

CHAPTER 2

EXPERIMENTAL PROGRAM

2.1 General

The aim of this study is to evaluate the performance of the Elco Grade 8, 5/16 in. diameter standoff screw functioning as a mechanical shear connector in composite joists. Specimen construction and testing were carried out at the Virginia Tech Structures and Materials Research Laboratory. The pushout test was the chosen testing method due to the relative ease of fabricating the specimens, as well as the ability to examine a variety of test parameters in a timely fashion. Pushout tests are small-scale tests that are widely used to determine the capacity of shear connectors in composite beams and joists. A typical pushout test specimen is shown in Figure 2.1.

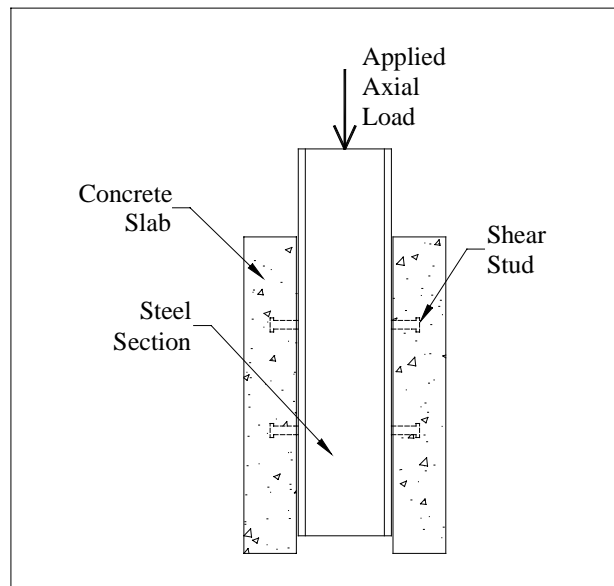


Figure 2.1 Typical Pushout Specimen

The horizontal shear force at the concrete-steel interface in full-scale composite beams and joists is modeled as an axial load applied vertically to the top of the steel section in pushout tests. Shear connectors embedded in the concrete resist this applied axial load.

2.2 Fabrication of Test Specimens

Each half test specimen consisted of a concrete slab attached to a steel section by a varying number and size of standoff screws. The screw heights that were examined were 2 in., 2.5 in., 3 in., and 3.5 in. The screw dimensions are identical for each height with the exception of standoff length and total length. Detailed dimensions of the screws used in this study are given in Figure 2.2. The steel section was fabricated from equal-leg double angles welded back-to-back to a plate running the full length of the double angles to effectively model the top chord of a composite joist. The double angle sizes ranged from 2L 1.25x1.25x0.109 to 2L 3.0x3.0x0.313. The full length plate was used instead of filler plates to eliminate premature buckling of the double angle sections during testing, a problem that existed in some of Hankins' tests (1994). The dimensions of a typical top chord section used in this study are shown in Figure 2.3.

The concrete slabs were formed with or without profiled steel deck and consisted of varying amounts of steel reinforcement. The deck profiles that were utilized in these tests are Vulcraft 0.6C, 1.0C, 1.5C, and 1.5VL. The details of the various deck types are provided in Figure 2.4. Steel reinforcement consisted of welded wire fabric and No. 4 bars. Each slab was 36 in. wide and between 31 and 36 in. in length. Slab depth ranged from 2.25 in. to 3.75 in.

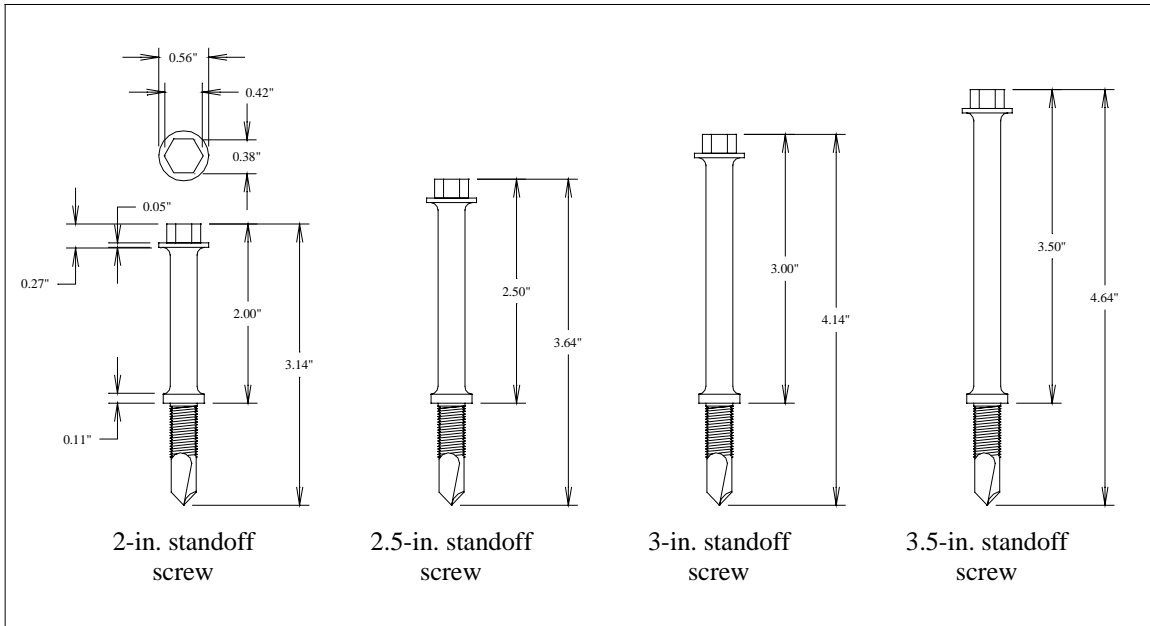


Figure 2.2 Standoff Screw Dimensions

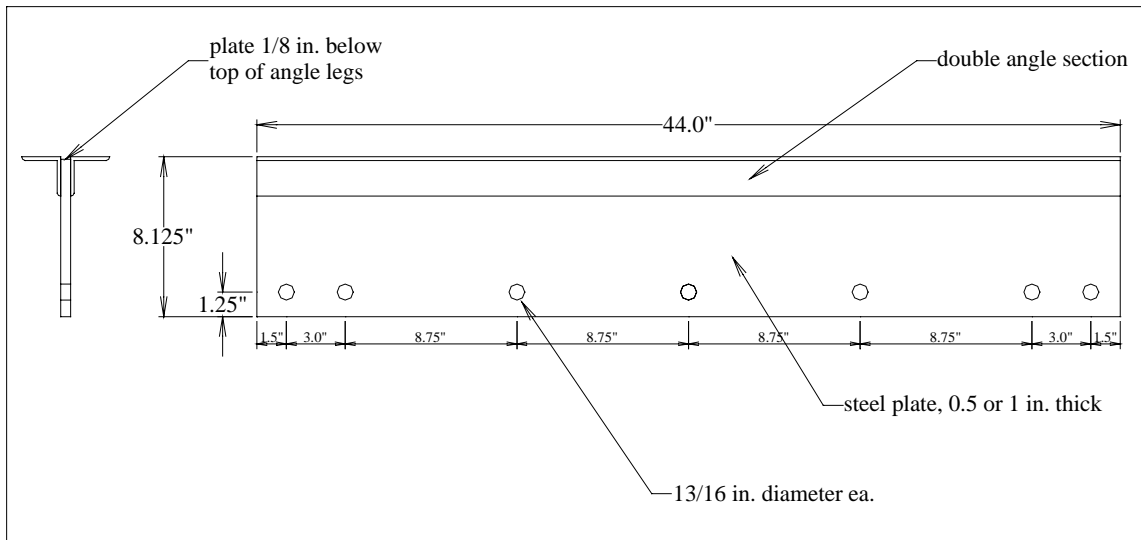


Figure 2.3 Typical Top Chord Section

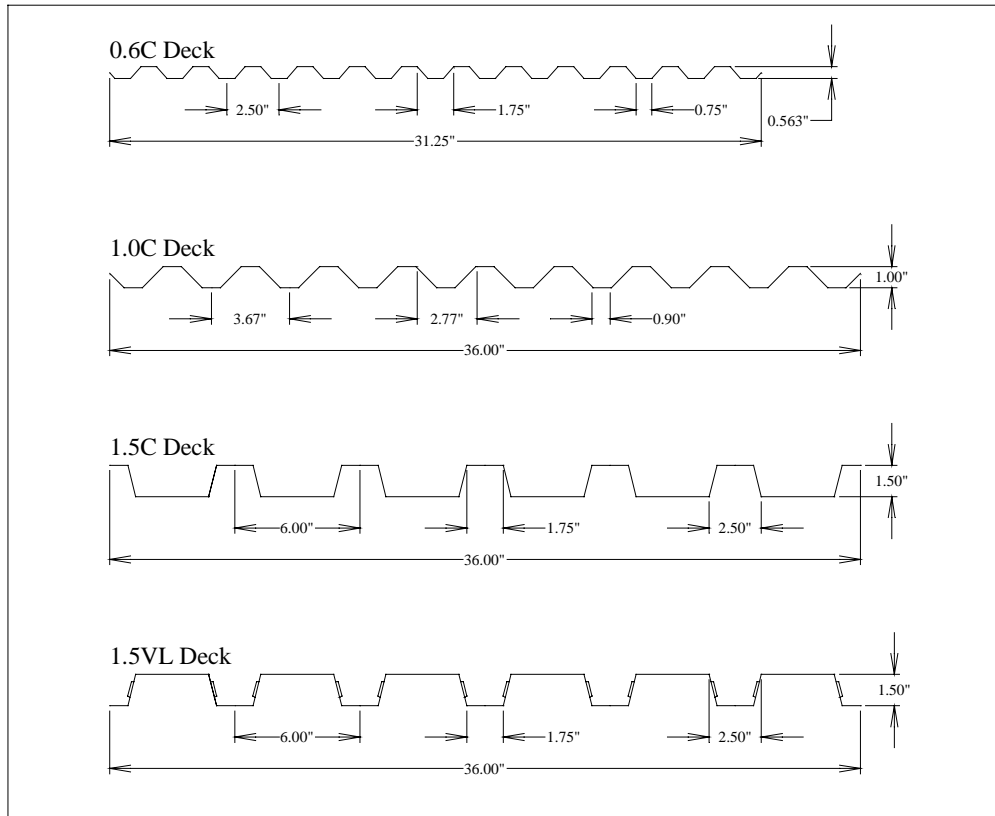


Figure 2.4 Vulcraft Deck Profiles

The fabrication of specimens utilizing profiled steel deck began with fastening cold-formed pour stop of a specified height around the edges of a piece of deck to create the slab dimensions listed above. The deck was then placed on top of the steel section with a 1.5 in. offset at the end of the top chord section to allow relative slip between the concrete and steel components. The deck ribs were oriented transverse to the direction of applied axial load for all tests. The standoff screws were then installed into the top chord section in the specified pattern for that particular test configuration. The screws were drilled through the deck and into the center of the angle leg using an electric screw gun. Next, the specified steel reinforcement was placed in the form. This procedure was repeated for each specimen half.

Concrete was then placed in the forms and concrete cylinders were cast. Small stone aggregate was used (maximum 0.75 in. diameter) in the concrete. The slabs and

cylinders were covered with plastic sheeting and moist-cured for seven days. After seven days, the pour stop was removed and the specimen halves were matched and bolted together. The specimens were then allowed to air-cure for at least 21 additional days before testing.

For solid slab specimens, the fabrication procedure was slightly different. The top chord section was placed in a wooden form to define the edges of the slab. The screws were attached directly to the top chord section, and reinforcement was placed in the form. Concrete was placed in the form and allowed to cure as discussed above. A typical pushout test specimen used in this study is illustrated in Figure 2.5.

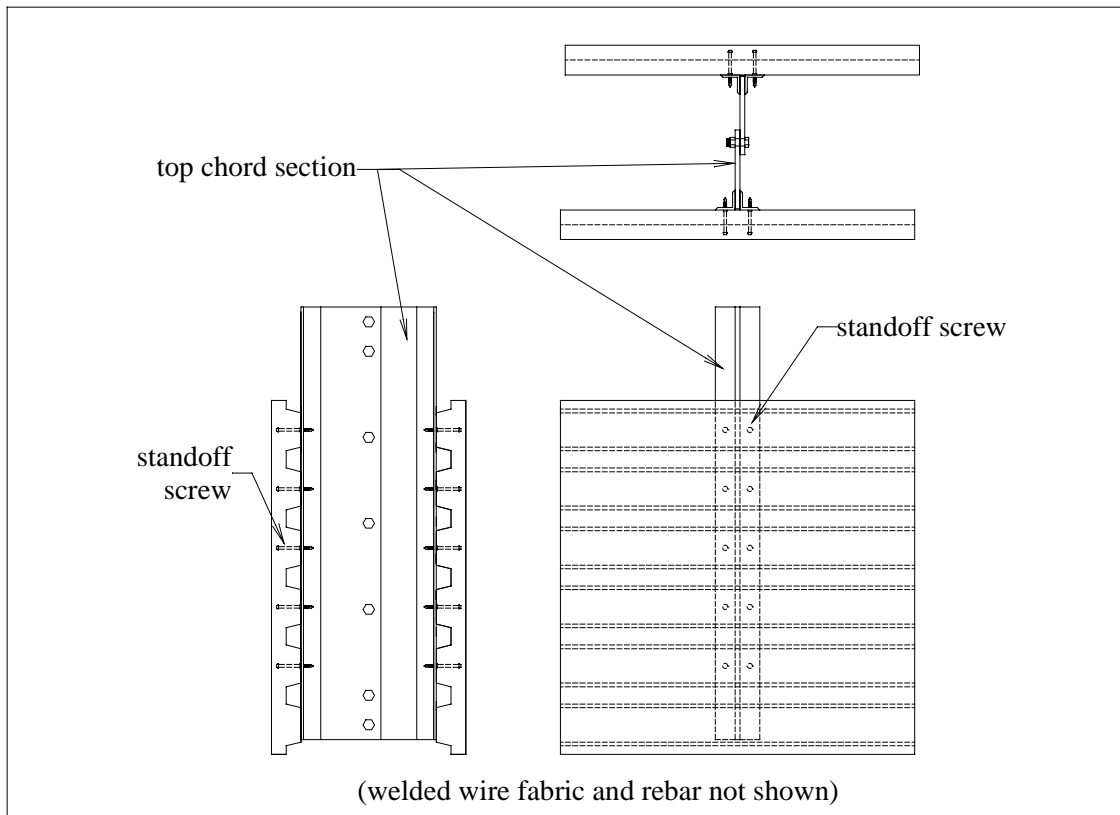


Figure 2.5 Typical Standoff Screw Pushout Specimen

2.2.1 Steel Reinforcement

The amount of welded wire fabric in each test specimen was determined according to ACI 318-95, Section 7.12.2.1(c), which specifies the amount of temperature and shrinkage reinforcement for “slabs where reinforcement with yield stress exceeding 60,000 psi measured at a yield strain of 0.35 percent is used.” This section of the ACI Building Code Requirements requires that the area of temperature and shrinkage reinforcement to be provided shall be determined from the following ratio of reinforcement area to gross concrete area, and may not be less than 0.0014:

$$\frac{0.0018 \times 60,000}{f_y}$$

Assuming the yield strength of welded wire fabric to be at least 65,000 psi, as specified in ASTM A185, the minimum ratio of steel reinforcement to concrete area is 0.00166. Therefore, the area of welded wire fabric used in this testing program is greater than or equal to $0.00166 \times$ the gross concrete area in each slab.

Steel reinforcing bars were placed in each slab of series A, C, and D to prevent longitudinal splitting. To accomplish this, the maximum shear capacity of the standoff screws was first estimated. A conservative value of 7.6 kips per screw was used, as this is the maximum recorded shear capacity of the Elco Grade 8 standoff screw (Hankins 1994). This value was then multiplied by the total number of screws in the test specimen to obtain the maximum possible shear load that the pushout specimen could ultimately carry. Then, sufficient transverse reinforcing bars were specified so that the combined longitudinal shear resistance of the concrete, welded wire fabric, and reinforcing bars would be greater than the estimated shear capacity of the standoff screws. The amount of steel reinforcement to be placed in each slab was determined according to BS 5950 Part 3: Section 3.1 “Composite Beams.” The following equation represents the combined shear resistance of the concrete slab, welded wire fabric, and steel reinforcing bars (*Commentary on 1990*):

$$V_r = L(0.03\eta f_{cu} A_{cv} + 0.7 A_{sv} f_y) \quad (2.1)$$

where:

V_r = total combined shear resistance of each shear plane (kips/in.)

L = longitudinal length of shear plane (in.)

η = 1.0 for normal weight concrete and 0.8 for lightweight concrete

f_{cu} = cube strength of concrete (ksi)

$$\approx 1.25 f'_c$$

A_{cv} = cross-sectional area of concrete per unit length of each shear plane (in.²/in.)

A_{sv} = amount of steel reinforcement crossing each shear plane (in.²/in.)

= area of welded wire fabric and reinforcing bars crossing each shear plane

f_y = yield strength of steel reinforcement (ksi)

2.3 Specimen Configuration

Five distinct series of tests were performed on the Elco Grade 8 standoff screw: the preliminary series, series A, series B, series C, and series D. Within each series are a certain number of groups of tests. These groups of tests consist of two or three tests that have identical test parameters. Each test is identified by a letter signifying the series, followed by a number that indicates the group and test number within the group. For example, test B11-2 is the second test in group 11 of series B.

2.3.1 Preliminary Series Configuration

The preliminary series of tests consisted of 11 groups of tests, P1 through P11. The purposes of the preliminary series were to examine the effects of different amounts of steel reinforcement in solid slabs and slabs utilizing steel deck; to examine the effects of different screw patterns; and to investigate the effect of deck lapping. In each test, the top chord section consisted of 2L-2x2x0.187 separated by a 0.5 in. steel plate running the length of the double angles.

Test groups P1 through P4 examined the effects of various amounts of reinforcement in slabs formed with Vulcraft 1.0C, 26 ga. deck. Total slab depth was 3.25 in. and each slab was 36 in. wide and 36 in. long. Each half specimen contained 16

screws (2 screws per deck rib), and the screw standoff length was 3 in. Increasing amounts of reinforcement were used from P1 to P4. Test group P1 had no reinforcement, P2 contained welded wire fabric only, P3 utilized welded wire fabric and two No. 4 steel bars placed parallel to the deck ribs, and P4 had welded wire fabric and four No. 4 bars. The configuration of test groups P1 through P4 is shown in Figure 2.6(a).

Test groups P5 and P6 were used to investigate the effects of different screw patterns. In both groups the slab dimensions and screw heights were the same as for P1 through P4, but only 8 screws were used in each half specimen in P5 and P6. In group P5, one screw was placed in each rib and staggered between the two angles of the top chord, whereas in P6, the screws were placed two per rib, every other rib. In both groups, welded wire fabric was the only reinforcement. The configurations of P5 and P6 are shown in Figure 2.6(b) and (c).

Solid slabs were used in test groups P7 through P10. These four groups were similar to P1 through P4 in their increasing amounts of steel reinforcement. Slab thickness for these slabs was 3 in., and 2.5 in. standoff screws were used. The screw pattern and quantity of screws for P7 through P10 was identical to that of P1 through P4. The configuration of test groups P7 through P10 is shown in Figure 2.6(d).

Test group P11 examined the effect of lapping the deck. The configuration was identical to that of group P2 except for the existence of a 2 in. deck lap in P11. Instead of using one 36 in. by 36 in. piece of metal deck, two 19 in. by 36 in. pieces were lap jointed together, the lap being 2 in. wide. The configurations of the preliminary series are summarized in Table 2.1.

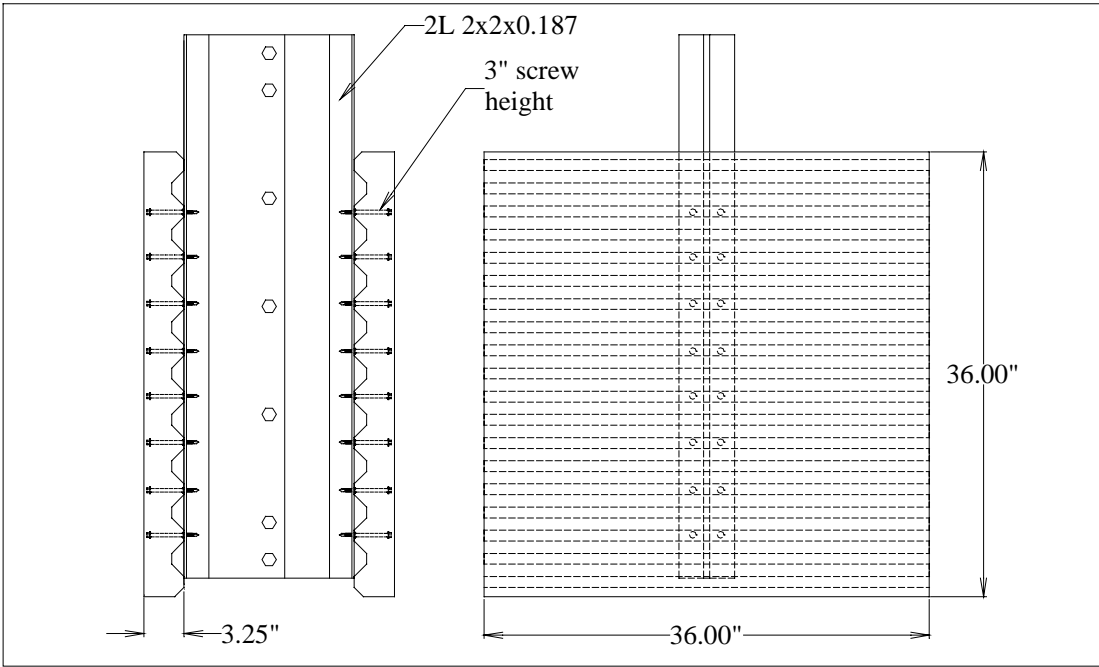


Figure 2.6(a) Test Groups P1-P4 Dimensions

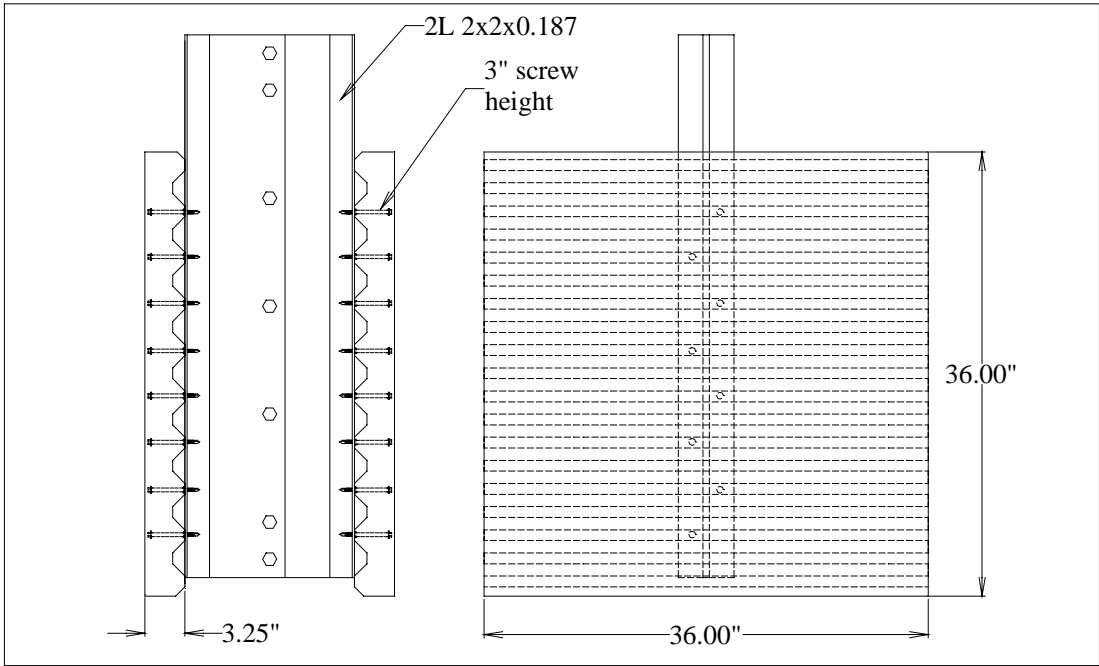


Figure 2.6(b) Test Group P5 Dimensions

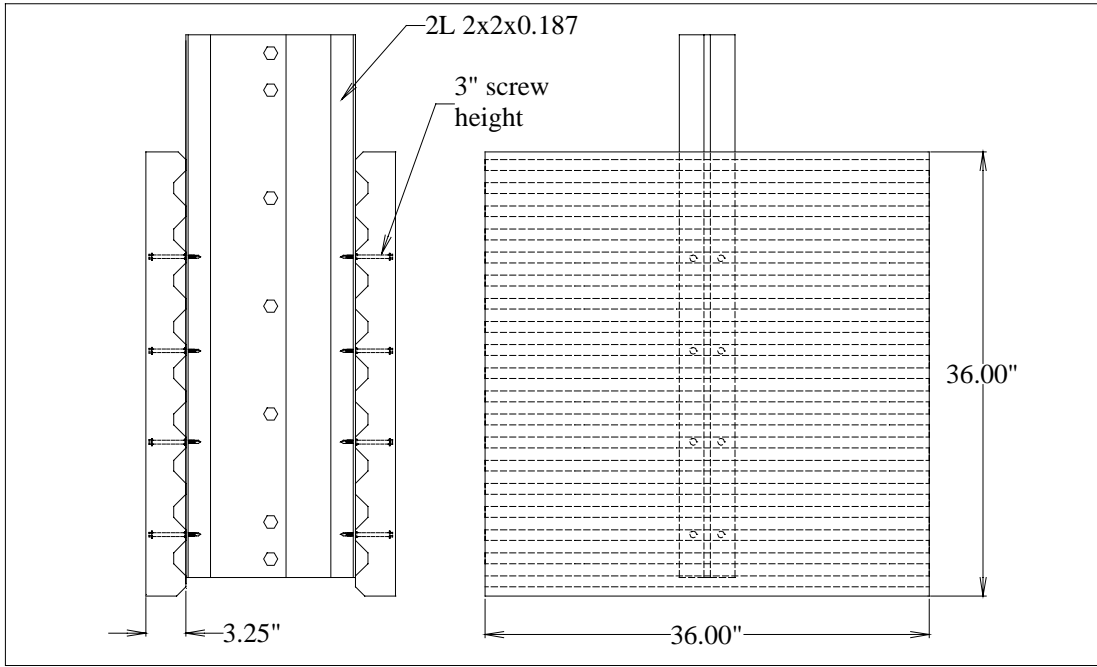


Figure 2.6(c) Test Group P6 Dimensions

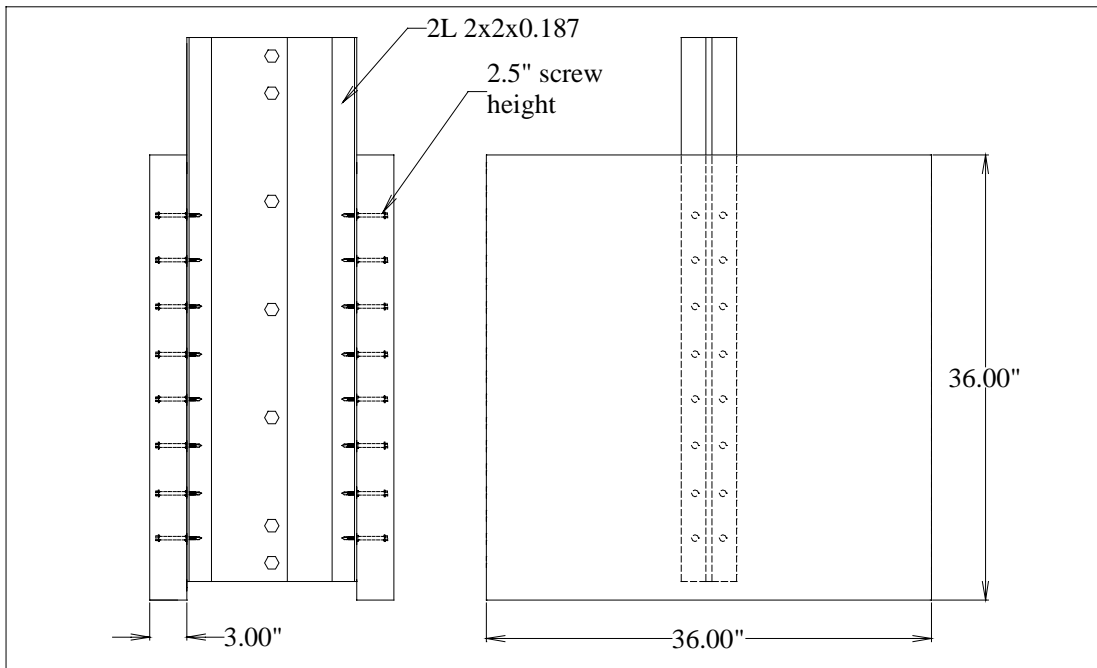


Figure 2.6 (d) Test Groups P7-P10 Dimensions

Table 2.1 Preliminary Series Configuration

Test Group	Deck Type	Top Chord Section	Plate Thickness (in.)	Screw Height (in.)	Slab Depth (in.)	Slab Width (in.)	Slab Length (in.)	Screws Per Half Specimen	Welded Wire Fabric	Rebar
P1	1.0C, 26 ga.	2L 2.00x2.00x0.187	0.5	3.0	3.25	36	36	16	none	none
P2	1.0C, 26 ga.	2L 2.00x2.00x0.187	0.5	3.0	3.25	36	36	16	6x6-W4.0xW4.0	none
P3	1.0C, 26 ga.	2L 2.00x2.00x0.187	0.5	3.0	3.25	36	36	16	6x6-W4.0xW4.0	2-No. 4
P4	1.0C, 26 ga.	2L 2.00x2.00x0.187	0.5	3.0	3.25	36	36	16	6x6-W4.0xW4.0	4-No. 4
P5	1.0C, 26 ga.	2L 2.00x2.00x0.187	0.5	3.0	3.25	36	36	8	6x6-W4.0xW4.0	none
P6	1.0C, 26 ga.	2L 2.00x2.00x0.187	0.5	3.0	3.25	36	36	8	6x6-W4.0xW4.0	none
P7	none	2L 2.00x2.00x0.187	0.5	2.5	3.00	36	36	16	none	none
P8	none	2L 2.00x2.00x0.187	0.5	2.5	3.00	36	36	16	6x6-W4.0xW4.0	none
P9	none	2L 2.00x2.00x0.187	0.5	2.5	3.00	36	36	16	6x6-W4.0xW4.0	2-No. 4
P10	none	2L 2.00x2.00x0.187	0.5	2.5	3.00	36	36	16	6x6-W4.0xW4.0	4-No. 4
P11	1.0C, 26 ga.*	2L 2.00x2.00x0.187	0.5	3.0	3.25	36	36	16	6x6-W4.0xW4.0	none

* lapped

2.3.2 Series A Configuration

Test series A consisted of eight groups of tests and was conducted to evaluate the performance of the Elco Grade 8 standoff screw in specimens using Vulcraft 0.6C, 28 ga. deck. Three different sizes of double angles were used as top chord sections in Series A, all separated by a 0.5 in. plate. Screw heights of 2 in. and 2.5 in. were investigated, and slab depth ranged from 2.25 in. to 2.75 in. Slab dimensions were 36 in. wide and 31.25 in. long. Test groups A1 and A2 utilized six screws in each half specimen, and the other six groups contained 11 screws in each half. The screws were staggered in all eight test groups, with groups A1 and A2 leaving an empty rib between screws. Screw locations for series A are shown in Figures 2.7(a) and (b). Each specimen half in series A was reinforced with 6x6-W2.9xW2.9 welded wire fabric and four No. 4 bars. The test configurations for series A are summarized in Table 2.2.

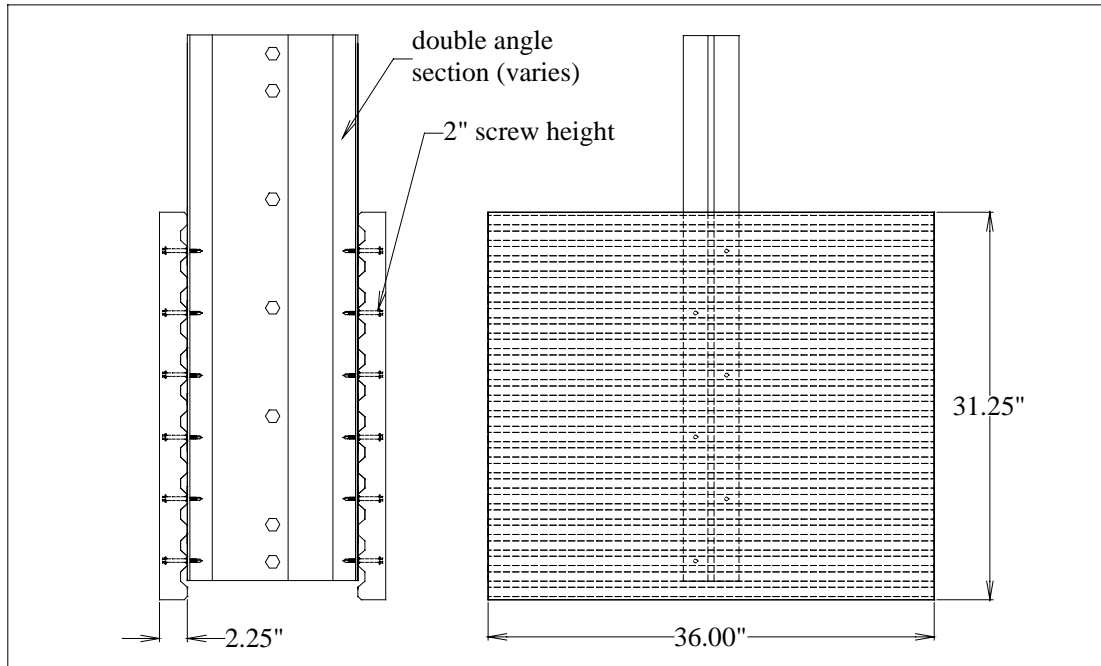


Figure 2.7(a) Test Groups A1-A2 Dimensions

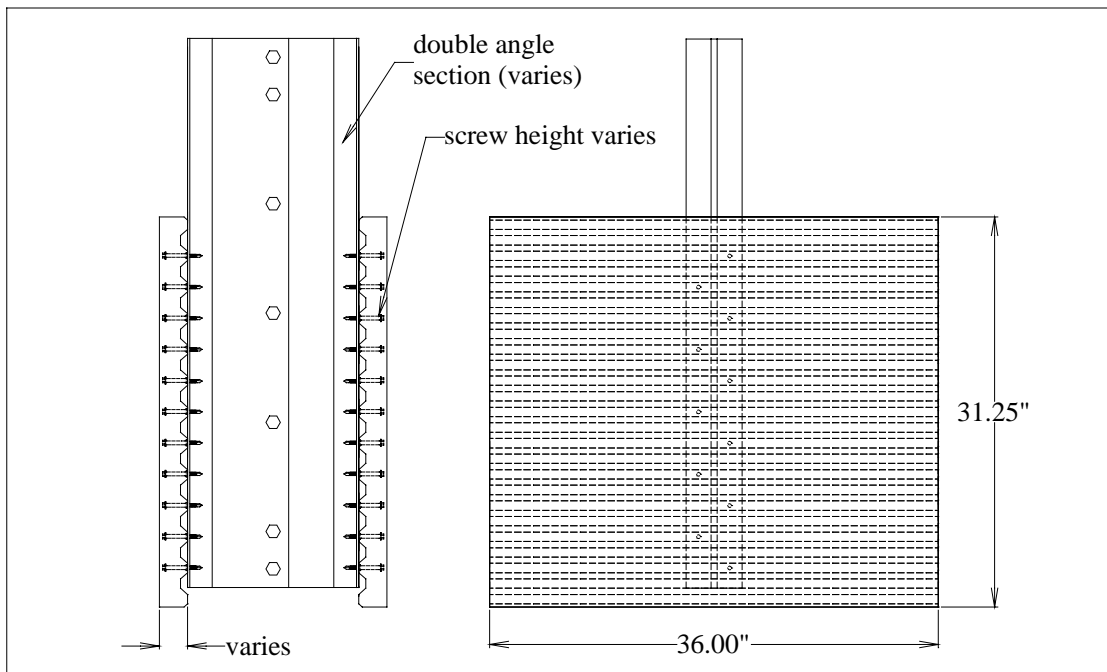


Figure 2.7(b) Test Groups A3-A8 Dimensions

Table 2.2 Series A Configuration

Test Group	Deck Type	Top Chord Section	Plate Thickness (in.)	Screw Height (in.)	Slab Depth (in.)	Slab Width (in.)	Slab Length (in.)	Screws Per Half Specimen	Welded Wire Fabric	Rebar
A1	0.6C, 28 ga.	2L 1.25x1.25x0.109	0.5	2.0	2.25	36	31.25	6	6x6-W2.9xW2.9	4-No. 4
A2	0.6C, 28 ga.	2L 2.00x2.00x0.187	0.5	2.0	2.25	36	31.25	6	6x6-W2.9xW2.9	4-No. 4
A3	0.6C, 28 ga.	2L 1.25x1.25x0.109	0.5	2.5	2.75	36	31.25	11	6x6-W2.9xW2.9	4-No. 4
A4	0.6C, 28 ga.	2L 2.00x2.00x0.187	0.5	2.5	2.75	36	31.25	11	6x6-W2.9xW2.9	4-No. 4
A5	0.6C, 28 ga.	2L 2.00x2.00x0.250	0.5	2.5	2.75	36	31.25	11	6x6-W2.9xW2.9	4-No. 4
A6	0.6C, 28 ga.	2L 1.25x1.25x0.109	0.5	2.0	2.25	36	31.25	11	6x6-W2.9xW2.9	4-No. 4
A7	0.6C, 28 ga.	2L 2.00x2.00x0.187	0.5	2.0	2.25	36	31.25	11	6x6-W2.9xW2.9	4-No. 4
A8	0.6C, 28 ga.	2L 2.00x2.00x0.250	0.5	2.0	2.25	36	31.25	11	6x6-W2.9xW2.9	4-No. 4

2.3.3 Series B Configuration

Test series B consisted of 11 groups of tests that were conducted on specimens utilizing Vulcraft 1.0C, 26 ga. deck. Five different top chord sections were investigated, each consisting of a 0.5 in. plate separating double angles of various sizes. Screw heights of 2, 2.5, and 3 in. were used with corresponding slab thicknesses of 2.25, 2.75, and 3.25 in. Each slab measured 36 in. wide and 36 in. long. Test groups B1 through B9 contained 8 screws per each half specimen in a staggered pattern. Sixteen screws were used in each half specimen of B10 and B11, with two screws in each rib. Figures 2.8(a) and (b) shows the screw locations for series B. Three different sizes of welded wire fabric were used as reinforcement. No reinforcing bars were used. The configurations for series B are summarized in Table 2.3.

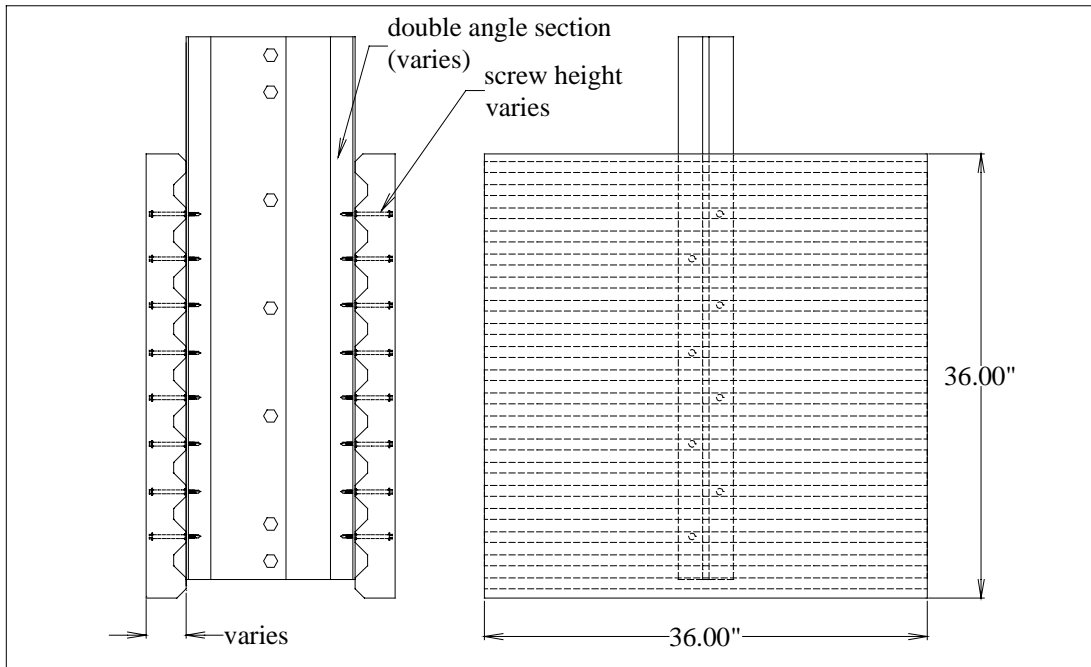


Figure 2.8(a) Test Groups B1-B9 Dimensions

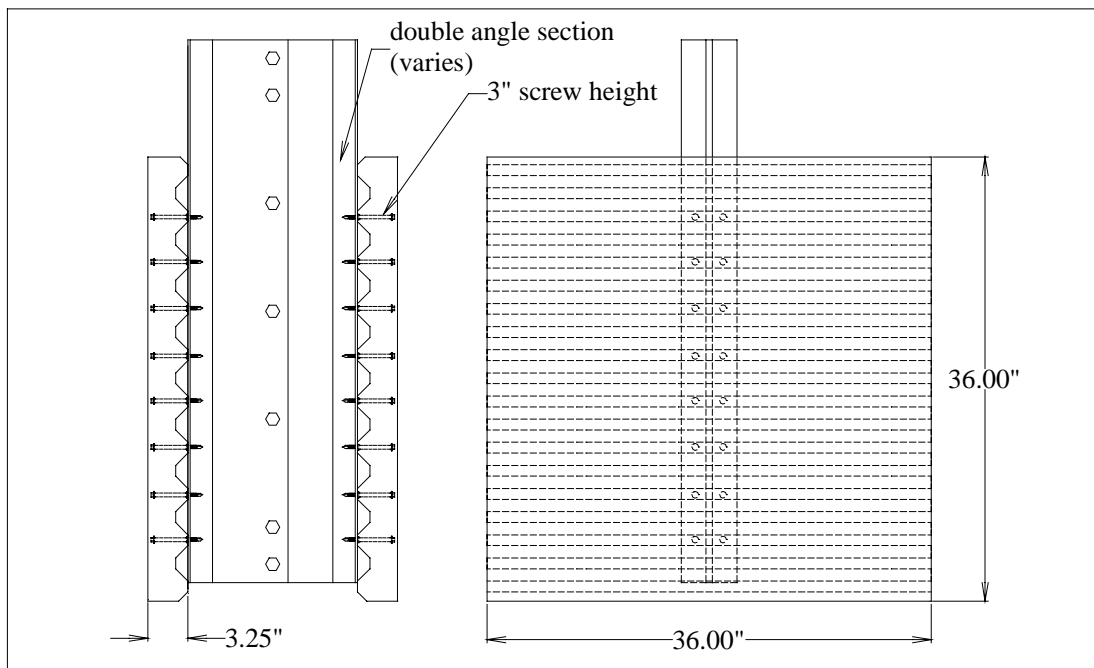


Figure 2.8(b) Test Groups B10-B11 Dimensions

Table 2.3 Series B Configuration

Test Group	Deck Type	Top Chord Section	Plate Thickness (in.)	Screw Height (in.)	Slab Depth (in.)	Slab Width (in.)	Slab Length (in.)	Screws Per Half Specimen	Welded Wire Fabric	Rebar
B1	1.0C, 26 ga.	2L 1.25x1.25x0.109	0.5	2.0	2.25	36	36	8	6x6-W2.1xW2.1	none
B2	1.0C, 26 ga.	2L 2.00x2.00x0.187	0.5	2.0	2.25	36	36	8	6x6-W2.1xW2.1	none
B3	1.0C, 26 ga.	2L 2.00x2.00x0.250	0.5	2.0	2.25	36	36	8	6x6-W2.1xW2.1	none
B4	1.0C, 26 ga.	2L 1.25x1.25x0.109	0.5	2.5	2.75	36	36	8	6x6-W2.9xW2.9	none
B5	1.0C, 26 ga.	2L 2.00x2.00x0.187	0.5	2.5	2.75	36	36	8	6x6-W2.9xW2.9	none
B6	1.0C, 26 ga.	2L 2.00x2.00x0.250	0.5	2.5	2.75	36	36	8	6x6-W2.9xW2.9	none
B7	1.0C, 26 ga.	2L 1.25x1.25x0.109	0.5	3.0	3.25	36	36	8	4x4-W2.1xW2.1	none
B8	1.0C, 26 ga.	2L 2.00x2.00x0.187	0.5	3.0	3.25	36	36	8	4x4-W2.1xW2.1	none
B9	1.0C, 26 ga.	2L 2.00x2.00x0.250	0.5	3.0	3.25	36	36	8	4x4-W2.1xW2.1	none
B10	1.0C, 26 ga.	2L 2.00x2.00x0.163	0.5	3.0	3.25	36	36	16	4x4-W2.1xW2.1	none
B11	1.0C, 26 ga.	2L 3.00x3.00x0.313	0.5	3.0	3.25	36	36	16	4x4-W2.1xW2.1	none

2.3.4 Series C Configuration

Test series C was conducted to examine the performance of the Elco Grade 8 standoff screw in Vulcraft 1.5C, 22 ga. deck and consisted of eight groups of tests. Four different sizes of double angles were used as top chord members, each separated by a 0.5 in. plate. The screw heights that were used were 3 and 3.5 in. and the corresponding slab depths were 3.25 and 3.75 in. Each slab was 36 in. in width and 36 in. in length. Test groups C1-C3 contained 5 screws per half specimen, C4-C6 had 10 screws per half specimen, and C7 and C8 had 20 screws per half specimen. The screw configurations for series C are shown in Figure 2.9(a), (b), and (c). Varying amounts of reinforcement were used. The configurations for series C are summarized in Table 2.4.

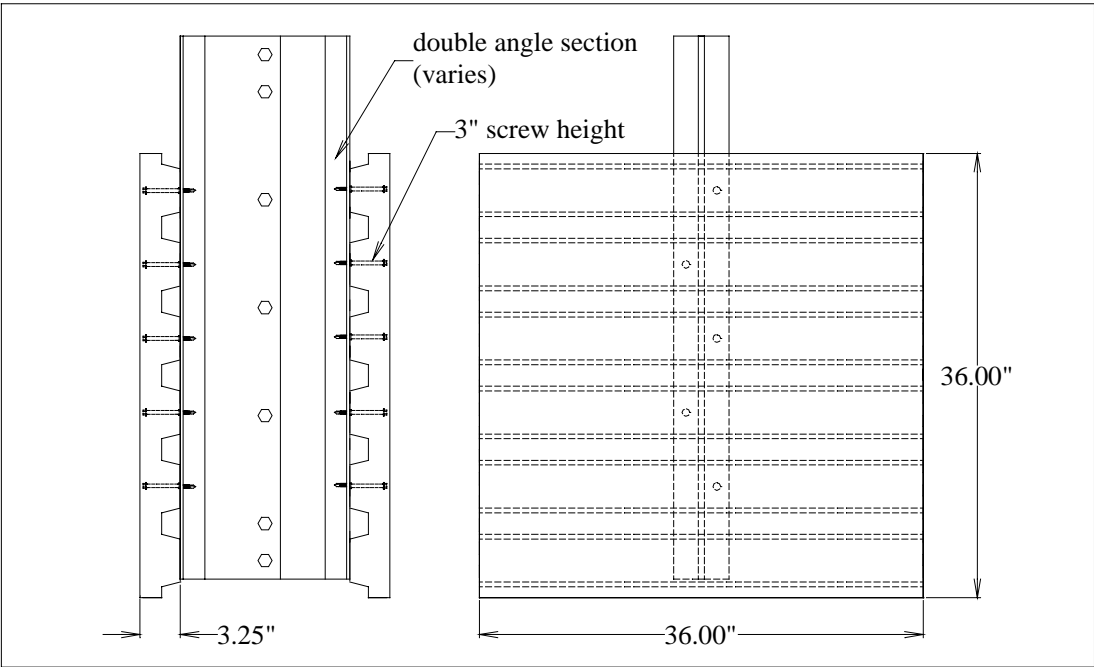


Figure 2.9(a) Test Groups C1-C3 Dimensions

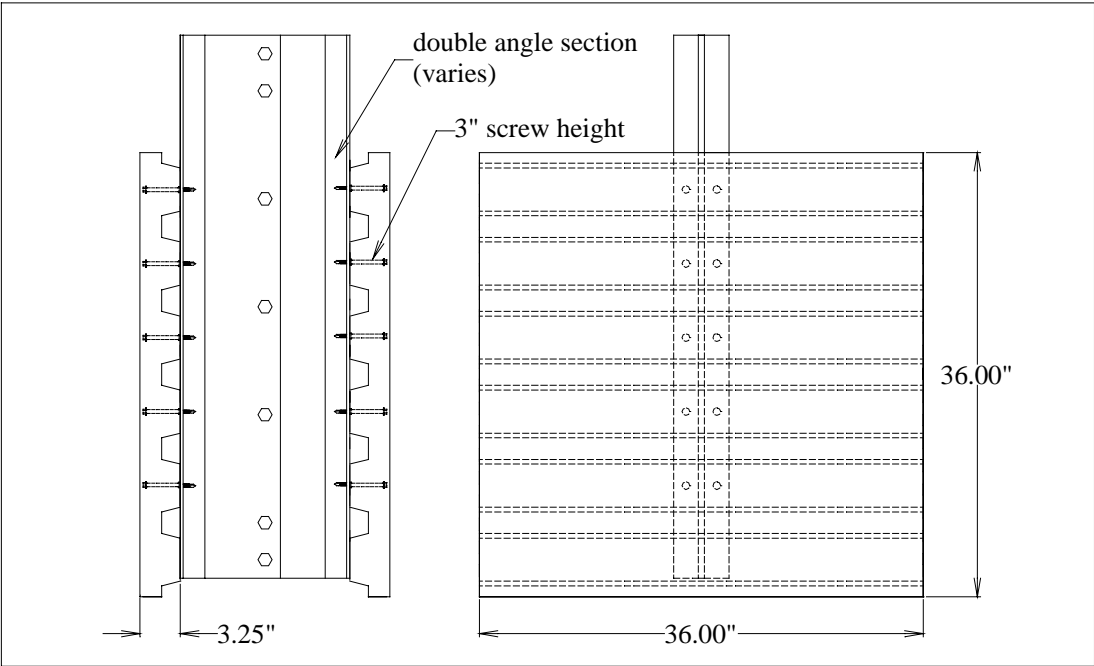


Figure 2.9(b) Test Groups C4-C6 Dimensions

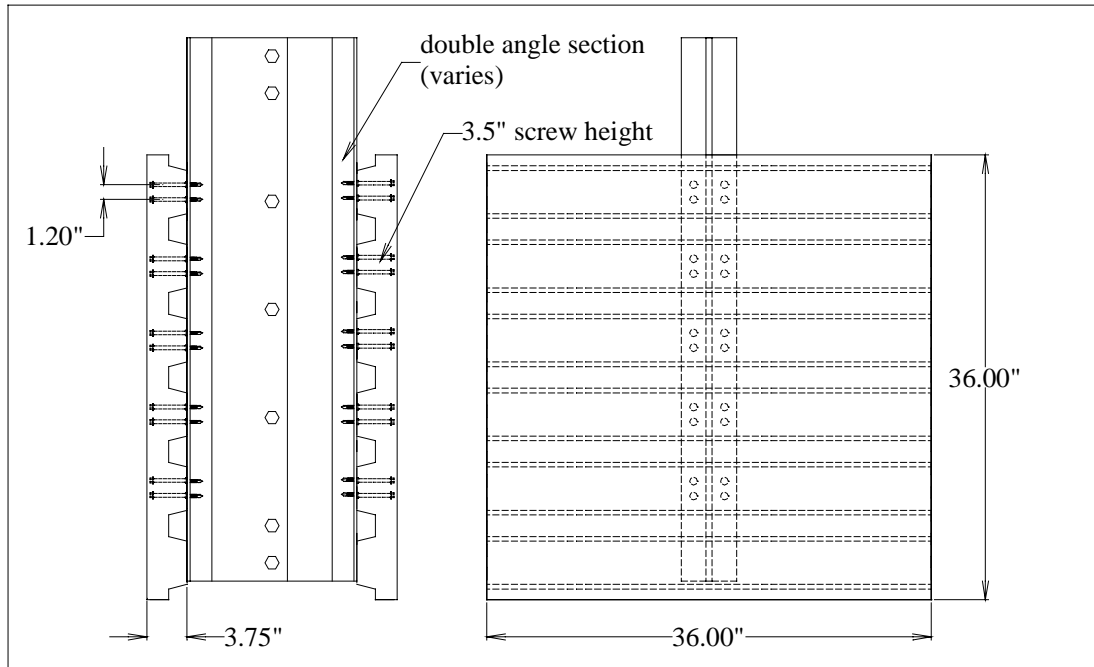


Figure 2.9(c) Test Groups C7-C8 Dimensions

Table 2.4 Series C Configuration

Test Group	Deck Type	Top Chord Section	Plate Thickness (in.)	Screw Height (in.)	Slab Depth (in.)	Slab Width (in.)	Slab Length (in.)	Screws Per Half Specimen	Welded Wire Fabric	Rebar
C1	1.5C, 22 ga.	2L 1.25x1.25x0.109	0.5	3.0	3.25	36	36	5	4x4-W2.1xW2.1	4-No. 4
C2	1.5C, 22 ga.	2L 2.00x2.00x0.187	0.5	3.0	3.25	36	36	5	4x4-W2.1xW2.1	4-No. 4
C3	1.5C, 22 ga.	2L 2.00x2.00x0.250	0.5	3.0	3.25	36	36	5	4x4-W2.1xW2.1	4-No. 4
C4	1.5C, 22 ga.	2L 1.25x1.25x0.109	0.5	3.0	3.25	36	36	10	4x4-W2.1xW2.1	4-No. 4
C5	1.5C, 22 ga.	2L 2.00x2.00x0.187	0.5	3.0	3.25	36	36	10	4x4-W2.1xW2.1	4-No. 4
C6	1.5C, 22 ga.	2L 2.00x2.00x0.250	0.5	3.0	3.25	36	36	10	4x4-W2.1xW2.1	4-No. 4
C7	1.5C, 22 ga.	2L 2.00x2.00x0.163	0.5	3.5	3.75	36	36	20	6x6-W4.0xW4.0	6-No. 4
C8	1.5C, 22 ga.	2L 2.00x2.00x0.250	0.5	3.5	3.75	36	36	20	6x6-W4.0xW4.0	6-No. 4

2.3.5 Series D Configuration

Test series D consisted of 12 groups of tests that were conducted on specimens utilizing Vulcraft 1.5VL, 22 ga. deck. Five different sizes of double angles were used in the top chord sections of the specimens. In groups D1-D6, the double angles were welded to a 0.5 in. plate and in D7-D12, a 1.0 in. plate was used between the angles. The thicker plate was used to prevent lateral buckling of the top chord section under the anticipated greater axial load in groups D7 through D12. A 3 in. screw height was used

in all series D tests while the slab depth varied from 3.25 in. for D1-D6 to 3.75 in. for D7-D12. The width and length of each slab was 36 in. The quantities of screws varied from 5 screws per half specimen to 30 screws per half specimen and were located as shown in Figures 2.10(a) through (e). Varying amounts of reinforcement were used. The configurations for Series D are summarized in Table 2.5.

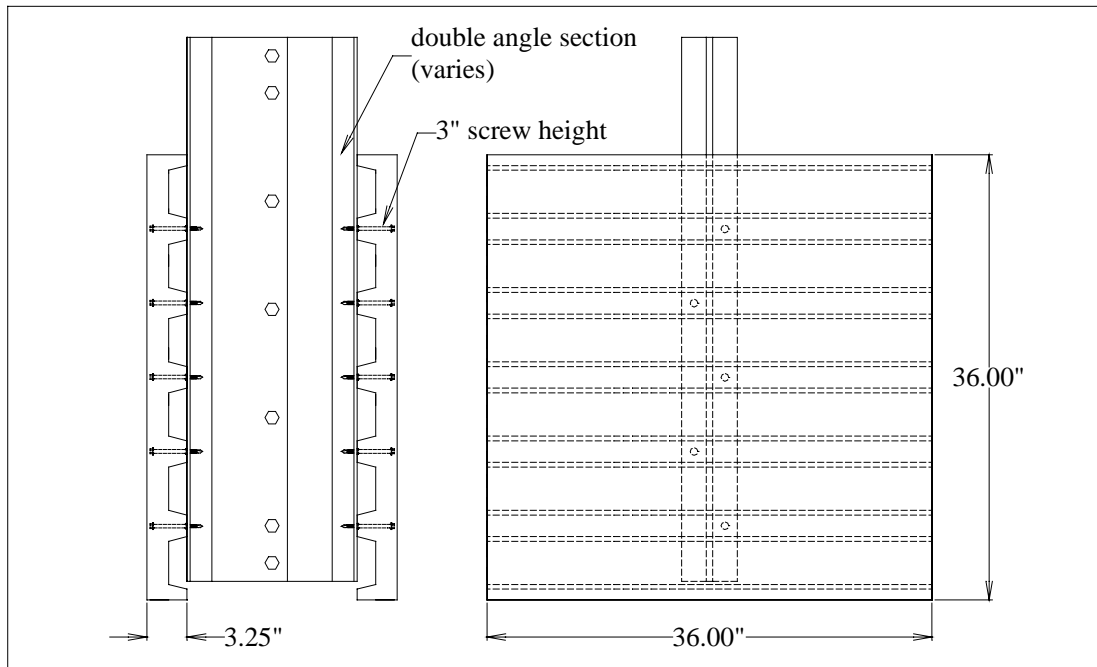


Figure 2.10(a) Test Groups D1-D3 Dimensions

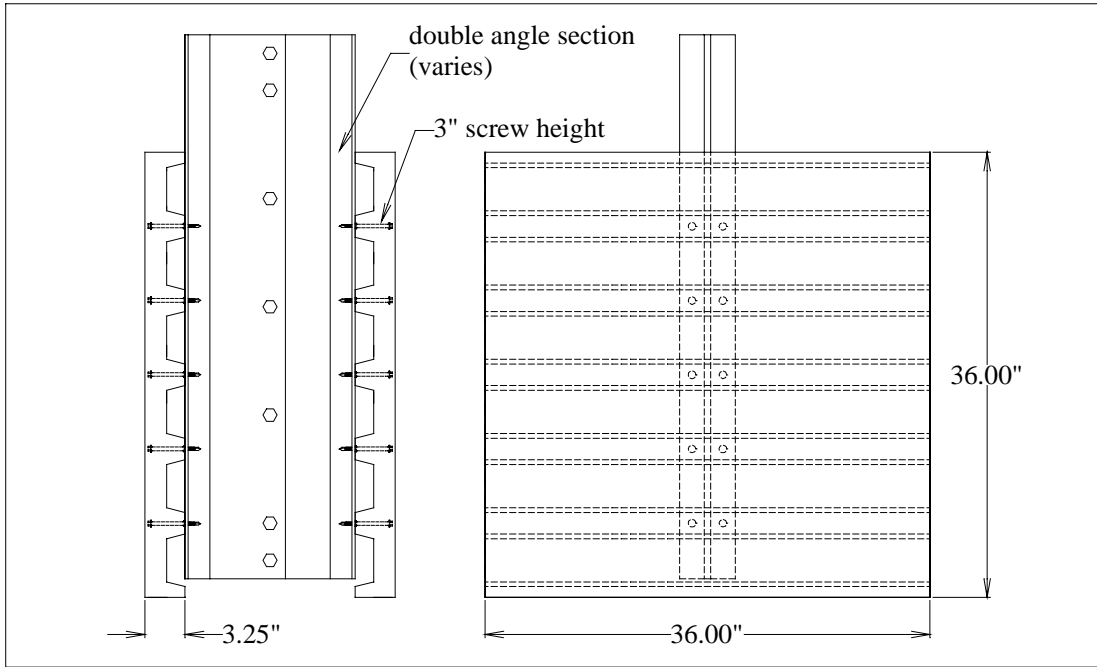


Figure 2.10(b) Test Groups D4-D6 Dimensions

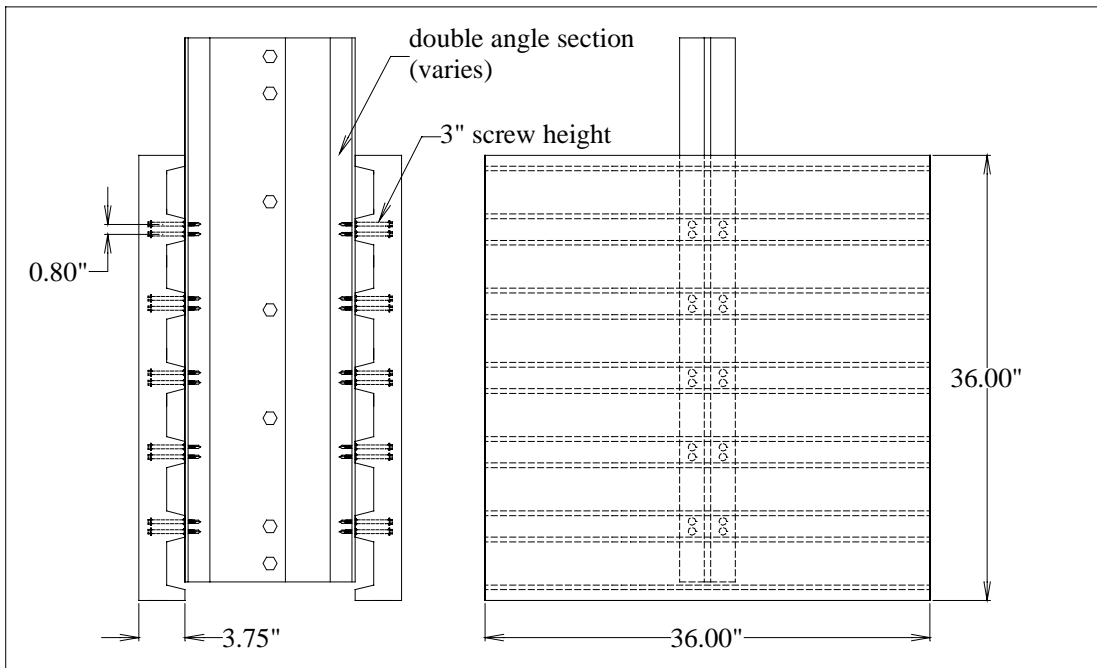


Figure 2.10(c) Test Groups D7-D8 Dimensions

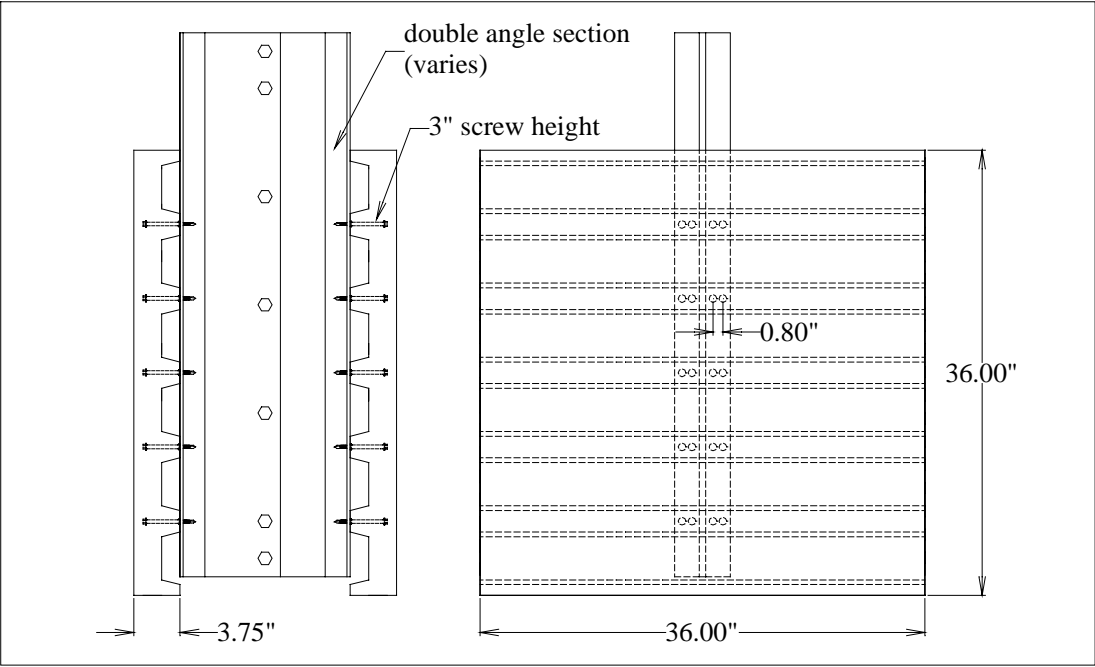


Figure 2.10(d) Test Groups D9-D10 Dimensions

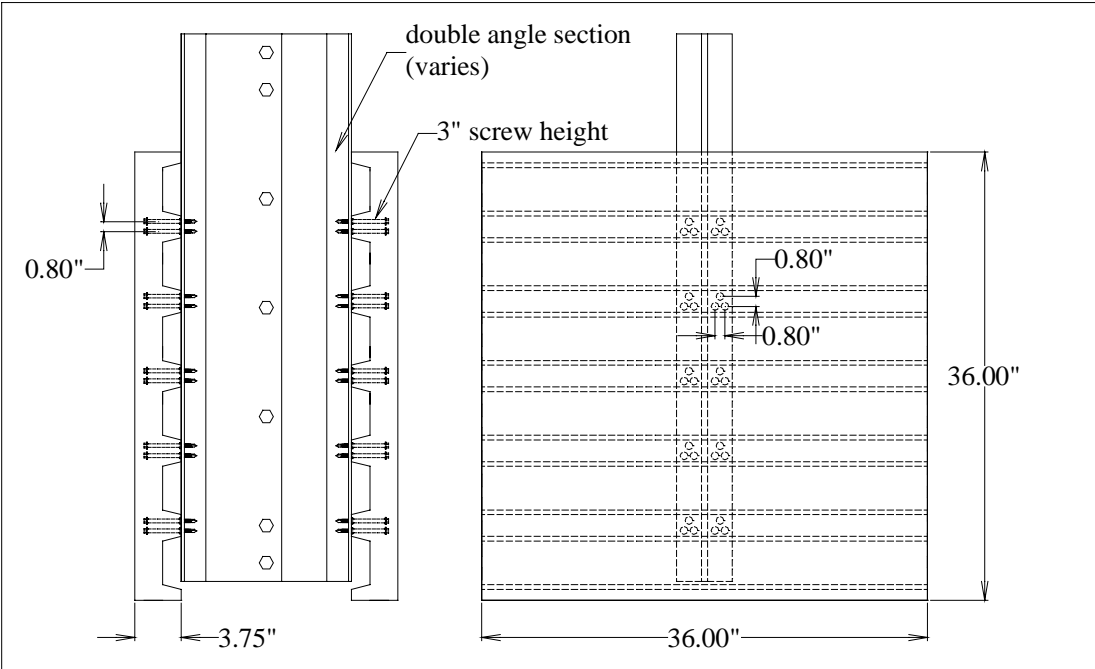


Figure 2.10(e) Test Groups D11-D12 Dimensions

Table 2.5 Series D Configuration

Test Group	Deck Type	Top Chord Section	Plate Width (in.)	Screw Height (in.)	Slab Depth (in.)	Slab Width (in.)	Slab Length (in.)	Screws Per Half Specimen	Welded Wire Fabric	Rebar
D1	1.5VL, 22 ga.	2L 1.25x1.25x0.109	0.5	3.0	3.25	36	36	5	6x6-W2.9xW2.9	4-No. 4
D2	1.5VL, 22 ga.	2L 2.00x2.00x0.187	0.5	3.0	3.25	36	36	5	6x6-W2.9xW2.9	4-No. 4
D3	1.5VL, 22 ga.	2L 2.00x2.00x0.250	0.5	3.0	3.25	36	36	5	6x6-W2.9xW2.9	4-No. 4
D4	1.5VL, 22 ga.	2L 1.25x1.25x0.109	0.5	3.0	3.25	36	36	10	6x6-W2.9xW2.9	4-No. 4
D5	1.5VL, 22 ga.	2L 2.00x2.00x0.187	0.5	3.0	3.25	36	36	10	6x6-W2.9xW2.9	4-No. 4
D6	1.5VL, 22 ga.	2L 2.00x2.00x0.250	0.5	3.0	3.25	36	36	10	6x6-W2.9xW2.9	4-No. 4
D7	1.5VL, 22 ga.	2L 2.00x2.00x0.163	1.0	3.0	3.75	36	36	20	4x4-W2.1xW2.1	6-No. 4
D8	1.5VL, 22 ga.	2L 2.00x2.00x0.250	1.0	3.0	3.75	36	36	20	4x4-W2.1xW2.1	6-No. 4
D9	1.5VL, 22 ga.	2L 2.00x2.00x0.163	1.0	3.0	3.75	36	36	20	4x4-W2.1xW2.1	6-No. 4
D10	1.5VL, 22 ga.	2L 2.00x2.00x0.250	1.0	3.0	3.75	36	36	20	4x4-W2.1xW2.1	6-No. 4
D11	1.5VL, 22 ga.	2L 2.00x2.00x0.163	1.0	3.0	3.75	36	36	30	4x4-W2.1xW2.1	10-No. 4
D12	1.5VL, 22 ga.	2L 2.00x2.00x0.250	1.0	3.0	3.75	36	36	30	4x4-W2.1xW2.1	10-No. 4

2.4 Test Setup

Each of the 106 pushout tests conducted in this study was performed at the Virginia Tech Structures and Materials Research Laboratory. The setup for these tests was virtually identical to that of Hankins (1994). The specimens were placed on 1 in. thick elastomeric bearing pads on a reaction floor and tested in a load frame consisting of structural steel members. The bearing pads were used to ensure a uniform loading surface across the bottom of the specimen. A loading plate was used on top of the specimen to distribute the axial load to the double angles of the top chord section. Care was taken to ensure that the stems of the two top chord sections bolted together were even and level. A swivel plate was then placed atop the loading plate to evenly distribute the axial load between the two specimen halves. The axial load was applied with a hydraulic ram suspended from a cross-head that was bolted to the cross members of the load frame.

To accurately model a full-scale composite joist floor system, a normal load apparatus was used to apply a load perpendicular to the surfaces of the two concrete slabs. This normal load simulates the gravity load in full-scale composite joist floor systems. The apparatus consisted of two wide flange steel beams that distributed the load on the slabs along the centerline of each top chord section. The normal load was applied to these spreader beams with a hydraulic ram in a distribution frame. The

distribution frame is a steel frame positioned horizontally that surrounds the specimen. The spreader beams were supported on steel plates until the normal load alone could hold them in position, at which point, the plates were removed. A typical test setup is illustrated in Figures 2.11 and 2.12.

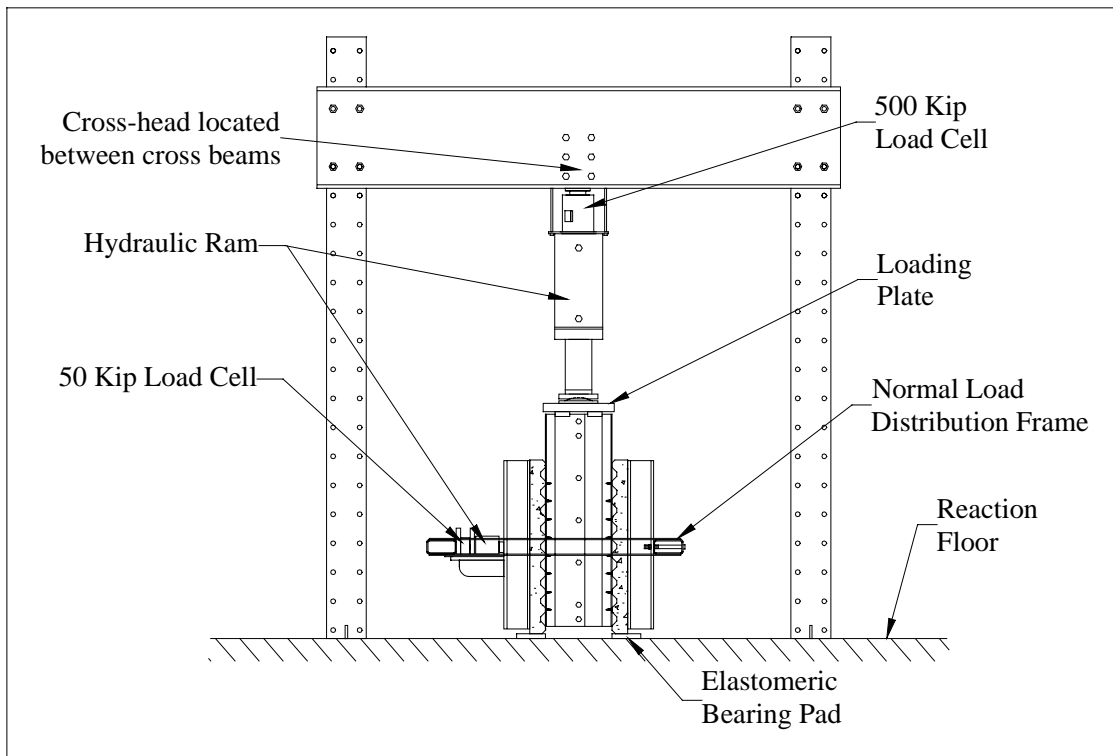


Figure 2.11 Typical Test Setup

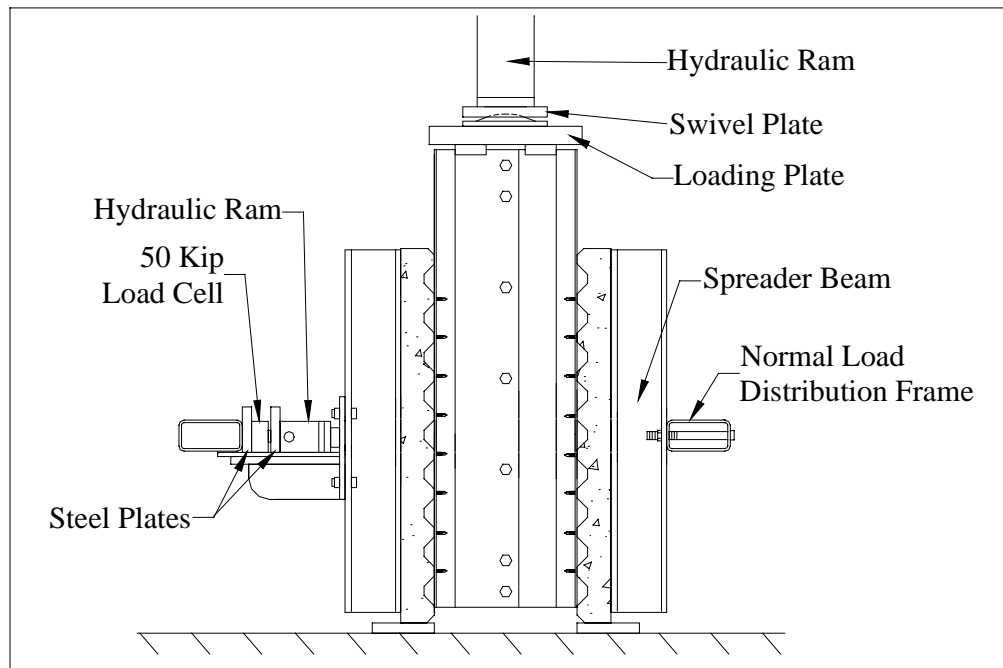


Figure 2.12 Test Setup Detail

Some variations to this test assembly were implemented as adjustments became necessary. In the preliminary series and series B, an apparatus was used to limit the extent of longitudinal splitting of the slabs. Longitudinal splitting is not considered a primary mode of failure in interior composite joists, due to the lateral restraint provided by the concrete on either side of the joist. In a pushout test using a 36 in. wide slab, longitudinal splitting occurs much more readily since there is significantly less lateral restraint. The apparatus consisted of two pairs of 2.5 in. angles that were placed horizontally on the sides of the slabs. The angles were connected with 0.75 in. threaded rods that passed through each angle and were inserted in bolt holes in the top chord section. These holes were located near the top and bottom of the slabs so that the slabs would be supported transversely throughout their length. Elastomeric pads, 0.5 in. thick, were placed between the angles and the sides of the slabs. The angles were then snug tightened to prevent the slabs from separating apart, should longitudinal splitting occur. Steel reinforcing bars were used in series A, C, and D to prevent longitudinal splitting,

thereby eliminating the need for this apparatus in those series. The apparatus described here is shown in Figure 2.13.

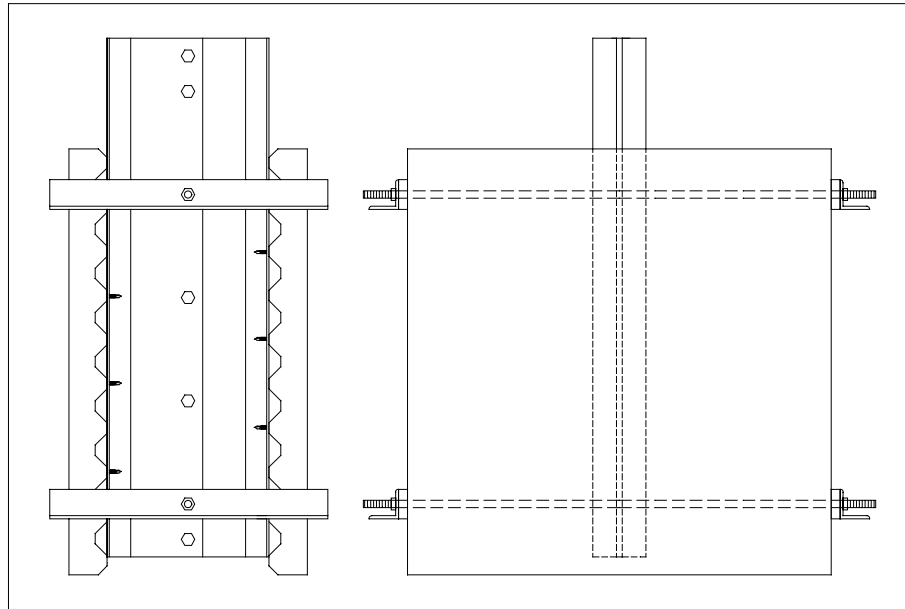


Figure 2.13 Apparatus Used to Limit Longitudinal Splitting

Another variation to the test setup was the addition of lateral bracing of the top chord section above the upper most standoff screws. The lateral bracing was intended to prevent buckling of the top chord, a failure mode that had occurred in several tests, especially those with very thin double angles in the top chord. This problem was also encountered by Hankins in his tests resulting in the use of a full length plate between the double angles in the top chord sections. The lateral bracing was implemented in test groups A5-A8, and the entire series C and D. The lateral bracing carried no load and in no way affected the performance of the standoff screws during testing. Test specimens had to be rotated 90 degrees in the load frame to utilize the lateral bracing apparatus, shown in Figure 2.14.

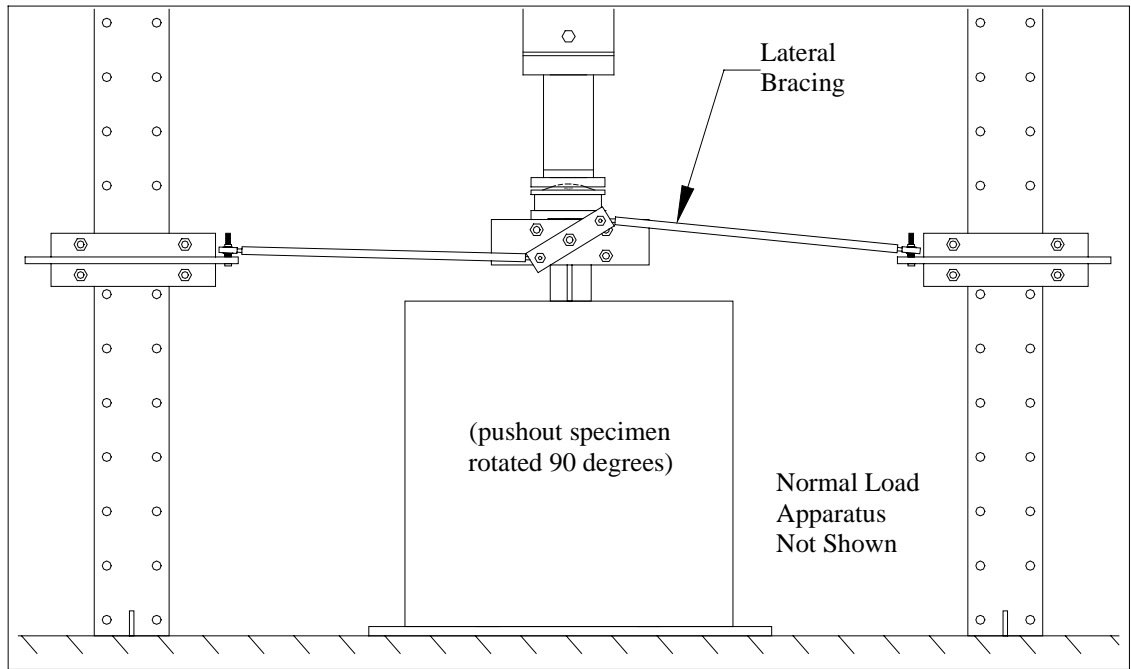


Figure 2.14 Lateral Bracing Apparatus

2.5 Instrumentation and Testing Procedure

Axial load, normal load, and relative slip between the concrete and steel were measured in each test. The axial load was measured with the use of a 500-kip load cell placed between the top of the hydraulic ram and the cross-head in the load frame. A 50-kip load cell placed between a hydraulic ram and the normal load distribution frame measured the normal load. The locations of the load cells can be seen in Figure 2.11.

The relative slip between the concrete and steel was measured by linear potentiometers. Eight potentiometers were used in each test to measure the slip at four different locations on each slab. Four oval-shaped holes approximately 1 in. long were cut in each piece of deck before concrete was cast. Before testing, holes measuring $5/32$ in. diameter by 1 in. deep were drilled into the concrete at the locations of the four holes in the deck. Nails were then placed in these holes and anchored with vinyl anchors. The heads of the nails protruded out of the slab about 2 in. The potentiometers were clamped to the top chord section with 1 in. C-clamps. The shaft of each potentiometer was then extended and the end was tied with steel wire to the nail.

The load cells and potentiometers were connected with wires to a data acquisition system. The Vishay Measurements Group System 4000 and System 5000 Data Acquisition Systems were used in this study.

The procedure for each test was identical. First, a relatively small normal load was applied to the specimen, i.e. 500-1000 lb. Then, an axial load was applied, generally in the range of 5-10 kips. The normal load was kept at approximately 10 percent of the axial load throughout the entire test. The system was then allowed to stabilize for approximately three minutes before recording the loads and respective slips from the data acquisition system. Any physical changes in the specimen were also noted, such as deck debonding or bulging. The normal and axial loads were incrementally increased until failure occurred. Data was recorded at each increment and carefully examined to ensure a uniform loading rate and relative slip. Approximately three minutes passed between recording data points to ensure static loading. Failure was defined by a decrease in axial load carrying capacity of the specimen.

Once failure had occurred, the specimen was unloaded and removed from the load frame and disassembled. Damage was noted and sketches of the damaged slabs were drawn.