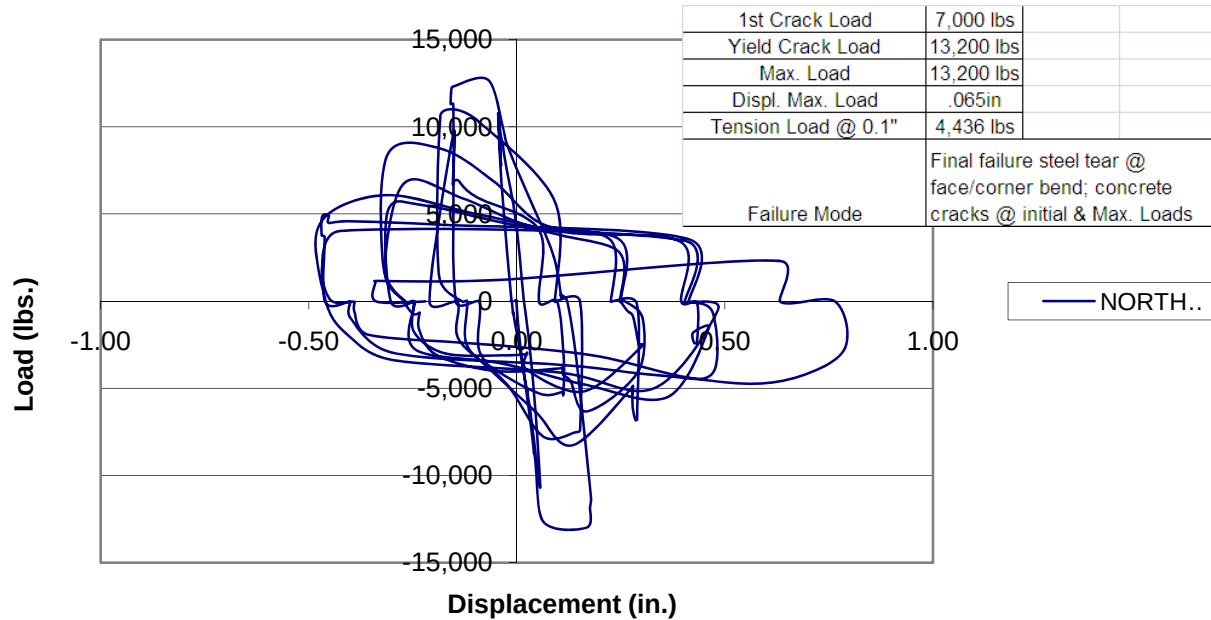
### Slab D Test 2: CYCLIC IN-PLANE SHEAR WITH TENISON



### Slab D Test 3: CYCLIC IN-PLANE SHEAR WITH TENSION



### Slab D Test 4: CYCLIC IN-PLANE SHEAR WITH TENSION



# **APPENDIX B**

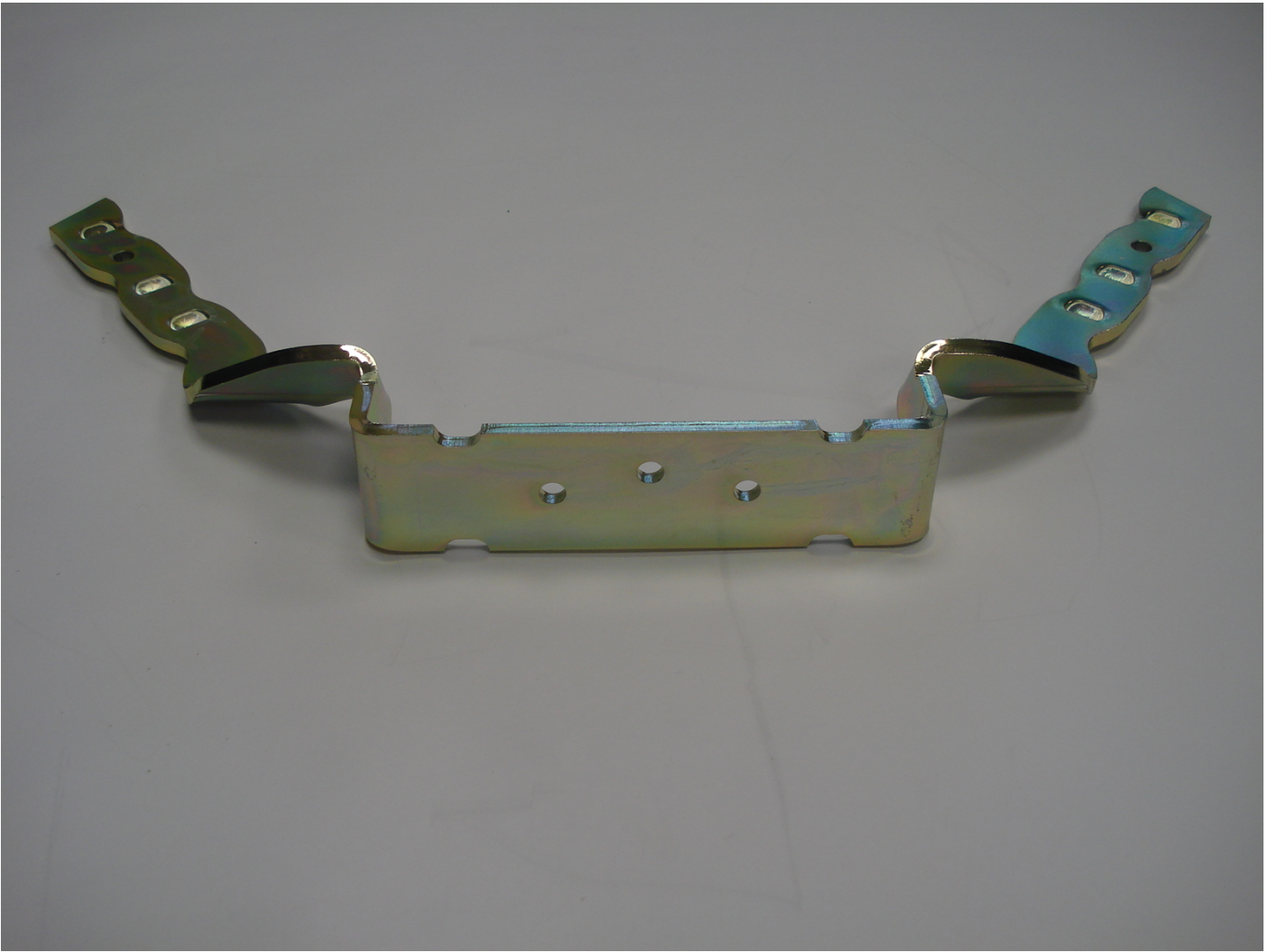


Figure 1 - Mid V



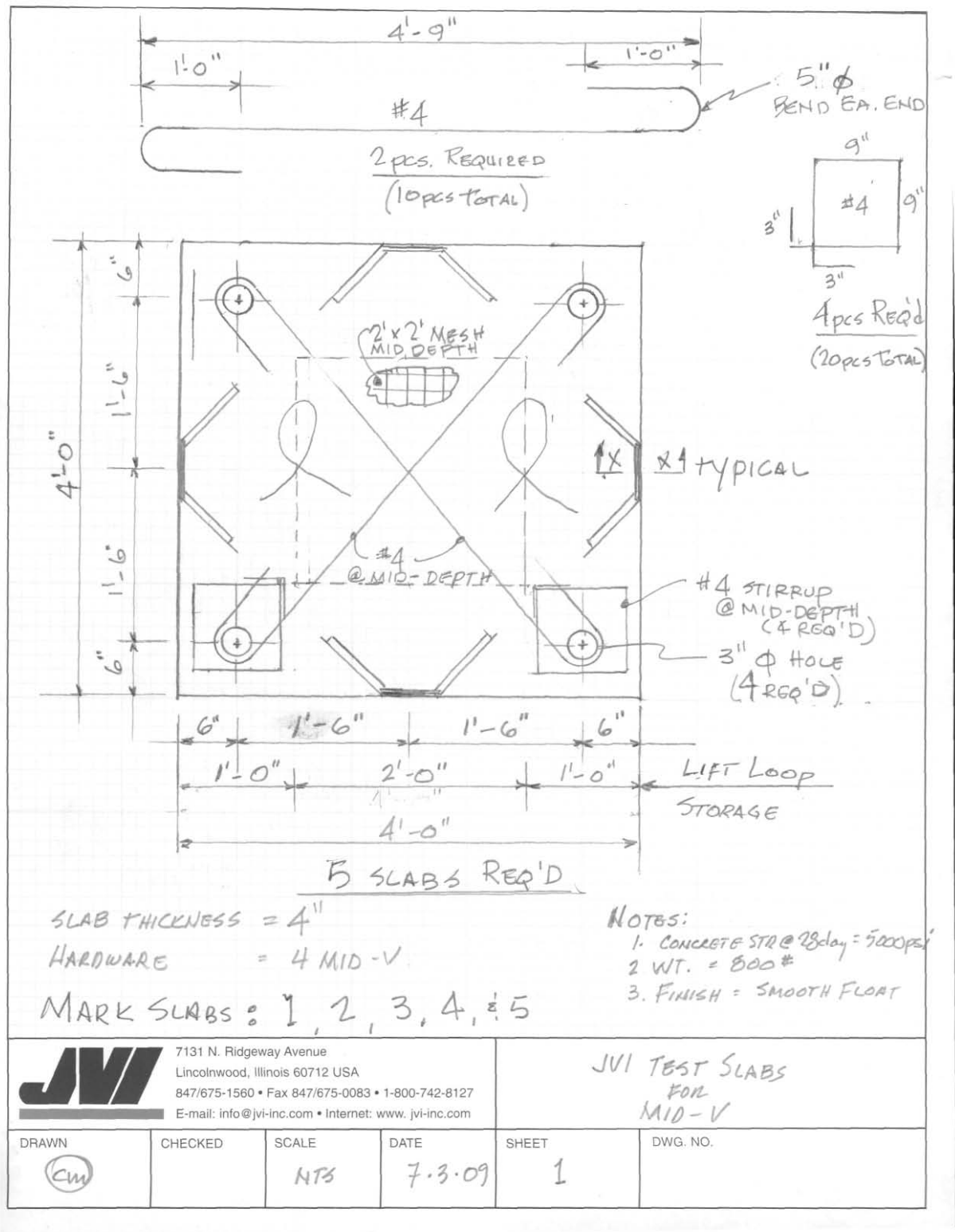


Figure 2 – test slab details and reinforcing

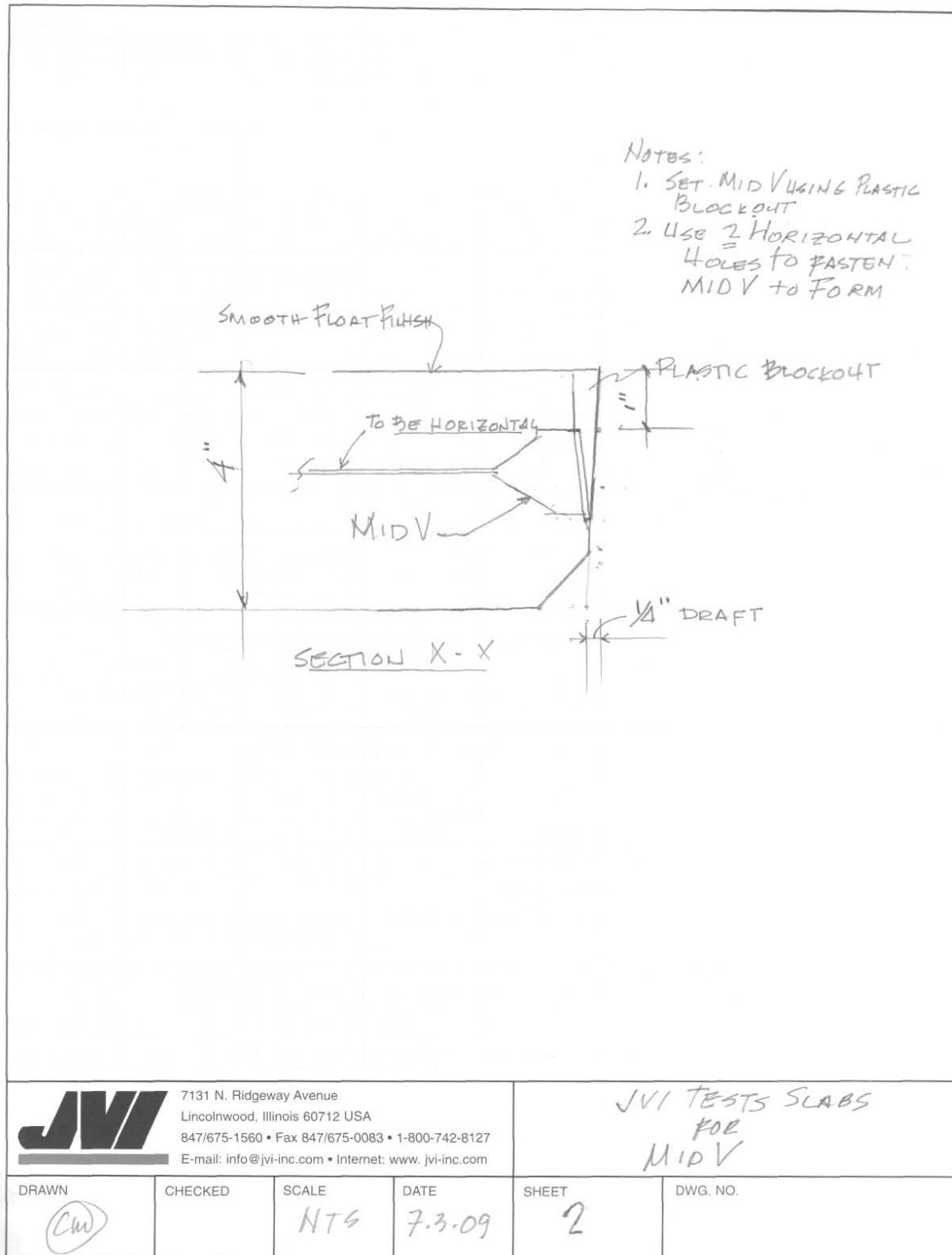


Figure 3 – Section thru Mid V in test slab

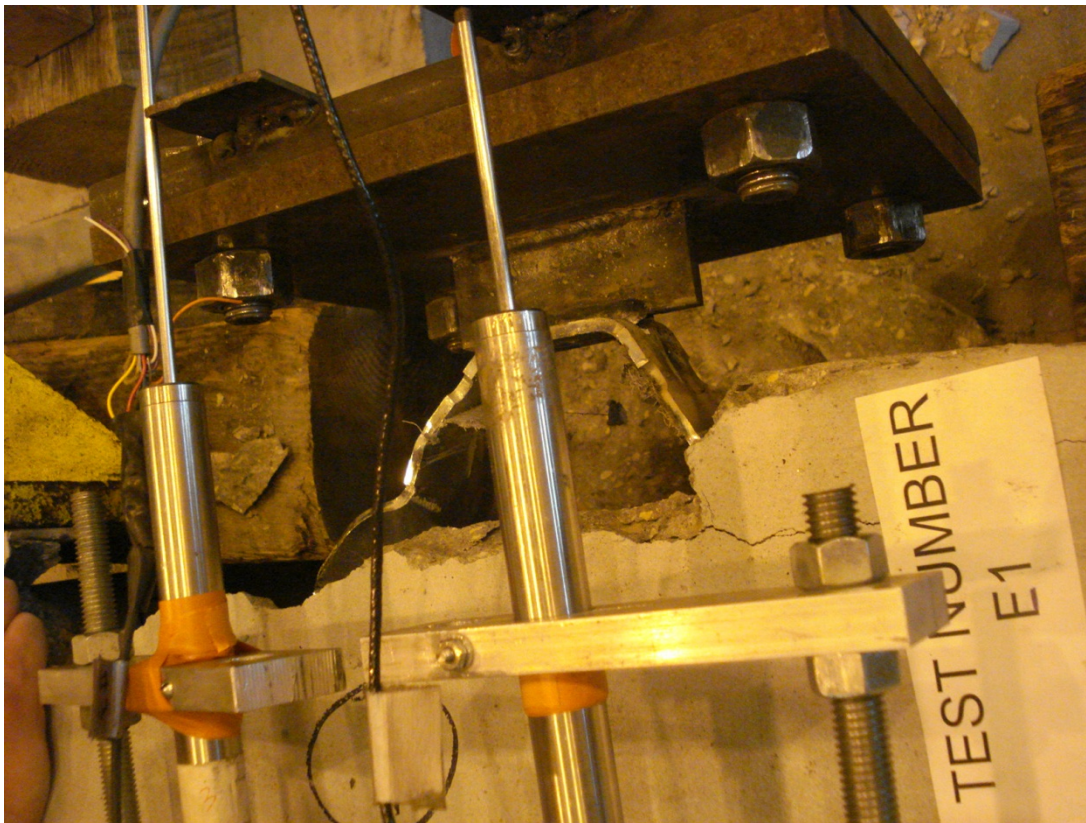


Figure 4 – Test E1A & B: In-Plane Tension

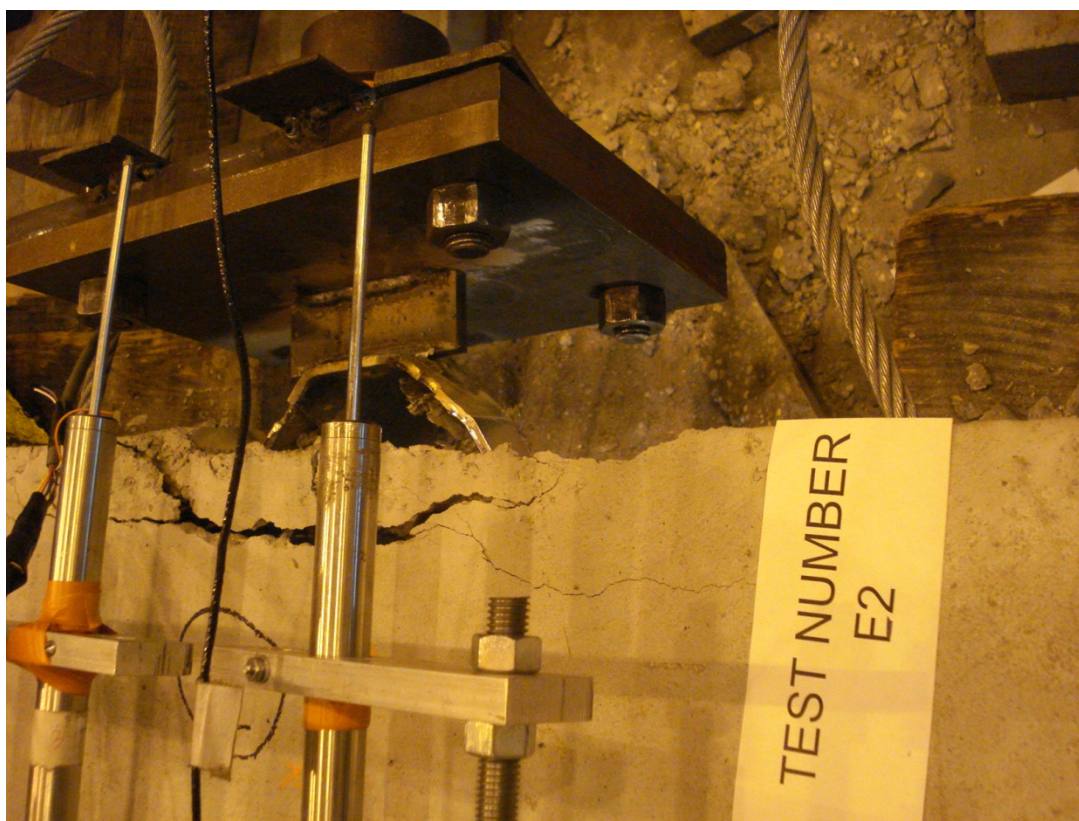


Figure 5 – Test E2: In-Plane Tension





Figure 6 – Test E3: In-Plane Tension



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

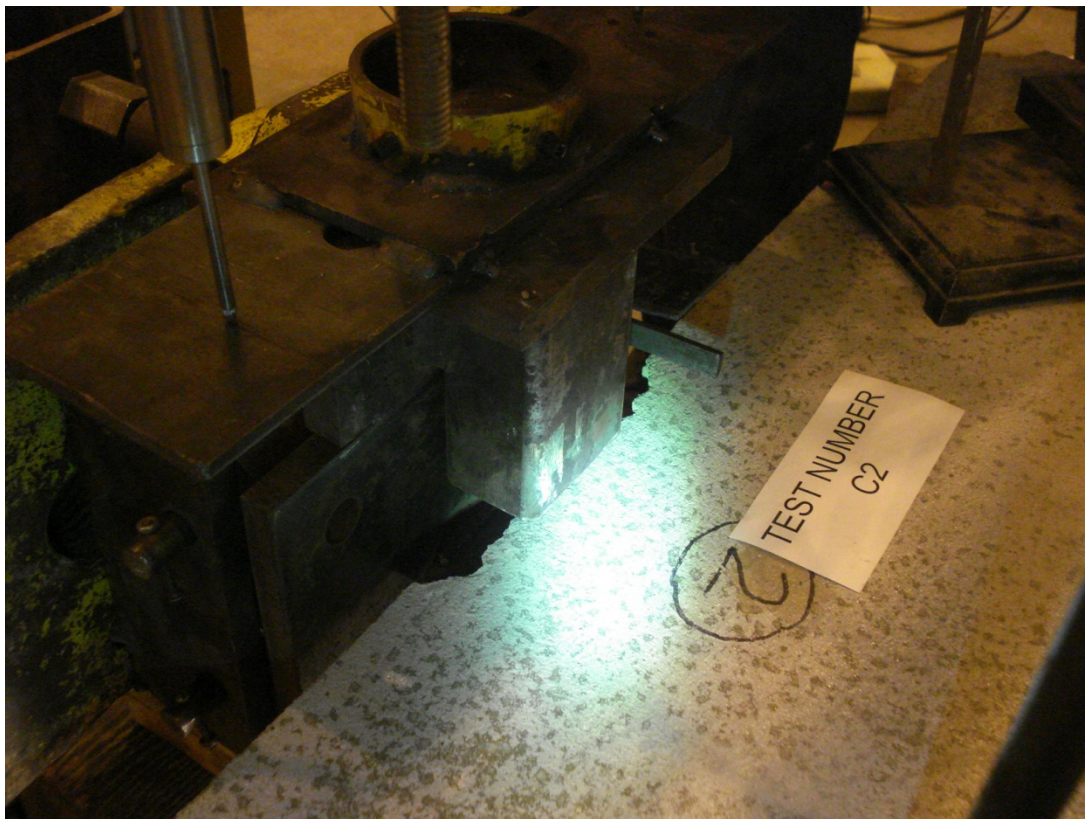


Figure 8 – Test C2: Out of Plane Shear w/ No Tension





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

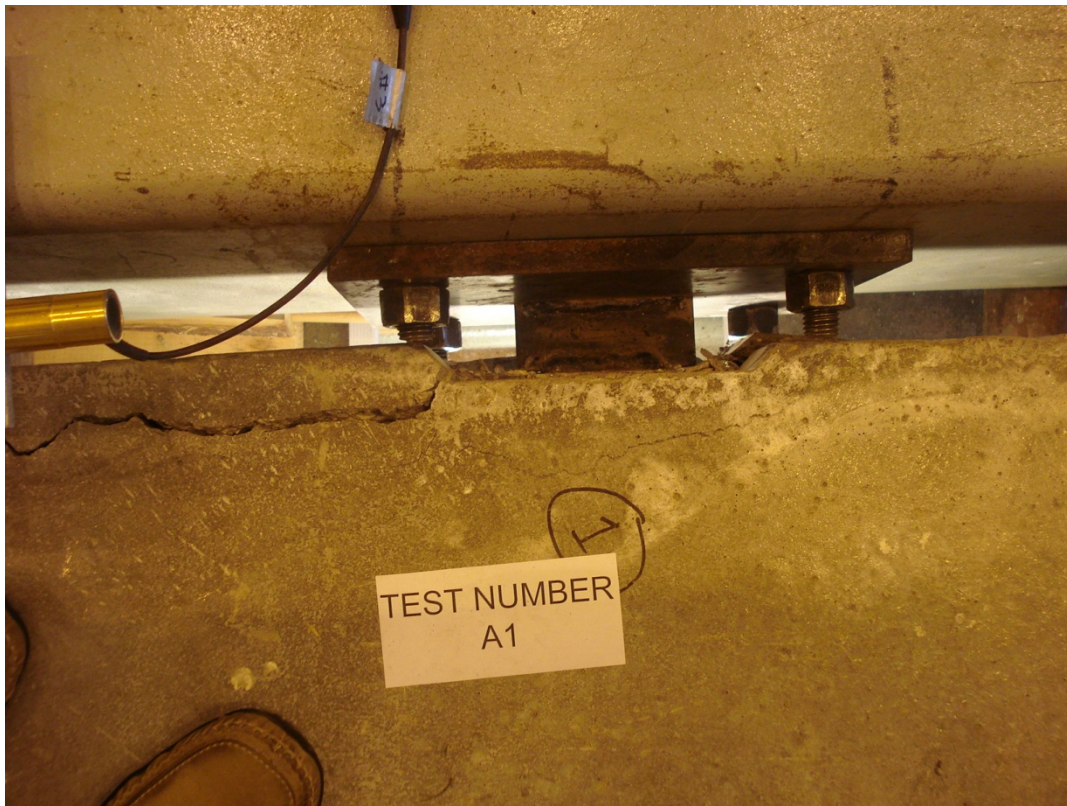


Figure 10 – Test A1: In-Plane Monotonic Shear w/ No Tension



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



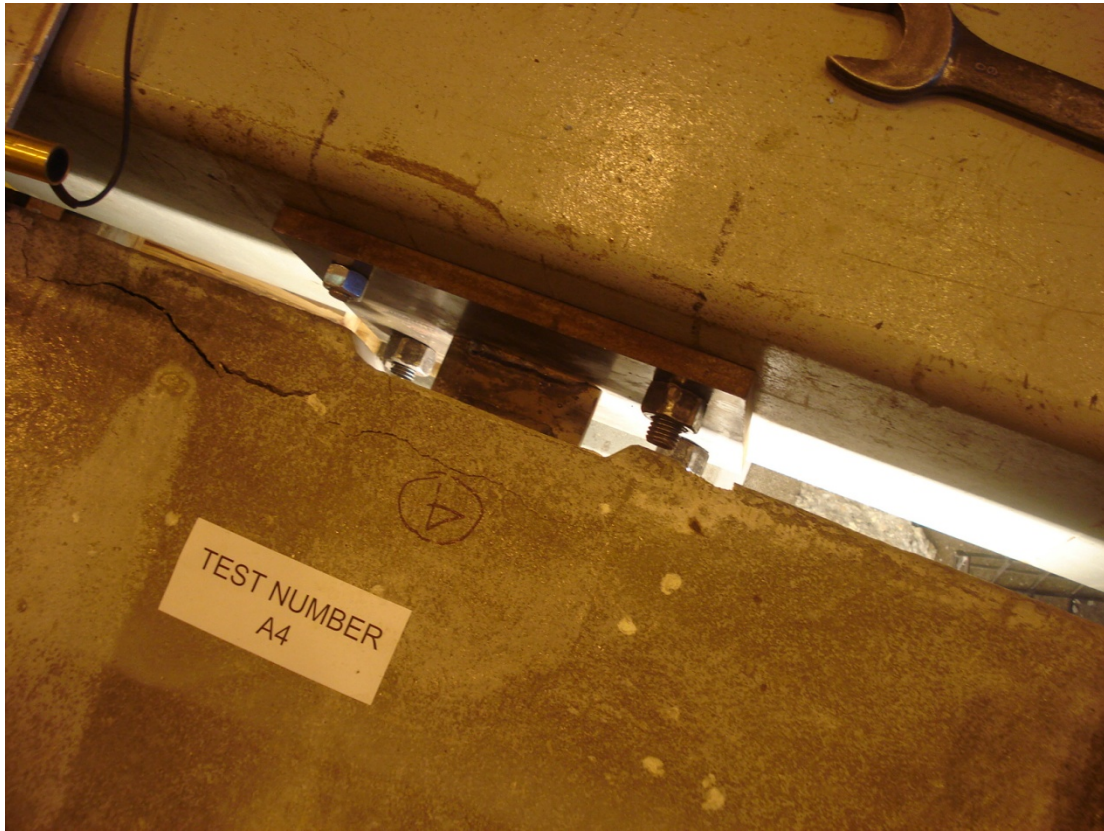


Figure 12 – Test A4: In-Plane Monotonic Shear w/ No Tension



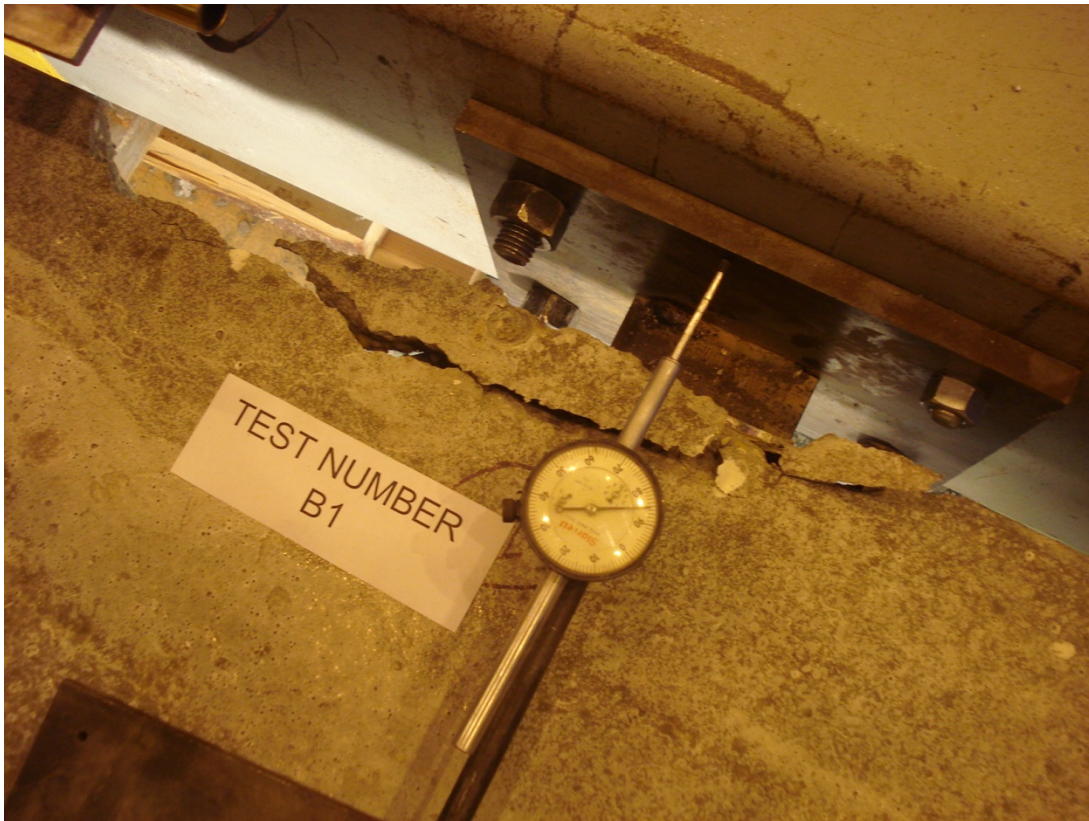


Figure 13 – Test B1: In-Plane Monotonic Shear w/ Tension



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





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

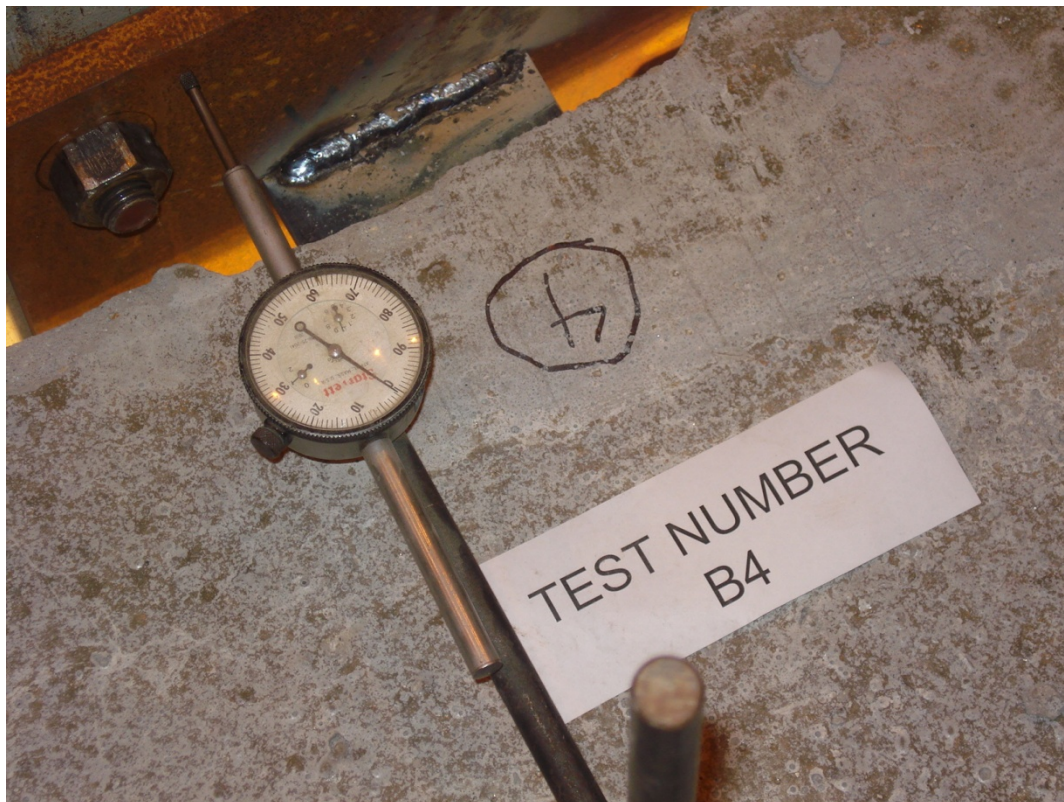


Figure 16 – Test B4: In-Plane Monotonic Shear w/ Tension





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

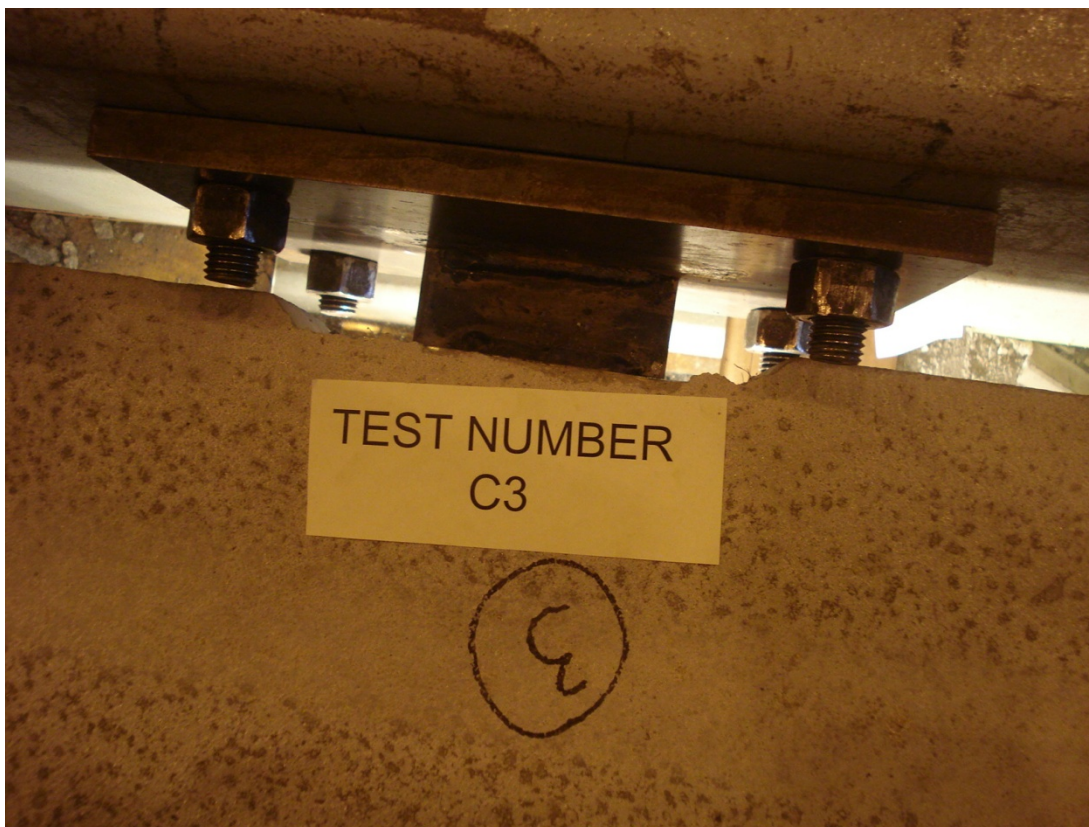


Figure 18 – Test C3: In-Plane Cyclic Shear w/ No Tension

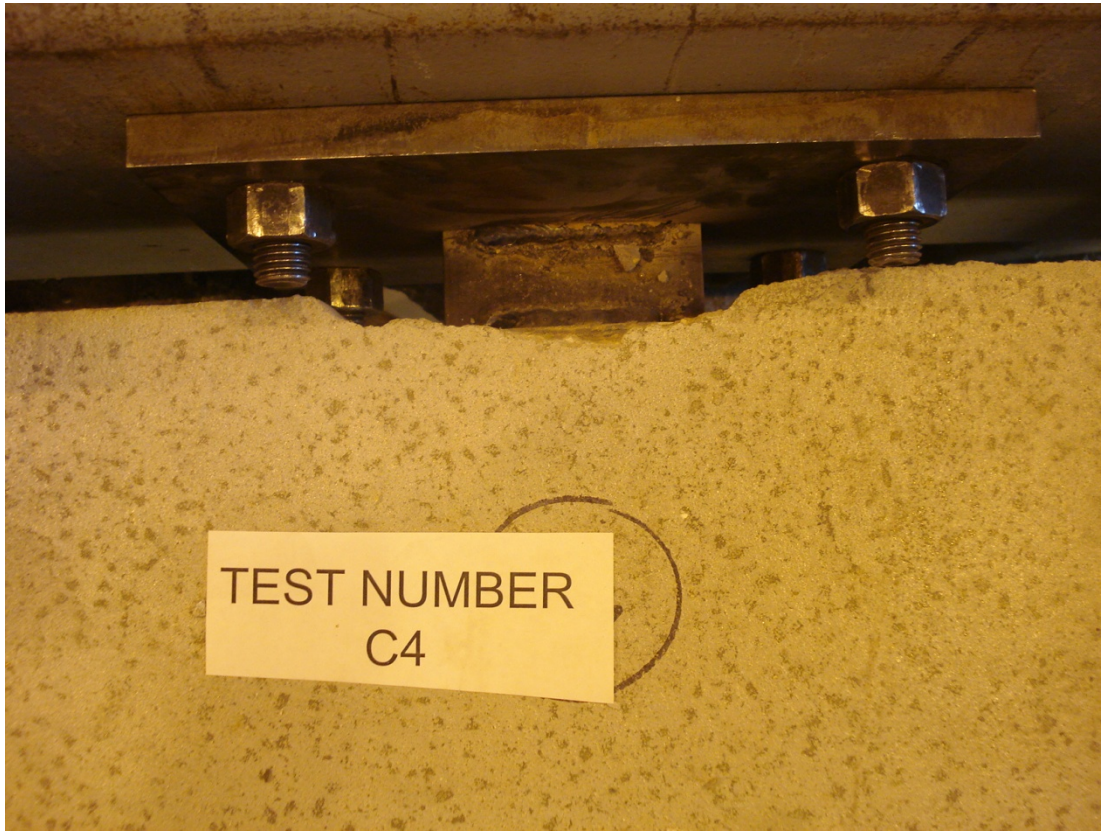


Figure 19 – Test C4: In-Plane Cyclic Shear w/ No Tension



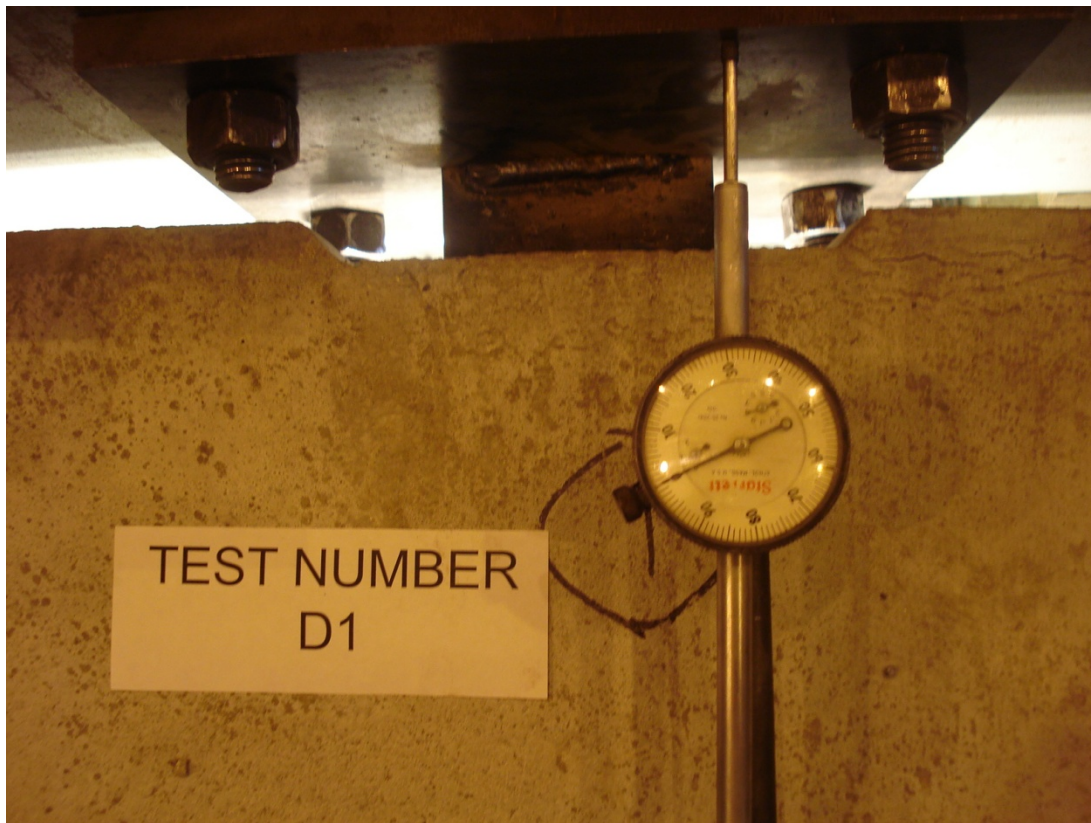


Figure 20 – Test D1: In-Plane Cyclic Shear w/ Tension



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



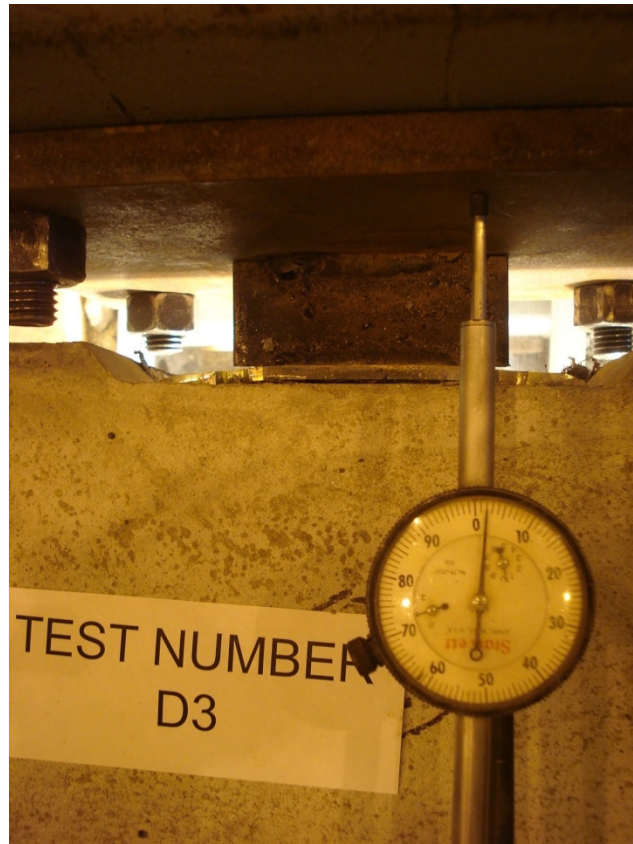


Figure 22 – Test D3: In-Plane Cyclic Shear w/ Tension



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



## **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:

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## 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**

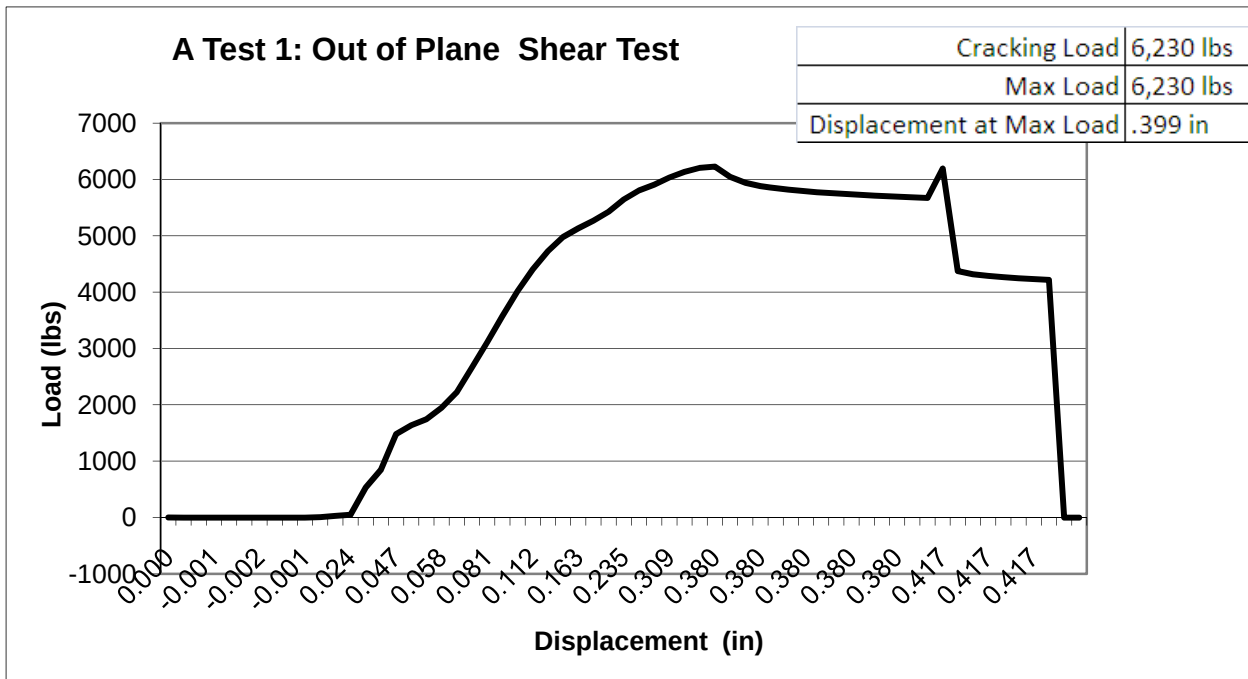


Figure 1

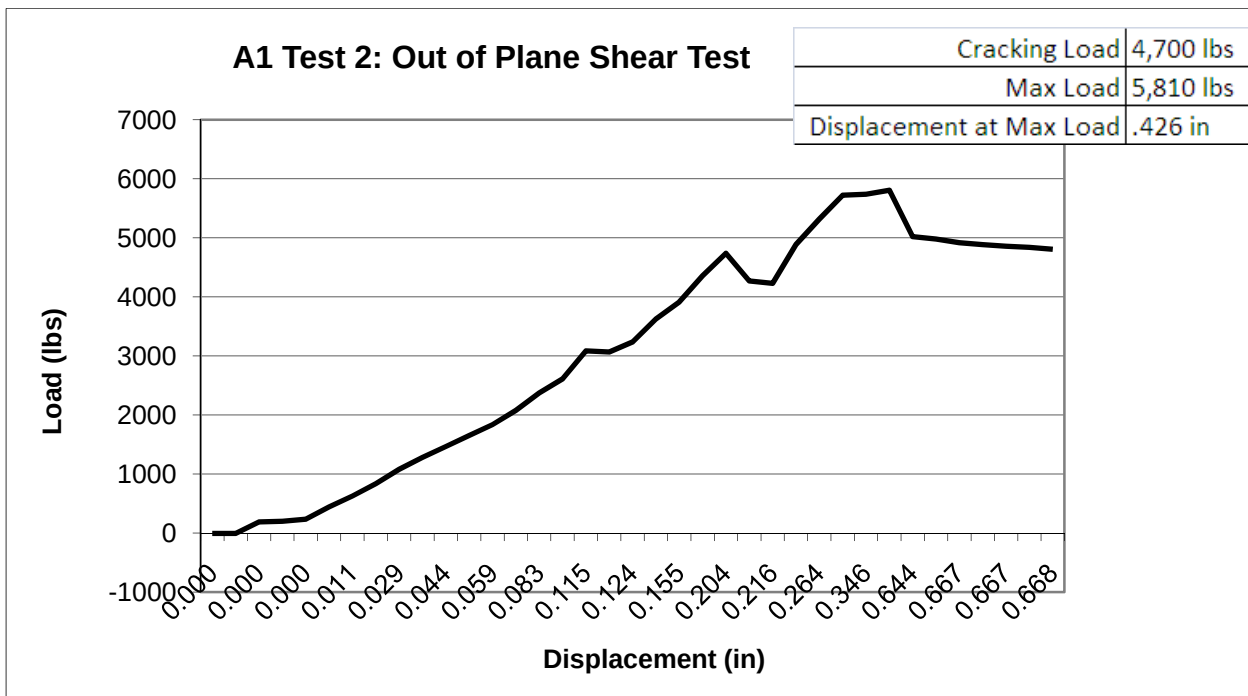


Figure 2

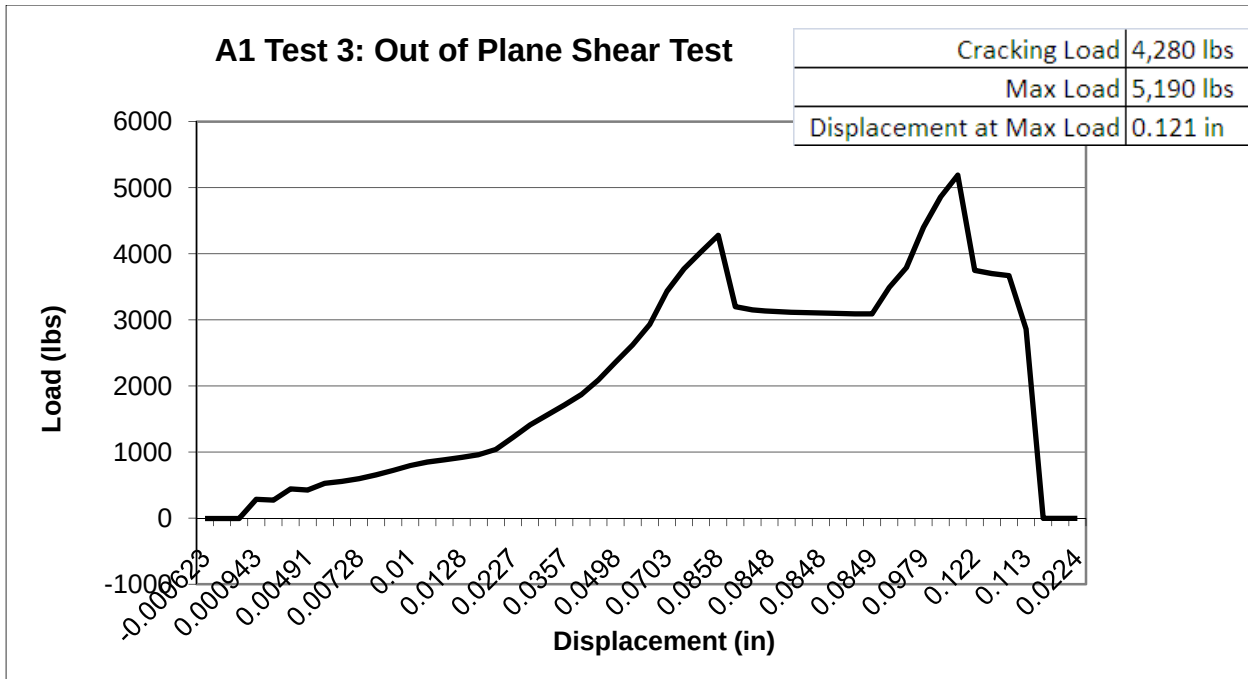


Figure 3

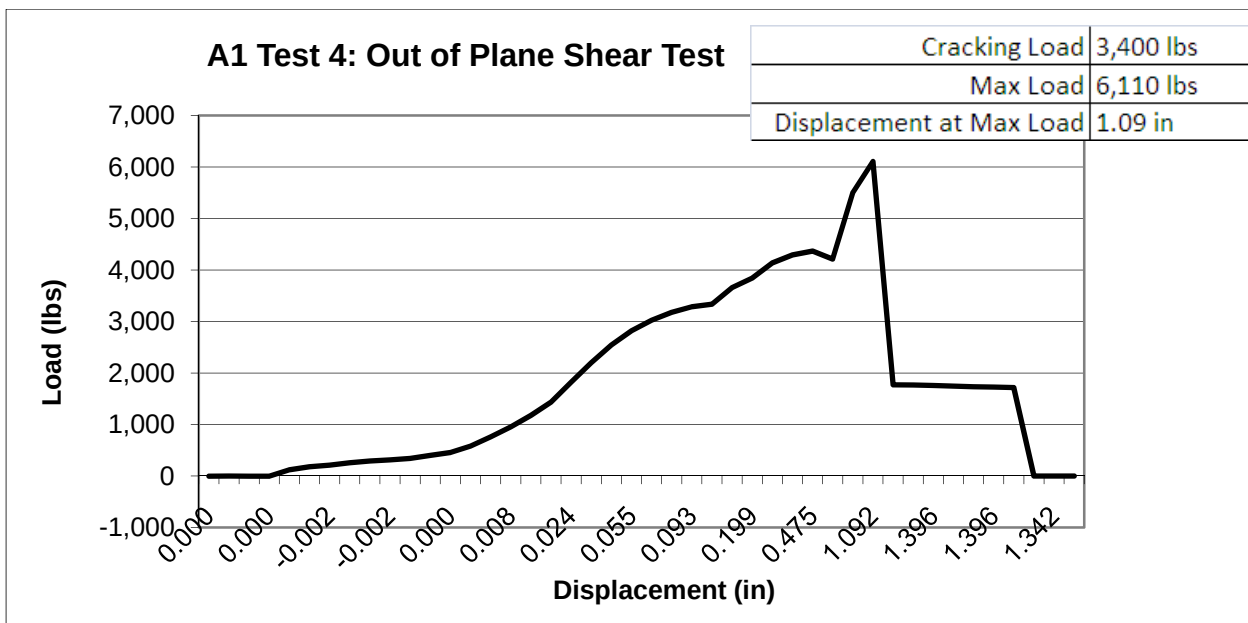


Figure 4



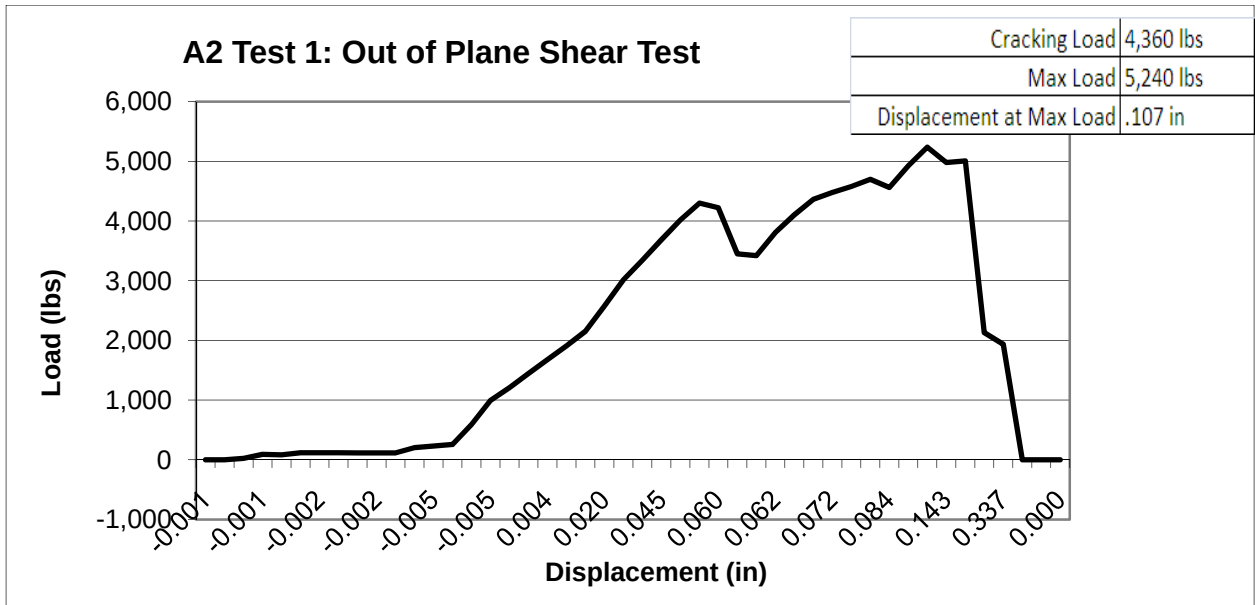


Figure 5

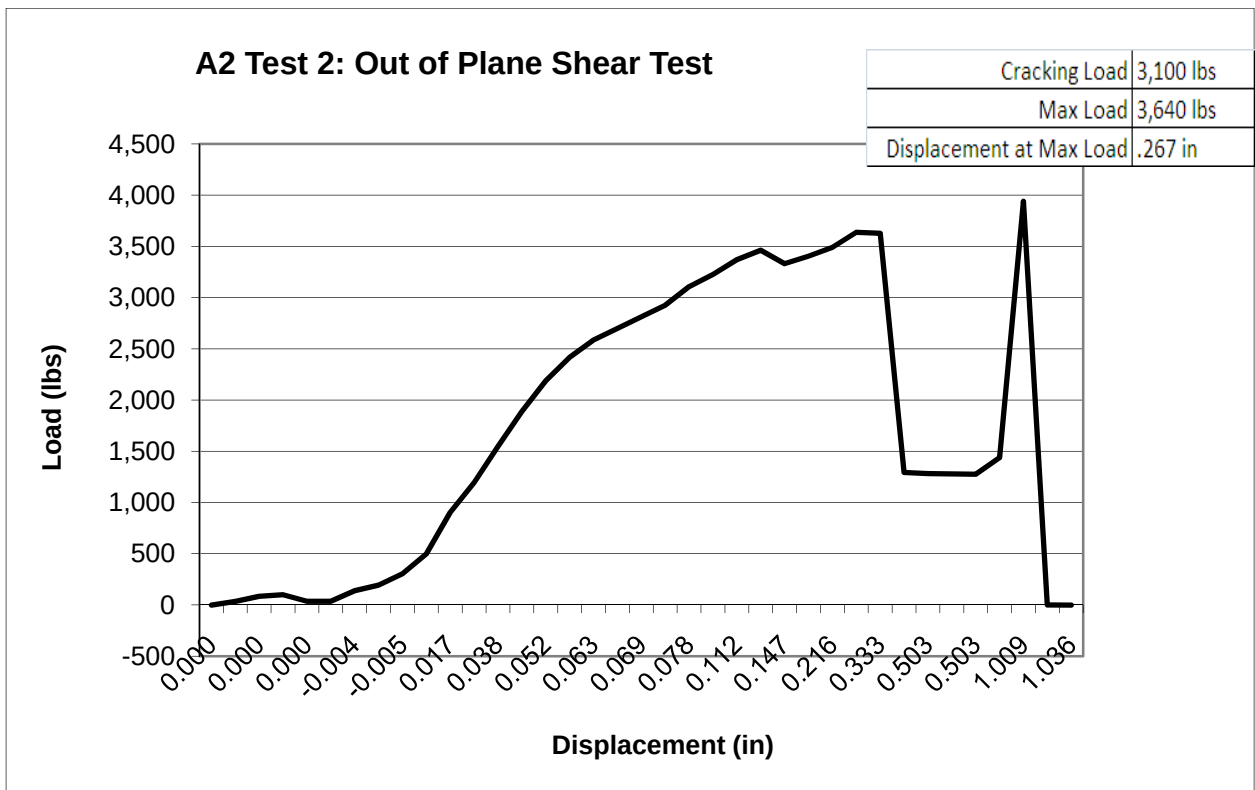


Figure 6

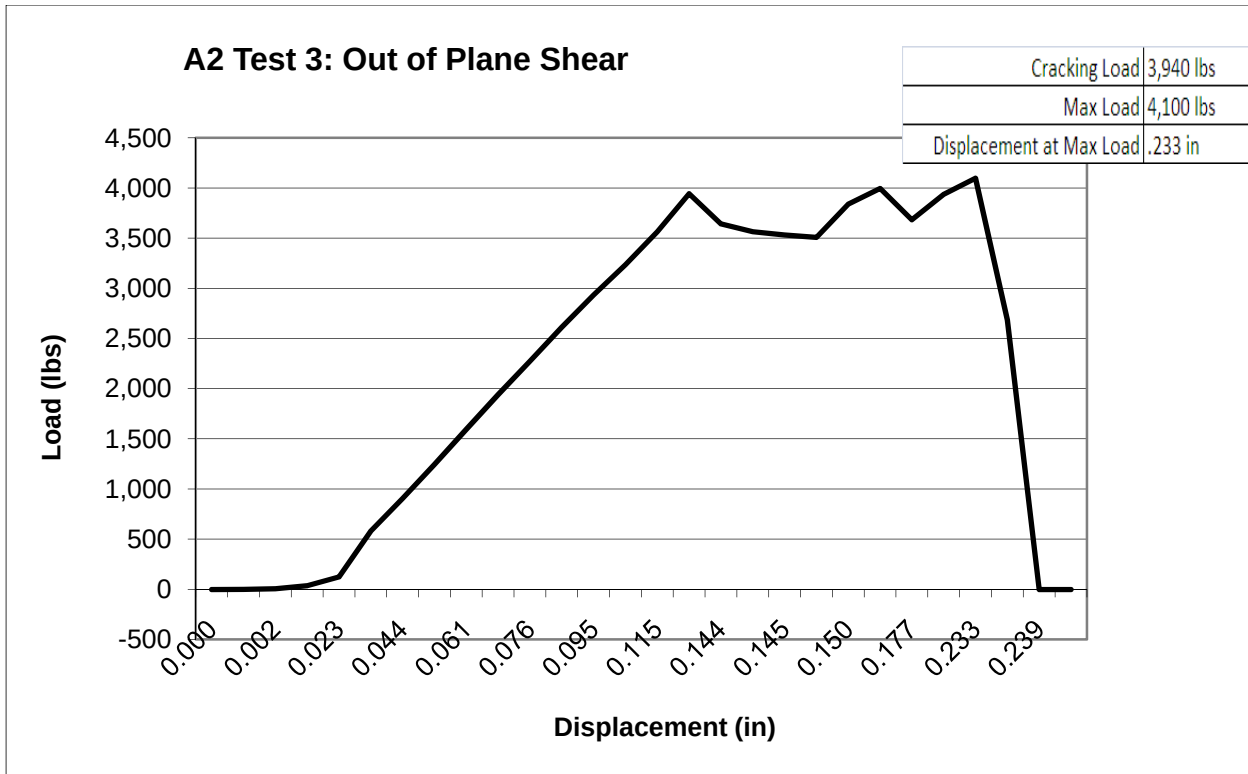


Figure 7

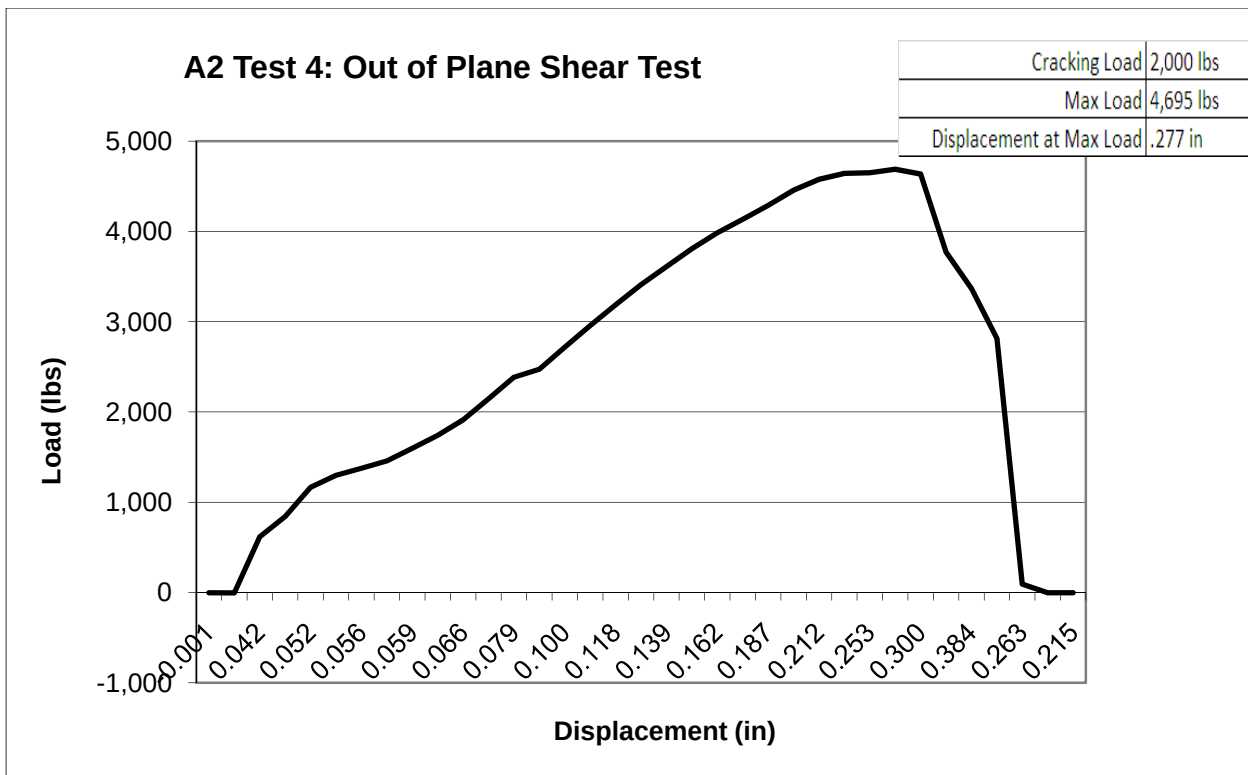


Figure 8

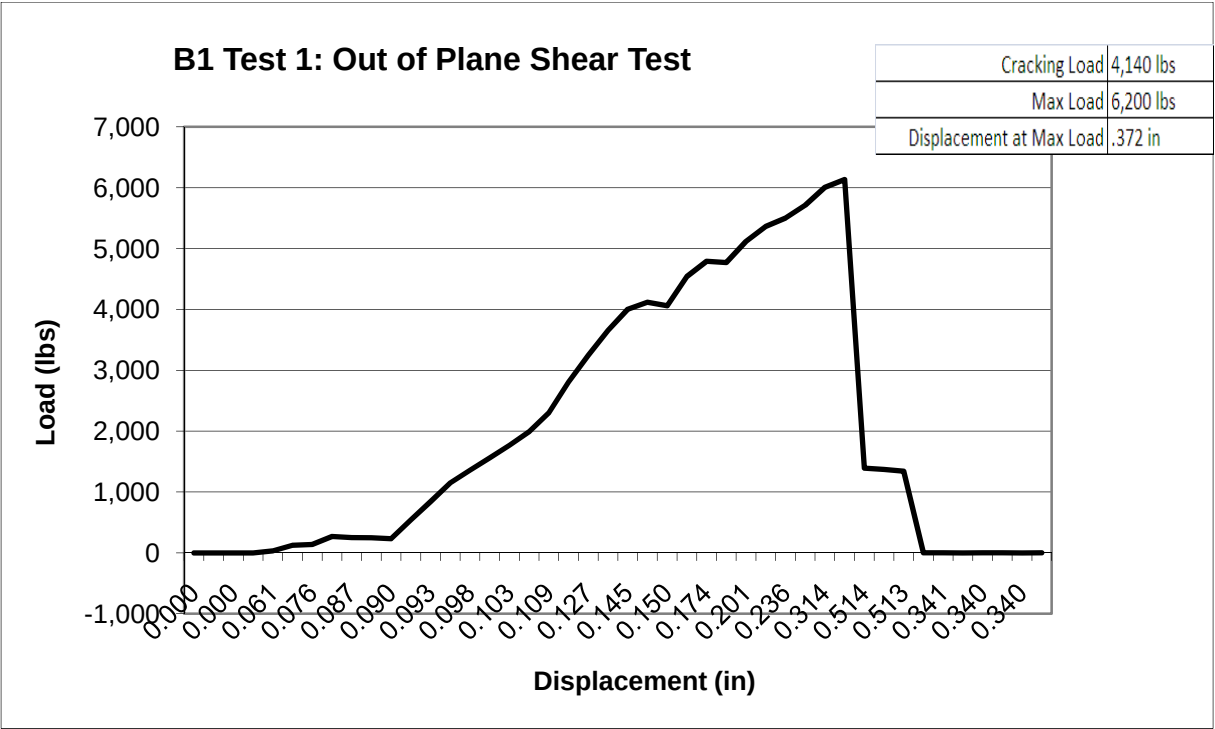


Figure 9

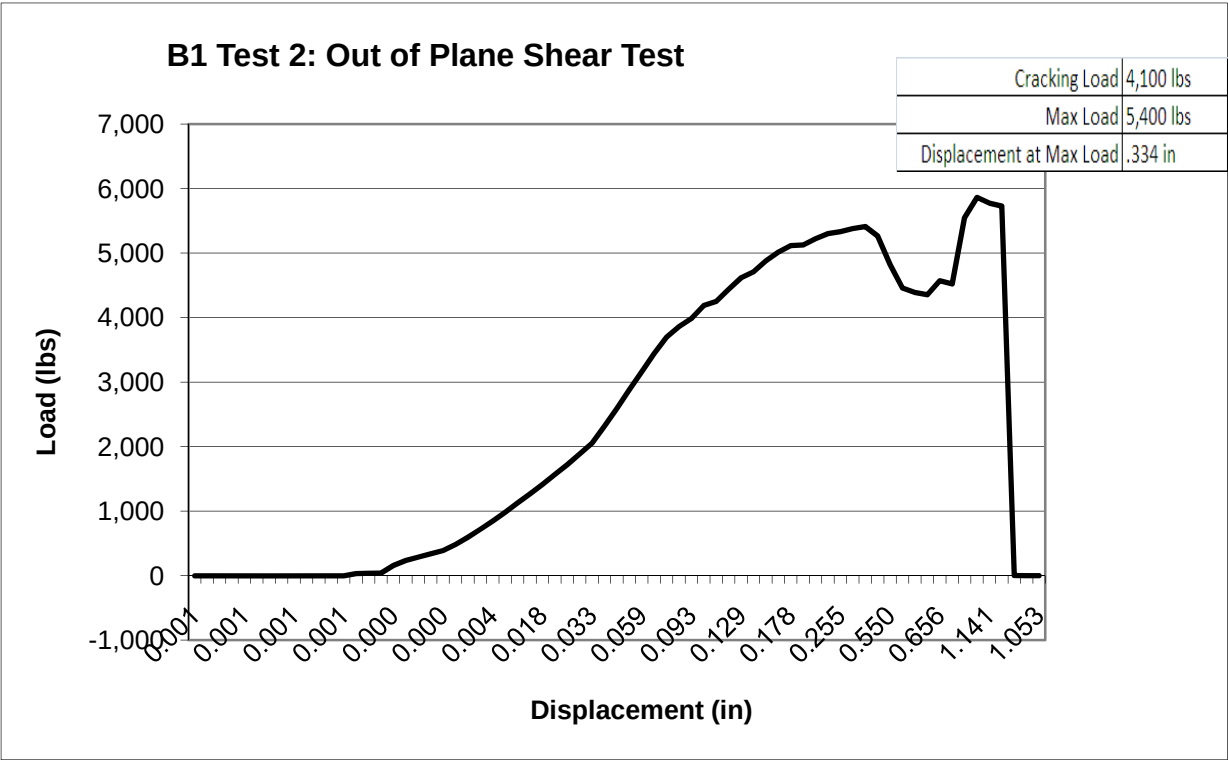


Figure 10

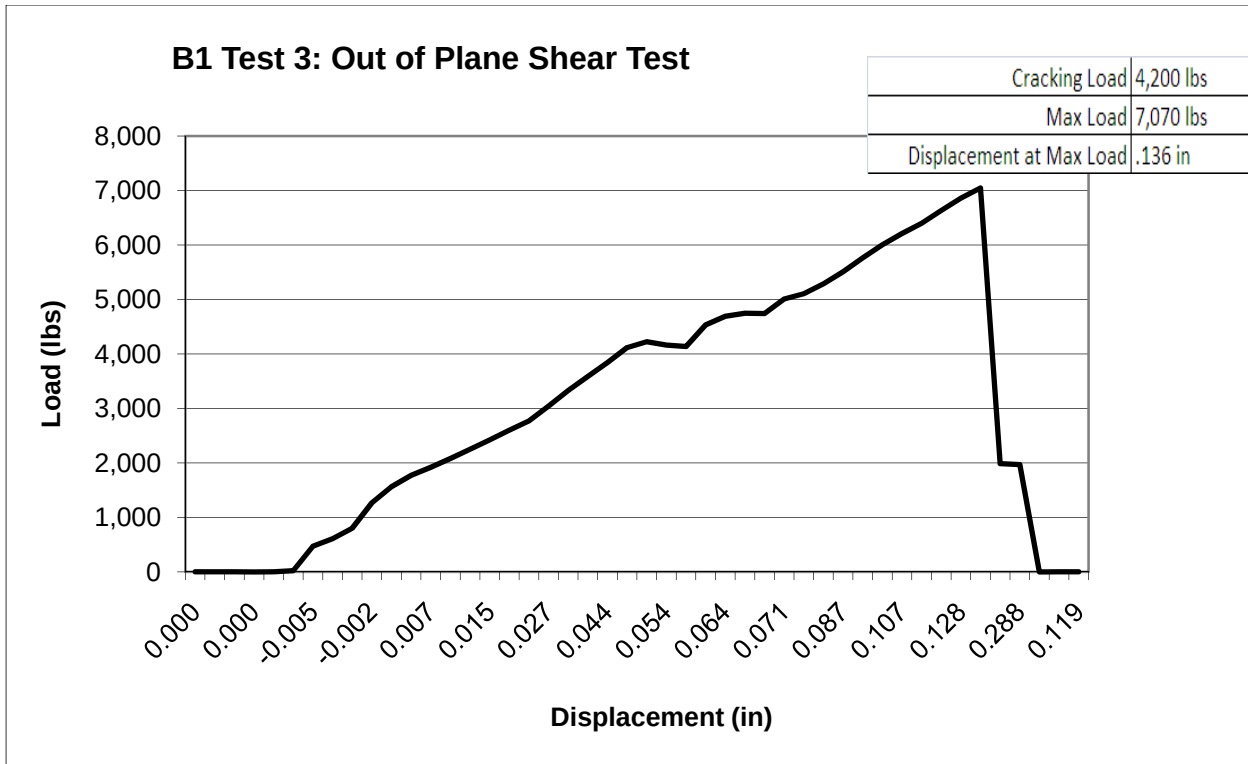


Figure 11

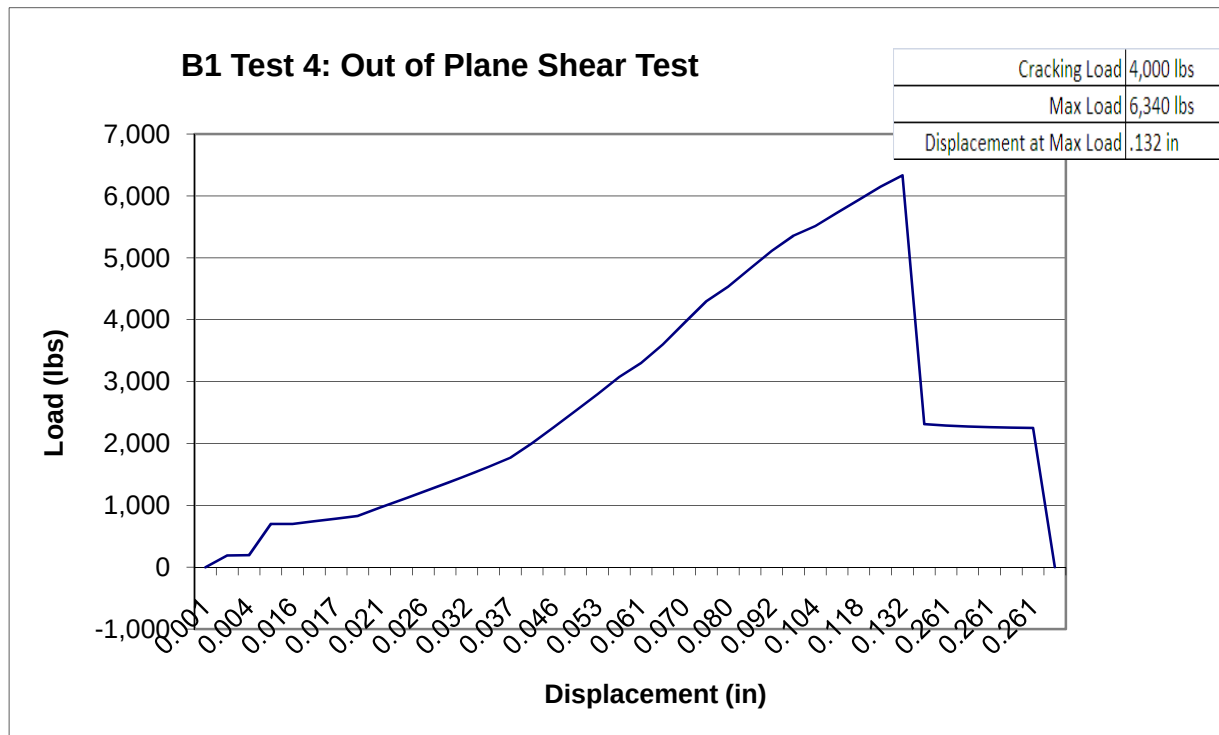


Figure 12

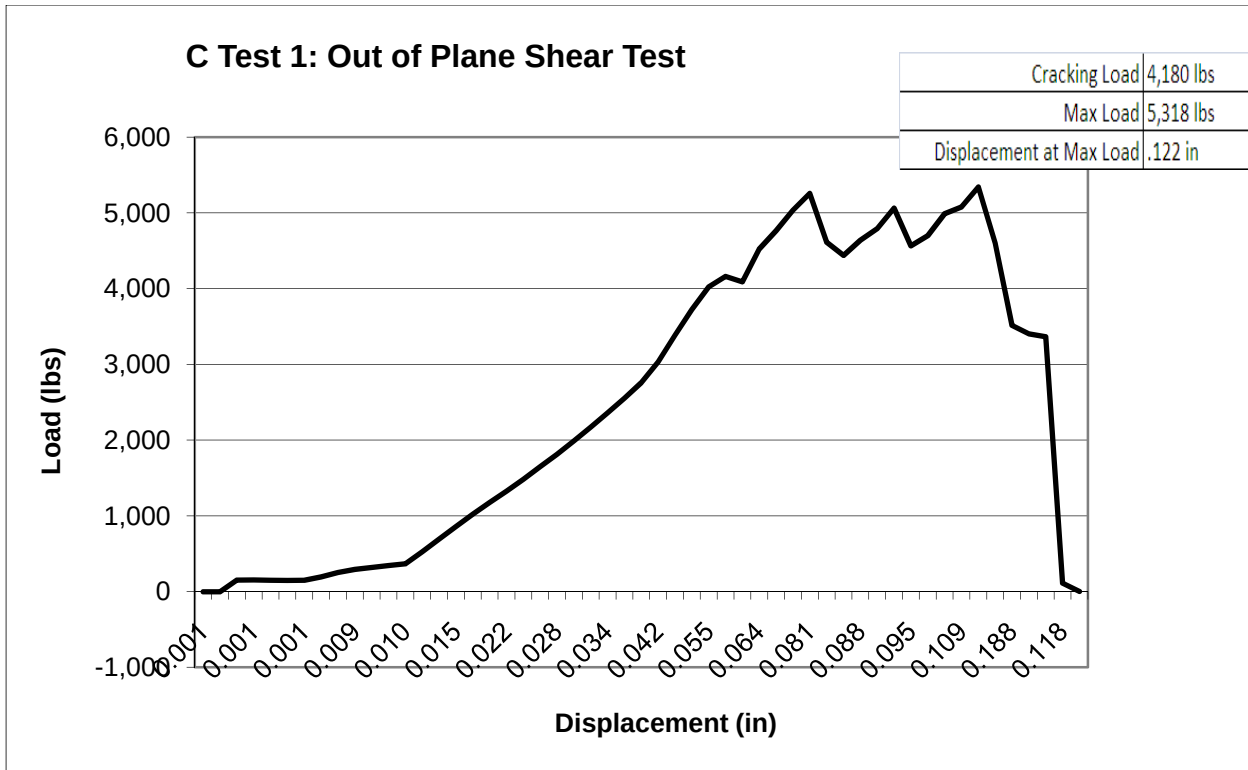


Figure 13

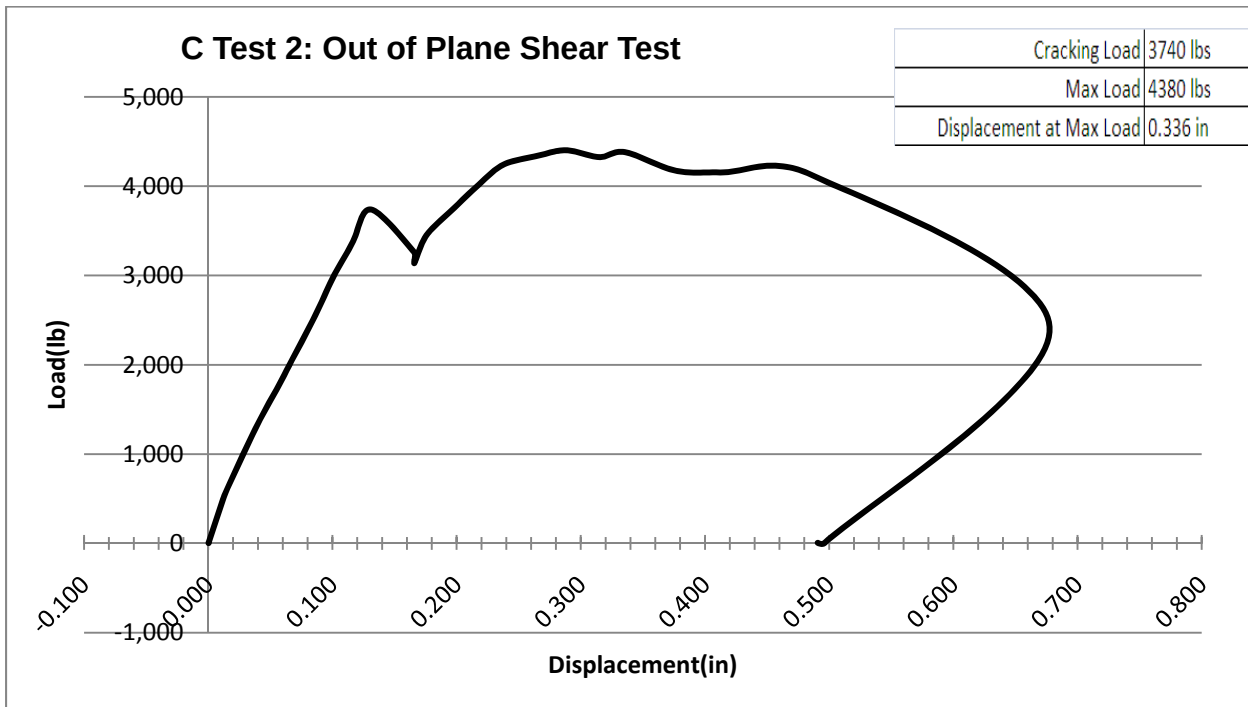


Figure 14



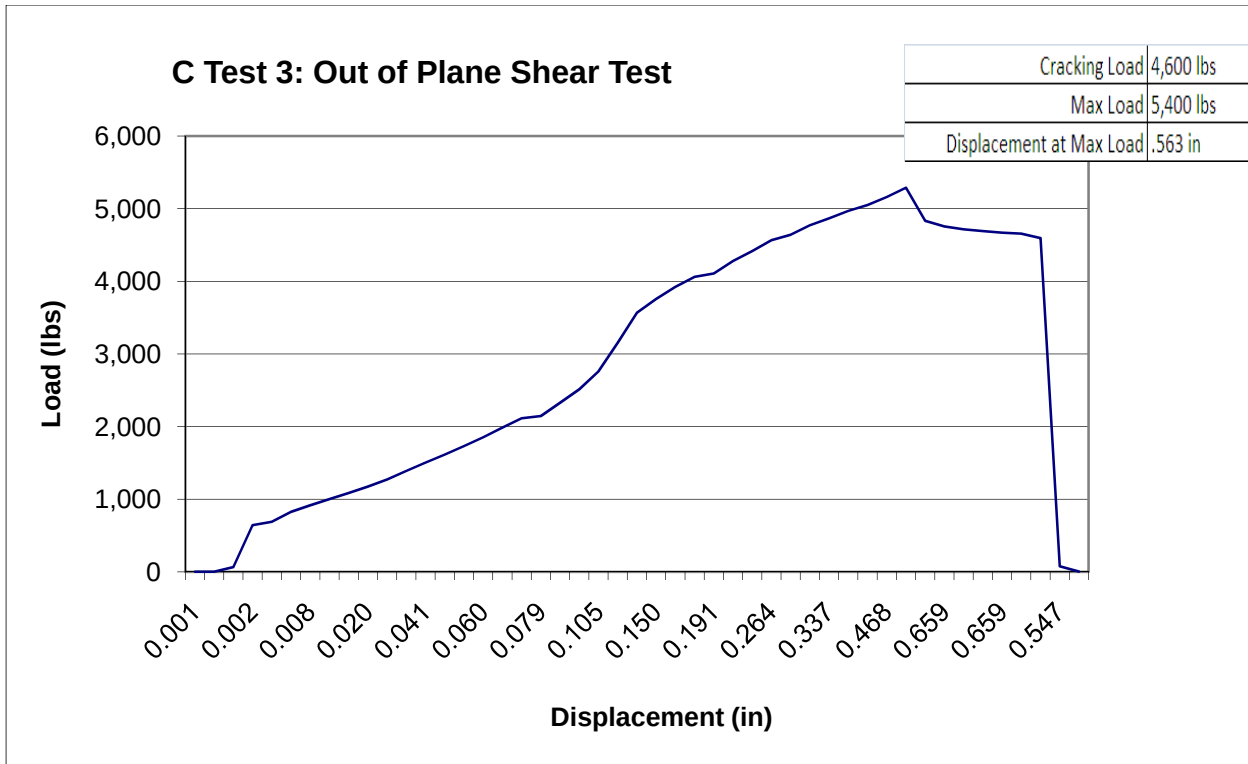


Figure 15

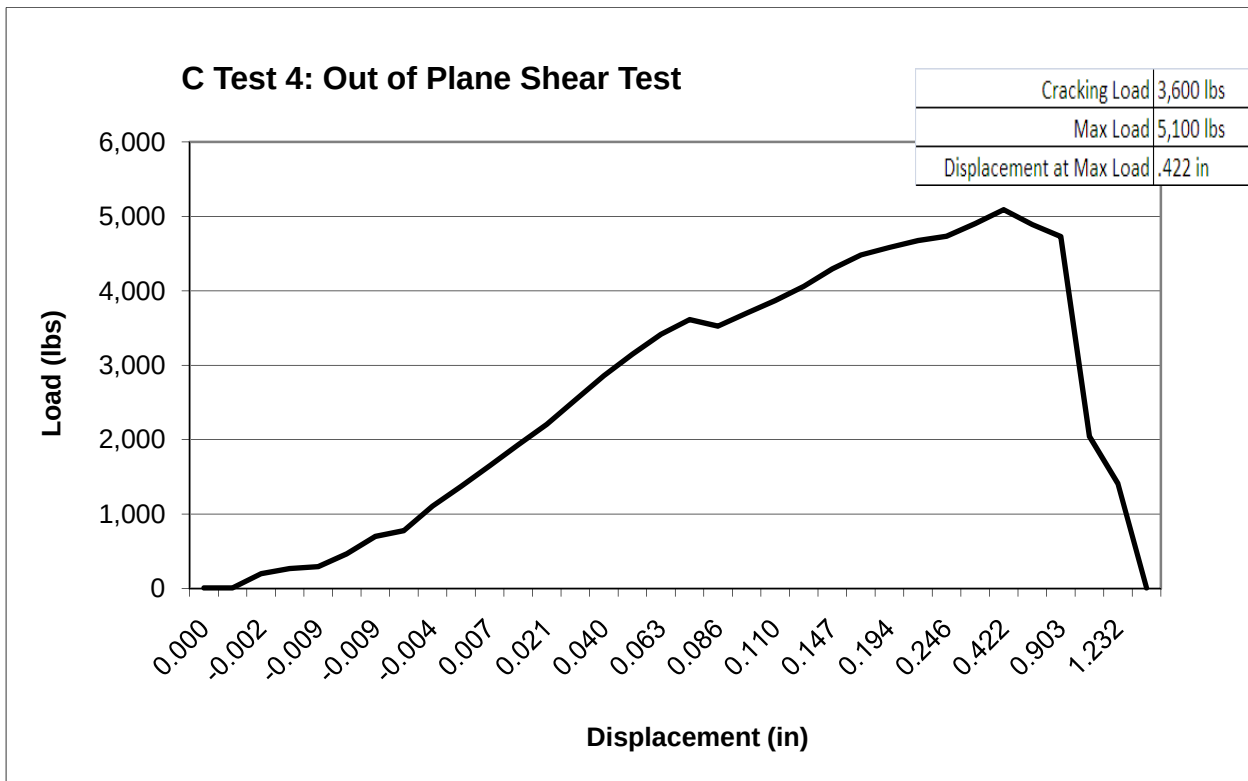


Figure 16

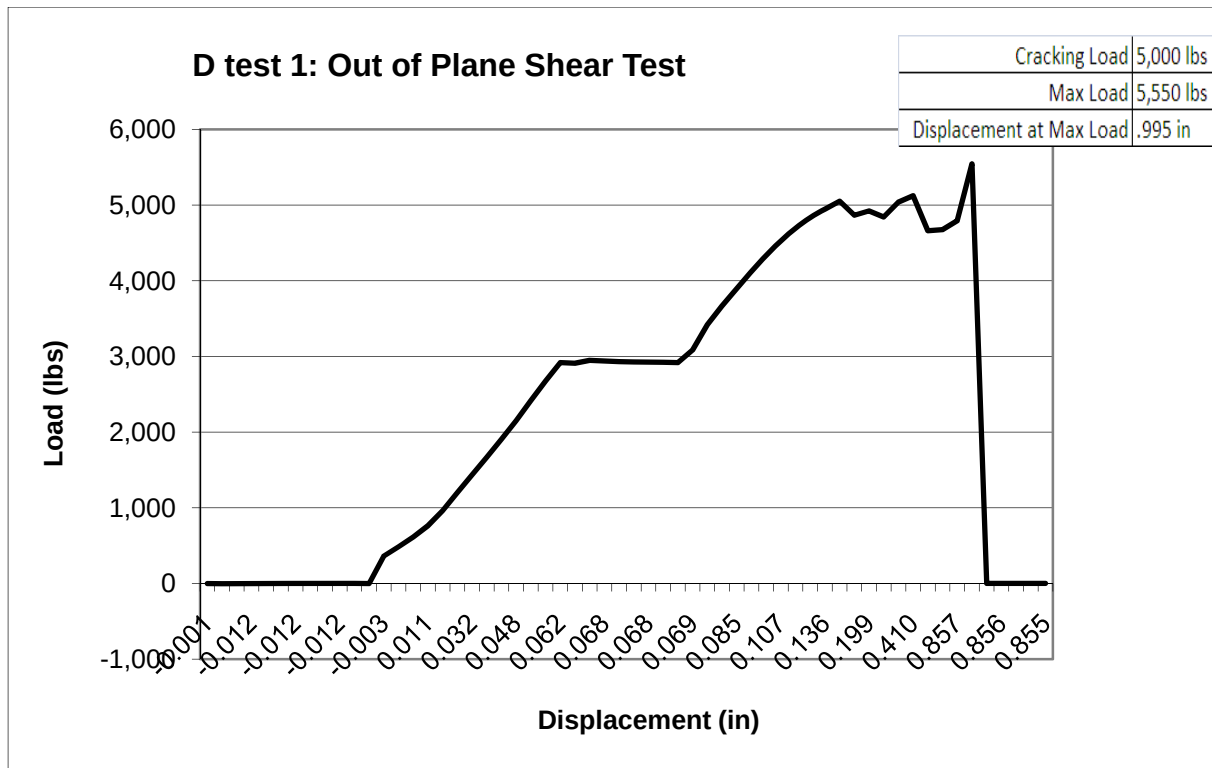


Figure 17

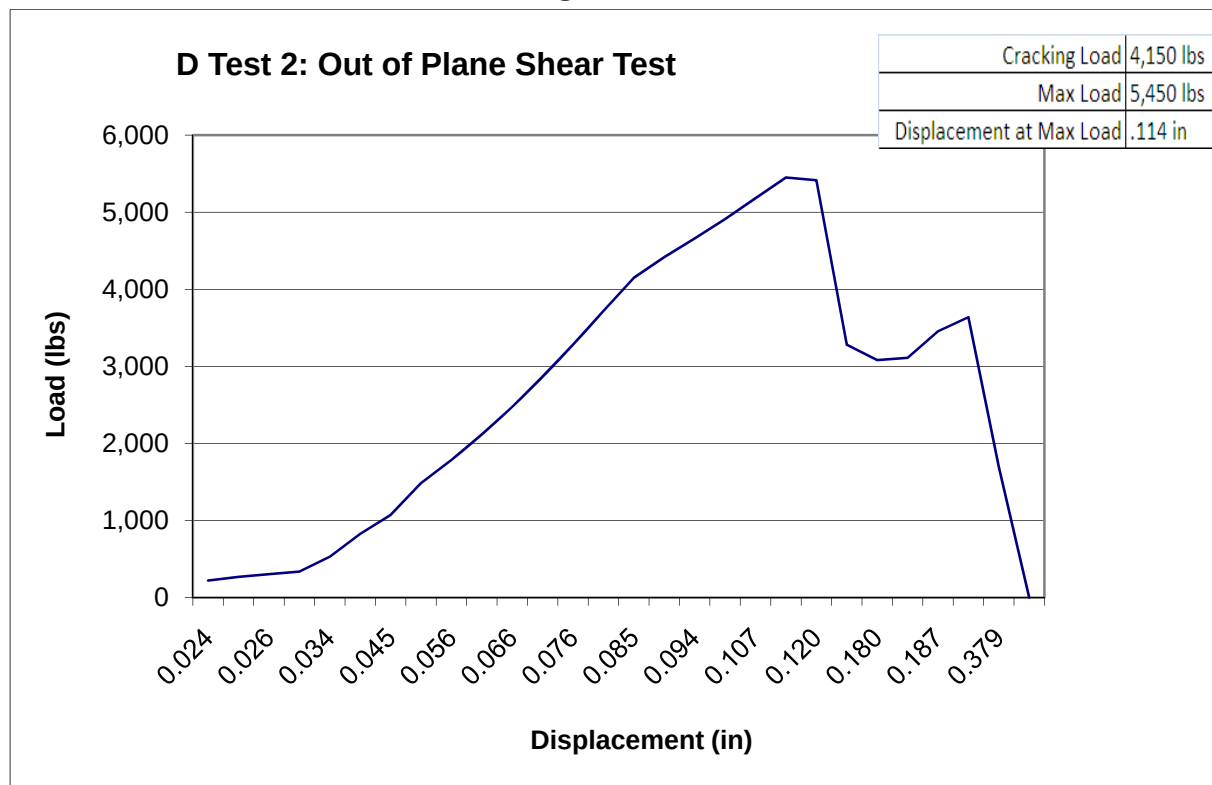


Figure 18

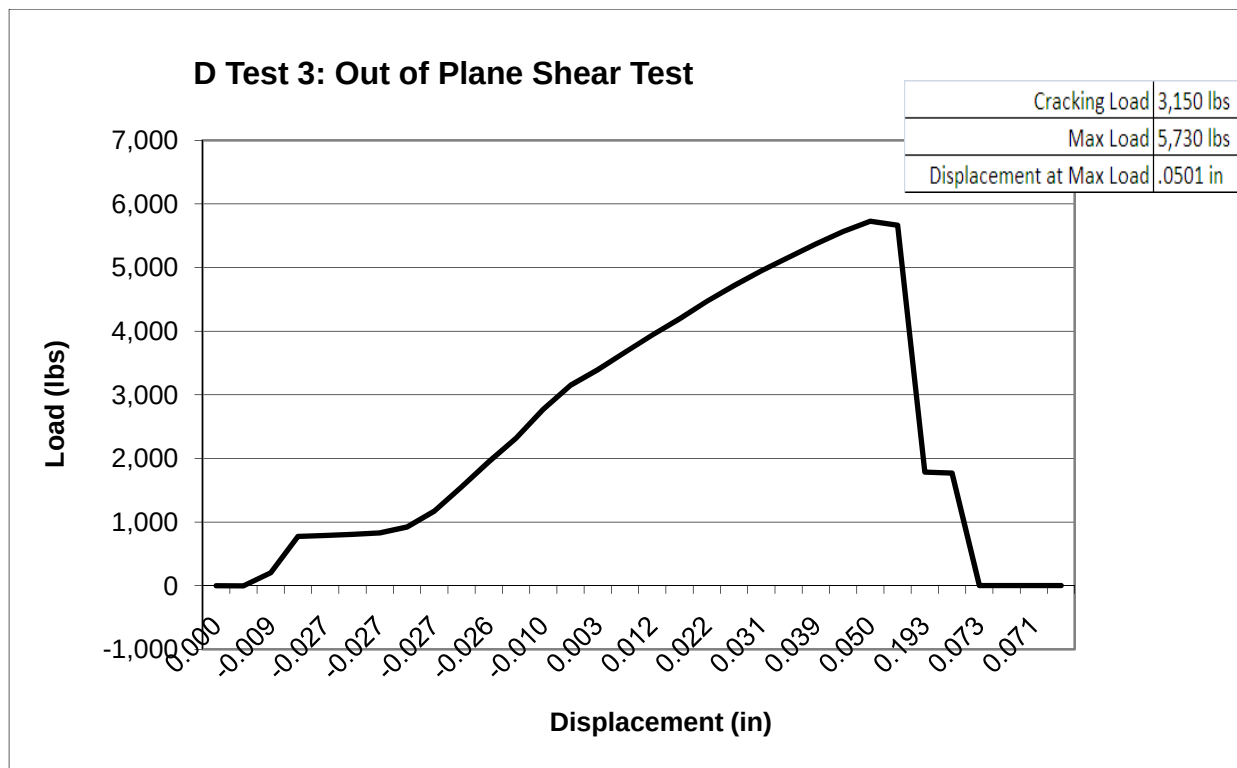


Figure 19

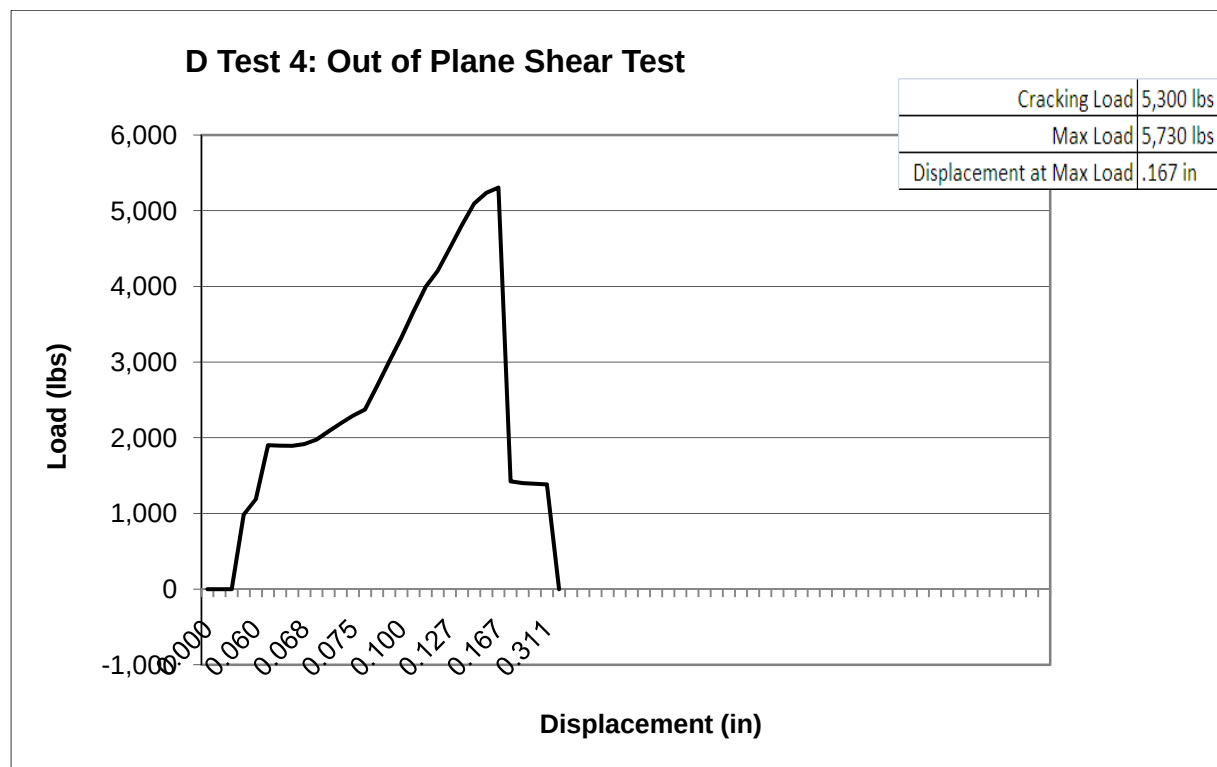


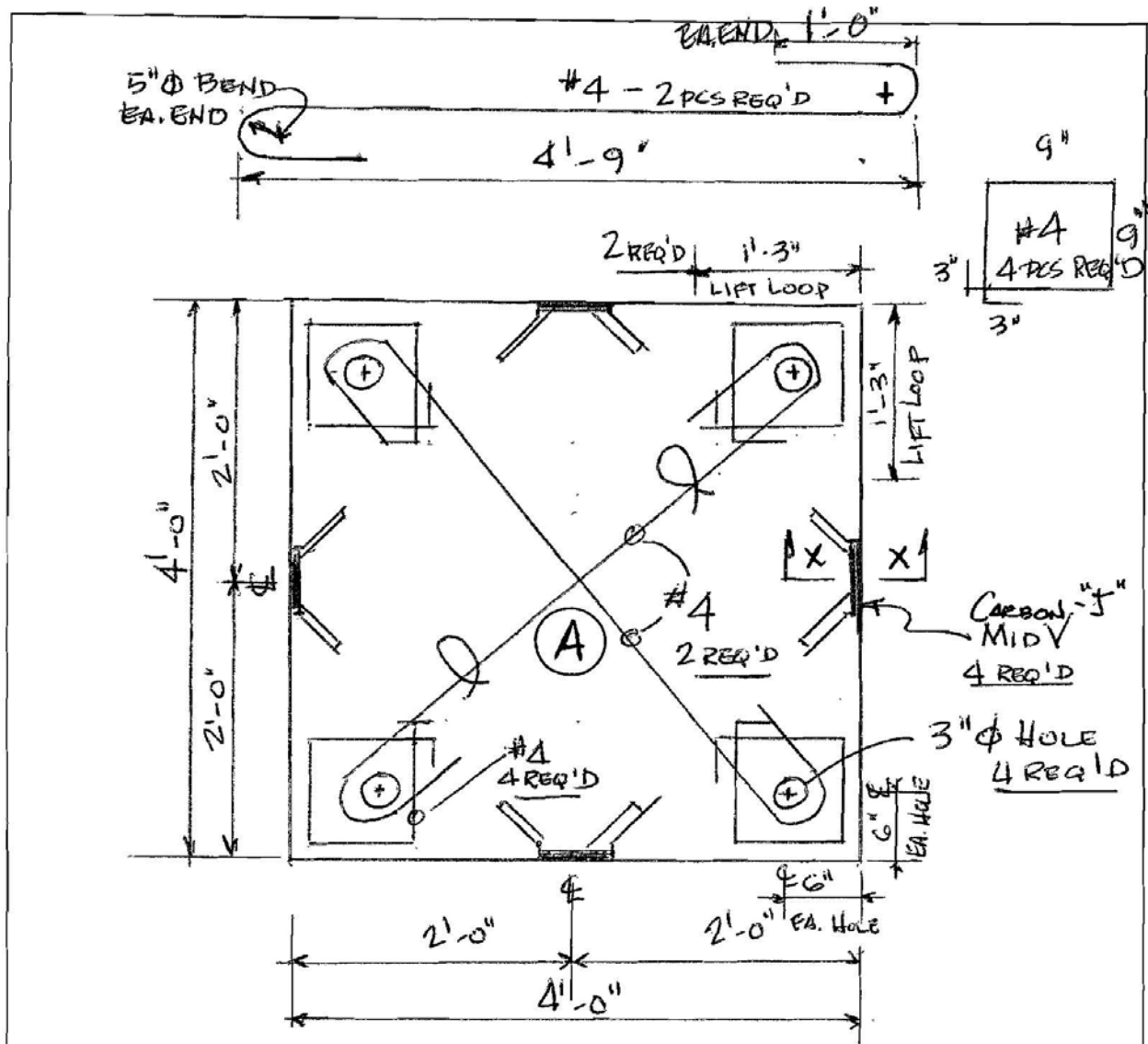
Figure 20

## **APPENDIX B**



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





# NOTES:

1. CONCRETE STRENGTH = 5000 psi @ 28 days
2. WEIGHT = 800#
3. FINISH = SMOOTH FLOAT
4. SLAB THICKNESS = 4"
5. NO MESH 6. MID V - Carbon w/ 'J' finish

**SLAB (A)**

**1 X REQUIRED**

SEE SHEET #2 for details



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

JVI TEST SLAB (A)  
for  
MID V

|           |         |              |                 |            |          |
|-----------|---------|--------------|-----------------|------------|----------|
| DRAWN<br> | CHECKED | SCALE<br>NTS | DATE<br>12/3/10 | SHEET<br>1 | DWG. NO. |
|-----------|---------|--------------|-----------------|------------|----------|

Figure 22 – Test Slab A reinforcing

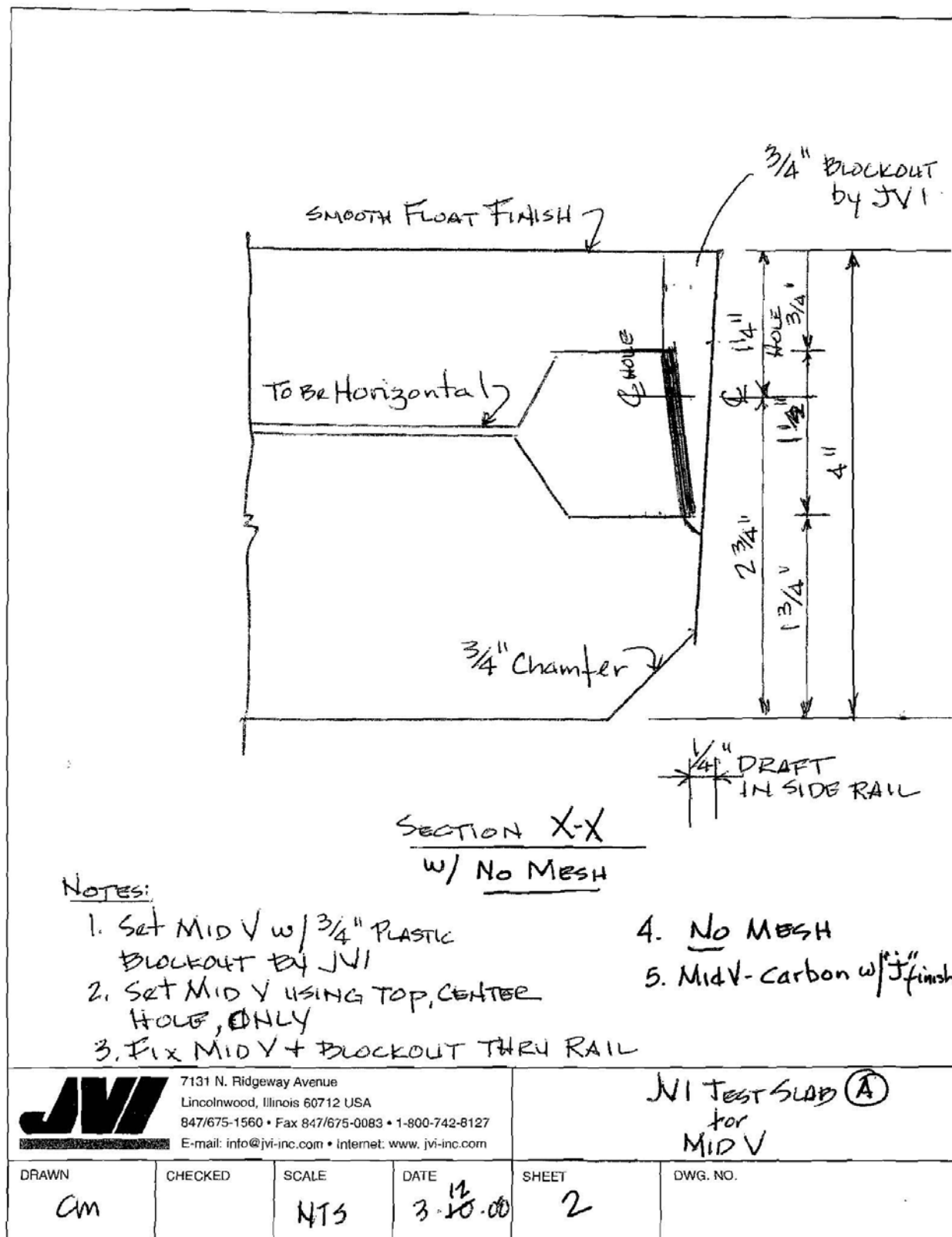
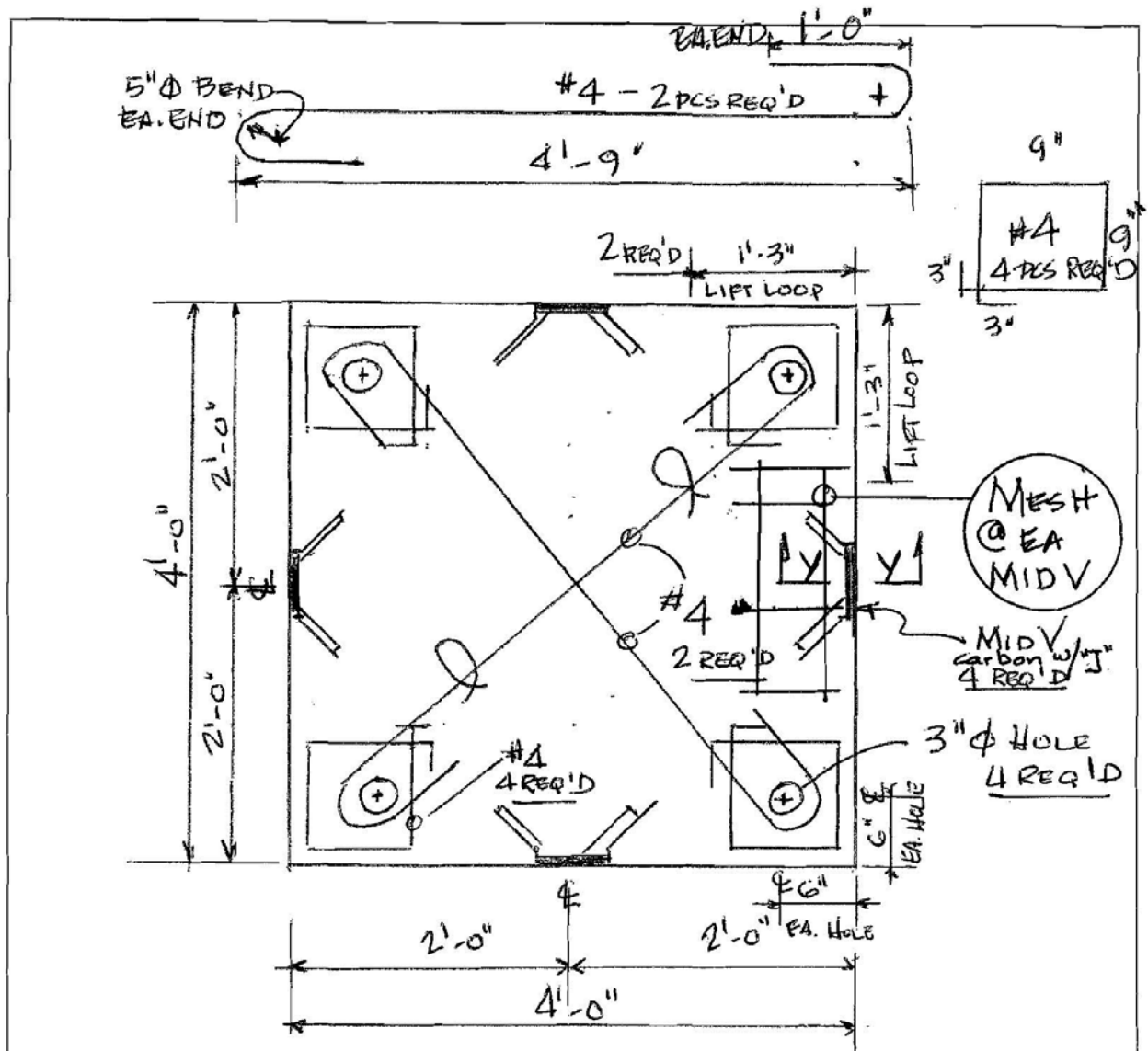


Figure 23 – Test A Details



#### NOTES:

1. CONCRETE STRENGTH = 5000 psi @ 28 days
2. WEIGHT = 800#
3. FINISH = SMOOTH FLOAT
4. SLAB THICKNESS = 4"
5. MESH REQ'D 2' x 2' @ MID V

SLAB (B)

1 REQUIRED

See Sheet #4 for details

6. Mid V - carbon w/ J finish

JVI TEST SLAB (B)  
for  
MID V



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

| DRAWN | CHECKED | SCALE | DATE         | SHEET | DWG. NO. |
|-------|---------|-------|--------------|-------|----------|
|       |         | NTS   | 12<br>3-8-10 | 3     |          |

Figure 24 – Test Slab B reinforcing

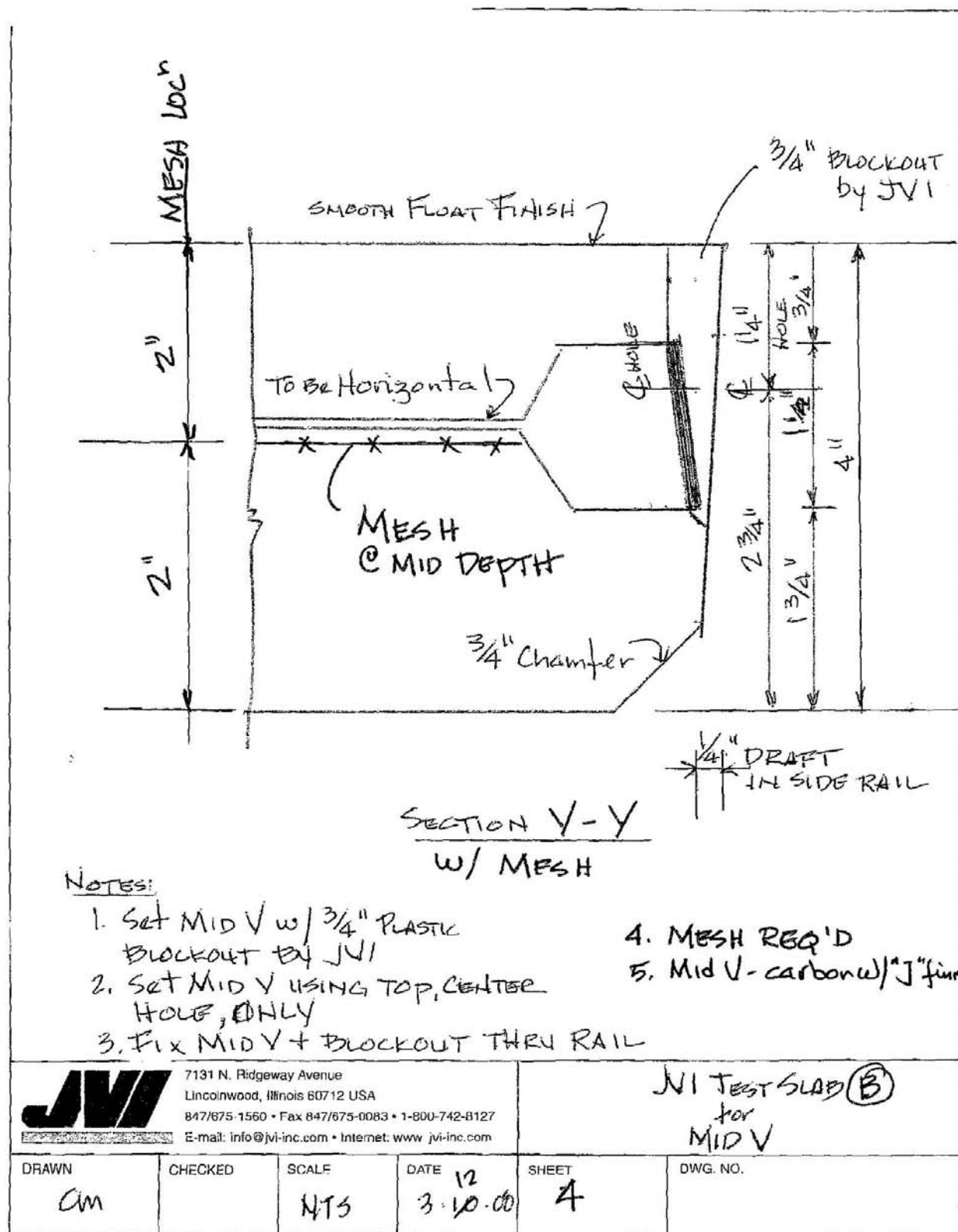
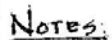


Figure 25 – Test Slab B Details



- SLAB (C)  
↓ REQUIRED



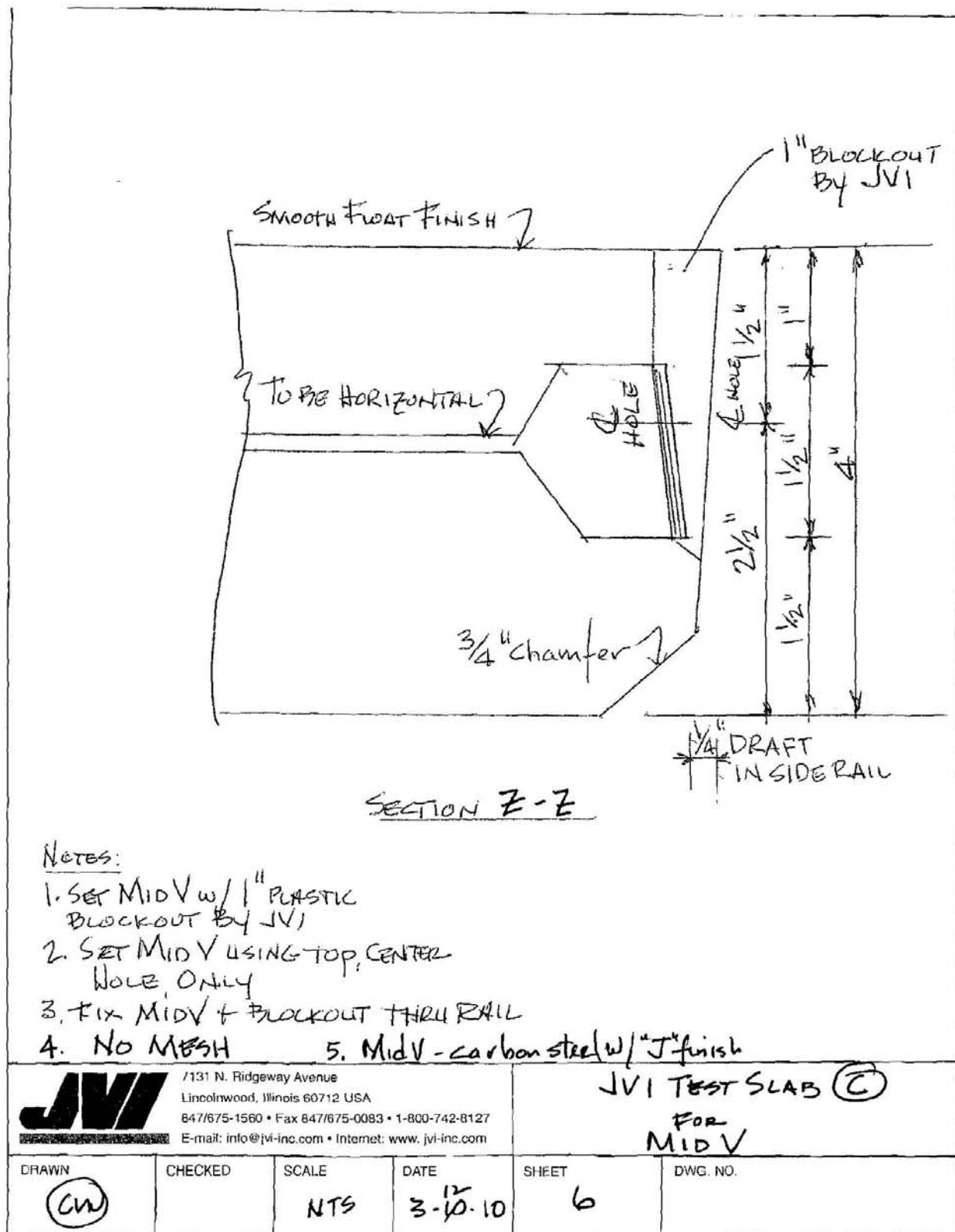


Figure 27 – Test Slab C Details



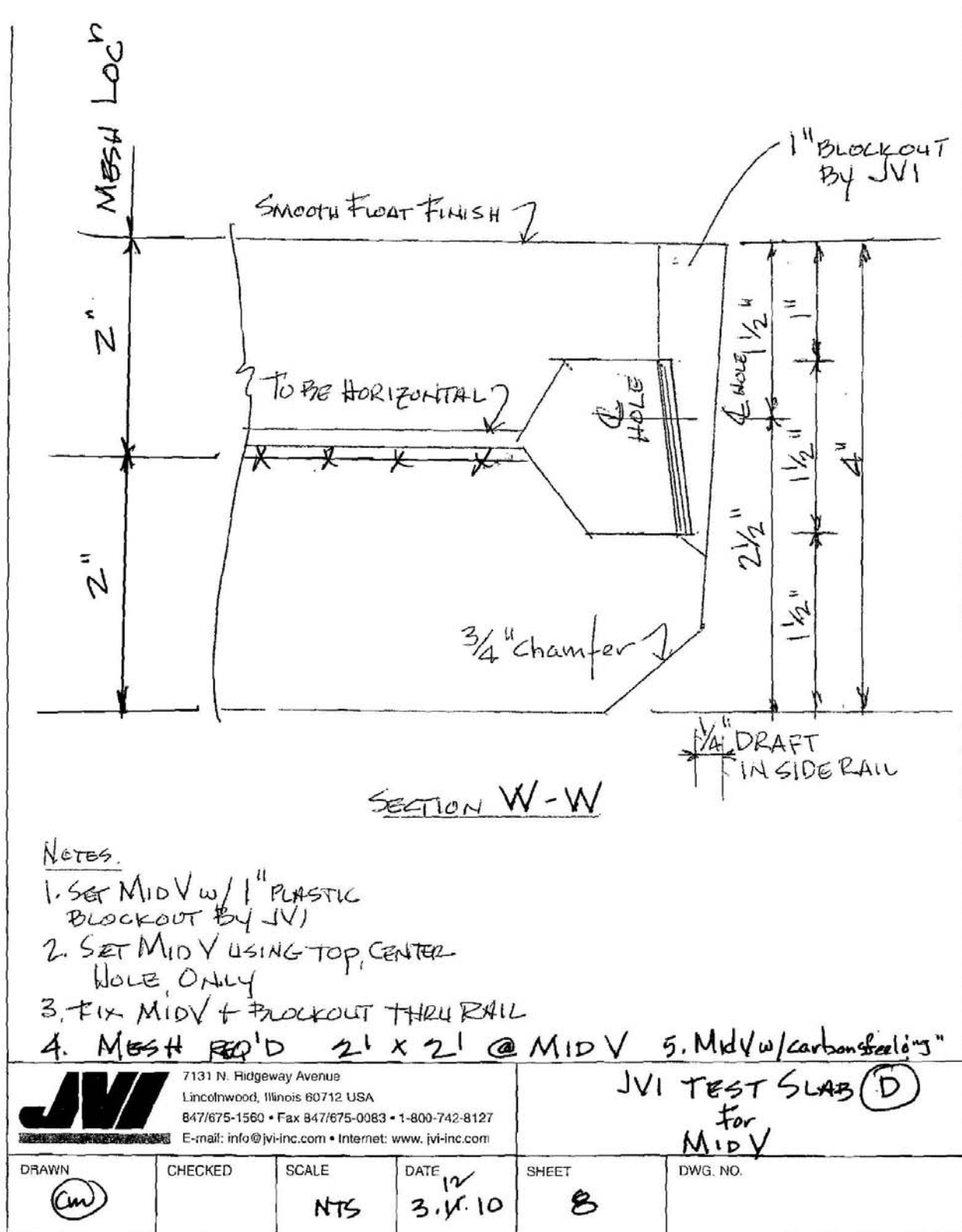


Figure 29 – Test Slab D Details

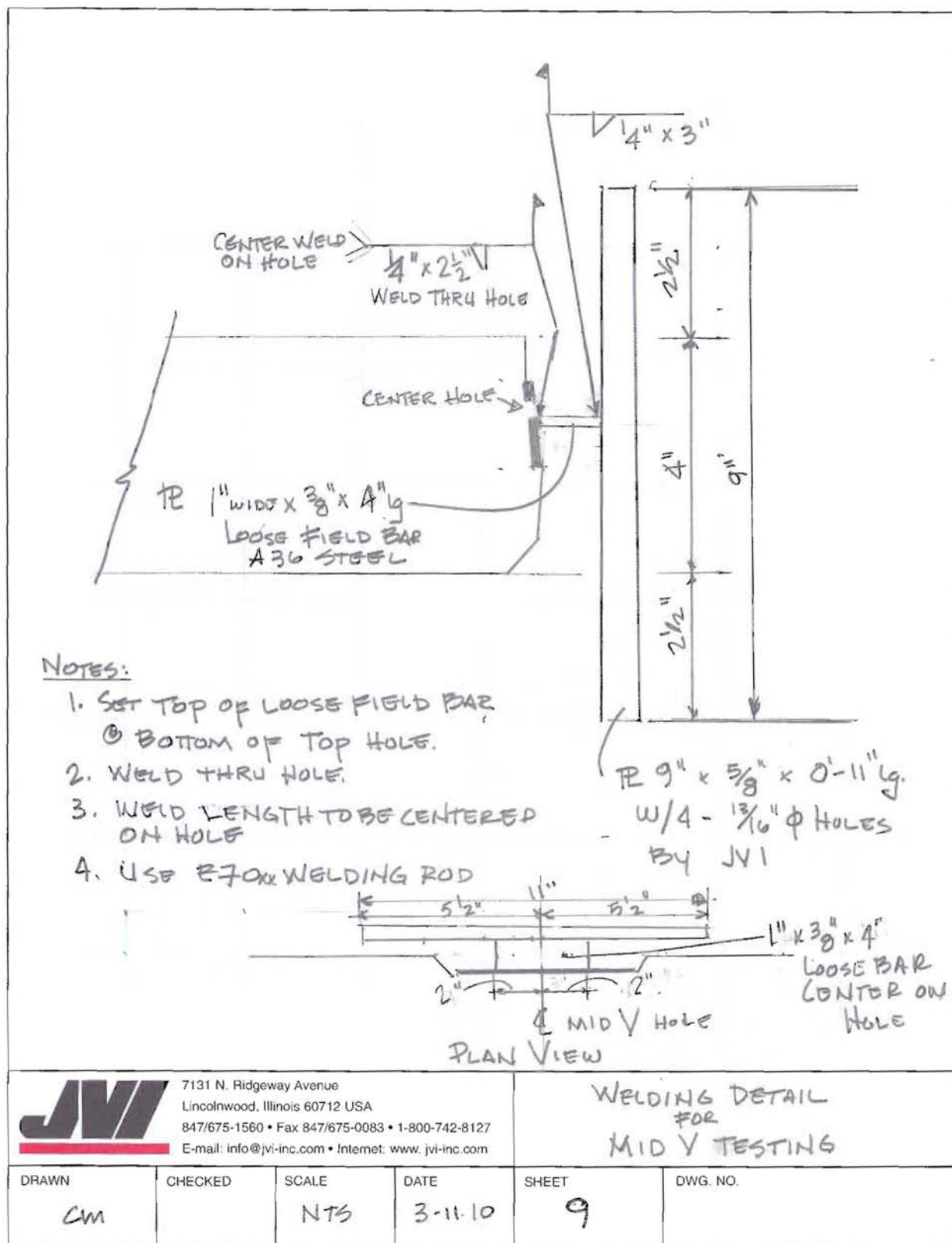


Figure 30 – Welding Detail



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

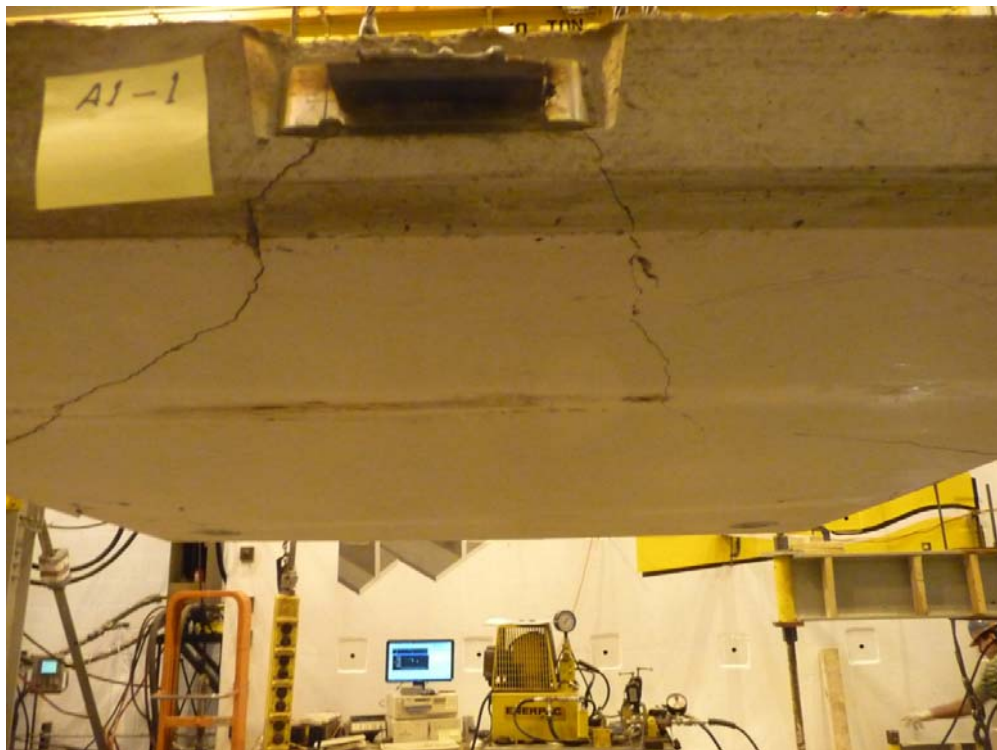


Figure 32 – Test A1-1 Failure Mode – bottom side view





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

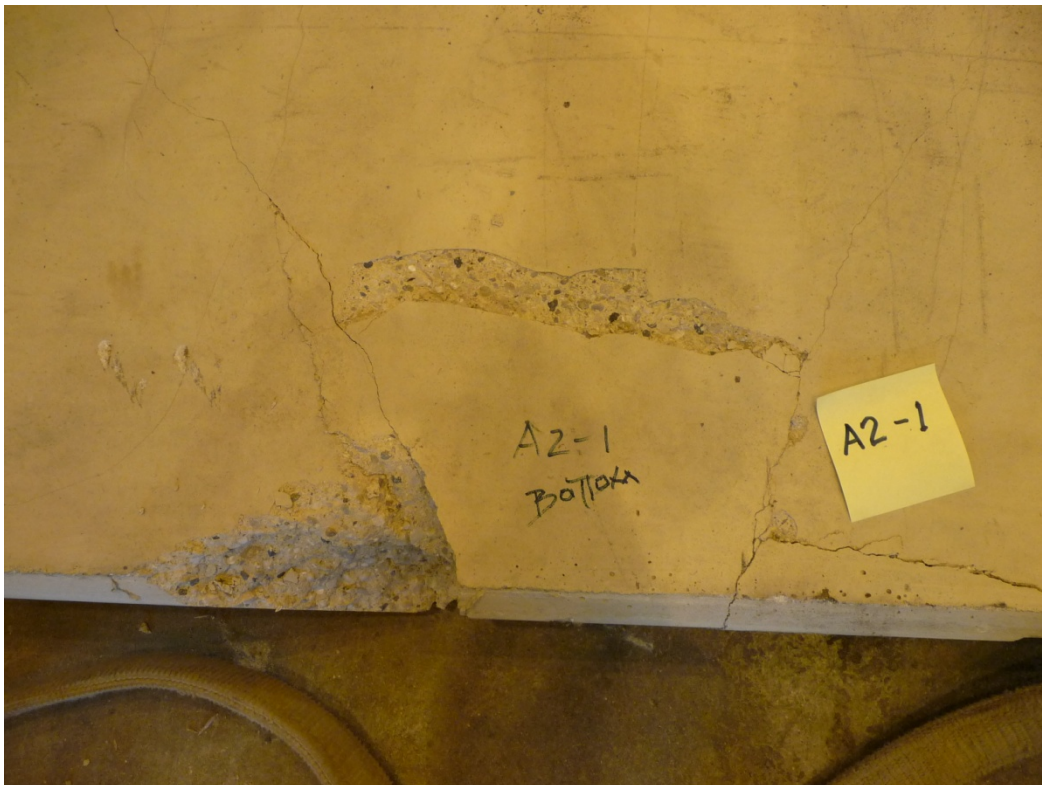


Figure 40 – Test A2-1 Failure Mode – bottom side view

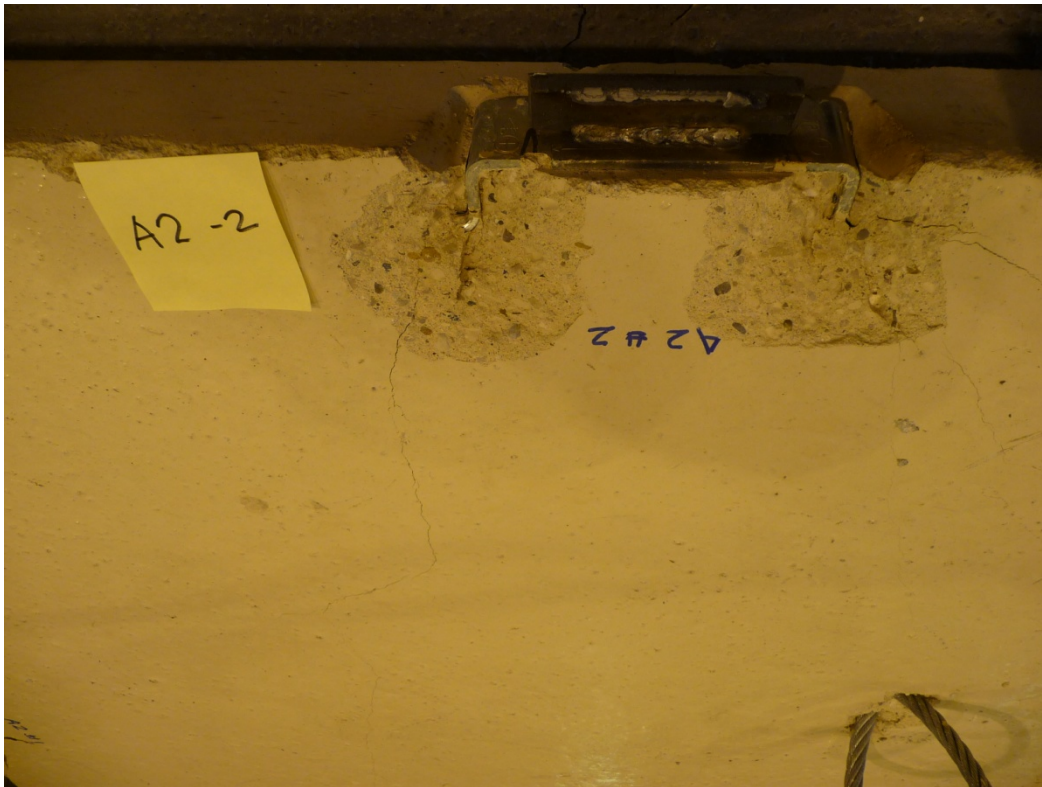


Figure 41 – Test A2-2 Failure Mode – top side view



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





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

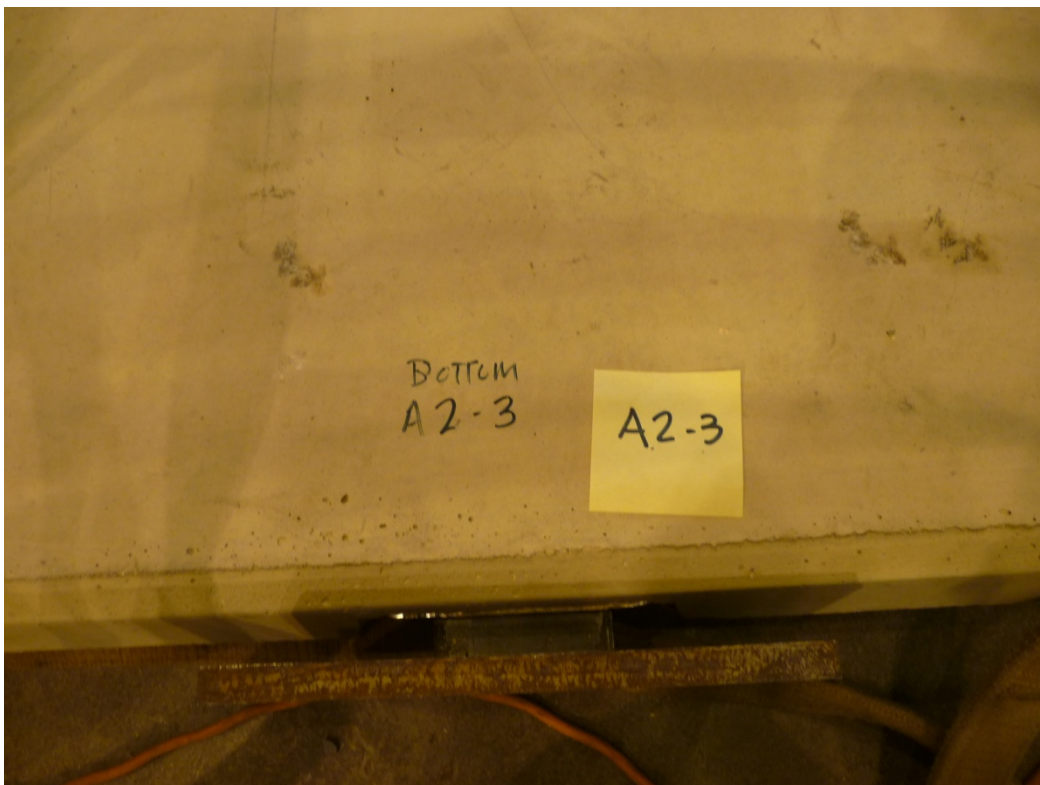


Figure 44 – Test A2-3 Failure Mode – bottom side view



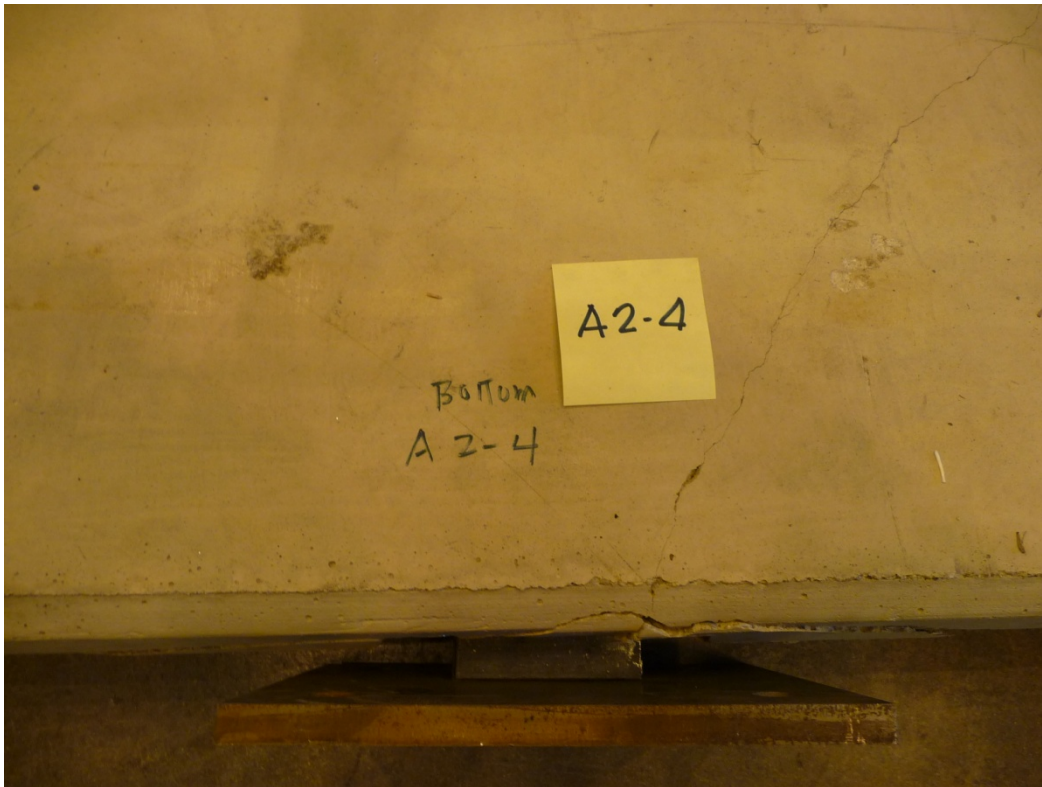


Figure 45 – Test A2-4 Failure Mode – top side view



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

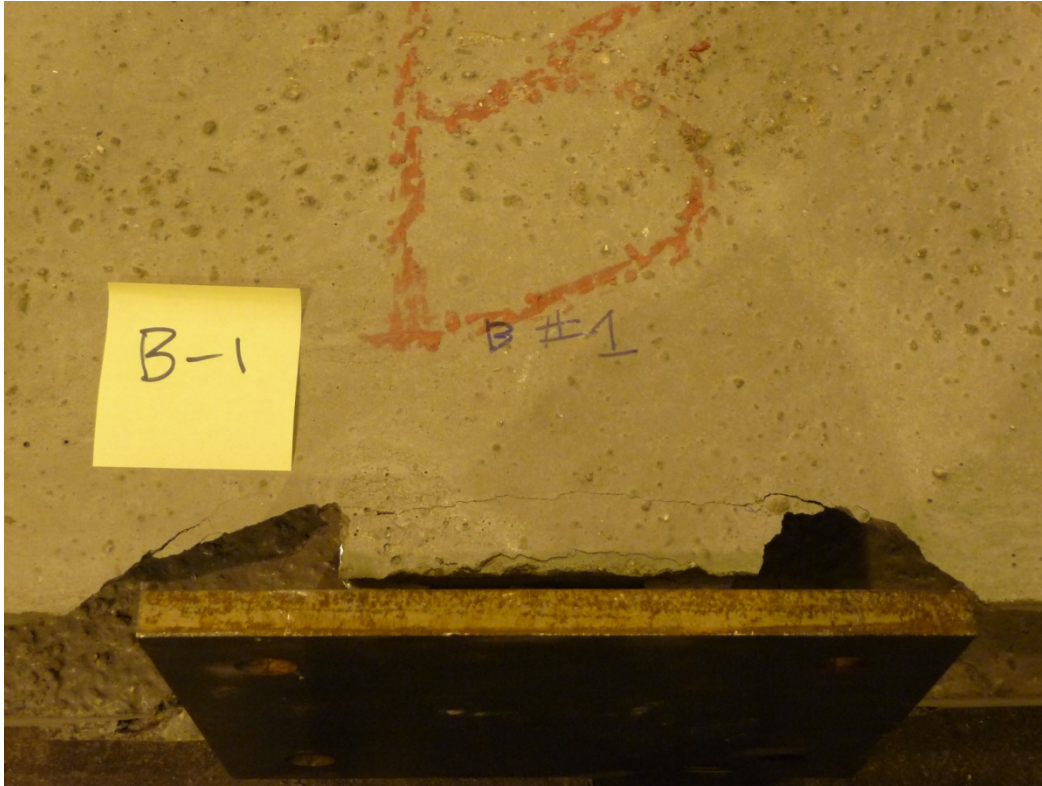


Figure 47 – Test B-1 Failure Mode – top side view

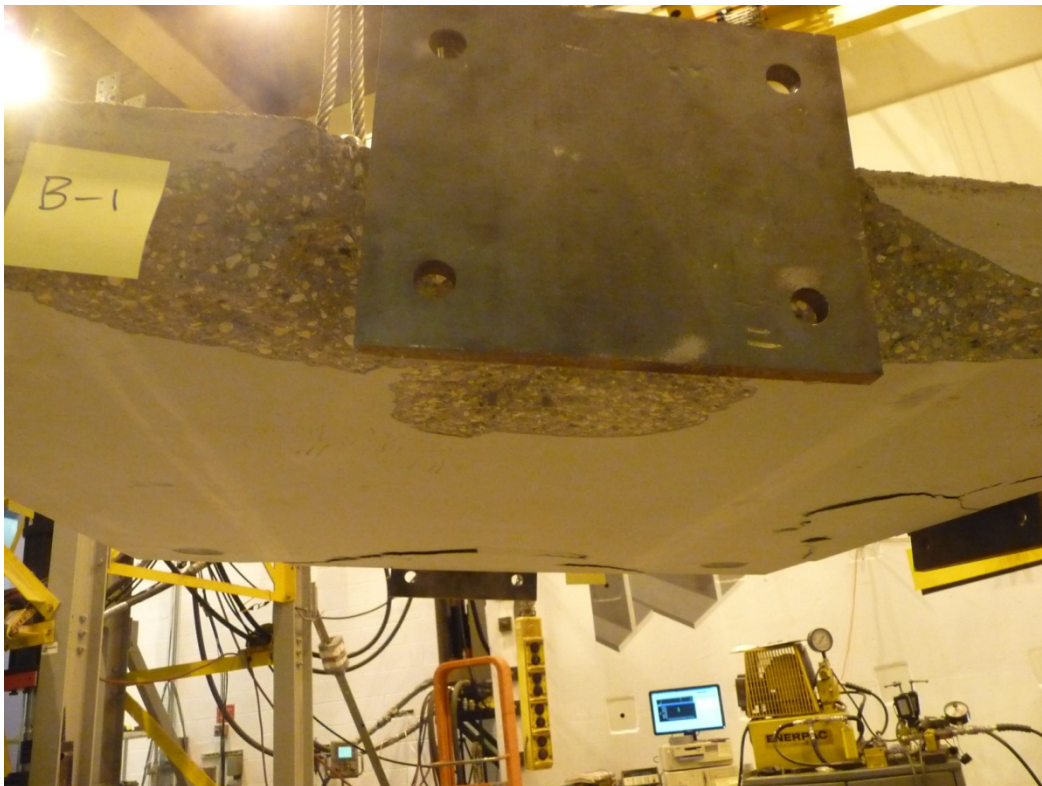


Figure 48 – Test B-1 Failure Mode – bottom side view



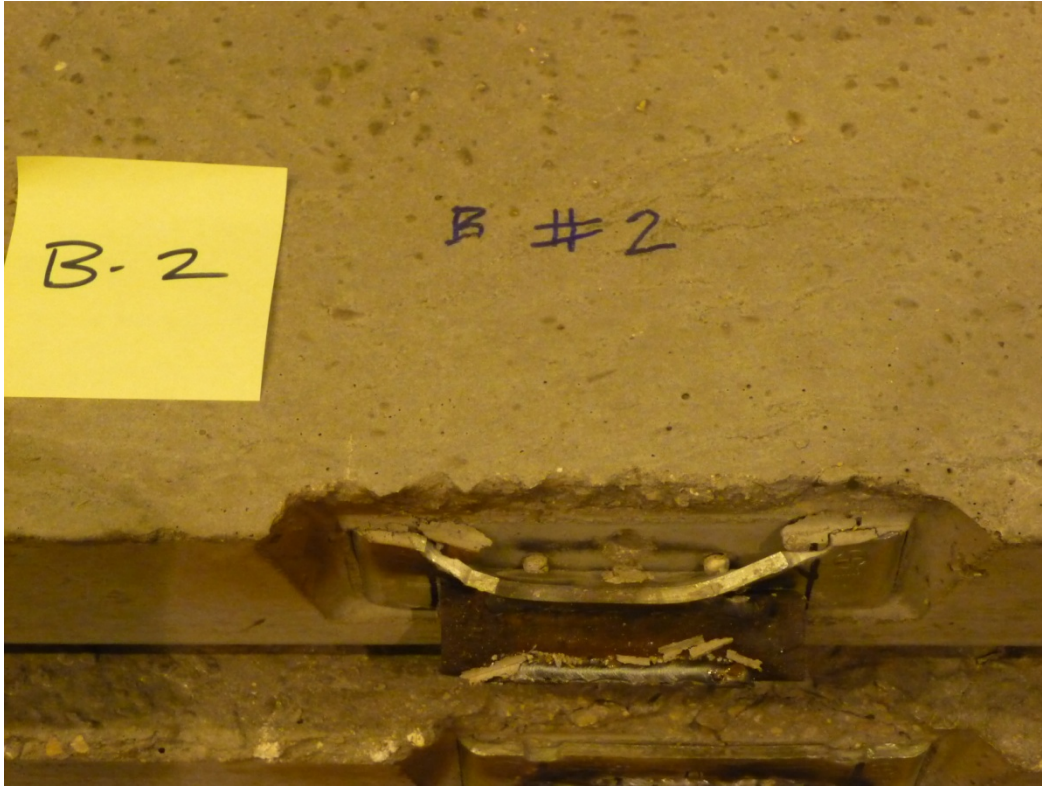


Figure 49 – Test B-2 Failure Mode – top side view



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

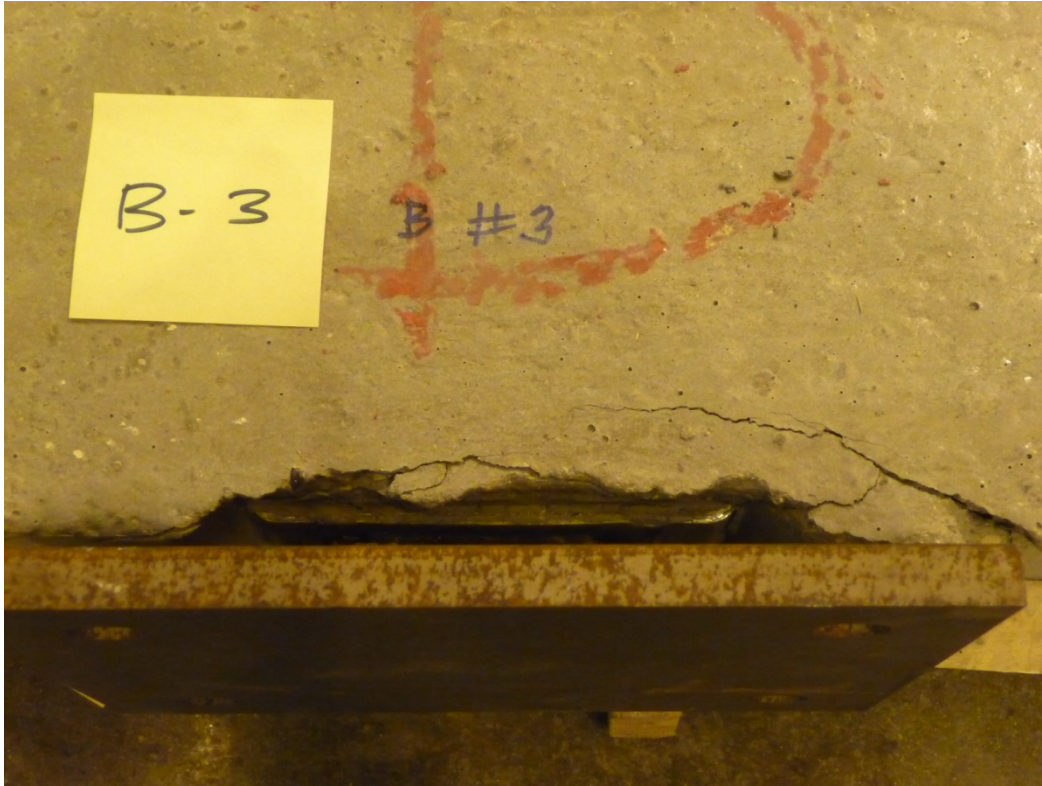


Figure 51 – Test B-3 Failure Mode – top side view



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



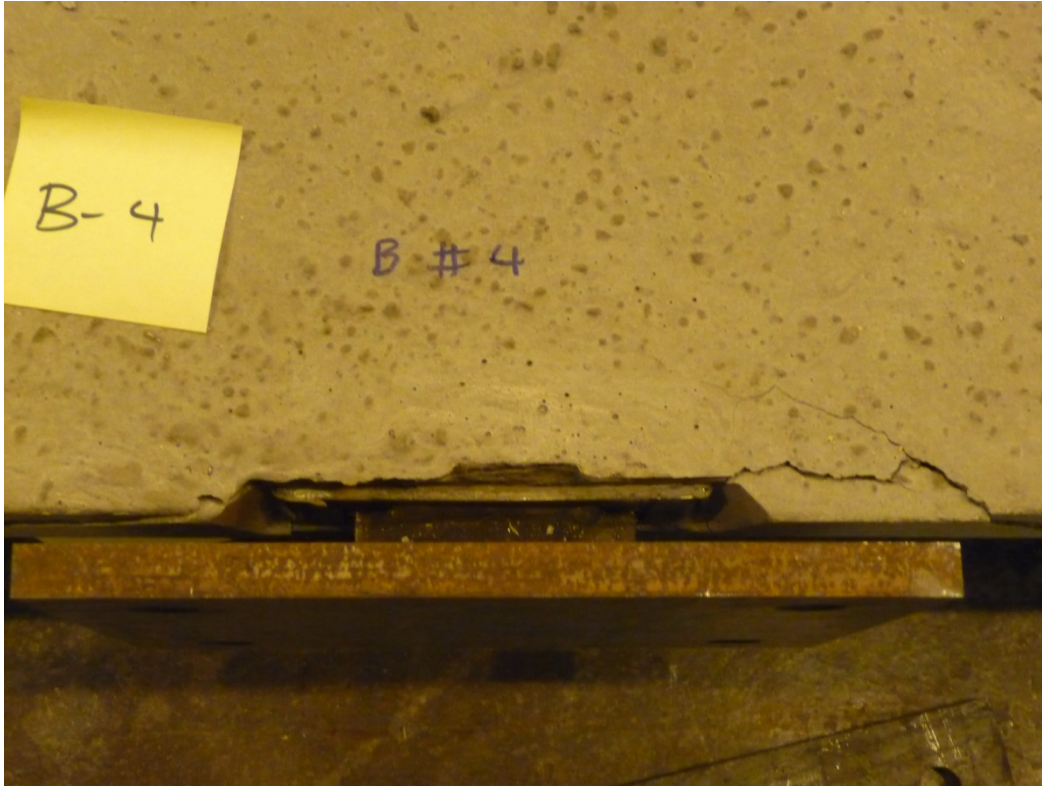


Figure 53 – Test B-4 Failure Mode – top side view



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

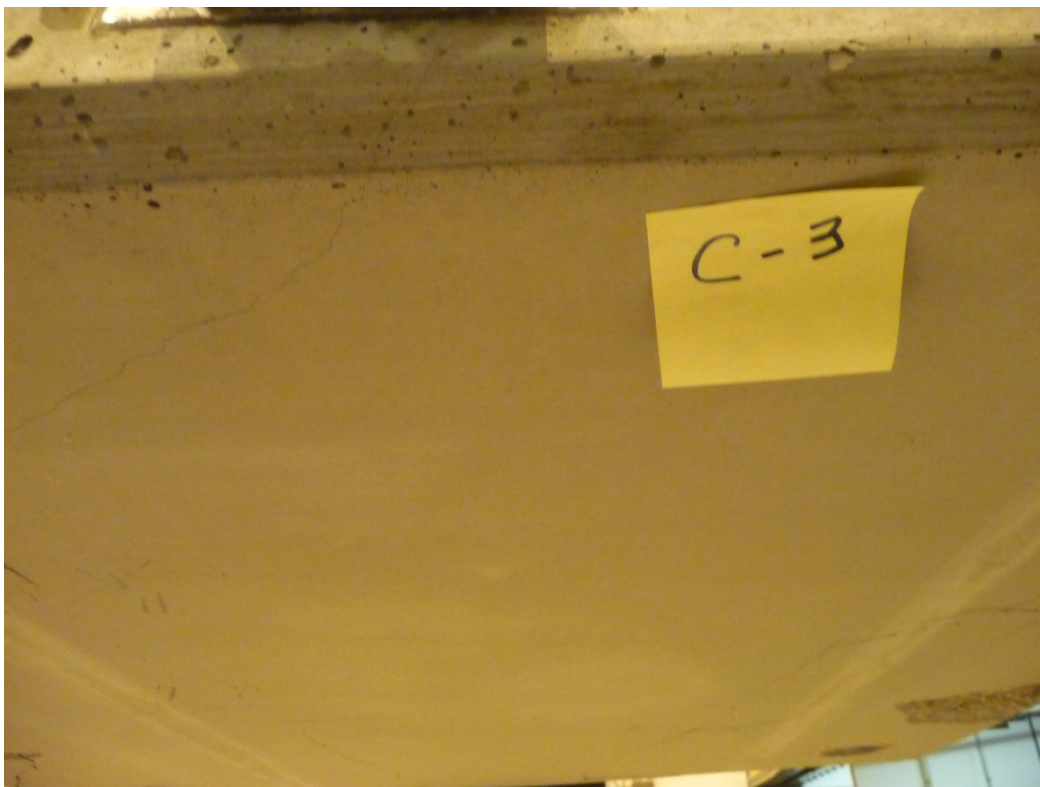


Figure 60 – Test C-3 Failure Mode – bottom side view



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



## Testing of the JVI Vector Connector 4 in 4" Slabs

Report No. 113012  
January, 2013

by

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Professor of Structural Engineering, and  
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### 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](http://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<br>& 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 &<br>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.

| <b>VC4 Mark #</b>                                                                                       | <b>VC Type</b> | <b>Gusset Stiffener at Corner</b> | <b>Material</b>          | <b>VC4 Center Faceplate Height (in.)</b> | <b>VC4 Left Corner Height (in.)</b> | <b>VC4 Right Corner Height (in.)</b> | <b>Loading Method</b> |
|---------------------------------------------------------------------------------------------------------|----------------|-----------------------------------|--------------------------|------------------------------------------|-------------------------------------|--------------------------------------|-----------------------|
| 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**



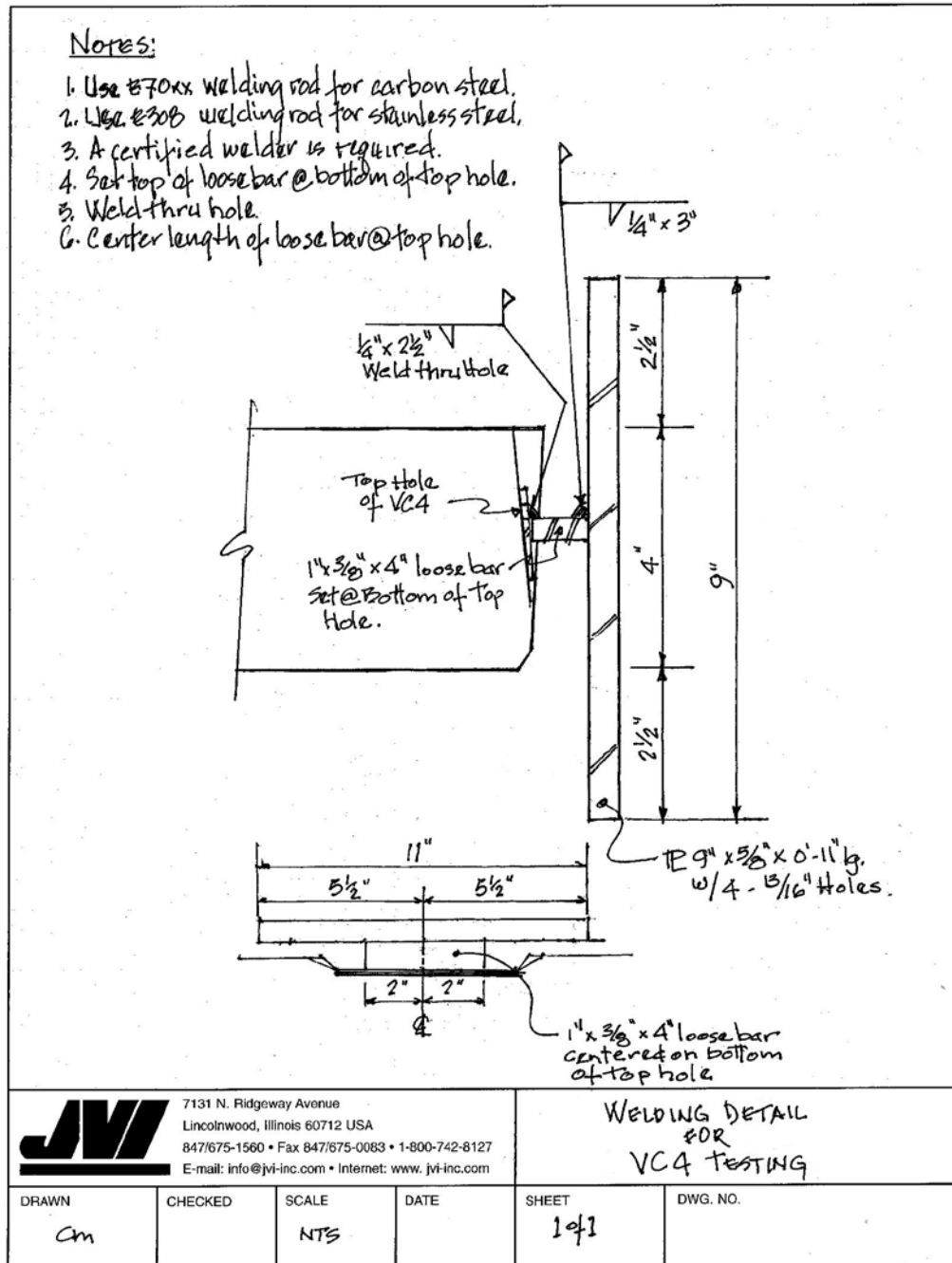
**VC4 without Gusset**

## 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 1/4" fillet x 2 1/2" 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.

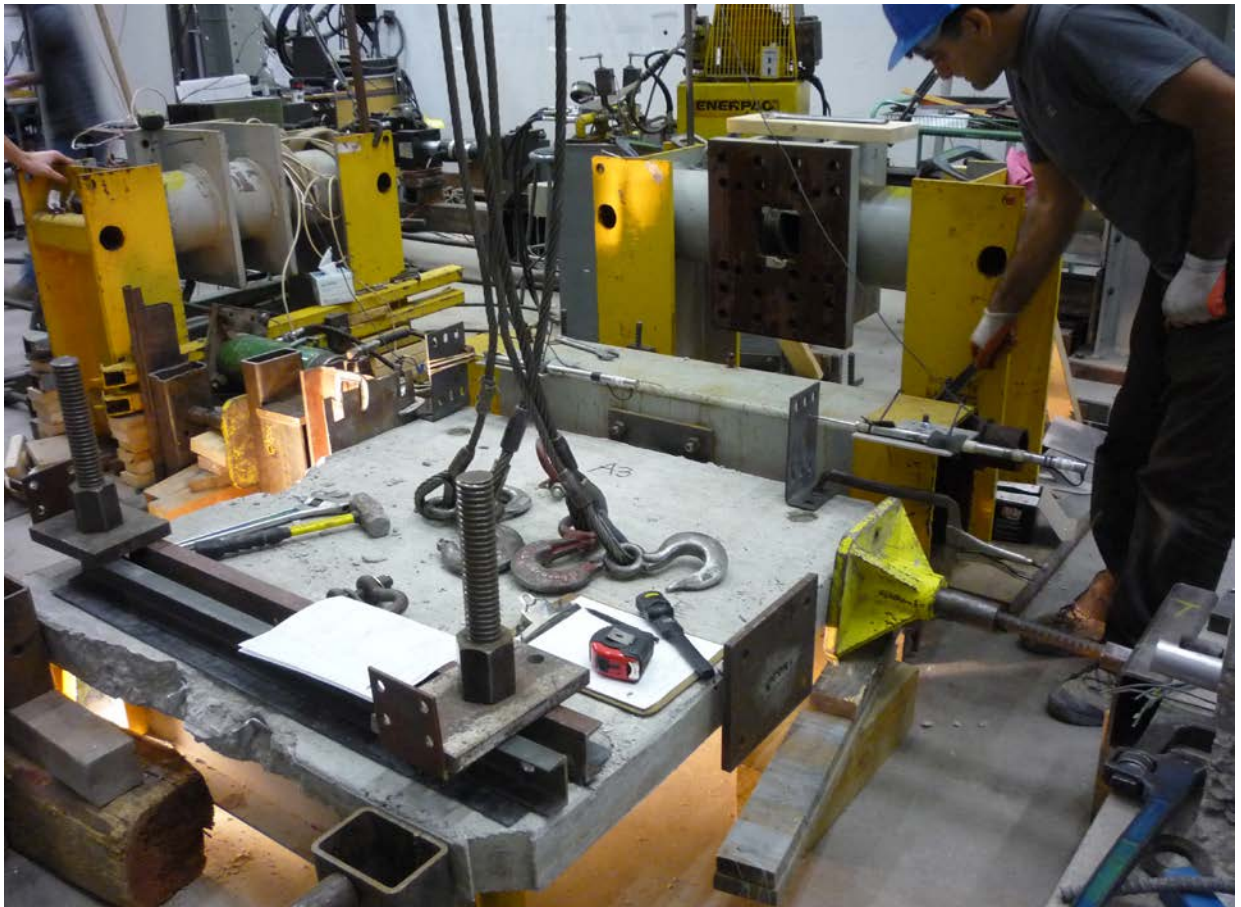
### **Monotonic Horizontal Shear without Tension**

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               | Concrete 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"              | Concrete failure, leg pullout on tension side                                                                                                                                                                                                                    |
| C4                                                                                                                                                                                                               | 11/30/12  | N              | 18,420                | 14,981                     | 1.00                     | 7,400             | 1.420"              | Concrete failure, leg pullout on tension side                                                                                                                                                                                                                    |
| D2                                                                                                                                                                                                               | 11/30/12  | N              | 19,525                | 20,171                     | 0.90                     | 7,000             | 1.440"              | Concrete failure, leg pullout on tension side                                                                                                                                                                                                                    |
| D4                                                                                                                                                                                                               | 11/30/12  | N              | 20,637                | 18,702                     | 0.92                     | 8,700             | 1.520"              | Concrete failure, leg pullout on tension side                                                                                                                                                                                                                    |
| Cyclic Shear with No Tension, VC4 with Gusset in corner, 1" Blockout, Grade 045 XLF Carbon<br>(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<br>(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<br>(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<br>(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**

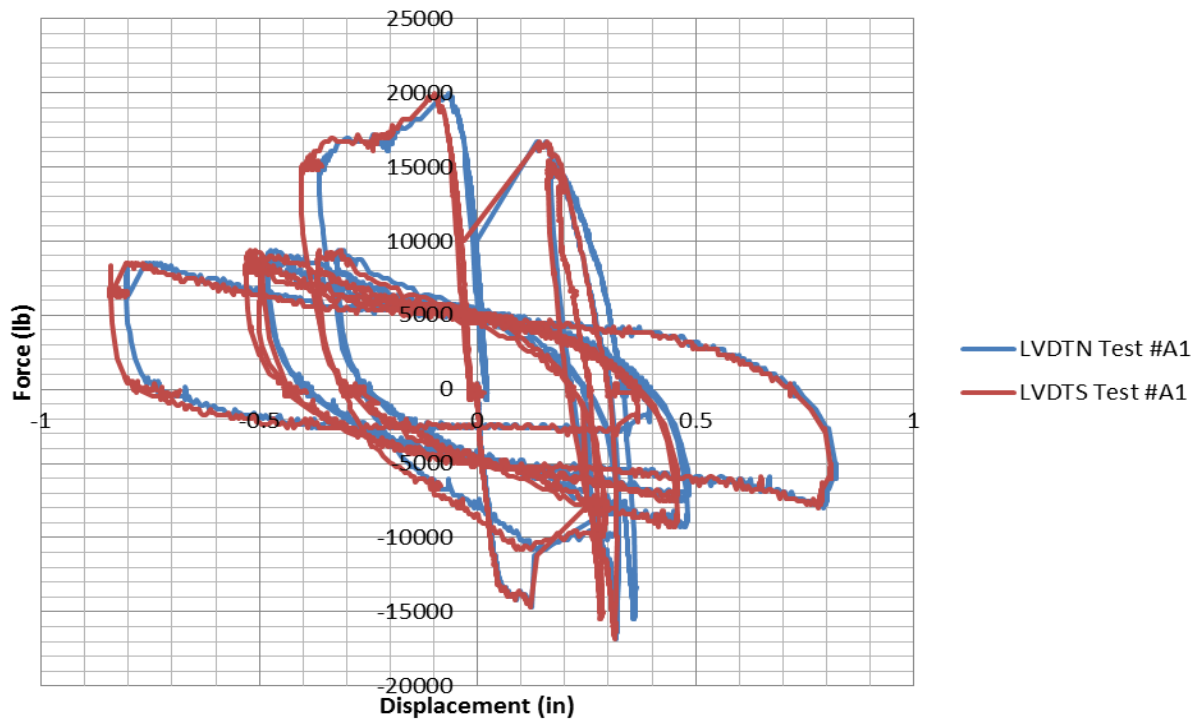
## **ACKNOWLEDGEMENT**

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.

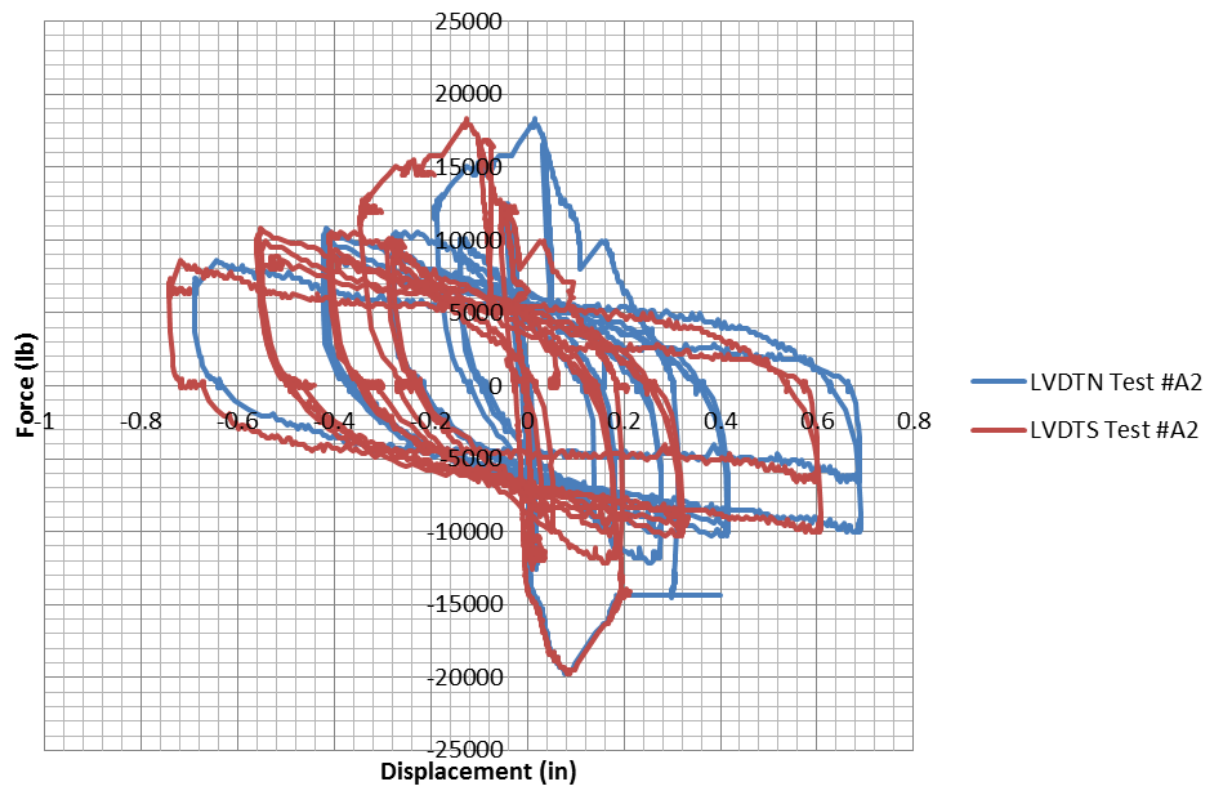
# **APPENDIX A**



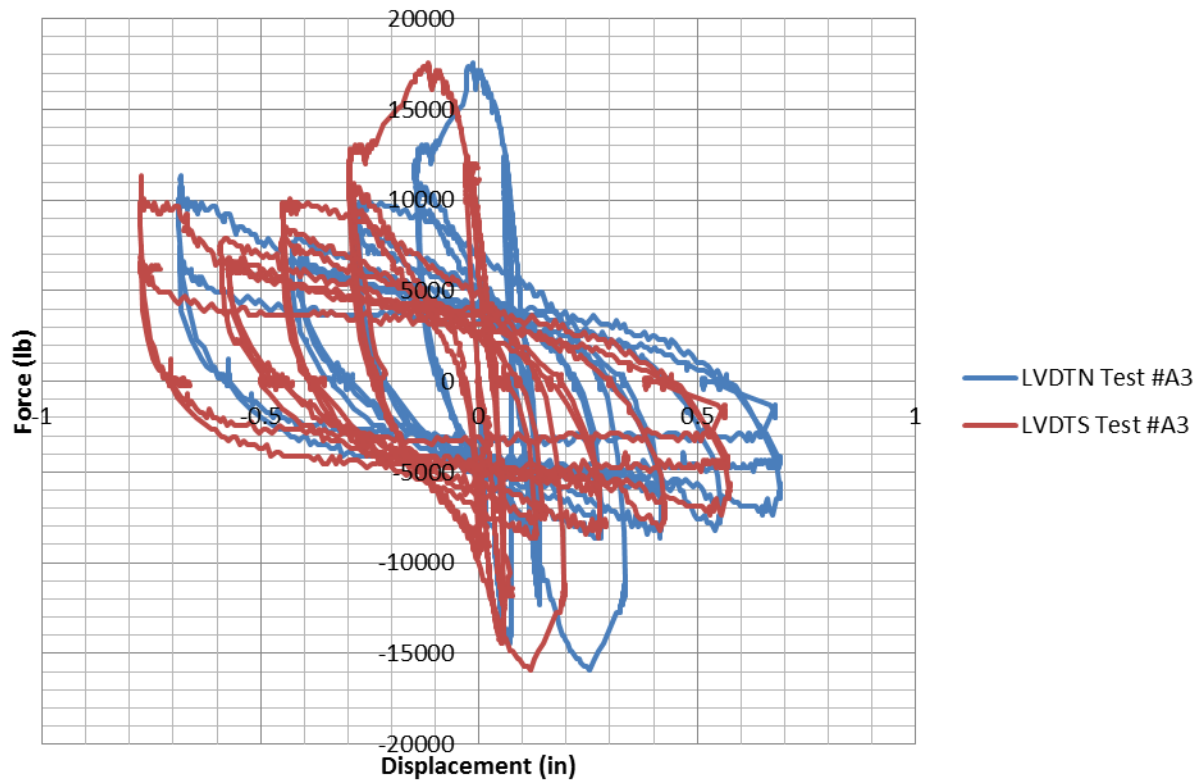
### LVDTN & LVDTs Test #A1



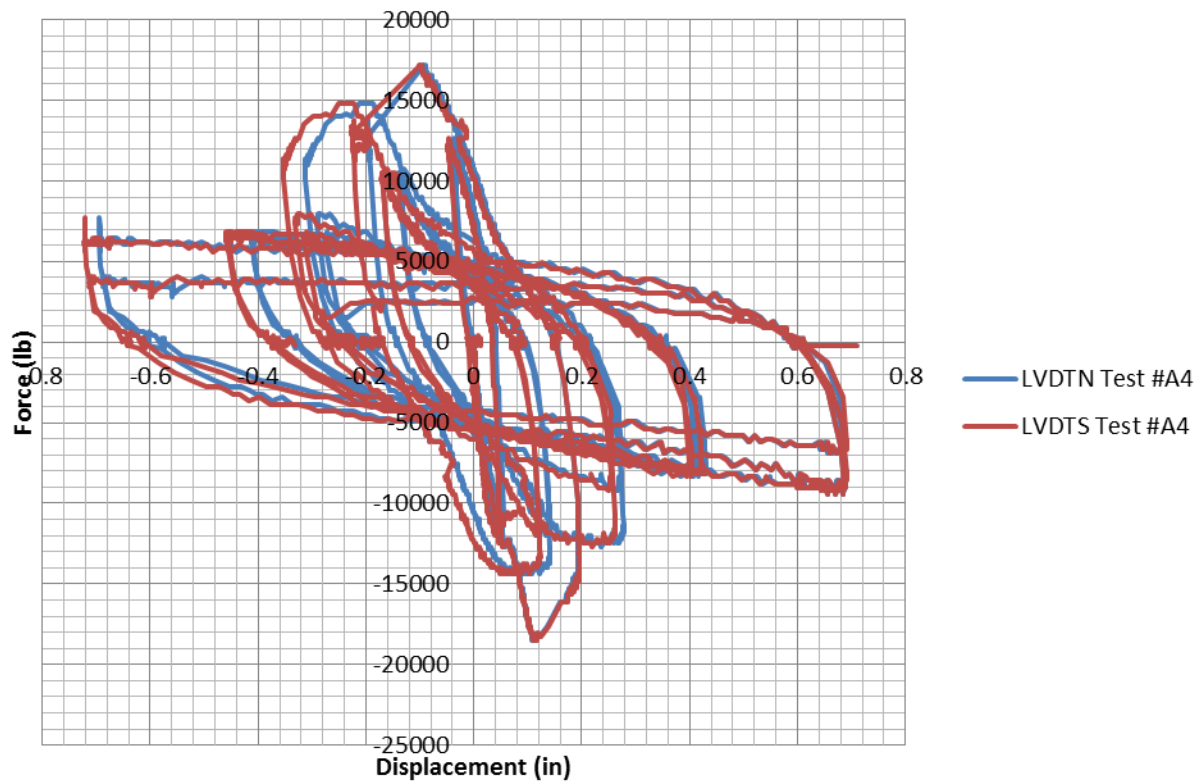
### LVDTN & LVDTs Test #A2



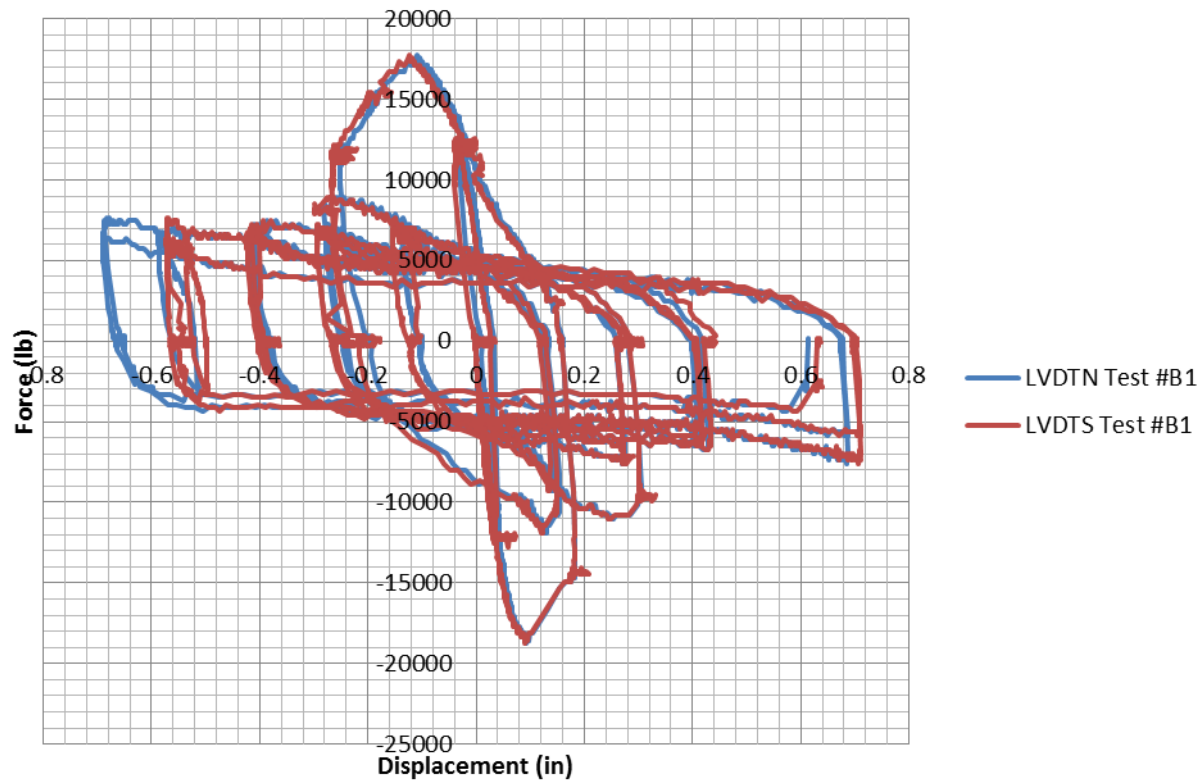
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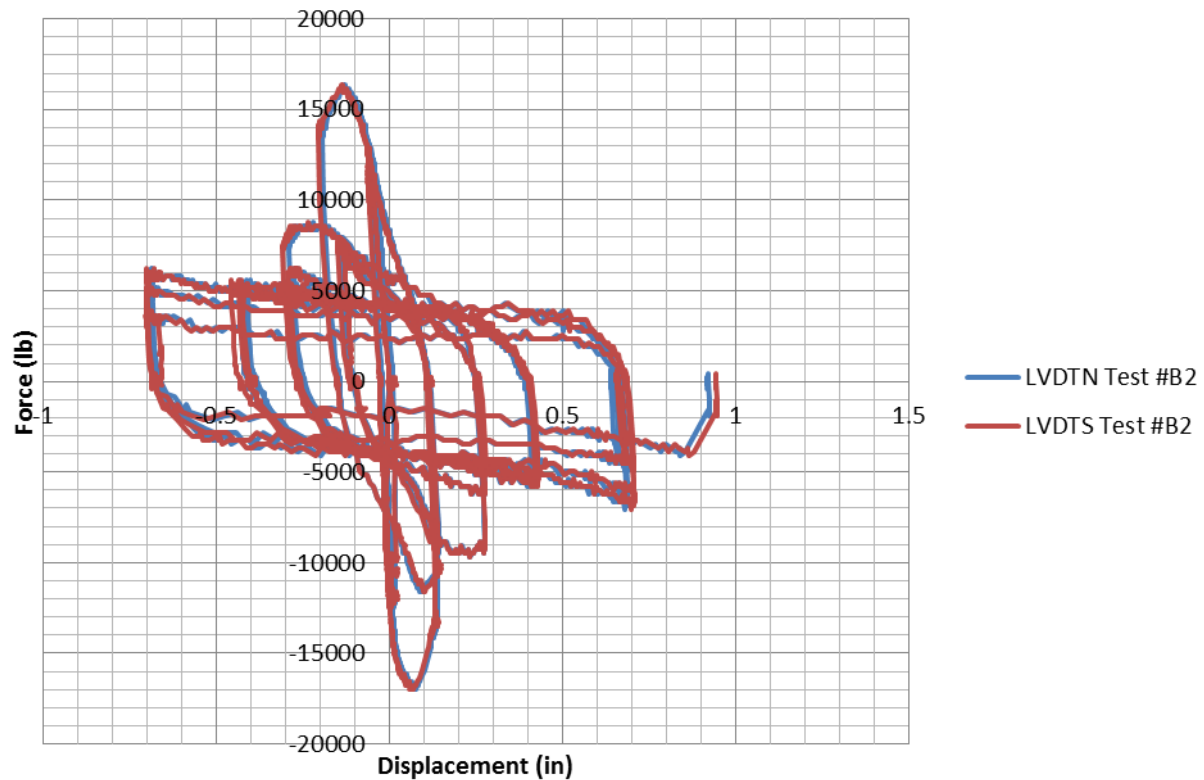
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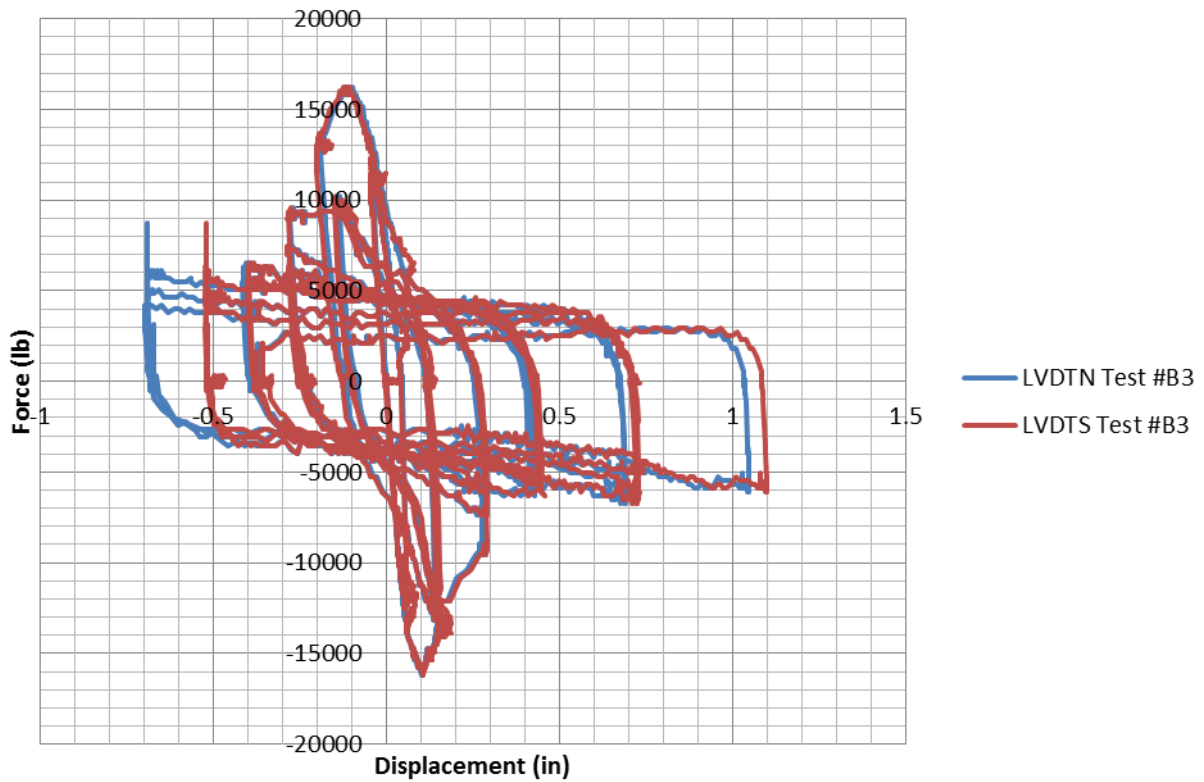
## LVDTN & LVDTs Test #B1



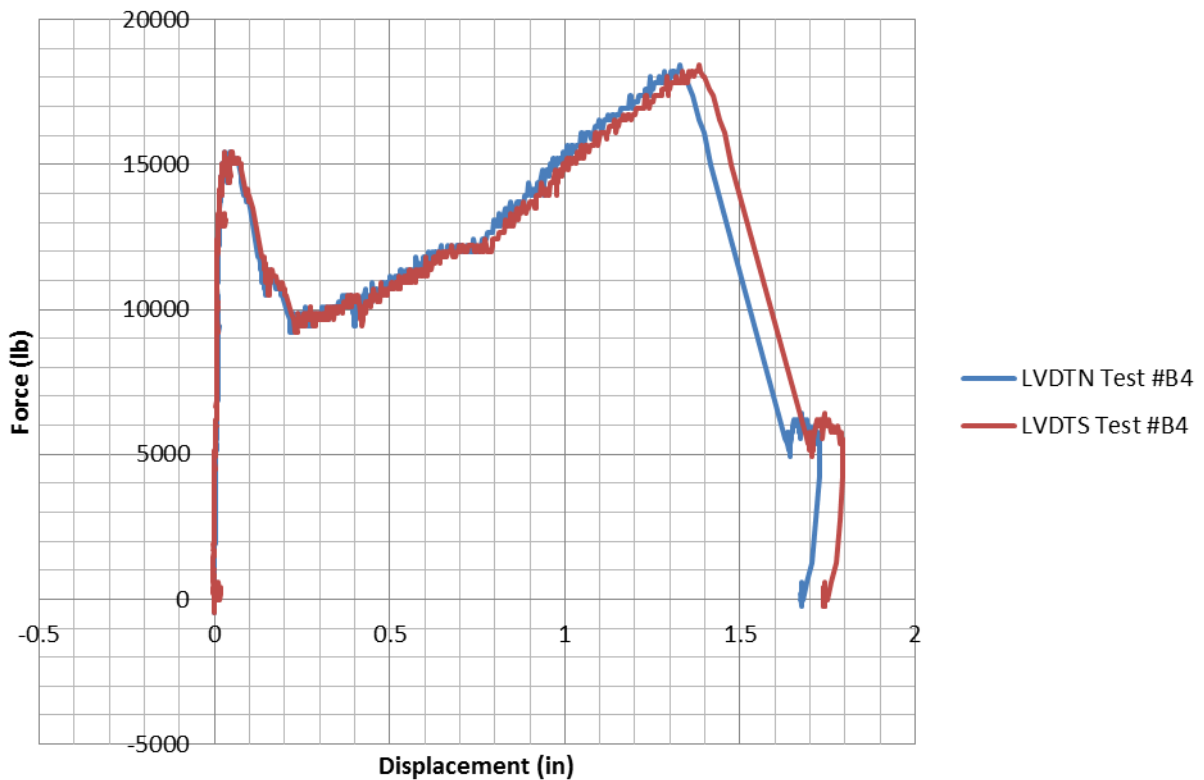
## LVDTN & LVDTs Test #B2



### LVDTN & LVDTs Test #B3

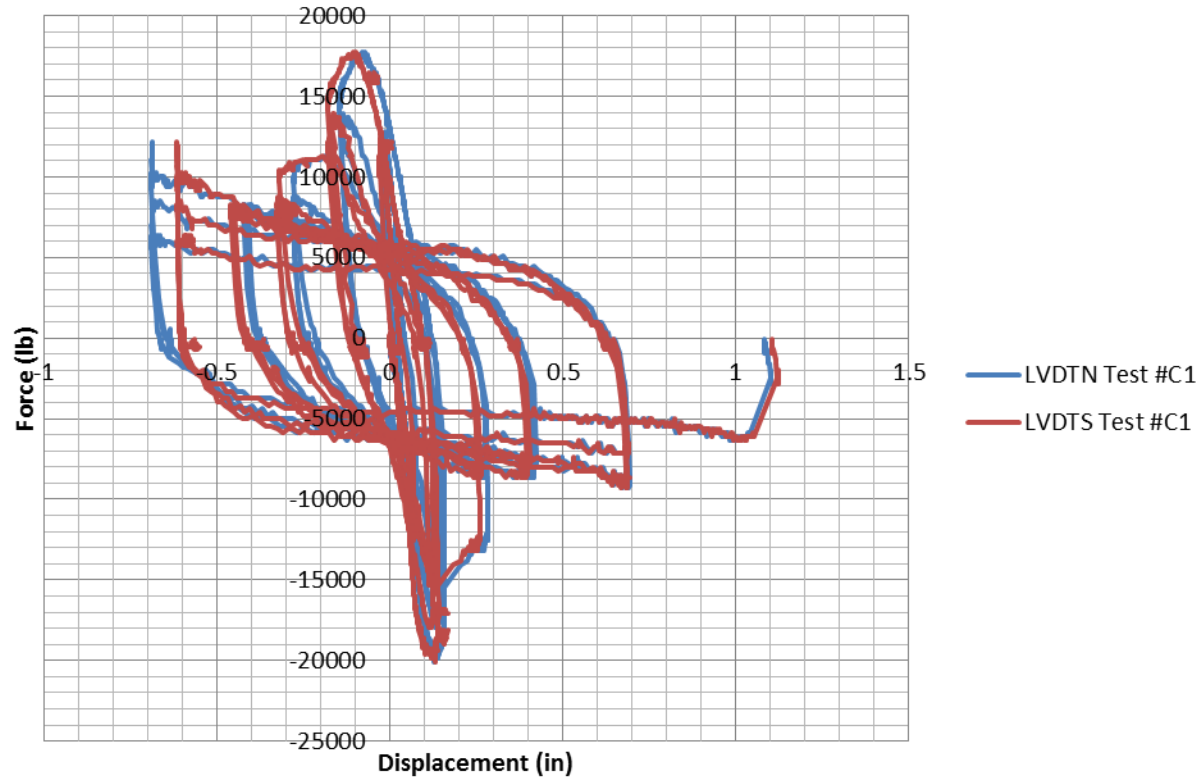


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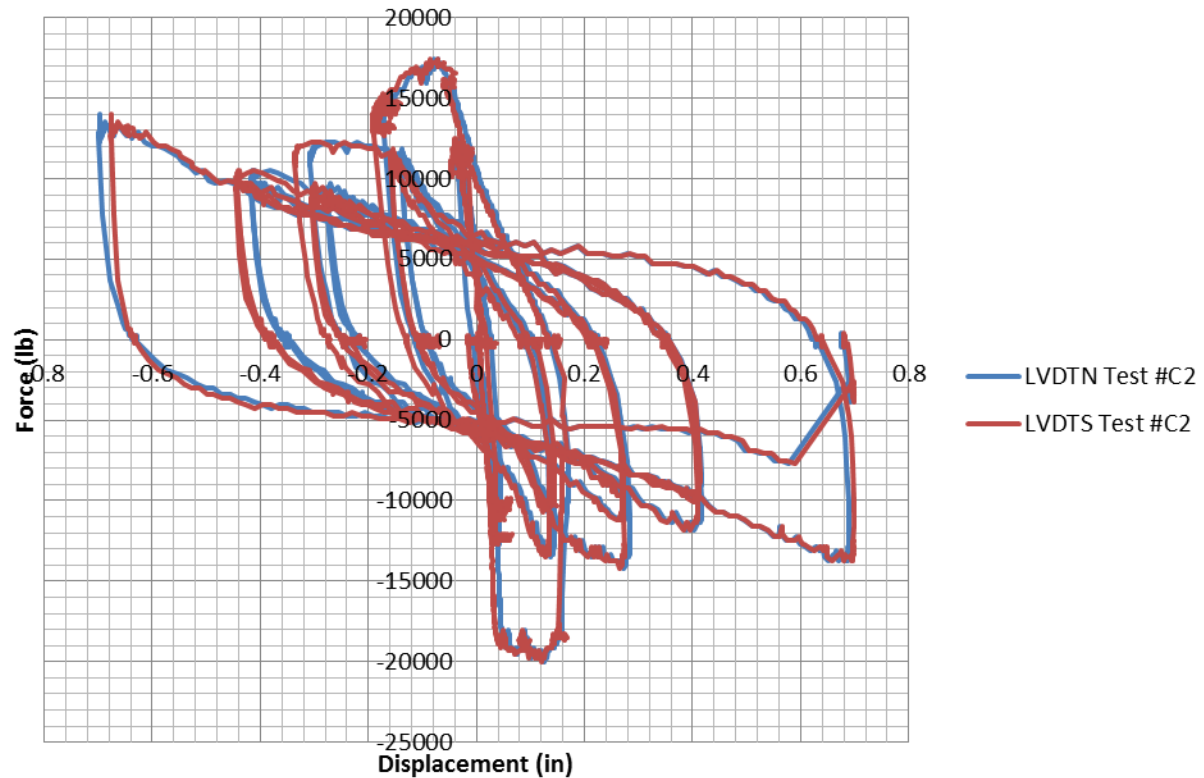




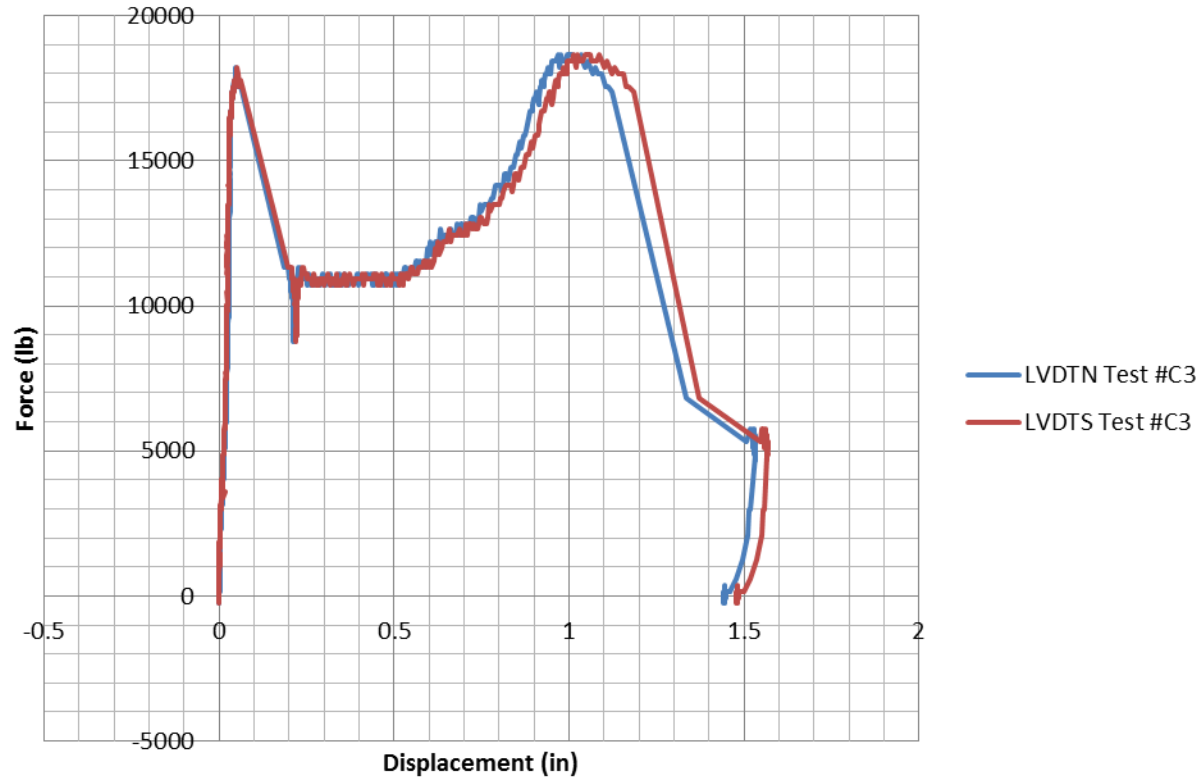
## LVDTN & LVDTs Test #C1



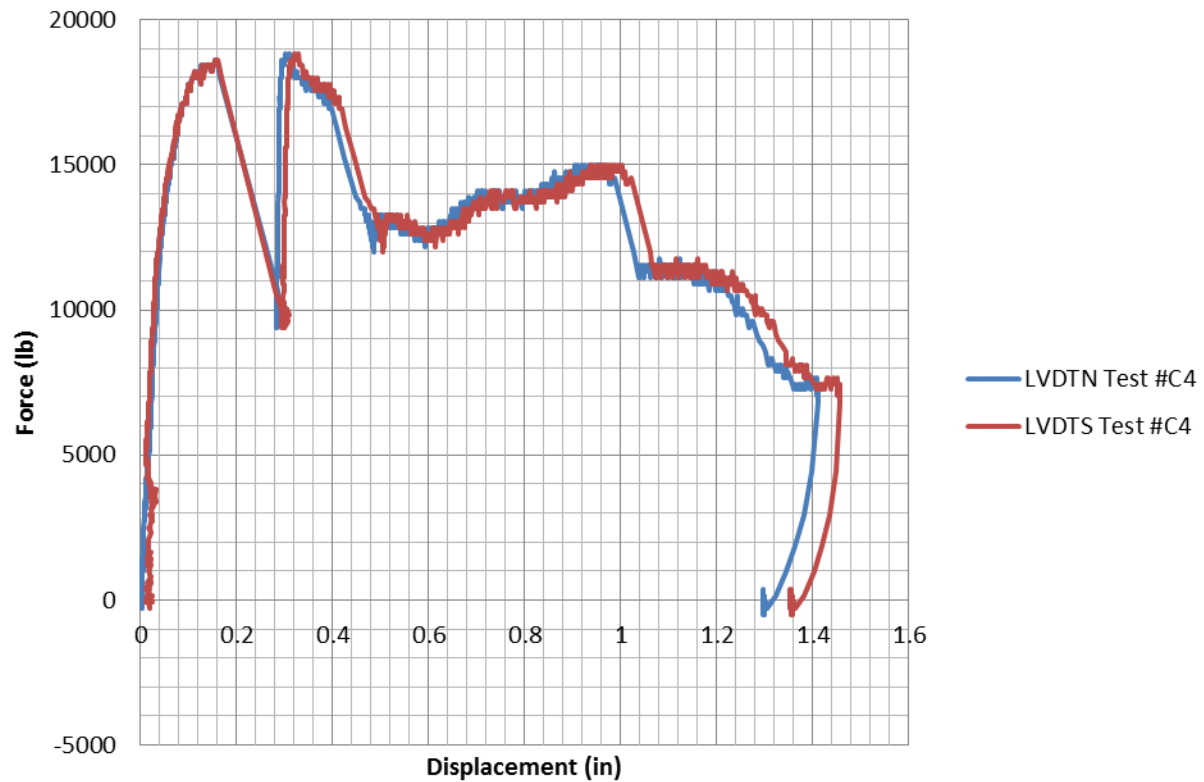
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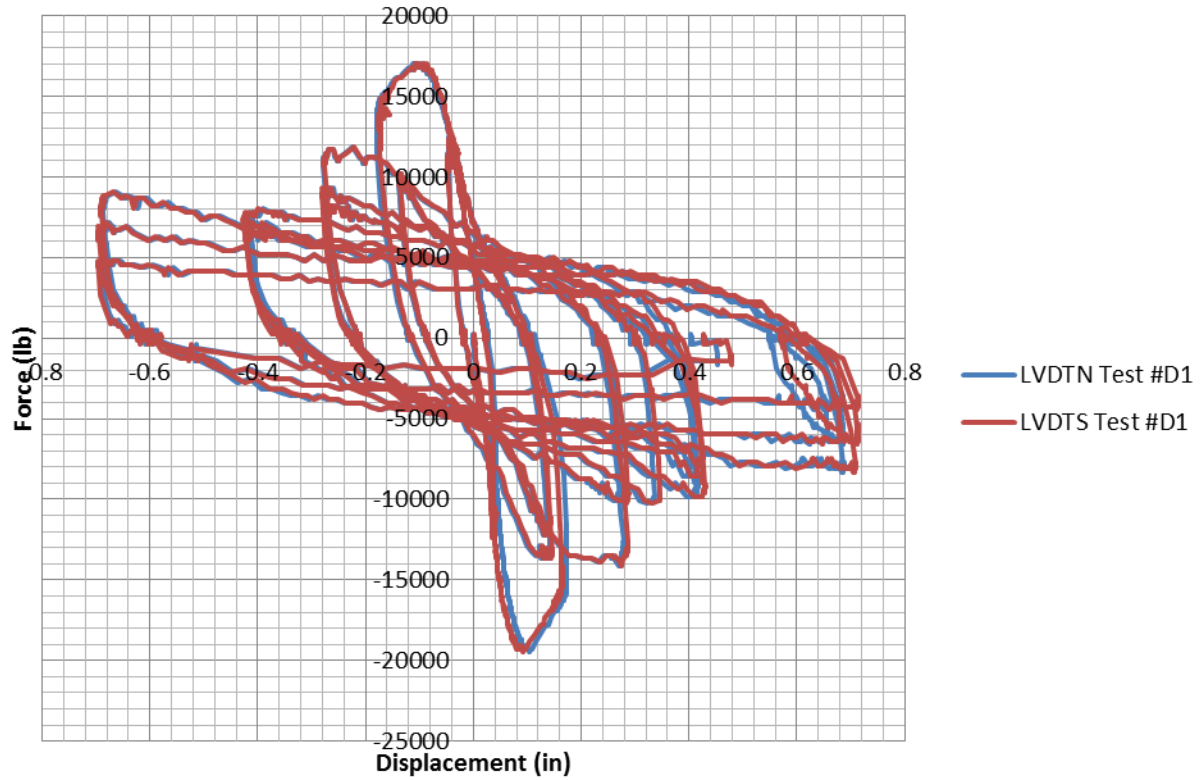
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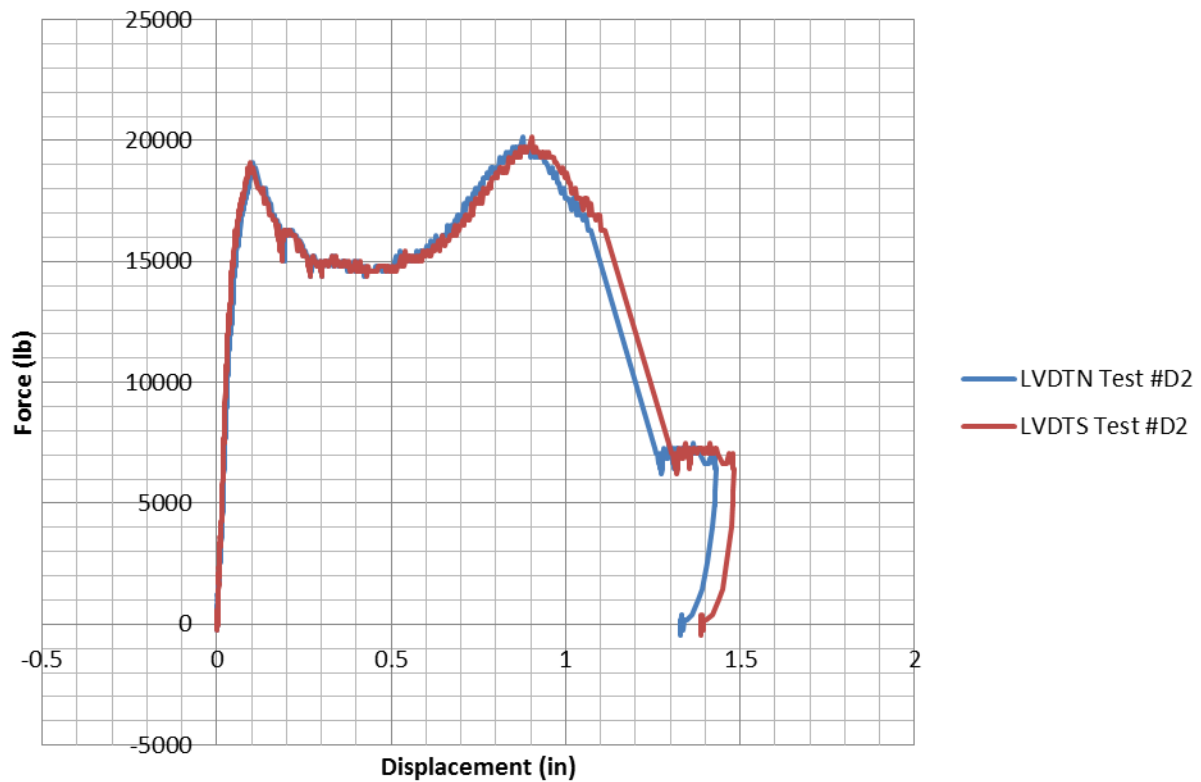
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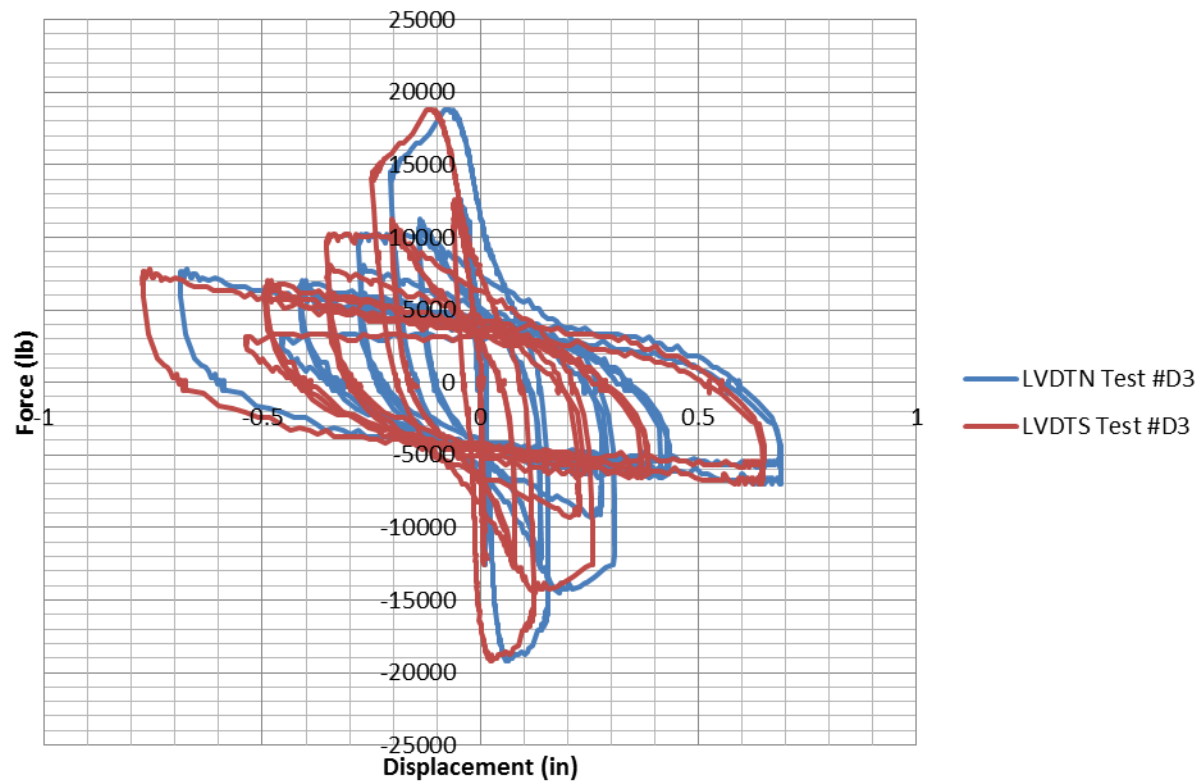
## LVDTN & LVDTs Test #D1



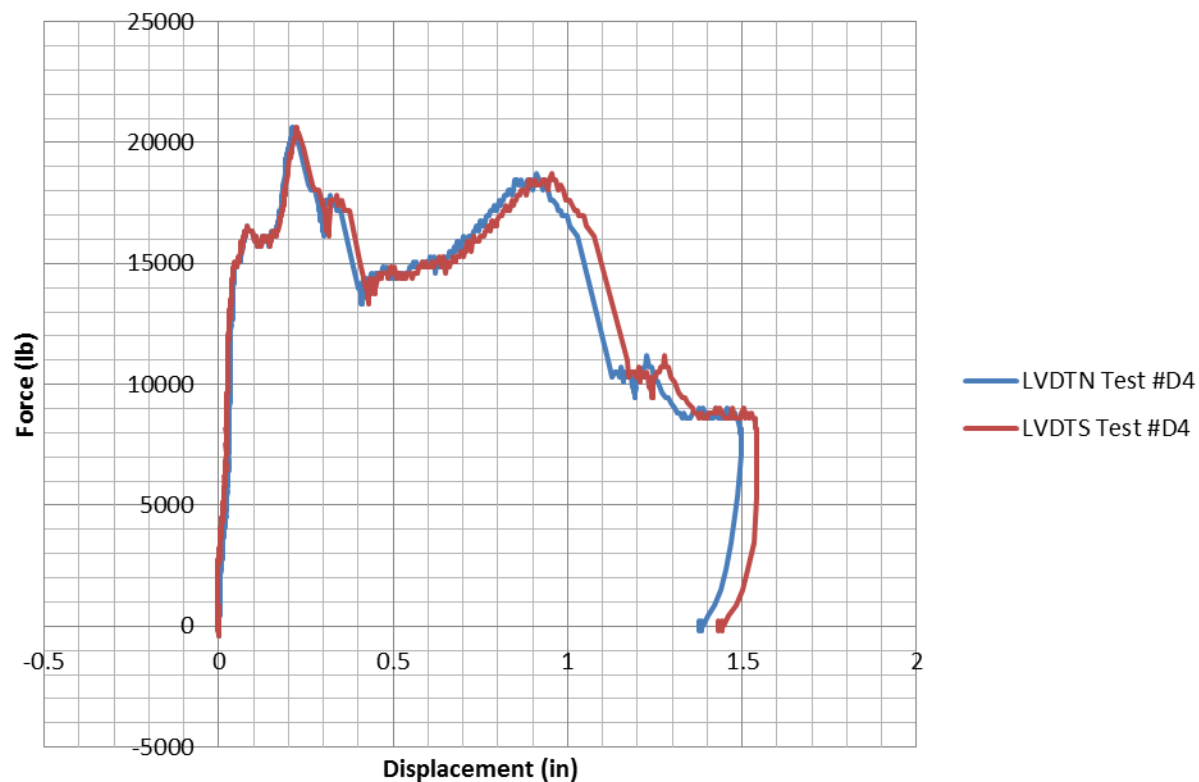
## LVDTN & LVDTs Test #D2



### LVDTN & LVDTs Test #D3

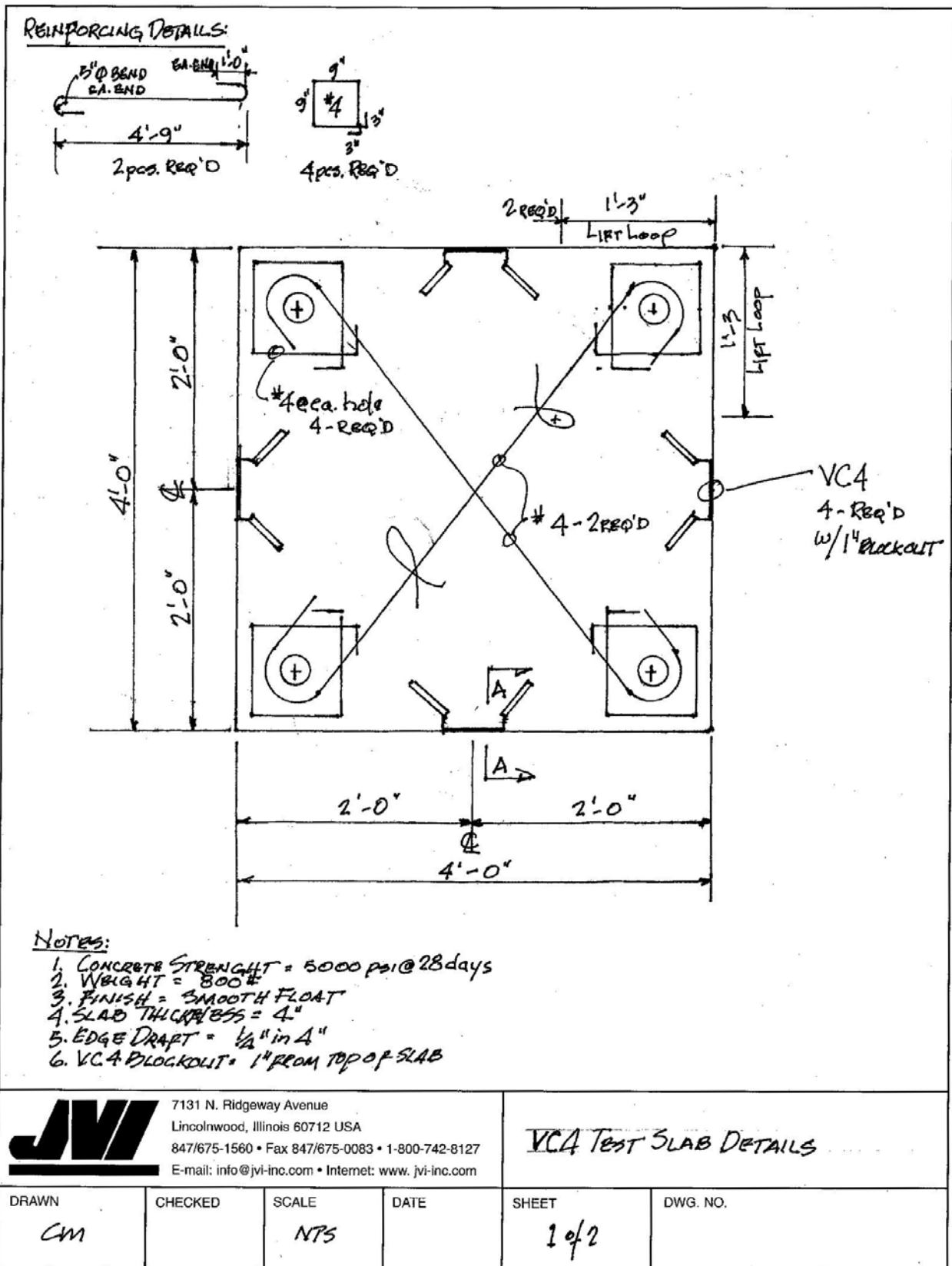


### LVDTN & LVDTs Test #D4





# **APPENDIX B**



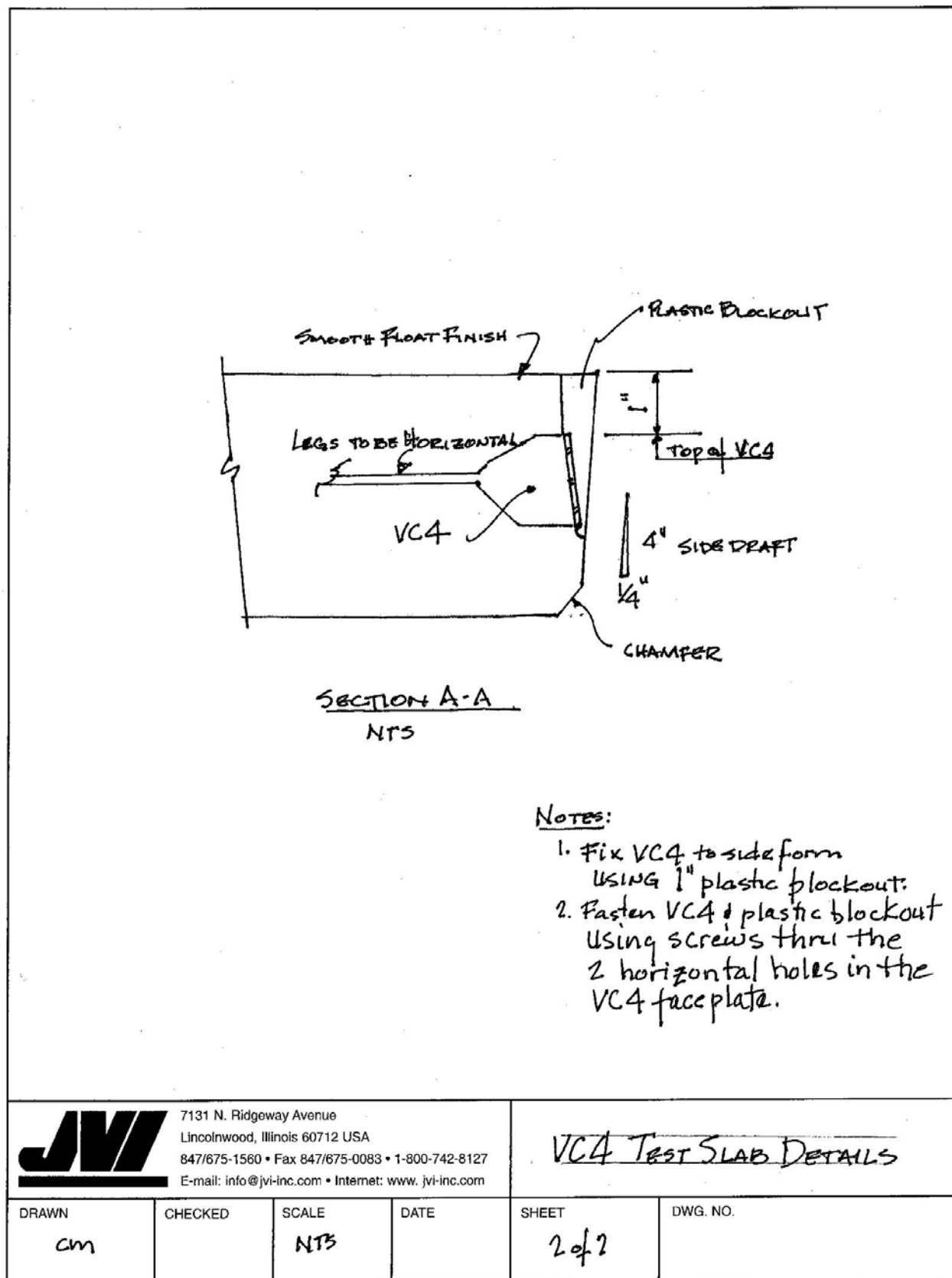


Figure 2 – Section thru VC4 in Test Slab



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<br>3379297                                                               | Revision No.<br>0    |
| Customer Order No.<br>141902-31242                                                          | Date<br>2012-10-22   |
| Sales Order No.<br>1393582 2.1                                                              | Mill Order No.       |
| B/L No.<br>WSC0884420                                                                       | Weight<br>46950 lbs  |
| Alloy / Grade<br>045 XLF                                                                    | Part No.<br>M-MIDV1J |
| Specification No.<br>SAE J1392 045XLF, SAE J2340                                            |                      |
| Description<br>Hot Rolled Pickled Temper Rolled<br>045 XLF<br>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

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Carbon Steel Material Mill Certification

