# FURTHER INVESTIGATION OF STANDOFF SCREWS USED IN COMPOSITE JOISTS

by

James E. Webler

Thesis submitted to the faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
IN
CIVIL ENGINEERING

APPROVED:

W. Samuel Easterling, Chairman

Thomas M. Murray

Thomas E. Cousins

January 2000
Blacksburg, Virginia

**Keywords:** Standoff Screws, Shear Connectors, Composite Joists

**FURTHER INVESTIGATION OF STANDOFF SCREWS USED IN COMPOSITE JOISTS**

by

James E. Webler

W. Samuel Easterling, Chairman

Civil Engineering

(ABSTRACT)

The purpose of this study is to further evaluate the performance of the 5/16 in. diameter Elco Grade 8 standoff screw as a mechanical shear connector in composite joists. Standoff screws are being investigated as viable an alternative to welded shear studs in short span composite joists. The data and results obtained from 59 pushout tests performed on the 5/16 in. diameter Elco Grade 8 standoff screw are presented. The test parameters investigated in this study include: standoff screw height, quantity of standoff screws per deck rib, standoff screw position, slab depth, base angle thickness, deck type, and amount of transverse reinforcement.

Test results gathered in this study are used in conjunction with selected test data from research performed by Alander (1998). This combined test data is used in determining the validity of existing predictive equations for the shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw. The influence of various independent variables on shear strength is investigated for all screw densities tested. The performance of the 5/16 in. diameter Elco Grade 8 standoff screw in solid slab applications is also investigated. Proposed predictive equations for the shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw based on screw-related failure modes, concrete cone failures and longitudinal splitting, are presented.

## ACKNOWLEDGEMENTS

I would first like to thank Dr. W. Samuel Easterling for his guidance and patience throughout the duration of this study. I would also like to thank Dr. Thomas M. Murray and Dr. Thomas E. Cousins for serving on my committee. Additionally, I express my sincere gratitude to all of the professors at Virginia Tech from whom I have learned so much.

I thank my parents, Donald and Stephanie Webler, for their love and support. I would also like to thank them for their efforts in allowing me to achieve my goals. Special thanks go to all my close friends for being the people they are and for helping me get through so many tough times. I hope they understand how much their friendship truly means.

Many people had a hand in helping with various aspects of this study. First, I would like to express my gratitude to Brett Farmer and Dennis Huffman for their help in fabricating test specimens and for making the Structures Lab an enjoyable place to work. Thanks also go to Ann Crate for her assistance in the preparation of this report. Many thanks go to all of the graduate students who a helped me in the classroom, particularly Aaron Bopp and Doug Neely, as well as those helping with this study. I owe a special debt of gratitude to Chad Alander for his assistance throughout this study and for his contributions to this report. The efforts of Carter Stinchcomb in the fabrication of test specimens are very much appreciated. Again, my sincere gratitude to all those who played a part in assisting with this study.

I would finally like to express my gratitude to Nucor Corporation for funding this research program and specifically to Mr. David Samuelson for his assistance.

**TABLE OF CONTENTS**

Page

## LIST OF FIGURES

## LIST OF TABLES

# CHAPTER 1
# INTRODUCTION

## 1.1 Background

Composite construction has been utilized in floor systems for more than three decades. A composite system generally consists of a concrete slab placed on top of a rolled, or built-up, steel section and interconnected with a shear connector. Cold form steel deck may be used as a stay-in-place form in composite systems. A section is said to be "composite" if sufficient connection is provided to resist the horizontal shear force at the steel/concrete interface. This shear force is developed in the section during bending. The use of composite construction has many advantages, which include (Salmon and Johnson 1996):

- Reduction in steel weight
- Shallower steel beams
- Increased floor stiffness
- Increased span length

In many cases, the use of open web steel joists instead of standard steel sections is more economical in floor systems. Steel joists typically have chords made up of light double angle sections and web members that are either round bars or small angles. Increasing the angle size in the bottom chord and reducing the angle size in the top chord can produce a more structurally efficient section. The open web configuration of the joists allow mechanical and electrical conduits to pass through as opposed to having to cut holes in the web of a standard steel section or increasing floor depth. Joists are also significantly lighter in weight than standard steel sections which can lead to substantial savings in material costs.

Many different types of shear connectors have been developed since composite systems were first introduced. Of these, the welded shear stud has, by far, been the most widely used. This type of connector is attached to the top flange or chord using a welding gun. The use of welded shear studs is acceptable in longer span systems and those that utilize beams as the steel section. When steel joists are used, it may not always be practical to use welded shear studs. The thin double angle top chord section of a short span (25 ft.-35 ft.) joist makes it difficult to satisfy the welding requirement that the stud diameter to flange thickness ratio be no greater than 2.5 (*Load and* 1993). It is common for burn-through to occur when welding into thin members. In cases where steel deck is used, it is also difficult to get a quality weld through the deck when the base members are thin. Some other drawbacks to using welded shear studs include the need for experienced welders and costly welding equipment. Obtaining the required electricity to run the welding equipment can often be difficult enough to warrant using a different means of shear connection.

On smaller scale projects, the use of welded shear studs may prove to be quite uneconomical. To this end, many non-welded shear connectors have been developed. These connectors are attached with shot-fired nails or are self-drilling and tapping. One of the more promising non-welded shear connectors is the self-drilling, self-tapping standoff screw. An ongoing research program is in place at Virginia Tech to determine the feasibility of the standoff screw. A typical standoff screw is shown in Figure 1.1. Standoff screws have variable standoff shank lengths for different amounts of concrete embedment to effectively resist induced shear in the composite system. They can be installed through steel deck into the top chord of joists with a standard screw gun eliminating the need for expensive equipment. Since there is no minimum base member thickness requirement for attachment, using standoff screws in short-span composite joists is an attractive alternative.

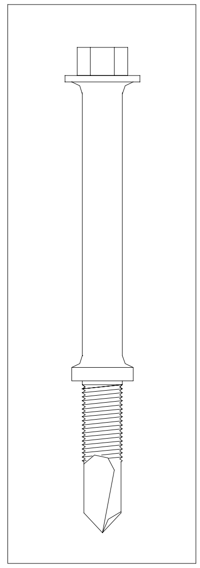


Figure 1.1 Typical Standoff Screw

**1.2 Literature Review**

Although composite joists have been used for many years, the use of standoff screws functioning as the means of shear connection is relatively new. For this reason, there has been little research done to determine the functionality of these screws. Since the majority of the research that has been conducted on the use of standoff screws has been performed at Virginia Polytechnic Institute and State University (Virginia Tech), this literature review will focus on these past studies.

Strocchia (1990) conducted the first significant research into the possible use of a standoff screw at Virginia Tech. Strocchia's research was based on 13 series of pushout tests, 36 tests in all, aimed at evaluating the strength and behavior of six different types of deck fasteners. Three of the deck fasteners used were types of standoff screws. These screws are shown in Figure 1.2. The screws tested were self-tapping with standoff sleeves of varying lengths. The standoff sleeve allows the screw to be driven such that a predetermined length of the screw is available for embedment. Standoff lengths investigated were 1.25 in., 1.75 in. and 2.25 in. while the diameters varied from 0.215 in. to 0.240 in. All tests in this study were constructed using Vulcraft 1.5 VL, 22 ga. deck, details of which are shown in Figure 1.3. The thickness, width and length of the concrete slabs were varied between test series. Initially, WT 5×11 sections were used as base members for the pushout tests but this was later abandoned in favor of using 2L 1.5×1.5×0.113 welded to a steel plate measuring 0.5 in. thick by 6 in. wide by 44 in. long. This was done to more accurately model the top chord of a typical steel joist.

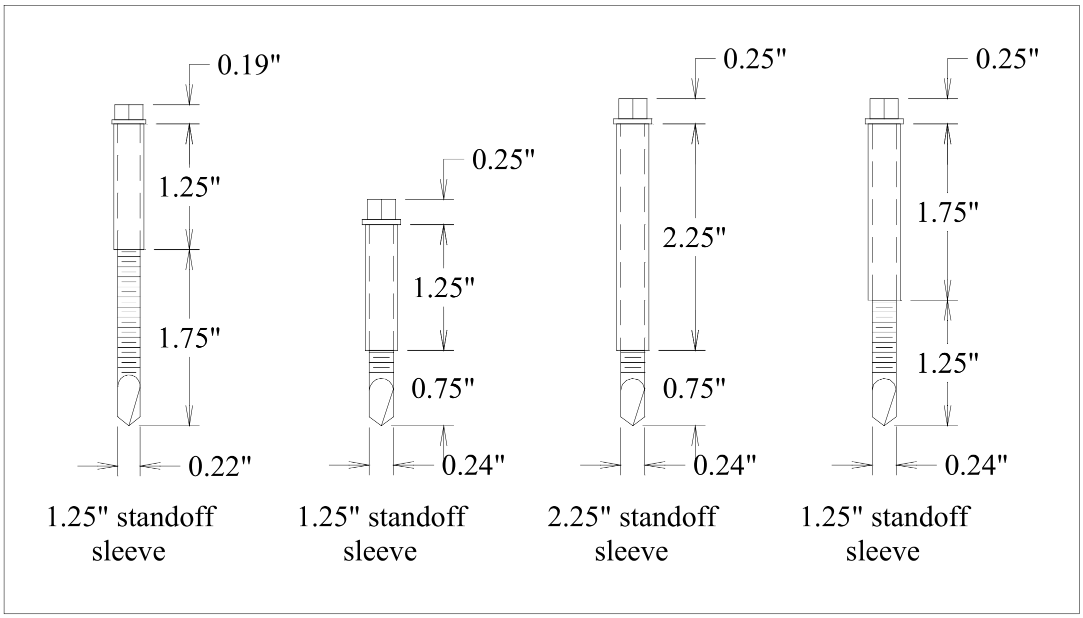



Figure 1.2 Self-tapping Screws with Standoff Sleeves (Strocchia 1990)

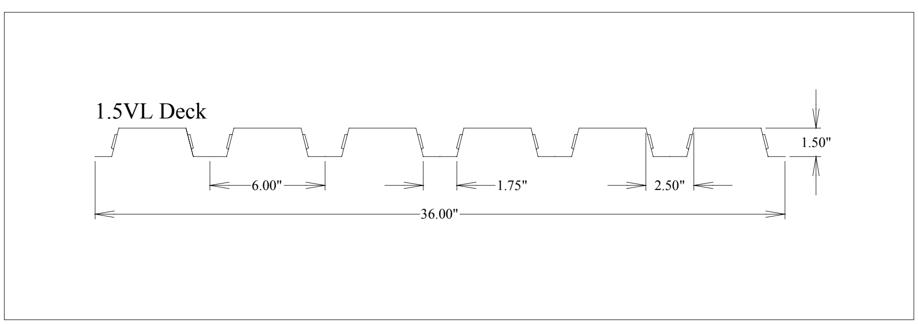



Figure 1.3 Vulcraft Deck Profile Used by Strocchia (1990)

Six of the 13 series of tests were focused on standoff screws. It was found that, in specimens with thin base angles, there was significant deformation of the base material and bending of the screws. Due to this rotation, many screws did not fail by direct shear, but by a combination of shear and tensile forces. Also observed by Strocchia was the influence of the embedment depth of the screws on the failure mode of the system. It was determined that, to realize their full capacity, the top of the screws had to be higher than the top of the deck profile. This was evident when comparing test results from specimens using 1.25 in. screw heights to results of specimens using 2.25 in. screw heights; a difference of 0.5 in. above and below the top of the deck profile. Tests incorporating the shorter screws failed primarily by shearing of the concrete ribs while tests with the longer screws failed by a more ductile failure of the screws. The ductile failure of the screws is a much more desirable failure mode for this type of system. One of the most probable contributing factors to the rib shear failure observed in this study was the relatively narrow width of the pushout specimens coupled with the relatively small rib area of the Vulcraft 1.5VL, 22 ga. deck. Slabs used were either 12 in. or 24 in. wide. The width of more recent pushout tests has been increased to reduce the possibility of this type of failure. Another change to the specimens made was to invert the steel deck. Inverting the steel deck increases the potential concrete rib failure plane thereby reducing the probability of a concrete rib shear failure. Specimens utilizing inverted deck exhibited a ductile screw failure as well as a higher ultimate load, proving the effectiveness of the modification.

Strocchia concluded that tests with greater screw embedment depth and inverted Vulcraft 1.5VL, 22 ga. deck displayed ideal behavior for a shear connection system. This was found true due to the ability of these series to provide enough strength to achieve composite action while exhibiting sufficient ductility. Strocchia also recommended modifications to the standoff screws used in his study. It was noted that the slit in the standoff sleeve may have been detrimental to the stiffness of the standoff screw. He proposed increasing the diameter of the standoff shaft in order to resist bending inside of the concrete ribs. Also, Strocchia proposed further testing of the standoff screws in different types of steel deck. His recommendations would be the basis for further research into the use of standoff screws at Virginia Tech.

Lauer (1994) conducted eight full-scale composite joist tests at Virginia Tech using six different types of shear connectors. Of the three tests that utilized standoff screws, two used the Buildex screw while one used the Elco Grade 8 standoff screw. The dimensions of both screws were 5/16 in. diameter by 2 in. in length. The standoff screws used in Lauer's study were similar to those used in following and current studies at Virginia Tech, shown in Figure 1.1. Each test utilized steel deck oriented perpendicular to the joist span direction. The two tests incorporating the Buildex screws, CSJ-1 and CSJ-2, were identical with the exception of the type of steel deck used. The CSJ-1 test used Vulcraft 1.0C, 26 ga. deck while the CSJ-2 test used Vulcraft 1.5VL, 22 ga. deck. Both tests were made up of 8 in. deep joists spanning 24 ft.-3in. on 40 in. centers. The concrete slabs were 3 in. in total depth and 80 in. wide. Screws were staggered and placed in every other rib in CSJ-1 and in every rib in CSJ-2 for a total of 14 screws per half span. The CSJ-8 test set-up, which utilized the 5/16 in. diameter Elco Grade 8 standoff screws, consisted of two 18 in. deep joists spanning 29ft.-7.5 in. on 40 in. centers. Vulcraft 1.0C, 26 ga. deck was used with a 4 in. slab and nine screws per half span.

In tests CSJ-1 and CSJ-2, Lauer noted that "although the overall behavior of the system was ductile, failure of the individual standoff screw shear connectors was somewhat brittle." He also noted significant screw rotation causing the anchoring top chord angles to distort. Some screws tore through the steel deck without shearing as the slip between the slab and joist increased. Lauer stated that screws did not begin to rupture until there was considerable progression in member deflection and interface slip. In the CSJ-8 test, none of the Elco Grade 8 screws exhibited a rupture failure. None of the standoff screws from these three tests pulled out of the top chord angles.

Lauer performed his analysis with the aid of pushout test results from Hankins' study (1994). With Hankins' test data, Lauer was able to estimate the shear connector capacity in tests CSJ-1, CSJ-2 and CSJ-8. Even though the slab thickness, concrete compressive strength and top chord thickness in CSJ-1 and CSJ-2 did not match exactly the parameters of the pushout tests, the full-scale tests did not significantly differ from the pushout test configurations. The top chord thickness, deck type and slab thickness of the CSJ-8 test matched those of the pushout tests. In each case, values obtained from pushout tests were used without modification. From equilibrium equations that represent the flexural model of a composite joist, Lauer calculated the experimental shear connection force in each test. These equations are as follows:

$$Q_{ae} \cdot e \pm N_a \cdot e' = M_{ae} \tag{1.1}$$

$$Q_{ae} \cdot e_t + T_a \cdot e' = M_{ae} \tag{1.2}$$

where:

$\Sigma Q_{ae}$ = measured shear connection

$N_a$ = top chord force due to applied load

$T_a$ = bottom chord force due to applied load

$M_{ae}$ = experimental midspan moment under applied load

$e$ = distance between bottom chord centroid and resultant concrete force, in.

$e'$ = distance between centroids of top and bottom chords, in.

$e_t$ = distance between top chord centroid and resultant concrete force, in.

Knowing the experimental applied moment on the joist and assuming a top chord force based on the value measured during testing, the experimental shear connection force was calculated. Then the remaining bottom chord force could be found from equilibrium. For values of the shear connection force to be acceptable, the top and bottom chord forces had to be close to the actual chord forces. The experimental shear connection force in CSJ-1, CSJ-2 and CSJ-8 compared favorably to the values obtained from Hankins' pushout test data, as seen in Table 1.1. Most likely due to the exact match of test parameters between the full-scale test and the corresponding pushout tests, the shear connection force from test CSJ-8 was the closest to its assumed value.

Table 1.1 Experimental Shear Connection (Lauer 1994)

| | $N_a$ (kips) | $N_{ae}$ (kips) | $T_a$ (kips) | $T_{ae}$ (kips) | **$Q_{ac}$ (kips)** | **$Q_{ae}$ (kips)** | **$Q_{ae}/Q_{ac}$** |
|---|---|---|---|---|---|---|---|
| CSJ-1 | 36.8 | 36.8 | 82.0 | 81.8 | **41.0** | **45.2** | **1.10** |
| CSJ-2 | 40.4 | 40.4 | 83.7 | 87.5 | **41.0** | **43.3** | **1.06** |
| CSJ-8 | 21.8 | 21.8 | 54.1 | 62.3 | **33.2** | **32.3** | **0.97** |

$N_a$ Top chord force due to applied loading, assumed value for use in Eq. (1.1)

$N_{ae}$ Experimental top chord force due to applied load

$T_a$ Bottom chord force due to applied load, found from horizontal force equilibrium

$T_{ae}$ Experimental bottom chord force due to applied load

$Q_{ac}$ Calculated shear connector capacity

$Q_{ae}$ Experimental shear connector capacity, back calculated using Eq. (1.1)

The most extensive research on standoff screws to date is that of Hankins (1994) and Alander (1998) at Virginia Tech. Hankins' research, which was a companion study to the full-scale tests done by Lauer, consisted of 65 pushout tests used to evaluate the performance of the 5/16 in. diameter Elco Grade 8 standoff screw. His research included a preliminary series of nine pushout tests used to compare three different types of standoff screw. In each test, the standoff screws were fastened to a base material made up of back-to-back angles separated by filler plates to simulate the top chord of an open web steel joist. Test parameters varied in these tests included deck geometry, base angle thickness, screw embedment depth, slab width and slab depth. The 74 total tests were divided into six series: a preliminary series and series 1 through 5.

The three standoff screws tested in the preliminary series included the Buildex, Elco Grade 5 and Elco Grade 8 screws. Three pushout tests were performed on each type of standoff screw. For all nine tests, the top chord sections were fabricated from 2L-1.5×1.5×0.123 and Vulcraft 1.0C, 26 ga. deck. The deck was positioned with the deck ribs perpendicular to the direction of the applied load. This configuration was used on all tests that utilized steel deck. The concrete slabs were 4 in. thick × 36 in. wide × 36 in. long and three screws, in a staggered configuration, were place in each specimen half. Hankins' found that the Elco screws to be much more ductile that the Buildex screws, failing at much greater slip values. Accordingly, the Elco screws were decided to be more promising for use in composite joists. The 5/16 in. diameter Elco Grade 8 screw was chosen over the 5/16 in. diameter Elco Grade 5 screw due to the higher theoretical shear and tensile strength of the Grade 8 screw (Hankins 1994). The following series of pushout tests, series 1 through 5, were then conducted to further evaluate the performance of the 5/16 in. diameter Elco Grade 8 standoff screw. Details of the 5/16 in. diameter Elco Grade 8 standoff screws evaluated are shown in Figure 1.4 and a typical pushout specimen is shown in Figure 1.5.

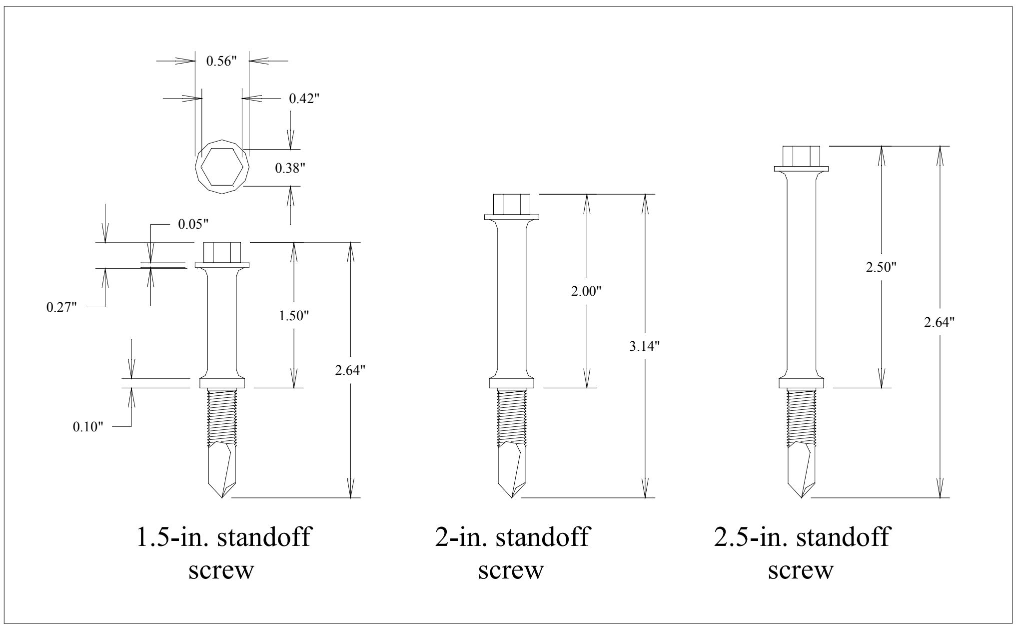



Figure 1.4 Standoff Screws Investigated by Hankins (1994)

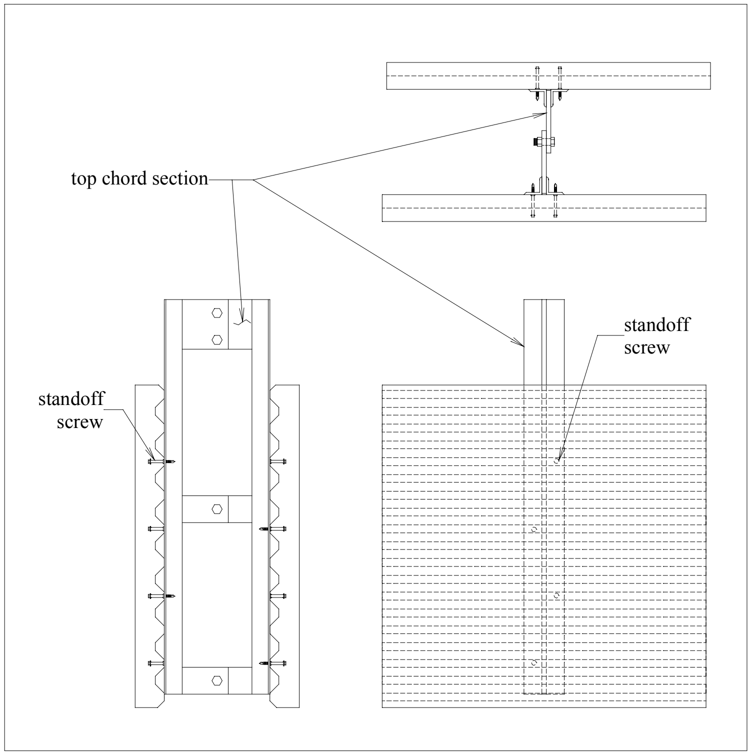



Figure 1.5 Typical Pushout Specimen Used by Hankins (1994)

Pushout test series 1 consisted of 20 tests that were conducted to study the performance of the 5/16 in. diameter Elco Grade 8 screw with a 2 in. standoff shank in specimens with solid slabs and varying top chord thicknesses. As in all the tests in series 1 through 5, four standoff screws were placed in each specimen half in a staggered pattern and welded wire fabric was used as reinforcement. The slab length and width were both 36 in. and the slab thickness varied. Pushout series 2 consisted of 12 tests to evaluate the performance of the 5/16 in. diameter Elco Grade 8 standoff screw with a 1.5 in. standoff shank when used in Vulcraft 0.6C, 28 ga. deck. The concrete slabs measured 36 in. long, 24 in. wide and 2 in. thick. Pushout series 3 consisted of 12 tests to evaluate the performance of the 5/16 in. diameter Elco Grade 8, 2 in. standoff screw in Vulcraft 1.0C, 26 ga. deck. Series 3 slabs measured 36 in. long, 36 in. wide and 2.5 in. thick. Series 4 and 5 used Vulcraft 1.5VL, 22 ga. deck and consisted of 12 and 9 tests, respectively. The slabs measured 36 in. by 36 in. with varying thicknesses. Screw height in series 4 was 2 in. and for series 5, it was 2.5 in.

Hankins observed five different failure modes in the pushout tests: screw shear, cone pullout, screw pullout from base angles, longitudinal splitting of the slab and angle buckling in the top chord section. Buckling of the top chord section was preceded by substantial rotation at the base of the standoff screws and considerable deformation of the base angle, illustrated in Figure 1.6. This deformation caused the development of a plastic hinge, allowing the top chord section to buckle laterally above the upper-most screws. Hankins also observed that base angle thickness greatly influenced the strength of the standoff screws. As base angle thickness increased, screw strength also increased. However, when the base angle thickness becomes too great, it acts relatively fixed and screw strength decreases. Therefore, Hankins concluded that greater connector strength could be achieved with a somewhat flexible base material, approximately 0.2 in. thick. Large rotation of the shear connector causes the connector to be loaded primarily in tension. Little or no rotation of the shear connector in a thicker base angle causes primarily shear loading of the connector. The drop in the strength of the standoff screws associated with a larger base thickness suggests an interaction between shear and tension. Hankins also noticed the great ductility of the 5/16 in. diameter Elco Grade 8 standoff screw, as evidenced in his plots of shear load vs. slip.

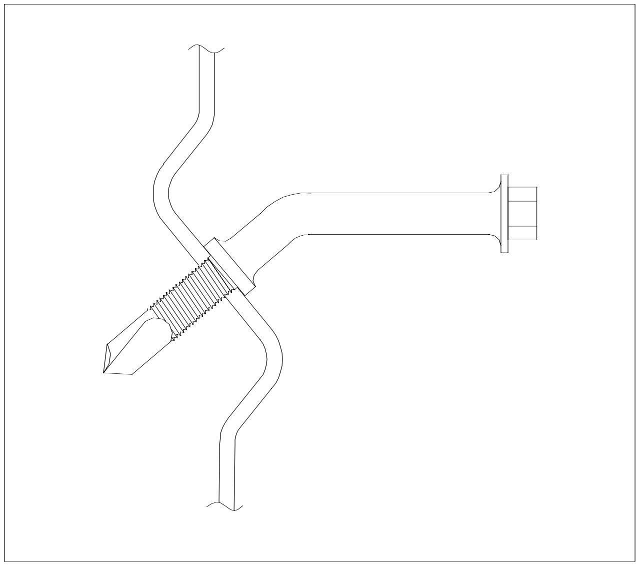


Figure 1.6 Typical Screw Rotation (Hankins 1994)

Hankins' analysis of the pushout test data consisted of applying several existing shear stud models to the test geometries of the 65 tests in series 1 through series 5. He then compared the analytical results to the experimental results to determine the predictability of the shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw.

Hankins concluded that the concrete splitting model developed by Oehlers (1989) predicts the strength of the standoff screw in solid concrete slabs with acceptable accuracy, provided that the indirect tensile strength of concrete is taken as $6\sqrt{f'_c}$ (an approximation of the split cylinder strength of concrete). Oehlers concrete splitting model is based on 50 reinforced and unreinforced pushout tests that failed by longitudinal cracking. He developed a method of predicting the occurrence of splitting due to the local action of individual connectors and global action of groups of connectors. The following equation was developed to predict a splitting crack in the concrete (Oehlers 1989):

$$P_s = \frac{0.6 h_a f_t b \pi}{\left(1 - \frac{d_s}{b}\right)^2} \tag{1.3}$$

where:

$P_s$ = concentrated connector force resulting in concrete splitting, N

$h_a$ = effective connector height, $1.8\times d_s$, mm

$f_t$ = indirect tensile strength of concrete, $N/mm^2$

$b$ = pushout specimen slab width, mm

$d_s$ = connector diameter, mm

Oehlers (1989) also investigated the effects of transverse reinforcement on the concrete splitting and determined that transverse reinforcement does not prevent splitting but does limit the propagation of the split, thus preserving some of the interaction and shear connection. Hankins questioned the applicability of using Eq. 1.3 for standoff screws, since standoff screws would be used, in most instances, in applications utilizing steel deck. When steel deck is used, failure by concrete tensile pullout is more common than longitudinal splitting of the concrete.

Attempting to predict the strength of the standoff screw in configurations utilizing steel deck, Hankins examined the stud strength model proposed by Lloyd and Wright (1990). Lloyd and Wright's model was based on a wedge shaped concrete failure surface that was a modification to a similar model developed by Hawkins and Mitchell (1984). The Lloyd and Wright model, shown in Figures 1.7 and 1.8, is based on a shear path of least resistance.

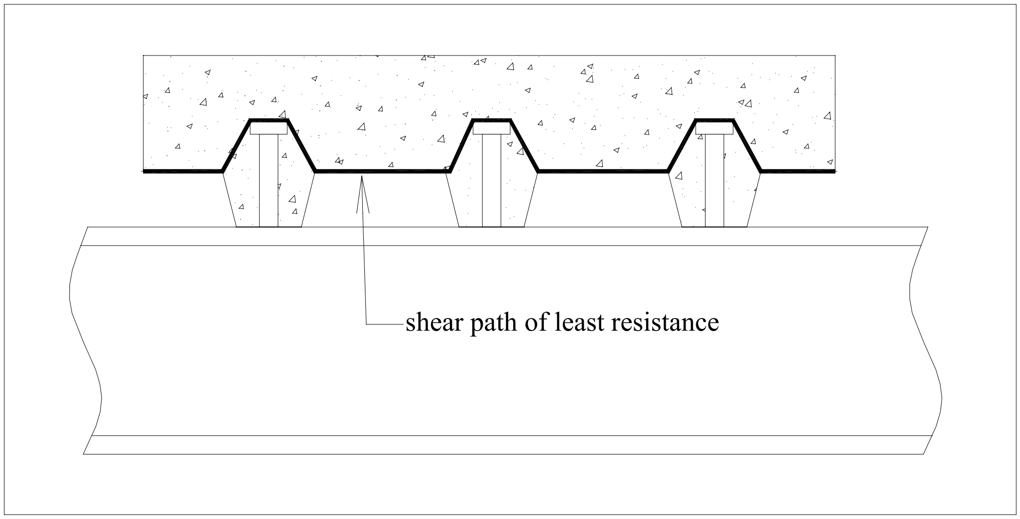



Figure 1.7 Longitudinal Shear Path (Lloyd and Wright 1990)

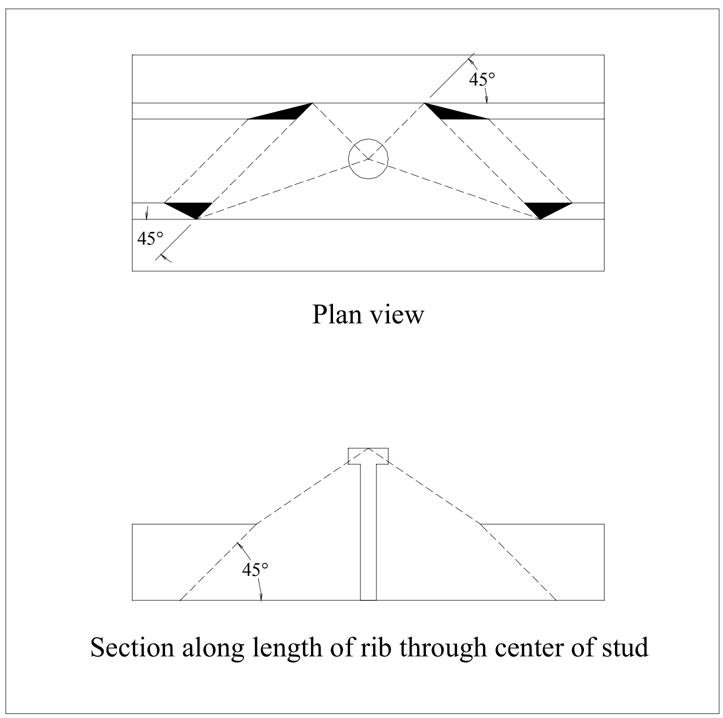



Figure 1.8 Wedged Shear Cone (Lloyd and Wright 1990)

Although the Lloyd and Wright model did not accurately predict the strength of the standoff screw, the wedged failure surface was consistent with the pullout failures observed in Hankins tests. Because no existing models accurately predicted the strength of the standoff screw in slab geometries utilizing profiled steel deck, Hankins developed an equation based on a rederivation of the Lloyd and Wright model which does so with acceptable accuracy. The equation is given by:

$$V_{wc} = 0.11\sqrt{A_{wc}\sqrt{f'_c}} \tag{1.4}$$

where:

$V_{wc}$ = connector strength, kips

$A_{wc}$ = surface area of wedge shaped tensile concrete pullout cone, in.$^2$

$$= 2w_{r2}\sqrt{\frac{w_{r2}^2}{4}+(H_s-h_r)^2}+w_{r2}\sqrt{w_{r2}^2+2(H_s-h_r)^2}+2w_{r1}\sqrt{3h_r^2}$$

$f'_c$ = concrete compressive strength, psi

$h_r$ = nominal rib height of steel deck, in.

$H_s$ = total length of shear connector, in.

$w_{r1}$ = concrete rib width at bottom of flange of steel deck, in.

$w_{r2}$ = concrete rib width at top of flange of steel deck, in.

Hankins concluded that the 5/16 in. diameter Elco Grade 8 standoff screw provided effective shear connection and could be used in lightweight joist applications where conventional headed shear studs cannot be used.

Alander (1998) conducted 106 pushout tests on the 5/16 in. diameter Elco Grade 8 standoff screw to supplement the study by Hankins. Alander's tests were divided into five series: a preliminary series and series A through D. The testing procedure and setup used was the same as that of Hankins. The primary differences in Alander's study were the use of greater quantities of screws per specimen and the further investigation into additional screw heights. Screw heights examined in his study were 2 in., 2.5 in., 3 in. and 3.5 in. Details of these screws are shown in Figure 1.9. As in earlier research, top chord sections were fabricated from double angles welded back-to-back. A key difference between tests conducted by Hankins and those done by Alander was the use of a full-length plate as a base member for which to weld the angles to. This was done to attempt to eliminate the premature buckling of the top chord section, a problem that existed in some of the tests in Hankins' study. The angles utilized in Alander's study ranged in size from 2L 1.25×1.25×0.109 to 2L 3.0×3.0×0.313. The concrete slabs were formed with and without steel deck and incorporated varying amounts of steel reinforcement in the form of welded wire fabric, No. 4 reinforcing bars or a combination of both. Different deck profiles tested included Vulcraft 0.6C, 1.0C, 1.5C and 1.5VL. Details of these deck profiles are illustrated in Figure 1.10.

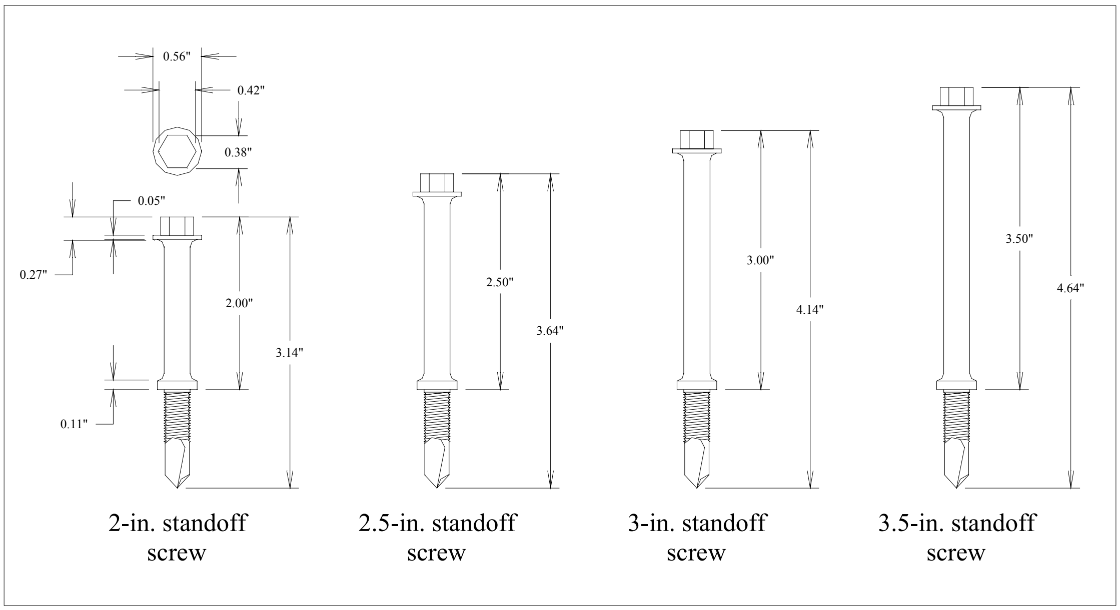



Figure 1.9 Standoff Screws Investigated by Alander (1998)

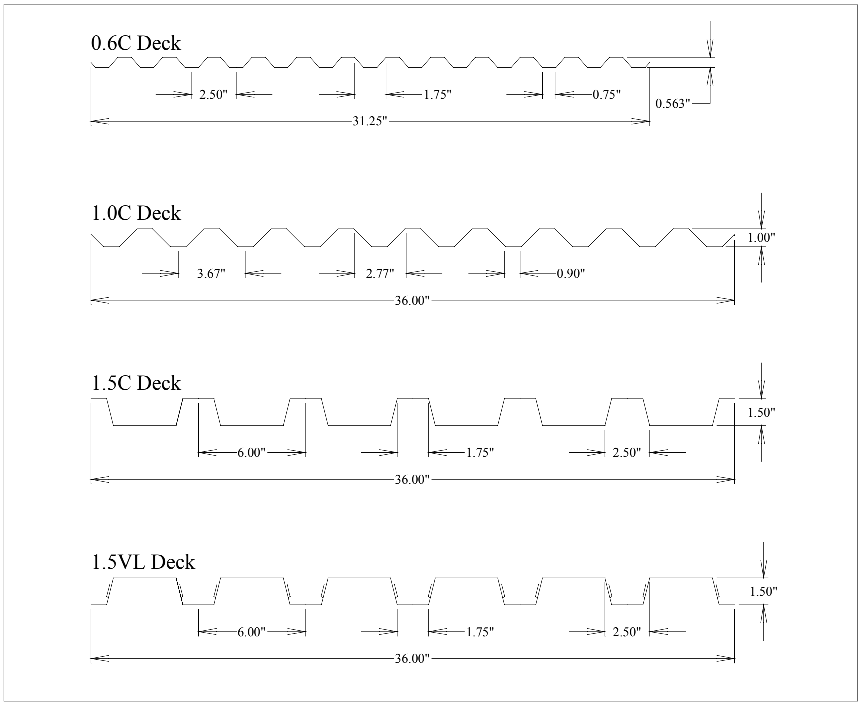



Figure 1.10 Vulcraft Deck Profiles Investigated by Alander (1998)

The focus of Alander's analysis was to determine the validity of the equation derived by Hankins (Eq. 1.4) to predict the capacity of the 5/16 in. diameter Elco Grade 8 standoff screw. In order to accurately compare results from different tests, the results were normalized to remove the effects of having different concrete compressive strengths. In his analysis, Alander investigated the effects of the different test parameters on the performance of the standoff screws. With the idea of serviceability in mind, Alander focused his analysis on test data at small slips, generally 0.2 in. Though numerous trend comparisons, tests from each series, excluding the preliminary series, were chosen to provide data for a multiple linear regression analysis. Tests that failed by top chord buckling were excluded from all analysis.

The first multiple linear regression was done on tests only having one screw per rib. The equation developed was based on the shear strength of the standoff screw that occurs at 0.2 in. slip and is as follows:

$$V_s = \sqrt{f_c'}\left(0.0293 + 0.00136A_r + 0.0960t_{TC}\right) \tag{1.5}$$

where:

$V_s$ = shear strength per screw, kips

$f_c'$ = concrete compressive strength, psi

$A_r$ = rib area, in.$^2$

= average rib width × nominal rib height

$t_{TC}$ = top chord thickness, in.

A comparison of predicted values obtained from Eq. 1.5 to experimental values from each test for a shear load at 0.2 in. slip found that the equation was a relatively accurate predictor of the screw capacity. Alander noted that the effects of grouping screws (i.e., more than one screw per rib) were minimal at low slips. As a result, a second multiple linear regression analysis was done including test results from all tests that failed by a screw-related behavior, screw shear or screw pullout from the top chord, not just those with one screw per rib. Equation 6 was developed from this second analysis:

$$V_s = \sqrt{f_c'}\left(0.034 + 0.0012A_r + 0.068t_{TC}\right) \tag{1.6}$$

This new equation predicts the shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw with notable accuracy. There are, however, limitations to Eq. 1.6. It is only applicable to the 5/16 in. diameter Elco Grade 8 standoff screw when the screw is embedded at least 1.5 in. above the top of the deck profile. This amount of embeddment was found to optimize screw performance. Also, it can only be used when the following statements are true:

- 0.6C deck, no more than one screw per rib
- 1.0C deck, no more than two screws per rib
- 1.5C deck, no more than four screws per rib
- 1.5VL deck, no more then two screws per rib

It was discovered that specimens formed with Vulcraft 1.5VL, 22 ga. deck were prone to premature, brittle rib failures when four or more screws were placed per rib. This failure mode was observed in six of the test groups investigated by Alander warranting further consideration. In cases where this type of failure controls, Eq. 1.6 is not applicable. To estimate the rib failure load, it was found that Hankins' (1994) equation, Eq. 1.4, could be modified by replacing the term representing the wedge-shaped concrete cone failure with Lloyd and Wright's (1990) representation of the rib shear failure surface area. This equation, shown below, is only applicable for specimens formed with Vulcraft 1.5VL, 22 ga. deck and more than two 5/16 in. diameter Elco Grade 8 standoff screws per rib.

$$V_{rs} = 0.11\sqrt{A_{rs}\sqrt{f'_c}} \tag{1.7}$$

where:

$V_{rs}$ = rib shear strength, in.

$A_{rs}$ = rib shear failure surface area, in.$^2$ (Lloyd and Wright 1990)

$$= w_{r2}\sqrt{\frac{b^2}{4}+\left(H_s-h_r\right)^2}+b\sqrt{\frac{w_{r2}^2}{4}+\left(H_s-h_r\right)^2}$$

$b$ = width of concrete rib, in.

$h_r$ = nominal rib height of steel deck, in.

$w_{r2}$ = concrete rib width at top flange of steel deck, in.

$f'_c$ = concrete compressive strength, psi

The performance of the standoff screws was also evaluated in solid slab applications. As a means of predicting the shear strength of the standoff screws in solid slabs, the resistance of the slab to longitudinal shear was calculated. This was done using the following equation adopted by The British Steel Construction Institute to calculate the shear resistance per unit length of each shear plane along a beam (*Commentary on* 1990).

$$v_r = 0.03\eta f_{cu} A_{cv} + 0.7 A_{sv} f_y \leq 0.8\eta A_{cv} \sqrt{f_{cu}} \quad (1.8)$$

where:

$v_r$ = shear resistance per unit length of each shear plane, kips/in.

$\eta$ = 1.0 for normal weight concrete

= 0.8 for lightweight concrete

$f_{cu}$ = cube strength of concrete, ksi

≈ 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.

$f_y$ = yield strength of steel reinforcement, ksi

To determine the total shear resistance of a specimen, the shear resistance per unit length, $v_r$, must be multiplied by the length of the slab and number of shear planes. For this study, the yield strength of the welded wire fabric and the steel reinforcing bars was assumed to be 65 ksi.

Alander concluded that the use of the 5/16 in. diameter Elco Grade 8 standoff screw as a means of shear connection is a viable alternative to the conventional welded shear stud in a short-span composite joist. Also, Alander noted that grouping screws does not enhance performance, but may often be detrimental. Recommendations made by Alander include continuing pushout tests to further evaluate the performance of the 5/16 in. diameter Elco Grade 8 standoff screw in new test configurations as well as conducting more full-scale tests. To this end, further research, this study included, is currently underway at Virginia Tech.

### 1.3 Scope of Research

This study is a continuation of research conducted at Virginia Tech by Hankins, Lauer and, most recently, Alander on the use of standoff screws as shear connectors. Hankins performed 74 pushout tests on both Buildex and Elco standoff screws to evaluate their performance in different deck profiles and slab dimensions. Lauer conducted eight full-scale composite joist tests. Three of these tests utilized standoff screws as the means of shear connection. Alander performed 106 pushout tests on the Elco Grade 8 standoff screw to supplement the data and results from research performed by Hankins. This study will be a direct continuation of work done by Alander. The testing procedure and setup are identical to that utilized by Alander. Differences are found only in the characteristics of the specimens tested. The most significant of these differences is in the quantity of screws per specimen and the investigation of additional screw heights and deck profiles. Data gathered from the pushout tests conducted in this study will be used in addition to data produced by Alander.

This report is divided into five chapters. Details of the experimental program are covered in Chapter 2. The experimental program covers the test specimen fabrication procedure, configurations of the tests conducted in this study, the test setup, instrumentation and the testing procedure. The results of all tests in this study are given in Chapter 3 as well as a comparison of the test results for each test series. Chapter 4 deals with the analysis of both data gathered in this study and that of Alander (1998). Interpretations of this data are also provided in Chapter 4. The final chapter, Chapter 5, contains a summary of the study, conclusions drawn from the analysis and recommendations for further research.

# CHAPTER 2
# EXPERIMENTAL PROGRAM

## 2.1 General

The focus of this study is to further evaluate the ability of the 5/16 in. diameter Elco Grade 8 standoff screw to function as a mechanical shear connector in composite joists. Pushout tests were done to evaluate the standoff screw. This testing method has been used for many years to study the behavior and strength of shear connectors in composite beams and joists. By utilizing pushout tests, a variety of different test parameters can be examined in a timely fashion. The test is relatively simple to construct as well as being easily reproducible. A typical pushout test specimen is shown in Figure 2.1.

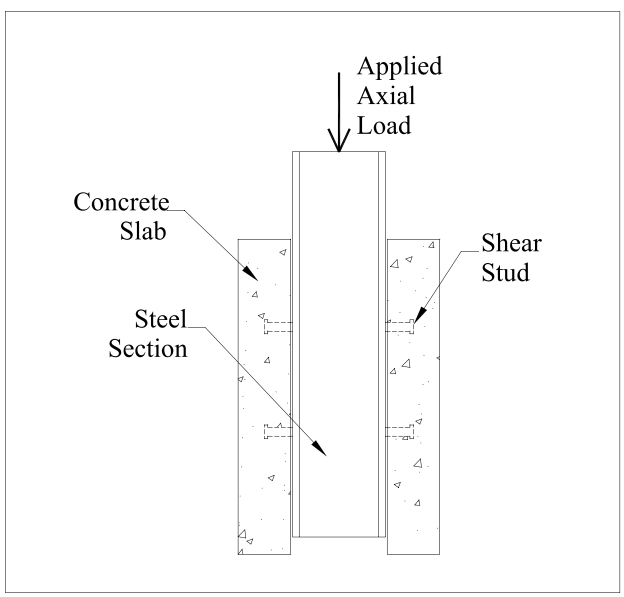



Figure 2.1 Typical Pushout Specimen

An axial load is applied to the top of the steel section to model the horizontal shear force at the concrete-steel interface of a full-scale composite beam or joist subjected to bending. Shear connectors embedded in the concrete slab resist the shear load induced by this axial force. Specimen fabrication and testing were conducted at the Virginia Tech Structures and Materials Laboratory.

## 2.2 Fabrication of Test Specimens

Specimens used in the past for pushout tests were constructed in a similar manner to those tested at Lehigh University by Ollgaard et al. (1971). This process of specimen fabrication introduces discontinuities in the specimen itself. Since specimens constructed in this manner utilize a rolled H shape, the concrete must be cast on two different days resulting in varying concrete properties between the two sides. An alternative to this method is to construct formwork allowing the slabs to be cast vertically and thus, simultaneously. This, however, causes the concrete to settle and cure in an atypical position (Viest, et al 1997).

To alleviate these conditions, specimens for this study, as well as previous studies conducted at Virginia Tech on the 5/16 in. diameter Elco Grade 8 standoff screw, were cast in halves. This made it possible to pour each concrete slab on the same day as well as in a horizontal position. Each half specimen consisted of a concrete slab attached to a steel section by means of a varying number standoff screws. Different screw heights were also evaluated in this study. Examined screw heights were 2.5 in., 3 in., 3.5 in. and 4 in. Dimensions of the standoff screws are identical with the exception of the length of the standoff shank and the overall length of the screw. Detailed dimensions of the screws tested in this study are shown in Figure 2.2.

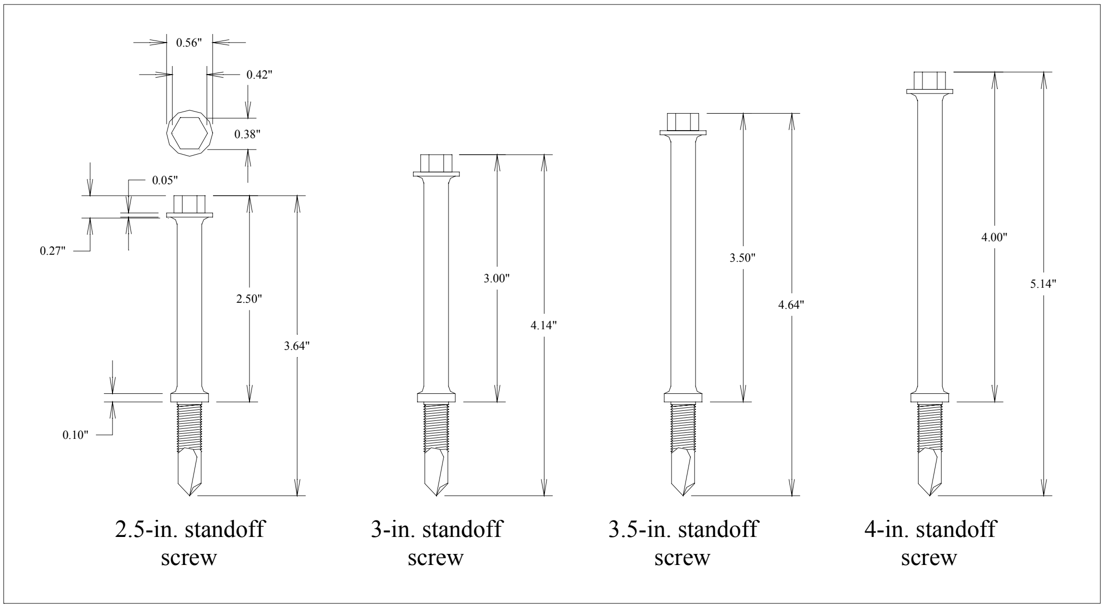



Figure 2.2 Standoff Screw Dimensions

Steel sections used in this study were fabricated from equal-leg double angles welded back-to-back to a filler plate running the full length of the angles. A full-length plate was used to provide resistance against the premature lateral buckling failures that were observed in Hankins' study. A typical top chord section is shown in Figure 2.3. The double angle sizes used in this study ranged from 2L 1.25×1.25×0.109 to 2L 3.5×3.5×0.375. A plate thickness of 0.5 in. or 1.0 in. was used based on the screw density of each individual test (Samuelson 1999a). In tests with low screw densities, the 0.5 in. filler plate was used to reduce weight which in turn reduced cost of the material. It was later found that specimens fabricated with the 0.5 in. plate were very susceptible to premature top chord buckling if the load was applied with even the slightest eccentricity. To aid in resisting any induced moments at the point of applied load, equal-leg angle sections were welded to the filler plates. The orientation of these angles is shown in Figure 2.4. The angles used were L 2×2×0.250 and were 24 in. in length. As a conservative measure, these stiffening angles were also welded to specimens fabricated using 1.0 in. plates. The thicknesses of the filler plates, as well as other specimen specifications, were determined by the project sponsor for each test series.

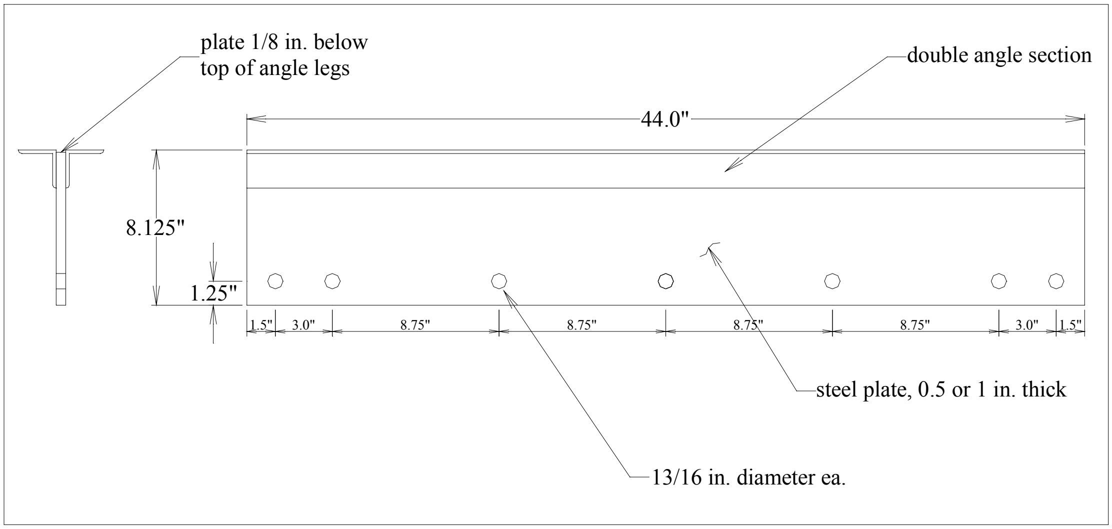



Figure 2.3 Typical Top Chord Section

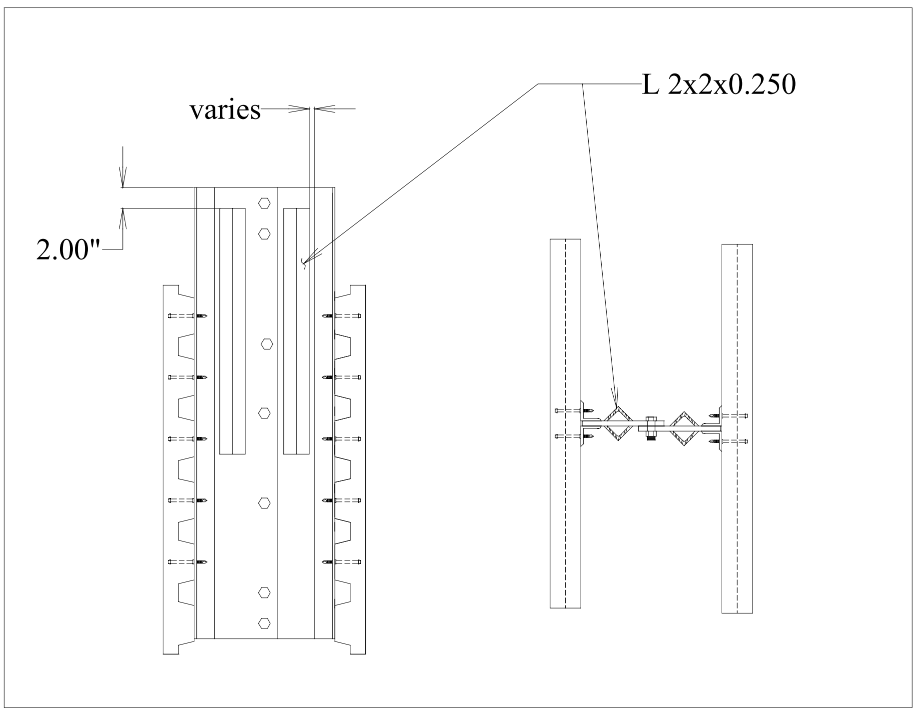



Figure 2.4 Orientation of Stiffening Angles

Concrete slabs for this study were constructed both with and without steel deck and consisted of varying amounts of steel reinforcement. The deck profiles investigated were Vulcraft 1.0C, 1.5C and 2.0VL. Details of these deck profiles are shown in Figure 2.5. The steel reinforcement consisted of welded wire fabric for control of temperature and shrinkage effects and No. 4 bars for reducing longitudinal splitting. Slabs were between 32 in. and 36 in. in length depending on the series and were 36 in. in width for all tests. Slab depths ranged from 2.75 in. to 4.5 in.

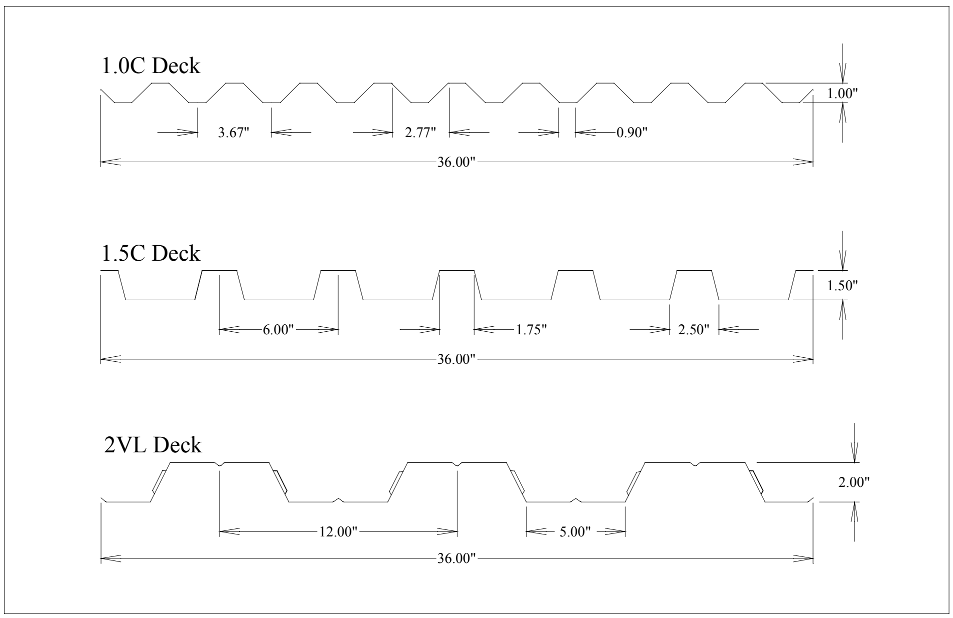



Figure 2.5 Vulcraft Deck Profiles

Fabrication of specimens that utilized steel deck profiles began with fastening cold-formed pour stop around the perimeter of the deck to create the proper slab dimensions. The pour stop was provided in varying heights to accommodate the slab thicknesses required. Next, the deck was positioned on top of the required steel section leaving a 1.5 in. offset to allow for relative slip between the components when subjected to load. Note that stiffening angles were welded to the steel sections before assembly of the test specimens whenever possible. The deck was oriented such that the ribs were transverse to the applied load for all tests in this study. Once the components were aligned, standoff screws were installed through the deck and into the top chord of the steel section by means of an electric screw gun. Placement of the screws was governed by the test configuration being fabricated. Finally, with the components attached, the specified reinforcement was placed in the form. This process was repeated for each specimen half.

The fabrication of solid slab specimens was somewhat different. In this case a wooden form was built to define the slab dimensions and the screws were attached directly to the top chord section. Reinforcement was placed in the forms in the same manner as specimens utilizing steel deck.

Once the forms were complete, the concrete slabs were poured. Small stone aggregate, generally smaller than 0.75 in. in diameter, was used to allow the concrete to be easily worked around the screws and reinforcement. A spud-type vibrator was used to ensure that the screws were properly enclosed in concrete and to minimize the amount of air voids in the slab. Test cylinders were also cast at this point. The slabs and cylinders were then covered with plastic sheeting and allowed to moist-cure for seven days. After seven days, the pour stop, or wooden forms, and cylinder forms were stripped and the specimens were allowed to air-cure a minimum of 21 additional days before testing. A typical pushout test specimen used in this study is shown in Figure 2.6.

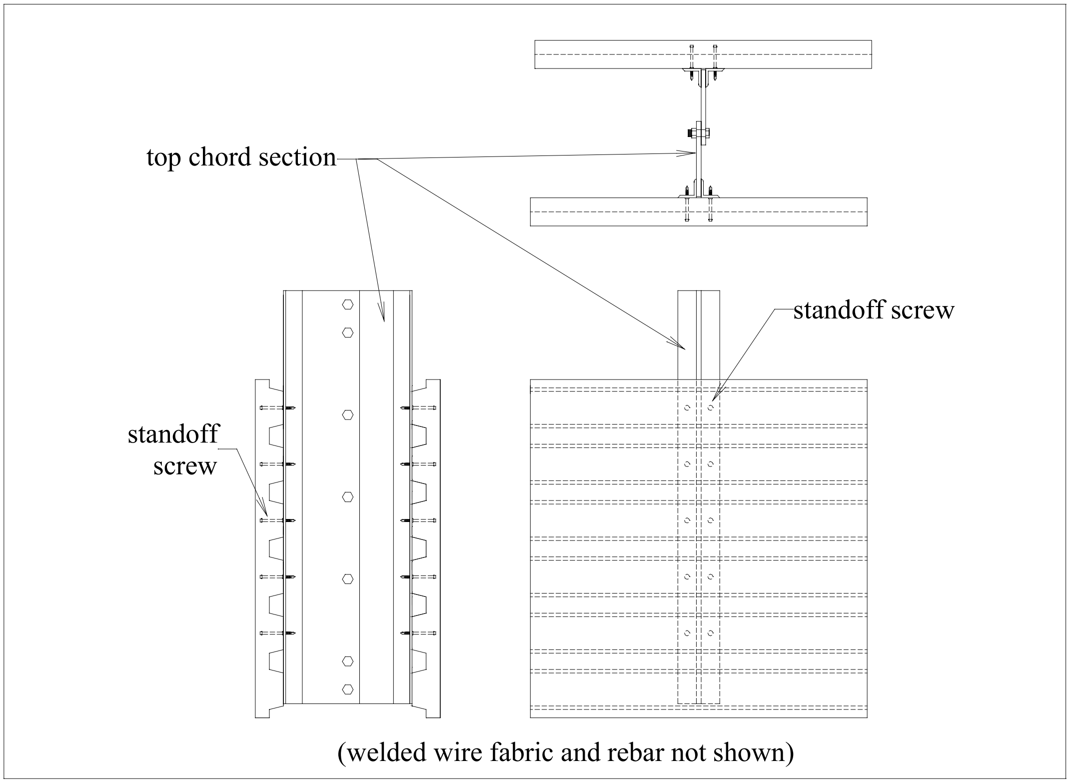



Figure 2.6 Typical Standoff Screw Pushout Specimen

### 2.2.1 Steel Reinforcement

Reinforcement for all specimens tested in this study was provided by a combination of welded wire fabric and steel reinforcing bars. The amount of welded wire fabric used in each slab was determined in accordance with the ACI Building Code Requirements for Structural Concrete, ACI 318-95. Section 7.12.2.1(c) of the code states that "slabs where reinforcement with yield stress exceeding 60,000 psi measured at a yield strain of 0.35 is used," the following ratio of reinforcement area to gross concrete area shall be provided and can not be less than 0.0014:

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

Assuming the yield strength of welded wire fabric is at least 65,000 psi, as specified in ASTM A185, the minimum ratio of shrinkage and temperature reinforcement to gross concrete area is 0.00166. As a result, the area of welded wire fabric used in all specimens in this study is greater than, or equal to, 0.00166×the gross area of concrete of each slab.

Steel reinforcing bars were used in all specimens, unlike the previous studies conducted by Hankins (1994) and Alander (1998), to prevent longitudinal splitting. The quantity of reinforcing bars required was determined based on the combined longitudinal shear resistance of the concrete, welded wire fabric and reinforcing bars being greater than the estimated capacity of the standoff screws for a specific configuration. The maximum shear capacity of the standoff screw was conservatively taken as 5.5 kips, 7.6 kips and 6.3 kips per screw for thin, intermediate and thick angle sections respectively. These values were the maximum capacities reported for the 5/16 in. diameter Elco Grade 8 standoff screw for these three general angle thicknesses (Hankins, et al 1994). The maximum capacity per screw can then multiplied by the number of screws per half specimen to obtain the maximum shear load a specimen configuration can sustain. BS 5950 Part 3: Section 3.1 "Composite Beams" gives the following equation for the combined shear resistance of the concrete slab, welded wire fabric and steel reinforcing bars:

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

where:

$V_r$ = total combined shear resistance of each shear plane, kips/in.

$L$ = longitudinal length of shear plane

$\eta$ = 1.0 for normal weight concrete

= 0.8 for lightweight concrete

$f_{cu}$ = cube strength of concrete, ksi

≈ $1.25 f'_c$

$A_{cv}$ = 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 in each shear plane

$f_y$ = yield strength of steel reinforcement

Estimating the quantity of steel reinforcing bars, Eq. 2.1 can be solved. It is important to note that No. 4 bars were used in all tests. The amount of reinforcement provided was said to be adequate when $V_r$ was found to be greater than the capacity of total number of standoff screws per half specimen.

## 2.3 Specimen Configuration

This study includes tests from four series of tests performed on the 5/16 in. diameter Elco Grade 8 standoff screw: series B, series C, series E and series F. It must be noted that series B and series C were investigated by Alander and that tests done in this study from these series were either retests or a continuation of the series. Retests of test groups were decided upon by the sponsor of this study. Reasons for retests include variance in test data between tests in a specific group and concrete strengths falling outside the targeted range of 3 ksi to 5 ksi. All series configurations discussed in this chapter are only for the tests conducted in this study. Series configurations for specimens investigated in Alander's study can be found in Standoff Screws Used in Composite Joists (Alander, et al 1998a).

Each series is comprised a specific number of test groups and each test group is further divided into either two or three individual test specimens of identical configuration. A letter signifying its series, followed by numbers representing its group and test number within its group identifies each test. For example, test E3-1 is the first test in group three of series E. In the case of a retest, an "R" is placed after the test designation. A retest of test E3-1 would be designated E3-1R.

### 2.3.1 Series B Configuration

Test series B consisted of eight groups of tests to further evaluate the performance of the 5/16 in. diameter Elco Grade 8 standoff screw in slabs formed using Vulcraft 1.0C, 26 ga. deck. This series included three groups of retests. Three different top chord sections were used, each consisting of a 0.5 in. plate separating double angle sections of varying dimensions. A screw height of 2.5 in. was used with a design slab thickness of

3.0 in. The term “design slab thickness” will be used from now on to define the thickness of the slab as designated by specifications provided by NUCOR Research and Development and the term “actual slab thickness” will be used to designate the thickness of the slab after curing. Due to variation in the actual slab thicknesses, this value was measured for each individual test and rounded to the nearest 1/4 in. Note that all values shown in tables and figures of this report are actual slab thicknesses. All slabs in this series measured 36 in. wide by 36 in. long. Test groups B12 and B13 contained eight screws per half specimen. The screws were placed one per rib in a staggered arrangement. Test groups B14, B15 and B16 each contained 16 screws per half specimen placed two per rib in every rib. Figures 2.7(a) and (b) show the screw locations for specimens in series B. Welded wire fabric as well as reinforcing bars were used in contrast to previous series B tests which contained no reinforcing bars. The configurations for series B are summarized in Table 2.1.

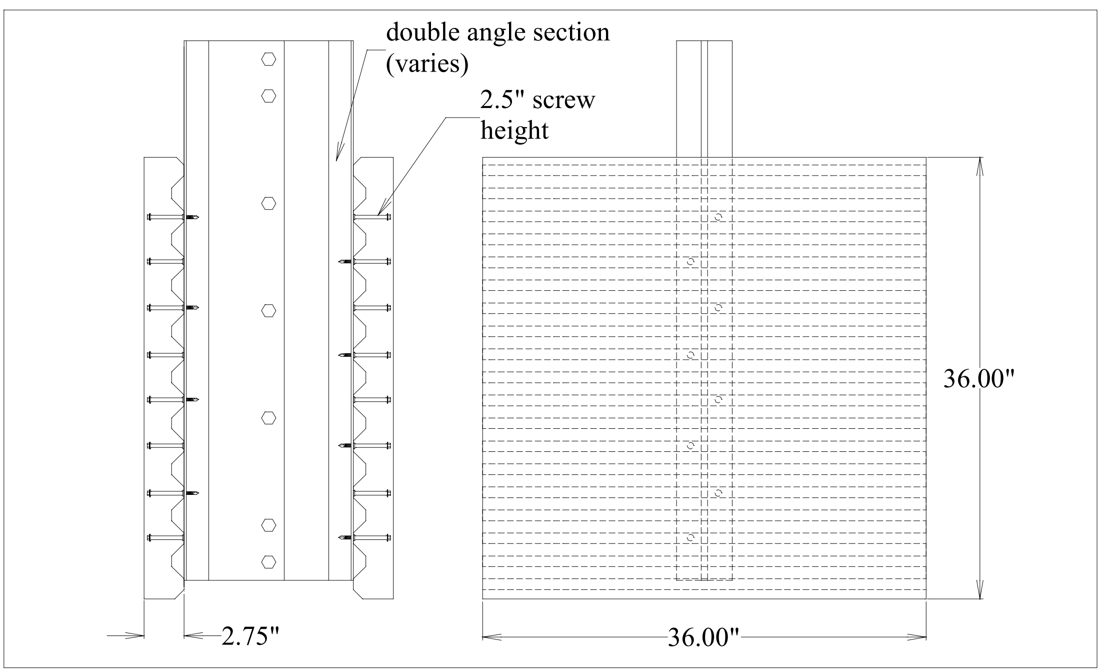



Figure 2.7(a) Test Groups B12-B13 Dimensions

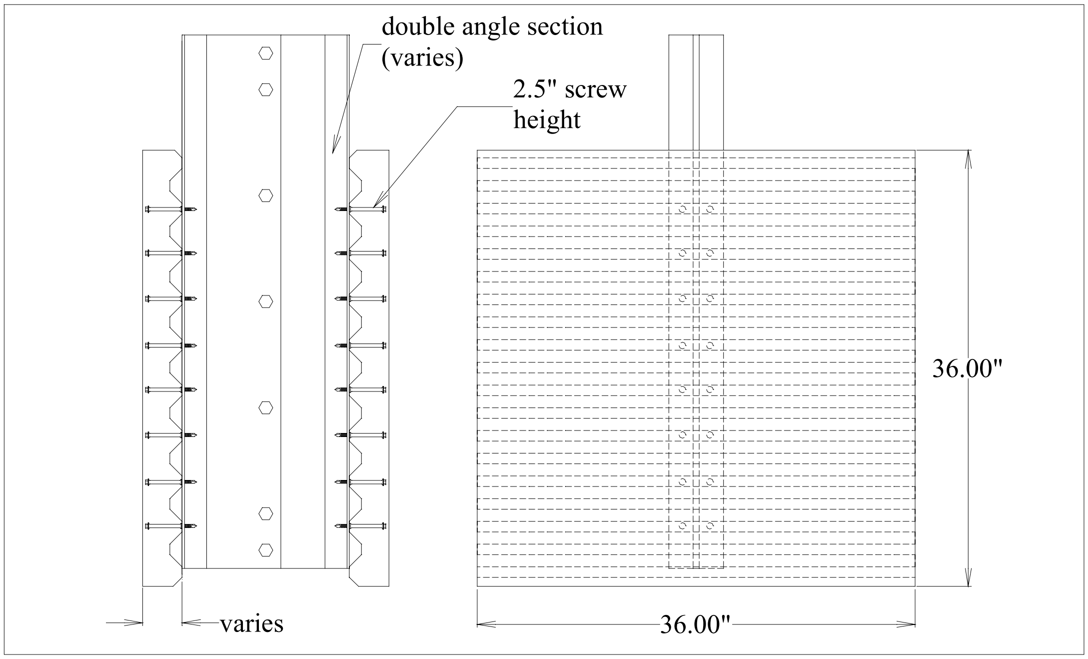



Figure 2.7(b) Test Groups B14-B16 Dimensions

Table 2.1 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 Per Half Specimen |
|---|---|---|---|---|---|---|---|---|---|---|
| B12 | 1.0C, 26 ga. | 2L 1.25x1.25x0.109 | 0.5 | 2.5 | 2.75 | 36 | 36 | 8 | 6x6-W2.9xW2.9 | 5-No. 4 |
| B13 | 1.0C, 26 ga. | 2L 2.00x2.00x0.187 | 0.5 | 2.5 | 2.75 | 36 | 36 | 8 | 6x6-W2.9xW2.9 | 5-No. 4 |
| B14 | 1.0C, 26 ga. | 2L 1.25x1.25x0.109 | 0.5 | 2.5 | 2.75 | 36 | 36 | 16 | 6x6-W2.9xW2.9 | 8-No. 4 |
| B14R | 1.0C, 26 ga. | 2L 1.25x1.25x0.109 | 0.5 | 2.5 | 2.75 | 36 | 36 | 16 | 6x6-W2.9xW2.9 | 8-No. 4 |
| B15 | 1.0C, 26 ga. | 2L 2.00x2.00x0.187 | 0.5 | 2.5 | 2.75 | 36 | 36 | 16 | 6x6-W2.9xW2.9 | 12-No. 4 |
| B15R | 1.0C, 26 ga. | 2L 2.00x2.00x0.187 | 0.5 | 2.5 | 3.00 | 36 | 36 | 16 | 6x6-W2.9xW2.9 | 12-No. 4 |
| B16 | 1.0C, 26 ga. | 2L 2.00x2.00x0.250 | 0.5 | 2.5 | 2.75 | 36 | 36 | 16 | 6x6-W2.9xW2.9 | 12-No. 4 |
| B16R | 1.0C, 26 ga. | 2L 2.00x2.00x0.250 | 0.5 | 2.5 | 3.00 | 36 | 36 | 16 | 6x6-W2.9xW2.9 | 12-No. 4 |

### 2.3.2 Series C Configuration

Test series C was done to further evaluate the performance of the 5/16 in. Elco Grade 8 standoff screw when used with Vulcraft 1.5C, 22 ga. deck. This series consisted of four test groups, two of which were retests. Four different top chord sections were used. Double angles were welded to a 0.5 in. plate in groups C1R and C2R while a 1.0

in. plate was used in the remaining tests. The screws used in this series were all 3 in. with a corresponding design slab thickness of 3.5 in. Slabs were 32 in. long for groups C1R and C2R and were 36 in. long for the remaining groups. The slab width for all groups was 36 in. Groups C1R and C2R each consisted of five screws per half specimen while groups C9 and C10 had 20 screws per half specimen. The screw locations for series C specimens are shown in Figures 2.8(a) and (b). Varying amounts of welded wire fabric and reinforcing bars were used in all tests. The configurations for series C are summarized in Table 2.2.

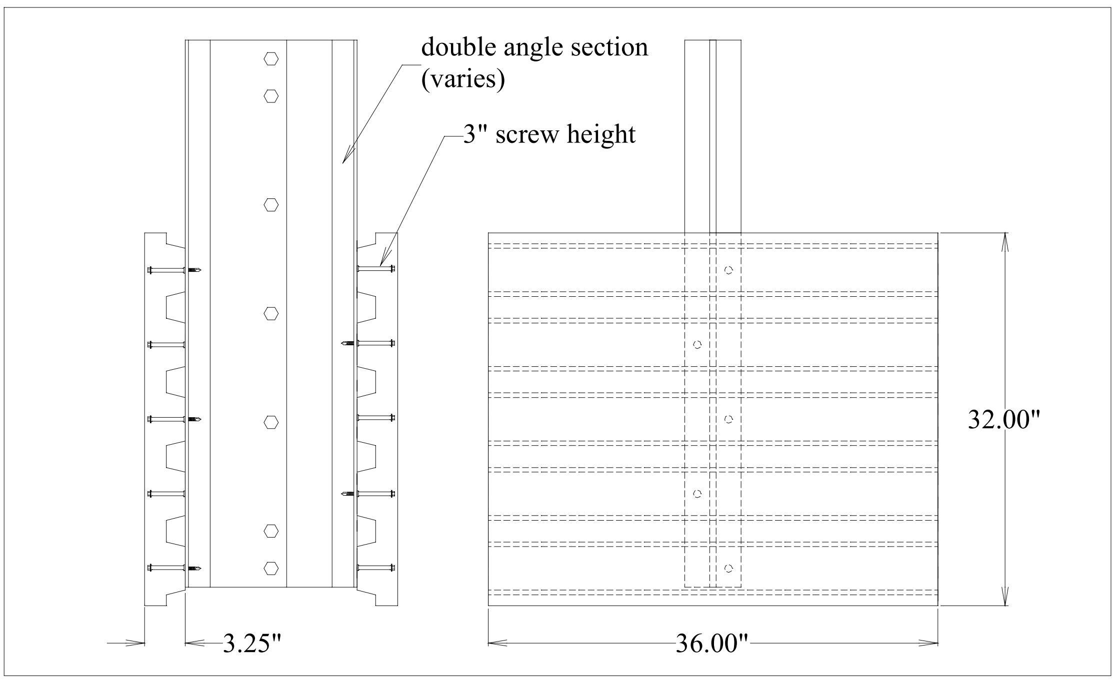



Figure 2.8(a) Test Groups C1R-C2R Dimensions

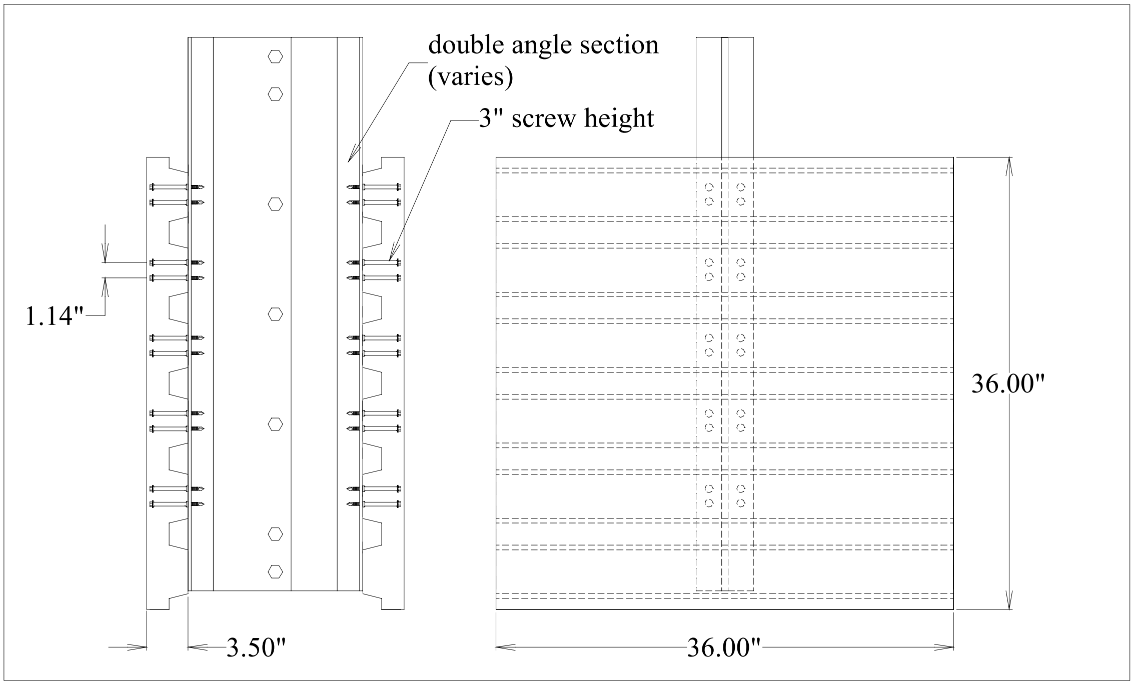



Figure 2.8(b) Test Groups C9-C10 Dimensions

Table 2.2 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 Per Half Specimen |
|---|---|---|---|---|---|---|---|---|---|---|
| C1R | 1.5C, 22 ga. | 2L 1.25x1.25x0.109 | 0.5 | 3.0 | 3.25 | 36 | 32 | 5 | 4x4-W2.1xW2.1 | 4-No. 4 |
| C2R | 1.5C, 22 ga. | 2L 2.00x2.00x0.187 | 0.5 | 3.0 | 3.25 | 36 | 32 | 5 | 4x4-W2.1xW2.1 | 4-No. 4 |
| C9 | 1.5C, 22 ga. | 2L 2.00x2.00x0.163 | 1.0 | 3.0 | 3.50 | 36 | 36 | 20 | 4x4-W2.1xW2.1 | 6-No.4 |
| C10 | 1.5C, 22 ga. | 2L 2.00x2.00x0.250 | 1.0 | 3.0 | 3.50 | 36 | 36 | 20 | 4x4-W2.1xW2.1 | 6-No.4 |

### 2.3.3 Series E Configuration

Test series E was conducted to evaluate the performance of the 5/16 in. diameter Elco Grade 8 standoff screw when used with Vulcraft 2VL, 22 ga. deck. This series consisted of 10 test groups, three of which were retests. Four different top chord sections were investigated in this test series. The double angle sections of specimens in groups E1, E1R, E2 and E2R were welded to a 0.5 in. plate while the remaining groups utilized a 1.0 in. plate. A screw height of 4.0 in. was used in all test groups with a corresponding design slab thickness of 4.5 in. Test groups E1-E3R contained eight screws per half specimen, groups E4 and E5 contained 16 screws per half specimen and groups E6 and E7 contained 24 screws per half specimen. The screw locations for series E are shown in Figures 2.9(a) through (c). Varying amounts of welded wire fabric and reinforcing bars were used in all tests. The configurations for series E are summarized in Table 2.4.

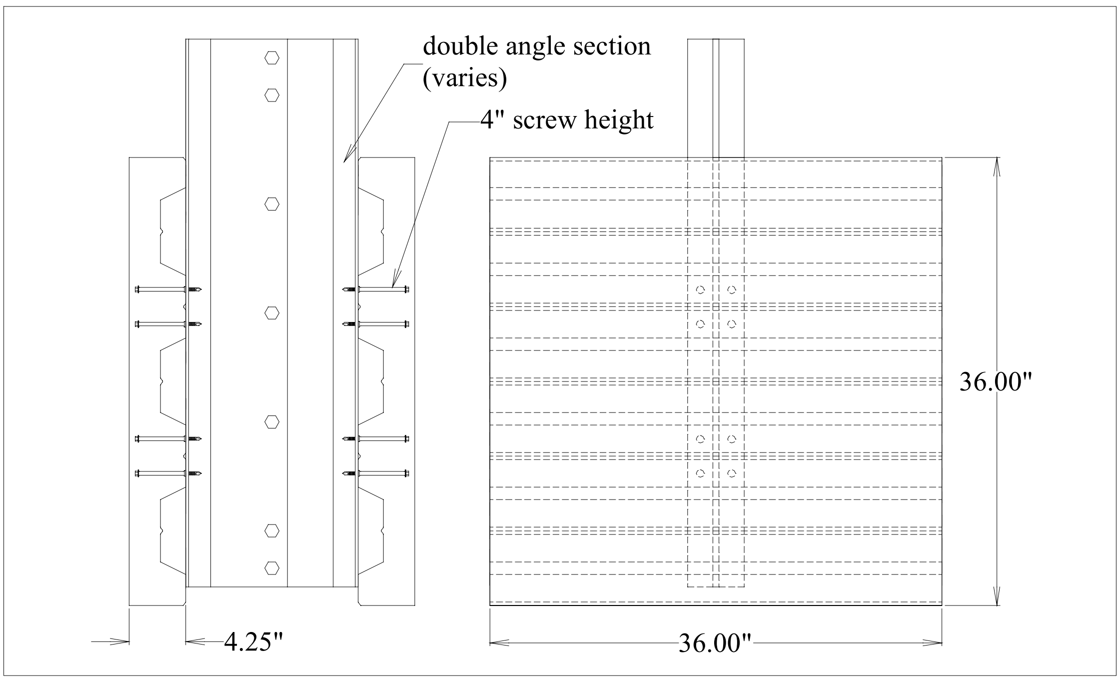



Figure 2.9(a) Test Groups E1-E3 Dimensions

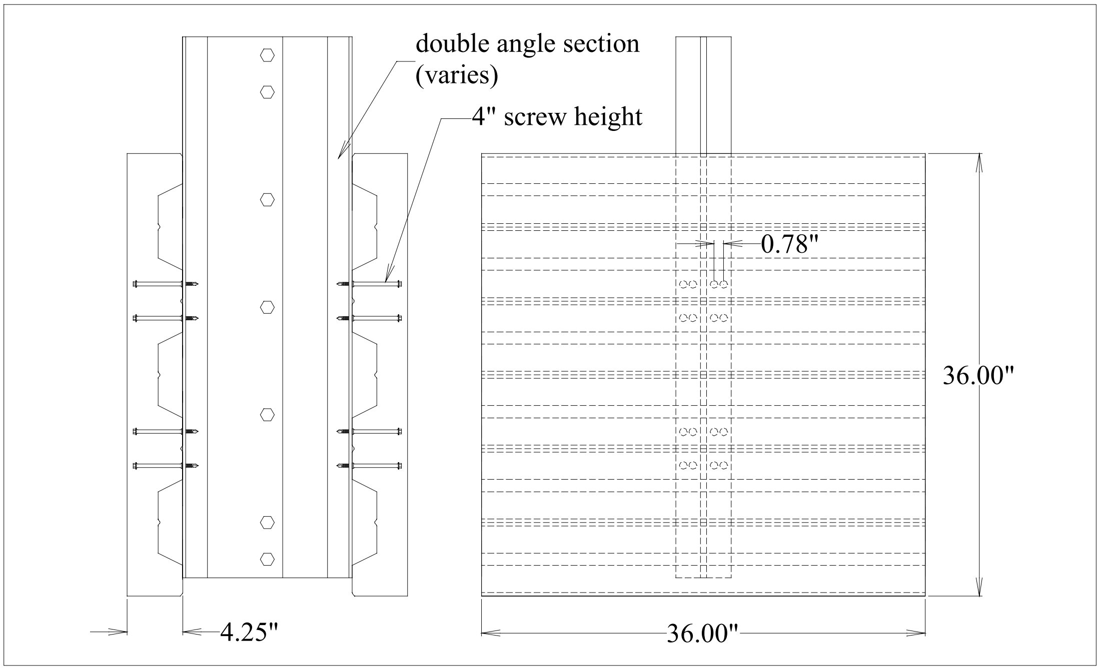



Figure 2.9(b) Test Groups E4-E5 Dimensions

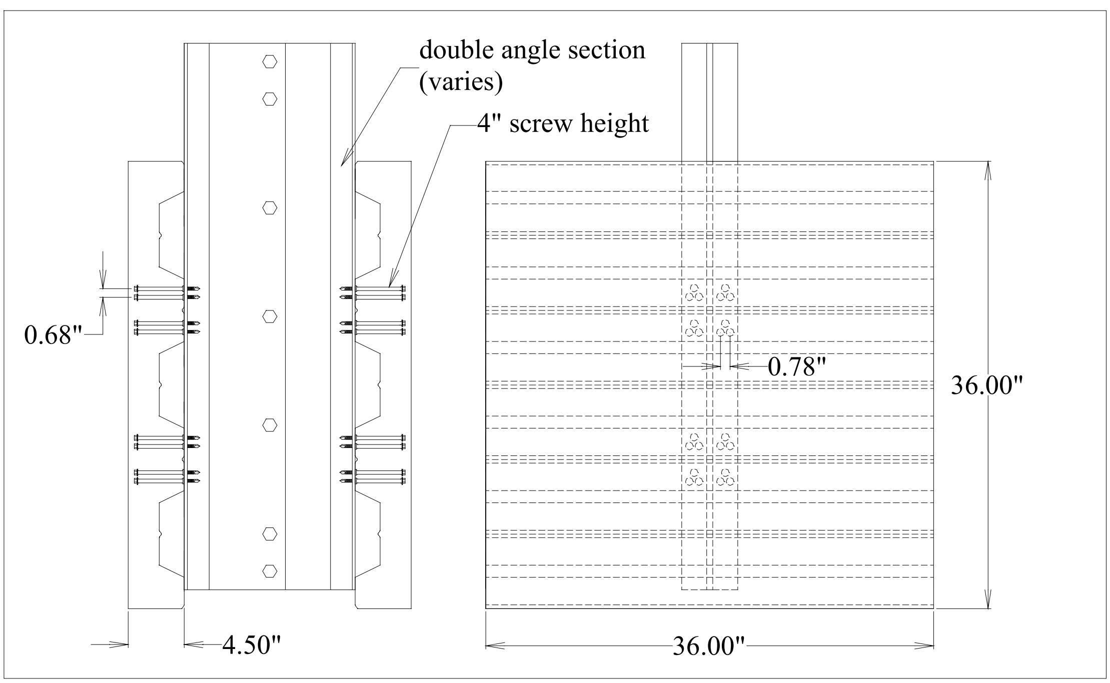



Figure 2.9(c) Test Groups E6-E7 Dimensions

Table 2.4 Series E 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 Per Half Specimen |
|---|---|---|---|---|---|---|---|---|---|---|
| E1 | 2VL, 22 ga. | 2L 1.25x1.25x0.109 | 0.5 | 4.0 | 4.25 | 36 | 36 | 8 | 6x6-W4xW4 | 4-No. 4 |
| E1R | 2VL, 22 ga. | 2L 1.25x1.25x0.109 | 0.5 | 4.0 | 4.25 | 36 | 36 | 8 | 6x6-W4xW4 | 4-No. 4 |
| E2 | 2VL, 22 ga. | 2L 2.00x2.00x0.187 | 0.5 | 4.0 | 4.25 | 36 | 36 | 8 | 6x6-W4xW4 | 4-No. 4 |
| E2R | 2VL, 22 ga. | 2L 2.00x2.00x0.187 | 0.5 | 4.0 | 4.25 | 36 | 36 | 8 | 6x6-W4xW4 | 4-No. 4 |
| E3 | 2VL, 22 ga. | 2L 2.00x2.00x0.250 | 1.0 | 4.0 | 4.25 | 36 | 36 | 8 | 6x6-W4xW4 | 4-No. 4 |
| E3R | 2VL, 22 ga. | 2L 2.00x2.00x0.250 | 1.0 | 4.0 | 4.25 | 36 | 36 | 8 | 6x6-W4xW4 | 4-No. 4 |
| E4 | 2VL, 22 ga. | 2L 2.00x2.00x0.163 | 1.0 | 4.0 | 4.25 | 36 | 36 | 16 | 6x6-W4xW4 | 4-No. 4 |
| E5 | 2VL, 22 ga. | 2L 2.00x2.00x0.250 | 1.0 | 4.0 | 4.25 | 36 | 36 | 16 | 6x6-W4xW4 | 4-No. 4 |
| E6 | 2VL, 22 ga. | 2L 2.00x2.00x0.163 | 1.0 | 4.0 | 4.50 | 36 | 36 | 24 | 6x6-W4xW4 | 8-No. 4 |
| E7 | 2VL, 22 ga. | 2L 2.00x2.00x0.250 | 1.0 | 4.0 | 4.50 | 36 | 36 | 24 | 6x6-W4xW4 | 8-No. 4 |

### 2.3.4 Series F Configuration

The goal of test series F was to evaluate the performance of the 5/16 in. Elco Grade 8 standoff screw in solid slab applications. Solid slab tests can be used to model composite joist girders where, in the case of a girder, the deck ribs would be oriented parallel to the top chord thereby inducing a solid slab condition. Six different top chord sections were investigated in this series. It should be noted that the majority of top chord sections utilized in this series were thicker than those used in previous series. This, again, was done to more accurately model the top chord of a composite joist girder. Double angle sections were welded to a 1.0 in. plate for all test groups in this series except for test group F4 which utilized a 0.5 in. plate. Screw heights of 2.0 in., 2.5 in. and 3.0 in. were tested with design slab thicknesses of 2.5 in., 3.0 in. and 3.5 in. respectively. Test groups F1 and F2 consisted of 14 screws per half specimen, groups F3 and F4 consisted of 18 screws per half specimen and groups F5 and F6 consisted of 36 screws per half specimen. Screw locations for series F are shown in Figures 2.10(a) through (c). Varying amounts of welded wire fabric and reinforcing bars were used in all tests. The configurations for series F are summarized in Table 2.5.

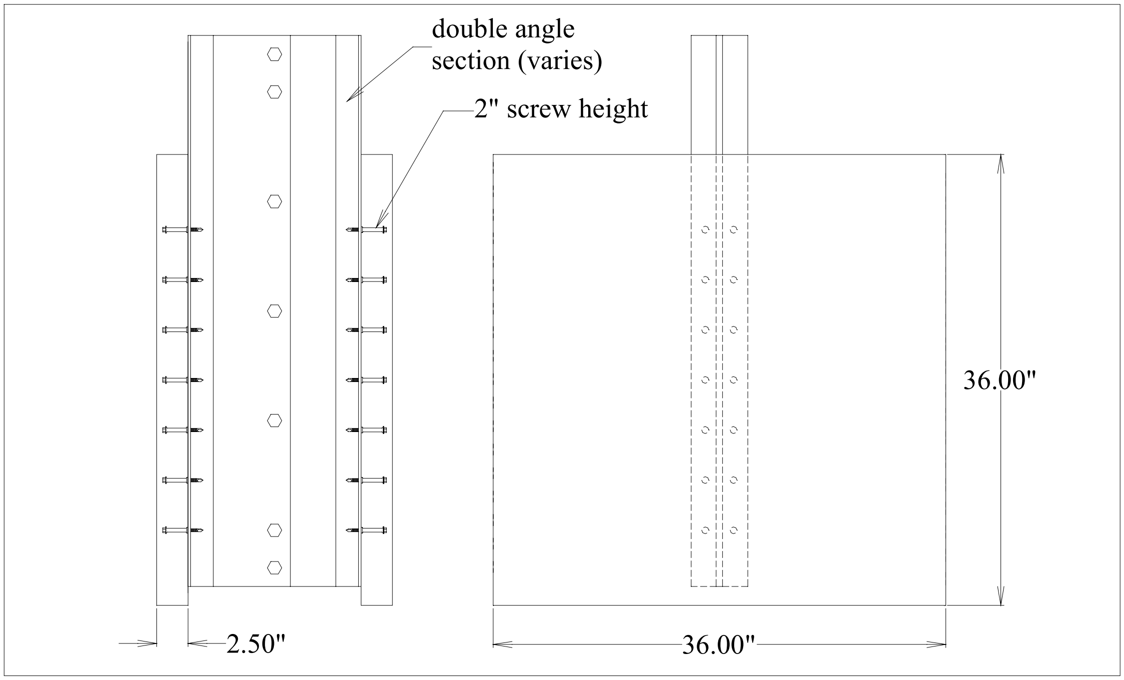



Figure 2.10(a) Test Groups F1-F2 Dimensions

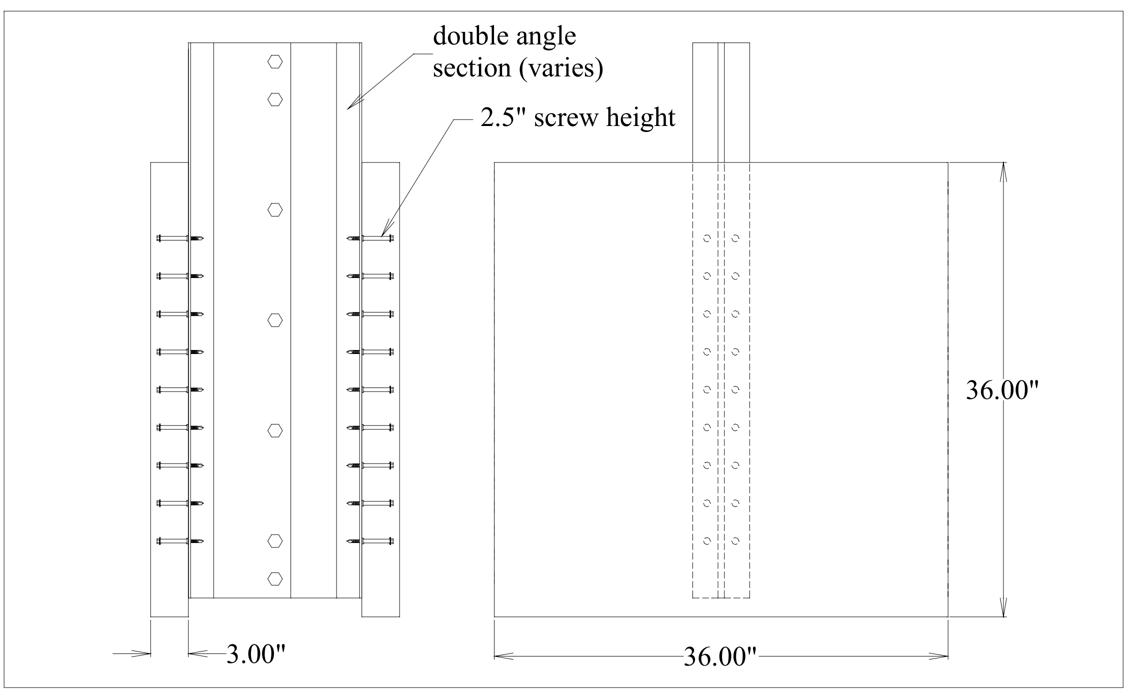



Figure 2.10(b) Test Groups F3-F4 Dimensions

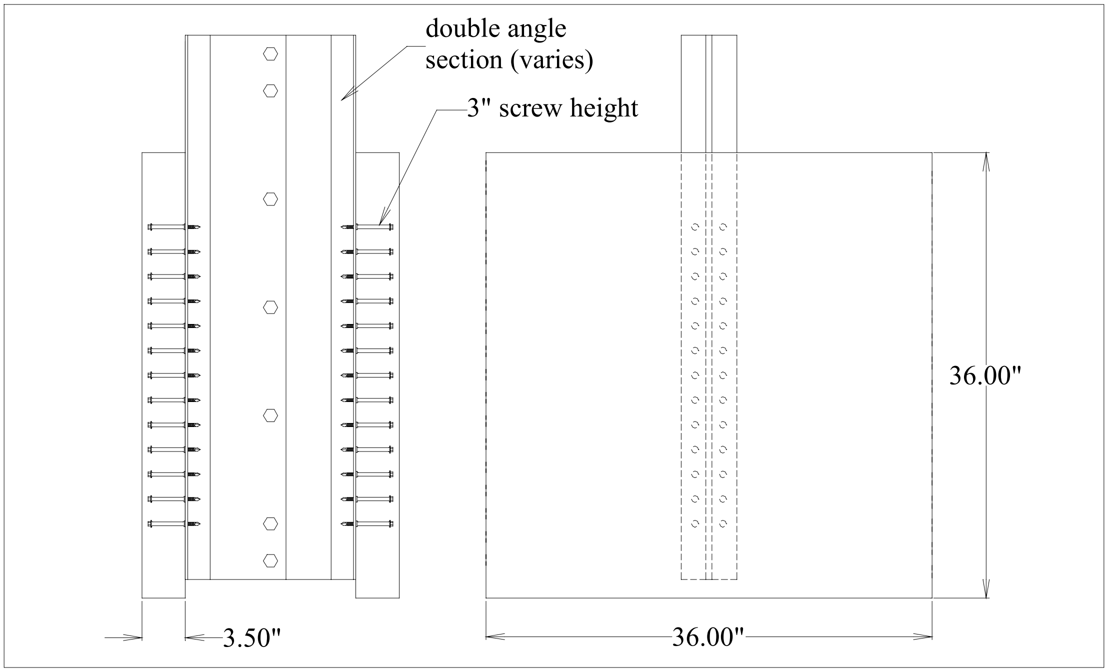



Figure 2.10(c) Test Groups F5-F6 Dimensions

Table 2.5 Series F 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 Per Half Specimen |
|---|---|---|---|---|---|---|---|---|---|---|
| F1 | none | 2L 2.00x2.00x0.163 | 1.0 | 2.0 | 2.5 | 36 | 36 | 14 | 6x6-W2.9xW2.9 | 4-No. 4 |
| F2 | none | 2L 2.00x2.00x0.250 | 1.0 | 2.0 | 2.5 | 36 | 36 | 14 | 6x6-W2.9xW2.9 | 4-No. 4 |
| F3 | none | 2L 2.50x2.50x0.212 | 1.0 | 2.5 | 3.0 | 36 | 36 | 18 | 4x4-W2.0xW2.0 | 4-No. 4 |
| F4 | none | 2L 3.00x3.00x0.313 | 0.5 | 2.5 | 3.0 | 36 | 36 | 18 | 4x4-W2.0xW2.0 | 4-No. 4 |
| F5 | none | 2L 3.00x3.00x0.227 | 1.0 | 3.0 | 3.5 | 36 | 36 | 26 | 6x6-W4.0xW4.0 | 6-No. 4 |
| F6 | none | 2L 3.50x3.50x0.375 | 1.0 | 3.0 | 3.5 | 36 | 36 | 26 | 6x6-W4.0xW4.0 | 6-No. 4 |

## 2.4 Test Setup

The test setup for all 59 tests was virtually identical to that used in research done by both Hankins (1994) and Alander (1998). Specimens were placed on 1 in. thick elastomeric bearing pads inside of a load frame constructed of structural steel members. The bearing pads served to evenly distribute load across the nonuniform bottom of the concrete slabs. A load plate was then placed on top of the specimen to distribute the load to the two specimen halves. Care was taken to ensure that the surface on which the loading plate was placed was level. A swivel plate, used to keep the applied load as level as possible, was then place on top of the load distribution plate. Load was supplied by a hydraulic ram suspended from a cross-head which was bolted to the test frame.

In order to more accurately simulate a composite joist, a normal load was applied to the specimens by means of a small load distribution frame. This load simulates the gravity load of a full-scale composite joist. The distribution frame consisted of two wide flange sections which distributed load to each slab in line with the top chord sections. These spreader beams were attached to the frame which surrounded the specimen. Load was supplied by a hydraulic ram. Thin bearing pads were placed between the spreader beams and the slabs to ensure an even contact area. Steel plates were used to support the spreader beams until the applied load alone was sufficient to hold them in position. The plates were then removed to avoid any load being distributed through them in bearing. A typical test setup is shown in Figures 2.11 and 2.12.

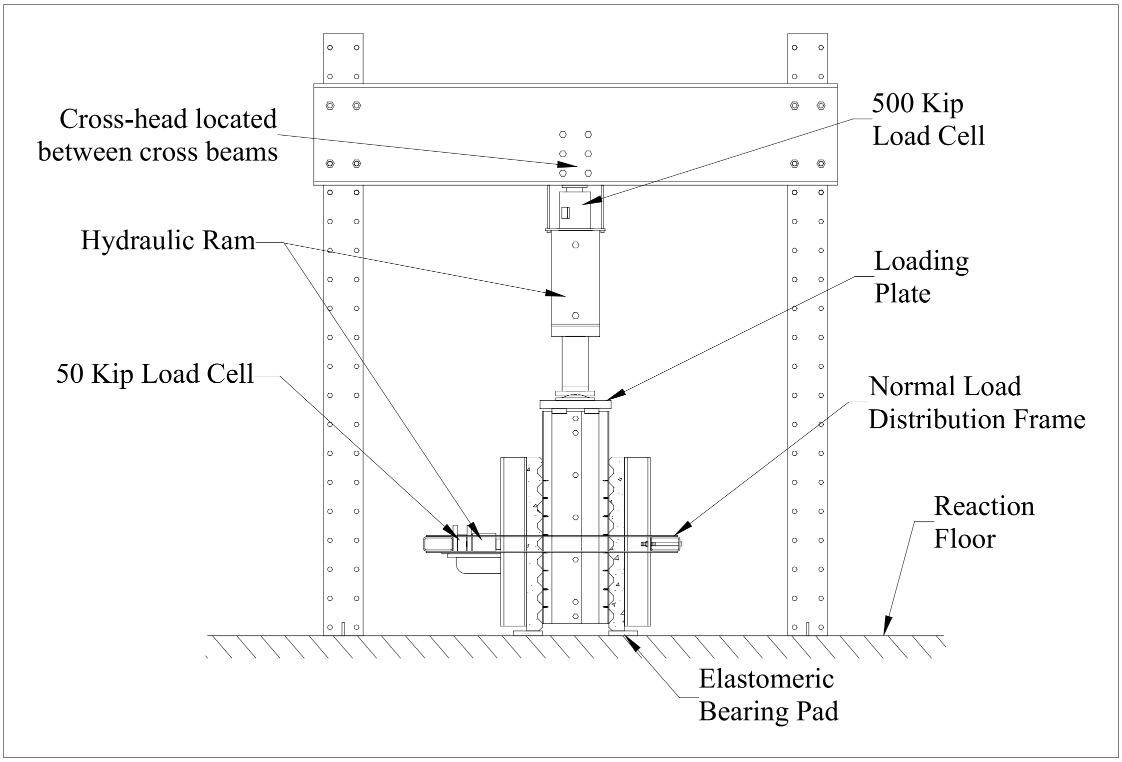



Figure 2.11 Typical Test Setup

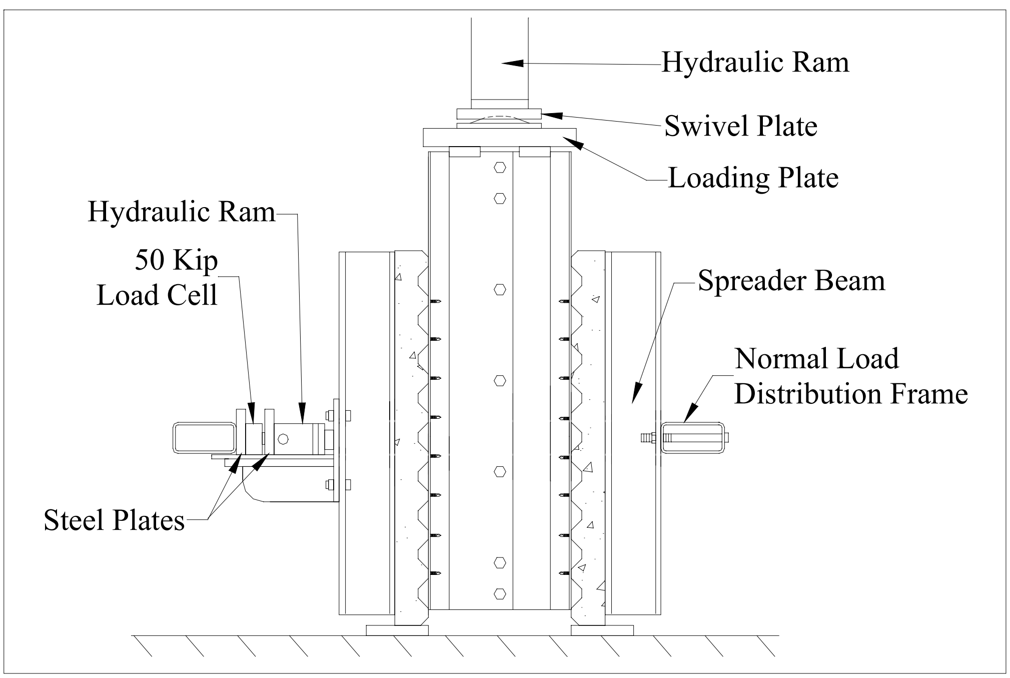



Figure 2.12 Test Setup Detail

In order to reduce the possibility of the top chord buckling failure observed in Hankins' study, lateral braces were used on specimens which were felt to be susceptible to this failure. This was done in addition to adding the stiffening angles as discussed earlier. In general, bracing was used on all tests which utilized the 0.5 in. filler plate, utilized thin double angle sections or had high screw densities. The bracing system did not carry any load and therefore did not have an effect on the results of tests where the system was used. In order to use the braces, the test specimen had to be turned 90 degrees in the load frame. The bracing system is shown in Figure 2.13.

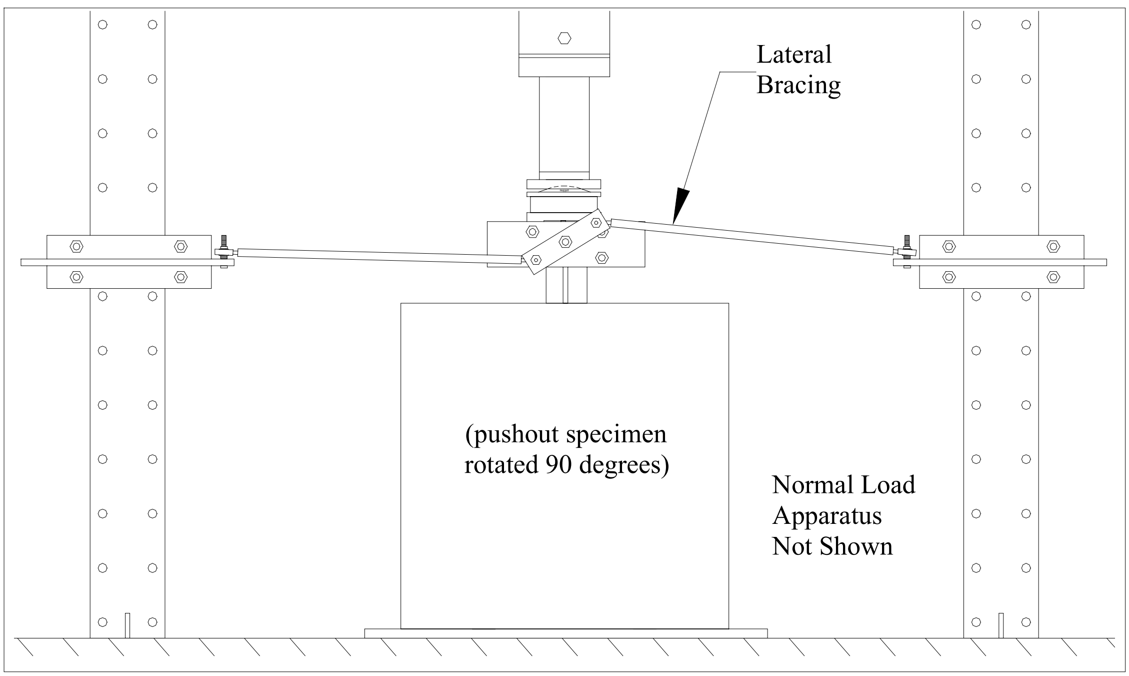



Figure 2.13 Lateral Bracing System

## 2.5 Instrumentation

Axial load, normal load and relative slip between the concrete and steel components were measured for each test. The axial load and normal load were measured using a 500 kip cell and a 50 kip load cell, respectively. The axial load will be referred to as the "shear" load for the remainder of this report. The position of these load cells is shown in Figure 2.11.

Linear transducers, also known as potentiometers, were used to measure relative slip values. Eight potentiometers were used per test to measure slip at four different locations on each slab. During fabrication, oval holes approximately 1 in. long were cut in the deck profiles at specified locations. Before the specimen halves were bolted together, holes measuring 5/32 in. in diameter were drilled 1 in. deep at the locations where the deck had been cut prior to placing the concrete. Nails were placed in these holes with vinyl anchors to ensure a snug fit. Approximately 2 in. of the nail was left protruding from the slab. The potentiometers were then clamped to the top chord section with 1 in. C-clamps. The potentiometers were then extended and tied to the nail anchors with 22 ga. steel wire. All measuring devices were wired into a data acquisition system. The Measurements Group System 4000 and System 5000 data acquisition systems were used in this study.

### 2.6 Test Procedure

The test procedure was identical for all tests performed in this study. First, a relatively small normal load was applied, generally less than 1 kip. Next, the shear load was applied. The magnitude of the initial shear load was in the range of 5-10 kips. The system was then allowed to stabilize for three minutes before data was recorded. Any physical changes in the specimen were noted at this time. The shear load was then increased by 5-10 kips depending on the specimen configuration. The normal load was maintained at 10% of the shear load for the entire test. This process was repeated until failure. Failure for this study is defined by a significant decrease in the load carrying capability of a specimen. Once failure had occurred, the specimen was removed from the load frame and disassembled. Damage was recorded and photographs of the specimen were taken.

# CHAPTER 3
# TEST RESULTS

## 3.1 General

Test results for each of the 59 pushout tests conducted in this study are presented in three page data packs which include a summary sheet, Load vs. Slip plots and raw test data. Data packs for all pushout tests conducted in this study can be found in the Appendix. These data packs should be referred to as the test results are discussed. As stated previously, some tests performed in this study are continuations of test series began by Alander. In these cases, series B and series C, data from tests performed by Alander will be included to provide a basis for discussion and comparison. Data packs for test conducted by Alander can be found in Standoff Screws Used in Composite Joists (Alander, et al 1998b).

### 3.1.1 Description of Data Pack

The first page of each data pack is a summary sheet which is divided into five sections: test identification information, specimen description, test results, test damage and comments.

The first section of the summary sheet consists of the test number, as discussed in Chapter 2, the date specimen was tested and a test designation. The test designation was developed by Hankins (1994) as a means of further identifying test specimens. The first term specifies the type of shear connector being tested. In this study, this term is “SC” for all tests denoting that all shear connectors were standoff screws. The next term further identifies the type of shear connector. This term is an “8” for all tests in this study indicating that the 5/16 in. diameter Elco Grade 8 standoff screw was used. The third term is the standoff length of the screw used in the test. The fourth value represents the thickness of the double angle sections that make up the top chord section. The fifth term in the test designation specifies the type of deck used. In cases where no deck was used, i.e., solid slab tests, this term is an "S." The sixth term represents the actual slab thickness measured for the specimen. The final term in the test designation is the specimen number for the test group being tested. This number is either a "1," "2" or "3." In the case of a redone test, the specimen number is followed by an "R" as discussed previously. A test designation of "SC-8-2.5-0.187-1.0C-2.75-2" indicates that this is the second test of a specimen consisting of a 2.5 in., 5/16 in. diameter Elco Grade 8 standoff screw placed in a 0.187 in. thick top chord section and embedded in a 2.75 in. slab formed with 1.0C deck. If this were a retest, the test designation would be "SC-8-2.5-0.187-1.0C-2.75-2R."

The "Specimen Description" section of the summary sheet contains the specifications of the test specimen. Dimensions, material properties and reinforcement information are included in this section. The number of screws per specimen value in this section represents the total number of screws. This number can be divided by two to find the number of screws per slab. The yield stress and ultimate stress of each type of deck and each top chord thickness tested were determined by averaging the results from three tensile tests performed on coupons fabricated per ASTM A370. Since materials were fabricated at different times, sometimes by different fabricators, and there was no means of knowing which materials where from the same "batch," properties found for a particular material were said to be representative for all similar sections. For example, the yield stress and ultimate stress calculated for an L 2×2×0.187 is assumed to be the same for all other L 2×2×0.187 sections used in this study. The concrete compressive strength for each test was determined by conducting compression tests on 4 in. by 8 in. cylinders fabricated per ASTM C192 on the day the specimen was tested. The "Height Above Deck" term refers to the amount of slab bolster placed in the slab and the "Mesh" term represents the type of welded wire fabric used.

The “Test Results” section of the summary sheet lists the peak shear load, the peak shear load per screw and the slip readings at the peak shear load. The peak shear load is defined as the maximum shear load recorded during the test. The peak shear load per screw was then determined by dividing this value by the total number of screws per specimen. The slip values reported in this section correspond to the readings taken at the peak shear load by the eight potentiometers attached to the specimen. Readings are designated “SC1” through “SC8” which correspond to “standoff screw location 1” through “standoff screw location 8.” The slabs of a test specimen are identified as “A” and “B” to distinguish them from each other. Slip readings SC1 through SC4 are reported values from slab A while readings SC5 through SC8 are from slab B. The approximate locations of the eight potentiometers are shown in Figure 3.1. While this figure shows the potentiometer locations on a specimen utilizing 1.0C deck, the locations on specimens using other deck profiles are similar.

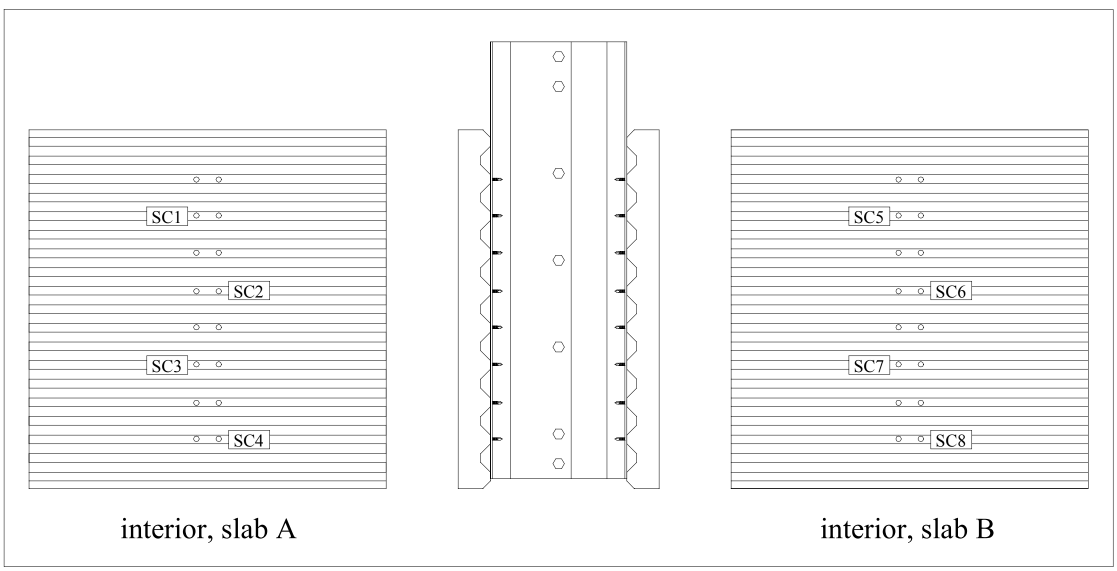



Figure 3.1 Potentiometer Locations

The “Damage” section of the summary sheet shows detailed sketches of the specimen after failure. These sketches were drawn using the photographs taken of the specimen once it had been removed from the test frame and disassembled. In cases where screw failures were observed, the failure of each individual screw is shown in the damage drawings. For example, screws that sheared off are designated with an "✕," screws that pulled out of the top chord are designated with a "☐" and screws that pulled out of the concrete slab are designated with a "Δ". It is important to note that the system for designating screws that failed by either pulling out of the top chord or by pulling out of the concrete slab was adopted after the study began and therefore not all summary sheets include this information. The side of the slab shown in the sketches, interior or exterior, was dependent upon how the specimen failed. In some cases, it was not possible to view the interior of a slab, when this occurred, the cracking pattern of the exterior was noted.

"Comments" is the final section of the summary sheet. In this section, observations noted both during and after the test are recorded. The primary failure mode is also stated in this section.

The second page of each data pack consists of plots of the applied shear load versus relative slip. Two plots are created for each test, one for slab A and a second for slab B. Slip values recorded at SC1 through SC4 are plotted for slab A and the values recorded at SC5 through SC8 are plotted for slab B.

The final page of each data pack consists of the raw data from the test. The recorded data includes the shear load, normal load and the eight slip readings. Data was recorded at three minute intervals. In some cases where slip values were large, the potentiometer anchors, or the clamps holding the potentiometers in position became dislodged rendering the readings invalid. Readings taken after this occurrence were ignored and not included as part of the data gathered. In a limited number of tests, one or more of the potentiometers did not function correctly and readings for these gauges were ignored. This occurrence is noted in the data packs when applicable.

### 3.2 Shear and Tensile Tests on the 5/16 in. Diameter Elco Grade 8 Standoff Screw

To determine the mechanical properties of the 5/16 in. diameter Elco Grade 8 standoff screws used in this study, tensile and shear tests were performed by Elco Textron. The test setups utilized are shown in Figures 3.2 and 3.3. All tests were conducted in accordance with the International Conference of Building Officials' (ICBO) Acceptance Criteria for Tapping Screw Fasteners, AC118 (1996). Tests were only conducted on the 2 in. and 4 in. standoff screws. These two screw sizes represent the shortest and longest screws produced. Since all screws were manufactured from the same size and grade of steel rod, have the same size tip and drill point, same head and were heat treated in the same manner, the only difference between the screw sizes is the length of the standoff shank. Therefore, the mechanical properties of the screws should be similar for all lengths (Samuelson 1999b). The results of the tensile and shear tests are summarized in Tables 3.1 and 3.2.

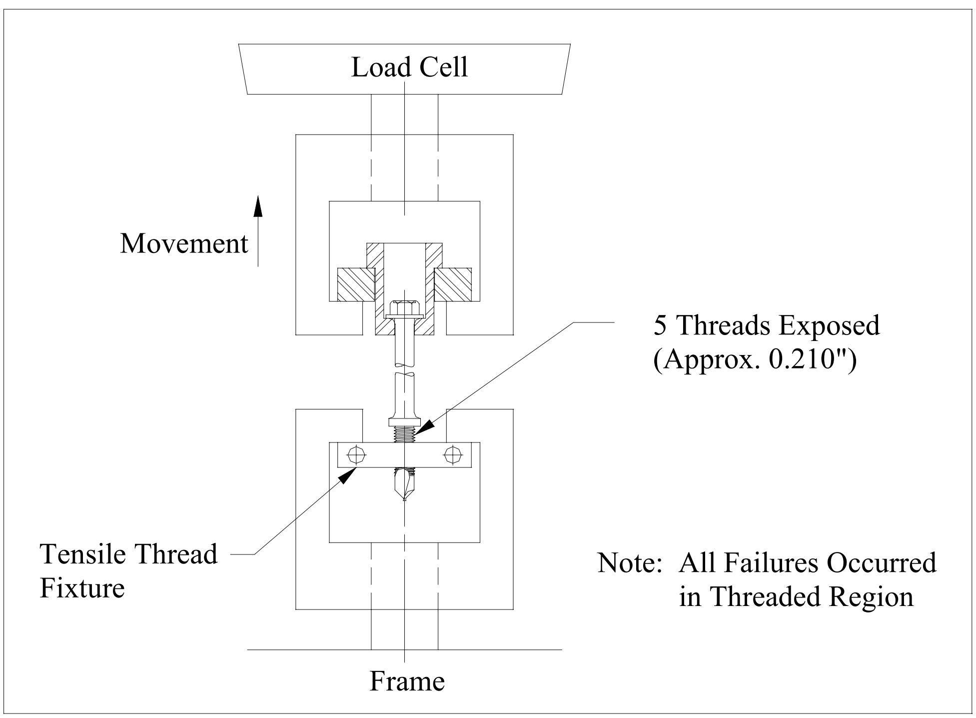



Figure 3.2 Elco's Tensile Test Setup

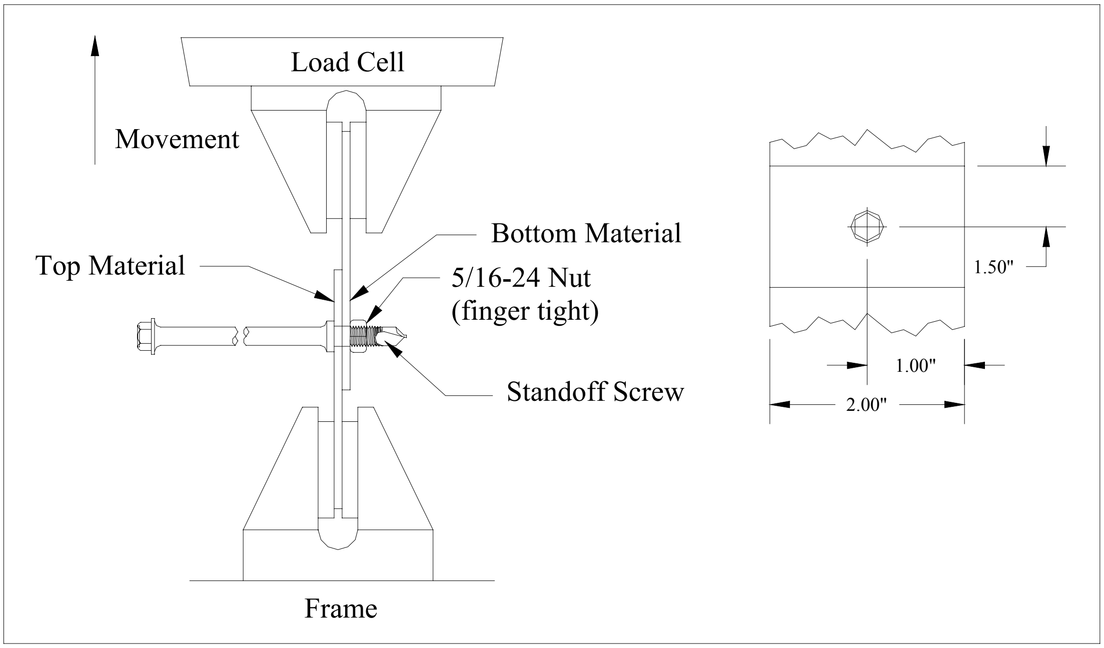



Figure 3.3 Elco's Shear Test Setup

Table 3.1 Elco's Tensile Test Results

| Screw Size (in) | Cross-sectional Area Through Shank ($in^2$) | Peak Load (lbs) | Peak Stress (psi) | Break Stress (psi) | Off Yield Stress (psi) | % Elongation |
|---|---|---|---|---|---|---|
| 2 | 0.058 | 9,701 | 167,258 | 137,468 | 147,633 | 14.8 |
| 2 | 0.058 | 9,700 | 167,237 | 134,432 | 150,837 | 13.1 |
| 2 | 0.058 | 9,685 | 166,985 | 123,325 | 151,005 | 15.4 |
| 2 | 0.058 | 9,424 | 162,470 | 128,628 | 146,360 | 12.7 |
| 2 | 0.058 | 9,359 | 161,365 | 133,621 | 144,297 | 10.0 |
| *Average* | *0.058* | *9,574* | *165,063* | *131,495* | *148,026* | *13.2* |
| 4 | 0.058 | 9,300 | 160,345 | 137,862 | 145,718 | 7.5 |
| 4 | 0.058 | 9,765 | 168,363 | 142,045 | 151,058 | 14.3 |
| 4 | 0.058 | 9,899 | 170,662 | 148,596 | 151,437 | 12.0 |
| 4 | 0.058 | 9,526 | 164,243 | 139,351 | 147,512 | 10.4 |
| 4 | 0.058 | 9,572 | 165,027 | 135,594 | 149,201 | 11.4 |
| *Average* | *0.058* | *9,612* | *165,728* | *140,690* | *148,985* | *11.1* |

Table 3.2 Elco's Shear Test Results

| Screw Size (in) | Cross-sectional Area Through Shank ($in^2$) | Peak Load (lbs) | Peak Stress (psi) | Elongation at Peak Load (in) | Yield Load (lbs) | Yield Stress (psi) |
|---|---|---|---|---|---|---|
| 2 | 0.05798 | 5,819 | 100,365 | 0.136 | 4,916 | 84,790 |
| 2 | 0.05811 | 5,928 | 102,010 | 0.139 | 4,862 | 83,681 |
| 2 | 0.05811 | 5,769 | 99,284 | 0.143 | 4,888 | 84,116 |
| *Average* | *0.05807* | *5,839* | *100,553* | *0.139* | *4,889* | *84,196* |
| 4 | 0.05798 | 5,806 | 100,147 | 0.136 | 4,930 | 85,029 |
| 4 | 0.05811 | 5,959 | 102,549 | 0.132 | 4,950 | 85,194 |
| 4 | 0.05811 | 5,831 | 100,362 | 0.130 | 4,905 | 84,405 |
| *Average* | *0.05807* | *5,865* | *101,019* | *0.133* | *4,928* | *84,876* |

### 3.3 Pushout Test Results

The results of all pushout tests conducted in this study will be presented in this section. Test results are summarized in two tables for each series. The first table presents specimen specifications as well as pertinent test results while the second provides a summary of the average results for each test group. In addition to the specimen specifications, the concrete compressive strength, peak shear load, peak shear load per screw, average slip at peak shear load and the failure mode are reported in the results tables. Information on the concrete compressive strength as well as the peak shear load and peak shear load per screw has been previously presented. Since the precision with which the concrete compressive strengths are measured is unknown, all $f'_c$ values given in this report and used for analysis will be rounded to the nearest hundred. Values for average slip at peak shear load were found by averaging the four slip readings from slab A or slab B depending on which was greater. In most cases, the average slip values were taken from the side of the specimen that failed.

Four primary failure modes were observed in the tests conducted in this study: screw shear, screw pullout, cone pullout and top chord buckling. A screw shear failure is characterized by one or more screws in a specimen failing in shear. The failure plane was in the threaded region of the screw for all tests where this failure mode controlled. A typical screw shear failure is shown in Figure 3.4. Screw pullout means that one or more screws pulled out of the top chord without shearing. This generally occurred in specimens utilizing thin top chord angles. Figure 3.5 shows the top chord of a specimen which failed by screw pullout. Cone pullout, labeled as rib failure in tests performed by Alander (1998), refers to one or more screws pulling out of the concrete slab while remaining attached to the top chord. This failure mode was generally limited to specimens fabricated with 1.5C and 2VL deck having more than one screw per rib. A typical cone pullout failure is illustrated in Figure 3.6. It should be noted that a rib failure mode was observed in specimens formed with 1.0C deck due to the relatively small rib size. This rib failure is shown in Figure 3.7. However, this failure is not considered primary since all specimens were able to sustain increased loading until another failure mode occurred. The final failure mode observed was top chord buckling. This mode of failure also occurred in tests conducted by both Hankins and Alander and is discussed in greater detail in Section 1.2. Results from tests that failed by top chord buckling will not be considered representative of the performance of the 5/16 in. diameter Elco Grade 8 standoff screw.

Figure 3.4 Typical Screw Shear Failure
(Note: concrete removed to provide clear view of sheared screw)

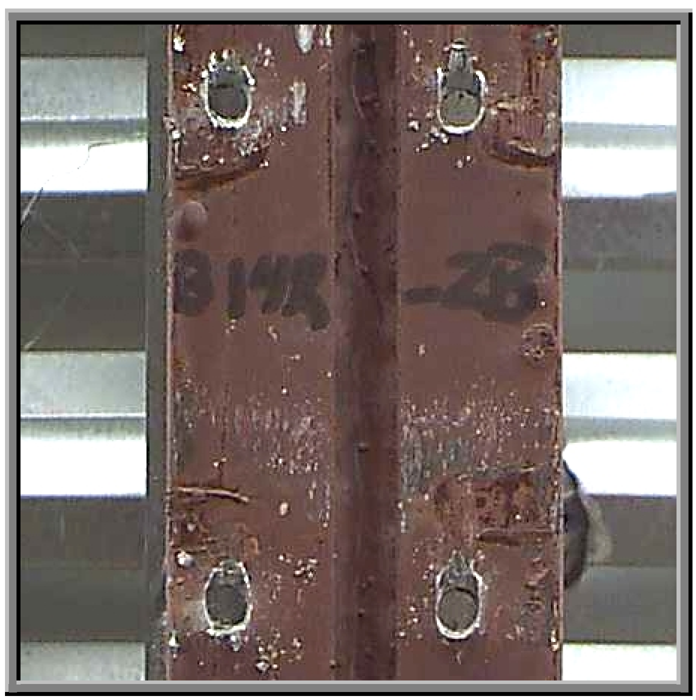


Figure 3.5 Typical Screw Pullout Failure

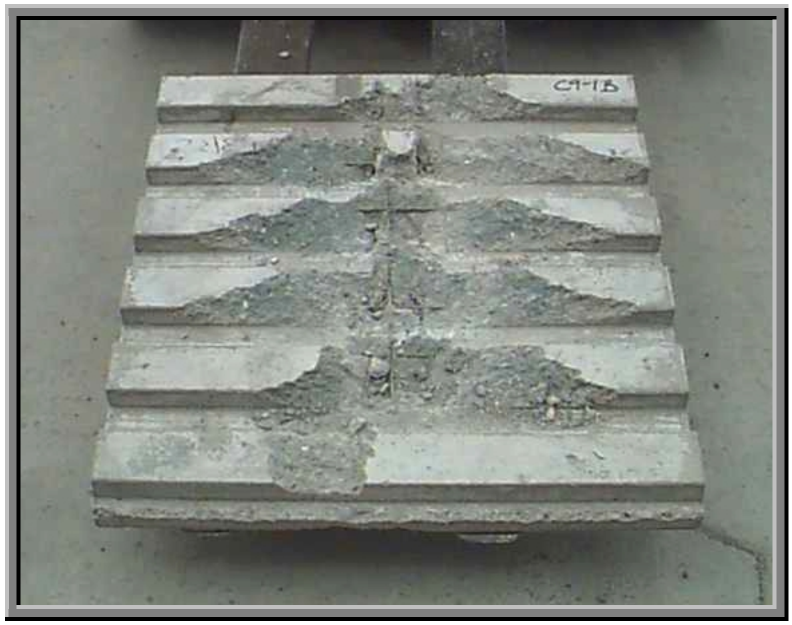



Figure 3.6 Typical Cone Pullout Failure

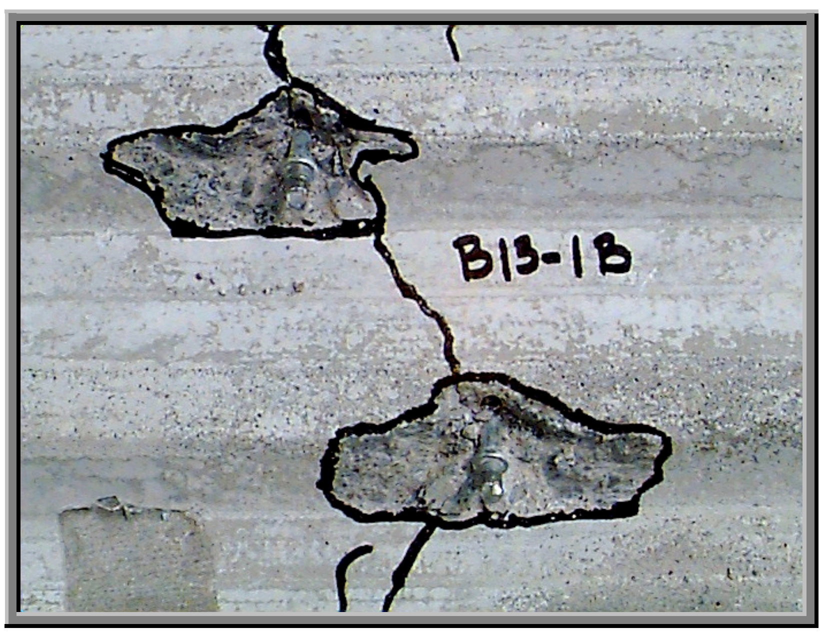



Figure 3.7 Typical Rib Failure Observed in Series B Tests

### 3.3.1 Series B Test Results

Test series B consisted of 17 tests in five groups conducted to further evaluate the performance of the 5/16 in. Elco Grade 8 standoff screw in specimens formed with Vulcraft 1.0C, 26 ga. deck. There were three sets of retests in this series. Varying amounts of reinforcement were used in all tests unlike the series B tests conducted by Alander which only utilized welded wire fabric. A complete discussion and summary of the test parameters for series B is contained in Section 2.3.1. The results of each individual test in series B as well as the average results for each test group are presented in Tables 3.3 and 3.4, respectively. Note that tests B1-B11 were tests performed by Alander (1998) and are included for comparison purposes.

## Table 3.3 Series B Results

| Test Number | Deck Type | Slab Depth (in.) | Screw Height (in.) | Screws Per Rib | Total Screws | Top Chord Thickness (in.) | Concrete f'$_c$ (psi) | Peak Shear Load (kips) | Peak Shear Load Per Screw (kips) | Average Slip at Peak Shear Load (in.) | Failure Mode |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B1-1 | 1.0C | 2.25 | 2.0 | 1 | 16 | 0.109 | 4300 | 51.63 | 3.23 | 1.018 | screw pullout |
| B1-2 | 1.0C | 2.25 | 2.0 | 1 | 16 | 0.109 | 4300 | 49.50 | 3.09 | 1.024 | screw pullout |
| *B1 Avg.* | | | | | | | *4300* | *50.57* | *3.16* | *1.021* | |
| B2-1 | 1.0C | 2.25 | 2.0 | 1 | 16 | 0.187 | 4300 | 56.03 | 3.50 | 0.768 | screw shear |
| B2-2 | 1.0C | 2.25 | 2.0 | 1 | 16 | 0.187 | 4300 | 58.79 | 3.67 | 0.709 | screw shear |
| *B2 Avg.* | | | | | | | *4300* | *57.41* | *3.59* | *0.739* | |
| B3-1 | 1.0C | 2.25 | 2.0 | 1 | 16 | 0.250 | 4300 | 54.40 | 3.40 | 0.625 | screw shear |
| B3-2 | 1.0C | 2.25 | 2.0 | 1 | 16 | 0.250 | 4300 | 51.40 | 3.21 | 0.596 | screw shear |
| *B3 Avg.* | | | | | | | *4300* | *52.90* | *3.31* | *0.611* | |
| B4-1 | 1.0C | 2.75 | 2.5 | 1 | 16 | 0.109 | 3800 | 57.79 | 3.61 | 0.828 | screw pullout |
| B4-2 | 1.0C | 2.75 | 2.5 | 1 | 16 | 0.109 | 3800 | 62.56 | 3.91 | 1.195 | screw pullout |
| *B4 Avg.* | | | | | | | *3800* | *60.18* | *3.76* | *1.012* | |
| B5-1 | 1.0C | 2.75 | 2.5 | 1 | 16 | 0.187 | 3800 | 73.74 | 4.61 | 0.920 | screw shear |
| B5-2 | 1.0C | 2.75 | 2.5 | 1 | 16 | 0.187 | 3800 | 73.37 | 4.59 | 0.954 | screw shear |
| *B5 Avg.* | | | | | | | *3800* | *73.56* | *4.60* | *0.937* | |
| B6-1 | 1.0C | 2.75 | 2.5 | 1 | 16 | 0.250 | 3800 | 63.94 | 4.00 | 0.630 | screw shear |
| B6-2 | 1.0C | 2.75 | 2.5 | 1 | 16 | 0.250 | 3800 | 62.94 | 3.93 | 0.631 | screw shear |
| *B6 Avg.* | | | | | | | *3800* | *63.44* | *3.97* | *0.631* | |
| B7-1 | 1.0C | 3.25 | 3.0 | 1 | 16 | 0.109 | 3800 | 60.30 | 3.77 | 0.807 | screw pullout |
| B7-2 | 1.0C | 3.25 | 3.0 | 1 | 16 | 0.109 | 3800 | 58.17 | 3.64 | 0.767 | screw pullout |
| *B7 Avg.* | | | | | | | *3800* | *59.24* | *3.71* | *0.787* | |
| B8-1 | 1.0C | 3.25 | 3.0 | 1 | 16 | 0.187 | 3800 | 77.39 | 4.84 | 0.962 | screw shear |
| B8-2 | 1.0C | 3.25 | 3.0 | 1 | 16 | 0.187 | 3800 | 77.26 | 4.83 | 0.894 | screw shear |
| *B8 Avg.* | | | | | | | *3800* | *77.33* | *4.84* | *0.928* | |
| B9-1 | 1.0C | 3.25 | 3.0 | 1 | 16 | 0.250 | 4700 | 70.10 | 4.38 | 0.652 | screw shear |
| B9-2 | 1.0C | 3.25 | 3.0 | 1 | 16 | 0.250 | 4700 | 70.10 | 4.38 | 0.673 | screw shear |
| *B9 Avg.* | | | | | | | *4700* | *70.10* | *4.38* | *0.663* | |
| B10-1 | 1.0C | 3.25 | 3.0 | 2 | 32 | 0.163 | 4700 | 111.93 | 3.50 | 0.591 | screw shear |
| B10-2 | 1.0C | 3.25 | 3.0 | 2 | 32 | 0.163 | 4700 | 108.29 | 3.38 | 0.727 | top chord buckling |
| *B10 Avg.* | | | | | | | *4700* | *110.11* | *3.44* | *0.659* | |
| B11-1 | 1.0C | 3.25 | 3.0 | 2 | 32 | 0.313 | 4800 | 95.47 | 2.98 | 0.448 | screw shear |
| B11-2 | 1.0C | 3.25 | 3.0 | 2 | 32 | 0.313 | 4800 | 102.13 | 3.19 | 0.382 | screw shear |
| *B11 Avg.* | | | | | | | *4800* | *98.80* | *3.09* | *0.415* | |
| B12-1 | 1.0C | 2.75 | 2.5 | 1 | 16 | 0.109 | 6600 | 57.29 | 3.58 | 0.745 | screw pullout |
| B12-2 | 1.0C | 2.75 | 2.5 | 1 | 16 | 0.109 | 6600 | 65.45 | 4.09 | 0.730 | screw pullout |
| *B12 Avg.* | | | | | | | *6600* | *61.37* | *3.84* | *0.738* | |
| B13-1 | 1.0C | 2.75 | 2.5 | 1 | 16 | 0.187 | 7000 | 88.25 | 5.52 | 0.848 | screw shear |
| B13-2 | 1.0C | 2.75 | 2.5 | 1 | 16 | 0.187 | 7000 | 77.95 | 4.87 | 0.869 | screw shear |
| *B13 Avg.* | | | | | | | *7000* | *83.10* | *5.20* | *0.859* | |
| B14-1 | 1.0C | 2.75 | 2.5 | 2 | 32 | 0.109 | 6500 | 116.45 | 3.64 | 0.710 | screw pullout |
| B14-2 | 1.0C | 2.75 | 2.5 | 2 | 32 | 0.109 | 6500 | 118.40 | 3.70 | 0.725 | screw pullout |
| *B14 Avg.* | | | | | | | *6500* | *117.43* | *3.67* | *0.718* | |
| B14R-1 | 1.0C | 2.75 | 2.5 | 2 | 32 | 0.109 | 5900 | 119.84 | 3.75 | 0.733 | screw pullout |
| B14R-2 | 1.0C | 2.75 | 2.5 | 2 | 32 | 0.109 | 5900 | 118.59 | 3.71 | 0.738 | screw pullout |
| *B14R Avg.* | | | | | | | *5900* | *119.22* | *3.73* | *0.736* | |
| B15-1 | 1.0C | 2.75 | 2.5 | 2 | 32 | 0.187 | 6700 | 151.57 | 4.74 | 0.868 | screw shear |
| B15-2 | 1.0C | 2.75 | 2.5 | 2 | 32 | 0.187 | 6700 | 160.17 | 5.01 | 0.898 | screw shear |
| *B15 Avg.* | | | | | | | *6700* | *155.87* | *4.88* | *0.883* | |
| B15R-1 | 1.0C | 3.00 | 2.5 | 2 | 32 | 0.187 | 5500 | 165.45 | 5.17 | 0.981 | screw shear |
| B15R-2 | 1.0C | 3.00 | 2.5 | 2 | 32 | 0.187 | 5500 | 163.44 | 5.11 | 0.989 | screw shear |
| *B15R Avg.* | | | | | | | *5500* | *164.45* | *5.14* | *0.985* | |
| B16-1 | 1.0C | 2.75 | 2.5 | 2 | 32 | 0.250 | 7300 | 106.03 | 3.31 | 0.472 | screw shear |
| B16-2 | 1.0C | 2.75 | 2.5 | 2 | 32 | 0.250 | 7300 | 109.98 | 3.44 | 0.365 | screw shear |
| *B16 Avg.* | | | | | | | *7300* | *108.01* | *3.38* | *0.419* | |
| B16R-1 | 1.0C | 3.00 | 2.5 | 2 | 32 | 0.250 | 5500 | 106.53 | 3.33 | 0.364 | screw shear |
| B16R-2 | 1.0C | 3.00 | 2.5 | 2 | 32 | 0.250 | 5500 | 97.49 | 3.05 | 0.336 | screw shear |
| B16R-3 | 1.0C | 3.00 | 2.5 | 2 | 32 | 0.250 | 5500 | 93.47 | 2.92 | 0.359 | screw shear |
| *B16R Avg.* | | | | | | | *5500* | *99.16* | *3.10* | *0.353* | |

Table 3.4 Series B Average Results

| Test Group | Deck Type | Slab Depth (in.) | Screw Height (in.) | Screws Per Rib | Top Chord Thickness (in.) | Concrete f'$_c$ (psi) | Peak Shear Load (kips) | Peak Shear Load Per Screw (kips) |
|---|---|---|---|---|---|---|---|---|
| B1 | 1.0C | 2.25 | 2.0 | 1 | 0.109 | 4300 | 50.57 | 3.16 |
| B2 | 1.0C | 2.25 | 2.0 | 1 | 0.187 | 4300 | 57.41 | 3.59 |
| B3 | 1.0C | 2.25 | 2.0 | 1 | 0.250 | 4300 | 52.90 | 3.31 |
| B4 | 1.0C | 2.75 | 2.5 | 1 | 0.109 | 3800 | 60.18 | 3.76 |
| B5 | 1.0C | 2.75 | 2.5 | 1 | 0.187 | 3800 | 73.56 | 4.60 |
| B6 | 1.0C | 2.75 | 2.5 | 1 | 0.250 | 3800 | 63.44 | 3.97 |
| B7 | 1.0C | 3.25 | 3.0 | 1 | 0.109 | 3800 | 59.24 | 3.70 |
| B8 | 1.0C | 3.25 | 3.0 | 1 | 0.187 | 3800 | 77.33 | 4.83 |
| B9 | 1.0C | 3.25 | 3.0 | 1 | 0.250 | 4700 | 70.10 | 4.38 |
| B10 | 1.0C | 3.25 | 3.0 | 2 | 0.163 | 4700 | 110.11 | 3.44 |
| B11 | 1.0C | 3.25 | 3.0 | 2 | 0.313 | 4800 | 98.80 | 3.09 |
| B12 | 1.0C | 2.75 | 2.5 | 1 | 0.109 | 6600 | 61.37 | 3.84 |
| B13 | 1.0C | 2.75 | 2.5 | 1 | 0.187 | 7000 | 83.10 | 5.20 |
| B14 | 1.0C | 2.75 | 2.5 | 2 | 0.109 | 6500 | 117.43 | 3.67 |
| B14R | 1.0C | 2.75 | 2.5 | 2 | 0.109 | 5900 | 119.22 | 3.73 |
| B15 | 1.0C | 2.75 | 2.5 | 2 | 0.187 | 6700 | 155.87 | 4.88 |
| B15R | 1.0C | 3.00 | 2.5 | 2 | 0.187 | 5500 | 164.45 | 5.14 |
| B16 | 1.0C | 2.75 | 2.5 | 2 | 0.250 | 7300 | 108.01 | 3.38 |
| B16R | 1.0C | 3.00 | 2.5 | 2 | 0.250 | 5500 | 99.16 | 3.10 |

The failure modes observed in series B were screw pullout, screw shear and top chord buckling. Screw pullout was the only mode observed in specimens utilizing the 0.109 in. thick top chord while all remaining tests except for B10-2 failed by screw shear. Even though test B10-2 failed by top chord buckling, which is not an applicable failure mode in this study, the data from this test is assumed valid since peak shear load had been achieved before buckling occurred (Alander, et al 1998a). It is important to note that the concrete surrounding the base of the screws in all specimens in this series crushed locally leaving the base of the screws unsupported. This local crushing can be attributed to the relatively small rib area of the Vulcraft 1.0C, 26 ga. deck. As a result, there was less resistance to screw rotation.

In tests conducted by Alander it was found that specimens using medium angle thicknesses, generally 0.187 in. thick, were able to achieve the greatest shear loads per screw due to the screws being subjected to a combination of shear and tensile forces. Shear loads were found to be the least in specimens with 0.109 in. thick top chords and in between for specimens with 0.250 in. thick top chords. In the case of tests B14-B16 this trend does not apply. Despite previous findings, the 0.250 in. thick top chord resulted in lower shear loads than the 0.109 in. thick top chord. One possibility for this occurrence is the configuration of these three test groups. These groups each use two screws per rib unlike the majority of tests in series B. This increased screw density can account for the nonconformity with previous test results. The use of Vulcraft 1.0C, 26, ga. deck with its small rib area in conjunction with having two screws per rib could also explain this unexpected result. However, one set of test results is not enough to conclude that the previous correlation between shear capacity and top chord thickness is invalid.

Since no transverse reinforcement was used in the series B tests conducted by Alander, the goal of some of the additional series B tests was to examine the effects of sufficiently reinforcing the slabs against longitudinal splitting. It can be seen by comparing tests B4 and B5 to tests B12 and B13, respectively, that the addition of transverse reinforcement slightly increases shear capacity per screw. By adding transverse reinforcement, the concrete is not apt to fail in a longitudinal splitting mode. With the concrete reinforced against splitting, the screws are better supported against excess rotation which, in turn, results in better performance. This reduction in rotation is evident by the average slip values of tests B4, B5, B12 and B13.

The tests using the 0.250 in. thick top chord exhibited substantially less slip at peak shear load than did the remaining tests which used thinner top chord sections. This is expected since the thicker base material induces a “fixed” support condition resulting in less screw rotation. However, it can be seen that the thinner base angle does not always result in the largest slip at peak shear load. In this series of tests, screw rotations were often largest in tests using the 0.187 in. thick top chord than those with the 0.109 in. thick top chord.

### 3.3.2 Series C Test Results

Test series C consisted of nine tests in four groups to further evaluate the performance of the 5/16 in. diameter Elco Grade 8 standoff screw when used in Vulcraft

1.5C, 22 ga. deck in various arrangements. Screws were placed in configurations of both one and four screws per rib. Reinforcement was placed in all specimens to prevent longitudinal splitting of the concrete slabs. A complete discussion and summary of the test parameters for series C is presented in section 2.3.2. The results of each individual test in series C as well as the average results for each test group are presented in Tables 3.5 and 3.6, respectively. Note that tests C1-C8, excluding C1R and C2R, were tests performed by Alander (1998) and are included for comparison purposes.

Table 3.5 Series C Results

| **Test Number** | **Deck Type** | **Slab Depth (in.)** | **Screw Height (in.)** | **Screws Per Rib** | **Total Screws** | **Top Chord Thickness (in.)** | **Concrete $f'_c$ (psi)** | **Peak Shear Load (kips)** | **Peak Shear Load Per Screw (kips)** | **Average Slip at Peak Shear Load (in.)** | **Failure Mode** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C1-1 | 1.5C | 3.25 | 3.0 | 1 | 10 | 0.109 | 5800 | 40.45 | 4.05 | 0.118 | screw shear |
| C1-2 | 1.5C | 3.25 | 3.0 | 1 | 10 | 0.109 | 5800 | 40.39 | 4.04 | 0.560 | screw shear |
| *C1 Avg.* | | | | | | | *5800* | *40.42* | *4.05* | *0.339* | |
| C1R-1 | 1.5C | 3.25 | 3.0 | 1 | 10 | 0.109 | 4100 | 54.02 | 5.40 | 0.434 | screw shear |
| C1R-2 | 1.5C | 3.25 | 3.0 | 1 | 10 | 0.109 | 4100 | 46.48 | 4.65 | 0.438 | screw shear |
| C1R-3 | 1.5C | | 3.0 | 1 | 10 | 0.109 | 4100 | 50.63 | 5.06 | 0.489 | screw shear |
| *C1R Avg.* | | | | | | | *4100* | *50.38* | *5.04* | *0.454* | |
| C2-1 | 1.5C | 3.25 | 3.0 | 1 | 10 | 0.187 | 5800 | 51.63 | 5.16 | 0.435 | screw shear |
| C2-2 | 1.5C | 3.25 | 3.0 | 1 | 10 | 0.187 | 5800 | 53.58 | 5.36 | 0.648 | screw shear |
| *C2 Avg.* | | | | | | | *5800* | *52.61* | *5.26* | *0.542* | |
| C2R-1 | 1.5C | 3.25 | 3.0 | 1 | 10 | 0.187 | 4100 | 58.67 | 5.87 | 0.497 | screw shear |
| C2R-2 | 1.5C | 3.25 | 3.0 | 1 | 10 | 0.187 | 4100 | 56.91 | 5.69 | 0.860 | screw shear |
| *C2R Avg.* | | | | | | | *4100* | *57.79* | *5.78* | *0.679* | |
| C3-1 | 1.5C | 3.25 | 3.0 | 1 | 10 | 0.250 | 4300 | 46.98 | 4.70 | 0.502 | screw shear |
| C3-2 | 1.5C | 3.25 | 3.0 | 1 | 10 | 0.250 | 4300 | 41.08 | 4.11 | 0.207 | screw shear |
| *C3 Avg.* | | | | | | | *4300* | *44.03* | *4.41* | *0.355* | |
| C4-1 | 1.5C | 3.25 | 3.0 | 2 | 20 | 0.109 | 4300 | 84.86 | 4.24 | 0.707 | screw shear/pullout |
| C4-2 | 1.5C | 3.25 | 3.0 | 2 | 20 | 0.109 | 4300 | 91.33 | 4.57 | 0.579 | screw pullout |
| *C4 Avg.* | | | | | | | *4300* | *88.10* | *4.41* | *0.643* | |
| C5-1 | 1.5C | 3.25 | 3.0 | 2 | 20 | 0.187 | 4300 | 109.98 | 5.50 | 0.816 | screw shear/rib failure |
| C5-2 | 1.5C | 3.25 | 3.0 | 2 | 20 | 0.187 | 4300 | 113.19 | 5.66 | 0.646 | screw shear/rib failure |
| *C5 Avg.* | | | | | | | *4300* | *111.59* | *5.58* | *0.731* | |
| C6-1 | 1.5C | 3.25 | 3.0 | 2 | 20 | 0.250 | 4300 | 91.33 | 4.57 | 0.738 | screw shear/rib failure |
| C6-2 | 1.5C | 3.25 | 3.0 | 2 | 20 | 0.250 | 4300 | 82.10 | 4.11 | 0.719 | screw shear |
| *C6 Avg.* | | | | | | | *4300* | *86.72* | *4.34* | *0.729* | |
| C7-1 | 1.5C | 3.75 | 3.5 | 4 | 40 | 0.163 | 4300 | 156.15 | 3.90 | 0.773 | screw shear/rib failure |
| C7-2 | 1.5C | 3.75 | 3.5 | 4 | 40 | 0.163 | 4300 | 189.94 | 4.75 | 1.024 | screw shear |
| *C7 Avg.* | | | | | | | *4300* | *173.05* | *4.33* | *0.899* | |
| C8-1 | 1.5C | 3.75 | 3.5 | 4 | 40 | 0.250 | 3900 | 163.25 | 4.08 | 0.592 | screw shear |
| C8-2 | 1.5C | 3.75 | 3.5 | 4 | 40 | 0.250 | 3900 | 145.35 | 3.63 | 0.392 | screw shear |
| *C8 Avg.* | | | | | | | *3900* | *154.30* | *3.86* | *0.492* | |
| C9-1 | 1.5C | 3.50 | 3.0 | 4 | 40 | 0.163 | 5400 | 136.87 | 3.42 | 0.600 | cone pullout |
| C9-2 | 1.5C | 3.50 | 3.0 | 4 | 40 | 0.163 | 5400 | 123.17 | 3.08 | 0.435 | cone pullout |
| *C9 Avg.* | | | | | | | *5400* | *130.02* | *3.25* | *0.518* | |
| C10-1 | 1.5C | 3.50 | 3.0 | 4 | 40 | 0.250 | 5400 | 138.19 | 3.45 | 0.834 | cone pullout |
| C10-2 | 1.5C | 3.50 | 3.0 | 4 | 40 | 0.250 | 5400 | 149.12 | 3.73 | 0.370 | cone pullout |
| *C10 Avg.* | | | | | | | *5400* | *143.66* | *3.59* | *0.602* | |

Table 3.6 Series C Average Results

| Test Group | Deck Type | Slab Depth (in.) | Screw Height (in.) | Screws Per Rib | Top Chord Thickness (in.) | Concrete $f'_c$ (psi) | Peak Shear Load (kips) | Peak Shear Load Per Screw (kips) |
|---|---|---|---|---|---|---|---|---|
| C1 | 1.5C | 3.25 | 3.0 | 1 | 0.109 | 5800 | 40.42 | 4.05 |
| C1R | 1.5C | 3.25 | 3.0 | 1 | 0.109 | 4100 | 50.38 | 5.04 |
| C2 | 1.5C | 3.25 | 3.0 | 1 | 0.187 | 5800 | 52.61 | 5.26 |
| C2R | 1.5C | 3.25 | 3.0 | 1 | 0.187 | 4100 | 57.79 | 5.78 |
| C3 | 1.5C | 3.25 | 3.0 | 1 | 0.250 | 4300 | 44.03 | 4.41 |
| C4 | 1.5C | 3.25 | 3.0 | 2 | 0.109 | 4300 | 88.10 | 4.41 |
| C5 | 1.5C | 3.25 | 3.0 | 2 | 0.187 | 4300 | 111.59 | 5.58 |
| C6 | 1.5C | 3.25 | 3.0 | 2 | 0.250 | 4300 | 86.72 | 4.34 |
| C7 | 1.5C | 3.75 | 3.5 | 4 | 0.163 | 4300 | 173.05 | 4.33 |
| C8 | 1.5C | 3.75 | 3.5 | 4 | 0.250 | 3900 | 154.30 | 3.86 |
| C9 | 1.5C | 3.50 | 3.0 | 4 | 0.163 | 5400 | 130.02 | 3.25 |
| C10 | 1.5C | 3.50 | 3.0 | 4 | 0.250 | 5400 | 143.66 | 3.59 |

The failure modes observed in series C were screw shear and cone pullout. Unlike tests in series B, specimens constructed with the 0.109 in. thick top chord in series C did not fail by screw pullout. This can be attributed to the increased amount of concrete surrounding the base of the screws due to the wider rib width of the Vulcraft 1.5C, 22 ga. deck. The increased amount of concrete surrounding the screws acts to inhibit the rotation necessary cause a screw pullout failure. In tests where there was more than one screw per rib, cone pullout was the typical mode of failure. This is a common result when screws are grouped in deck with wide ribs.

As is generally the case, the tests using the 0.187 in. thick top chord yielded the highest shear load per screw. The effects of grouping screws can also be seen. It is clear that grouping screws has a detrimental effect on the strength per screw and that when more screws are used this effect is magnified. However, this effect is greater when increasing the screws per rib from two to four than increasing from one to two. Note that there is no definite pattern in average slip at peak load values for tests in series C.

### 3.3.3 Series E Test Results

Test series E consisted of 19 tests comprising seven groups. This series contained three sets of retests. The goal of this series E was to evaluate the 5/16 in. diameter Elco Grade 8 standoff screw when used in Vulcraft 2VL, 22 ga. deck. Screws were placed in configurations of eight, 16 and 24 screws per rib in varying top chord thicknesses. All concrete slabs in this series were sufficiently reinforced against longitudinal splitting. A complete discussion and summary of the test parameters for series E is presented in section 2.3.3. The results of each individual test in series E as well as the average results for each test group are presented in Tables 3.7 and 3.8, respectively.

Table 3.7 Series E Results

| Test Number | Deck Type | Slab Depth (in.) | Screw Height (in.) | Screws Per Rib | Total Screws | Top Chord Thickness (in.) | Concrete $f'_c$ (psi) | Peak Shear Load (kips) | Peak Shear Load Per Screw (kips) | Average Slip at Peak Shear Load (in.) | Failure Mode |
|---|---|---|---|---|---|---|---|---|---|---|---|
| E1-1 | 2VL | 4.25 | 4.0 | 4 | 16 | 0.109 | 7400 | 56.60 | 3.54 | N.A. | top chord buckling |
| E1-2 | 2VL | 4.25 | 4.0 | 4 | 16 | 0.109 | 7400 | 65.33 | 4.08 | N.A. | top chord buckling |
| *E1 Avg.* | | | | | | | *N.A.* | *N.A.* | *N.A.* | *N.A.* | |
| E1R-1 | 2VL | 4.25 | 4.0 | 4 | 16 | 0.109 | 4700 | 63.32 | 3.96 | 0.628 | screw shear/pullout |
| E1R-2 | 2VL | 4.25 | 4.0 | 4 | 16 | 0.109 | 4700 | 62.44 | 3.90 | 0.532 | screw shear/pullout |
| *E1R Avg.* | | | | | | | *4700* | *62.88* | *3.93* | *0.580* | |
| E2-1 | 2VL | 4.25 | 4.0 | 4 | 16 | 0.187 | 7200 | 96.23 | 6.01 | 0.715 | screw shear |
| E2-2 | 2VL | 4.25 | 4.0 | 4 | 16 | 0.187 | 7200 | 98.81 | 6.18 | 0.812 | screw shear |
| *E2 Avg.* | | | | | | | *7200* | *97.52* | *6.10* | *0.764* | |
| E2R-1 | 2VL | 4.25 | 4.0 | 4 | 16 | 0.187 | 5000 | 93.09 | 5.82 | 0.957 | screw shear |
| E2R-2 | 2VL | 4.25 | 4.0 | 4 | 16 | 0.187 | 5000 | 89.70 | 5.60 | 0.739 | screw shear |
| *E2R Avg.* | | | | | | | *5000* | *91.40* | *5.71* | *0.848* | |
| E3-1 | 2VL | 4.25 | 4.0 | 4 | 16 | 0.250 | 7200 | 66.39 | 4.15 | 0.265 | screw shear |
| E3-2 | 2VL | 4.25 | 4.0 | 4 | 16 | 0.250 | 7200 | 77.64 | 4.85 | 0.281 | screw shear |
| *E3 Avg.* | | | | | | | *7200* | *72.02* | *4.50* | *0.273* | |
| E3R-1 | 2VL | 4.25 | 4.0 | 4 | 16 | 0.250 | 5000 | 66.71 | 4.17 | 0.535 | screw shear |
| E3R-2 | 2VL | 4.25 | 4.0 | 4 | 16 | 0.250 | 5000 | 83.67 | 5.23 | 0.836 | screw shear |
| E3R-3 | 2VL | 4.25 | 4.0 | 4 | 16 | 0.250 | 5000 | 81.03 | 5.06 | 0.560 | screw shear |
| *E3R Avg.* | | | | | | | *5000* | *82.35* | *5.15* | *0.698* | |
| E4-1 | 2VL | 4.25 | 4.0 | 8 | 32 | 0.163 | 5000 | 137.18 | 4.29 | 0.811 | cone pullout |
| E4-2 | 2VL | 4.25 | 4.0 | 8 | 32 | 0.163 | 5000 | 121.60 | 3.80 | 0.660 | cone pullout |
| *E4 Avg.* | | | | | | | *5000* | *129.39* | *4.05* | *0.736* | |
| E5-1 | 2VL | 4.25 | 4.0 | 8 | 32 | 0.250 | 4800 | 112.12 | 3.50 | 0.429 | cone pullout |
| E5-2 | 2VL | 4.25 | 4.0 | 8 | 32 | 0.250 | 4800 | 108.16 | 3.38 | 0.353 | cone pullout |
| *E5 Avg.* | | | | | | | *4800* | *110.14* | *3.44* | *0.391* | |
| E6-1 | 2VL | 4.50 | 4.0 | 12 | 48 | 0.163 | 4900 | 133.04 | 2.77 | 0.506 | cone pullout |
| E6-2 | 2VL | 4.50 | 4.0 | 12 | 48 | 0.163 | 4900 | 135.48 | 2.82 | 0.505 | cone pullout |
| *E6 Avg.* | | | | | | | *4900* | *134.26* | *2.80* | *0.506* | |
| E7-1 | 2VL | 4.50 | 4.0 | 12 | 48 | 0.250 | 3800 | 125.81 | 2.62 | 0.385 | cone pullout/shear |
| E7-2 | 2VL | 4.50 | 4.0 | 12 | 48 | 0.250 | 3800 | 132.91 | 2.77 | 0.440 | cone pullout/shear |
| *E7 Avg.* | | | | | | | *3800* | *129.36* | *2.70* | *0.413* | |

Table 3.8 Series E Average Results

| Test Group | Deck Type | Slab Depth (in.) | Screw Height (in.) | Screws Per Rib | Top Chord Thickness (in.) | Concrete $f'_c$ (psi) | Peak Shear Load (kips) | Peak Shear Load Per Screw (kips) |
|---|---|---|---|---|---|---|---|---|
| E1 | 2VL | 4.25 | 4.0 | 4 | 0.109 | N.A. | N.A. | N.A. |
| E1R | 2VL | 4.25 | 4.0 | 4 | 0.109 | 4700 | 62.88 | 3.93 |
| E2 | 2VL | 4.25 | 4.0 | 4 | 0.187 | 7200 | 97.52 | 6.10 |
| E2R | 2VL | 4.25 | 4.0 | 4 | 0.187 | 5000 | 91.40 | 5.71 |
| E3 | 2VL | 4.25 | 4.0 | 4 | 0.250 | 7200 | 72.02 | 4.50 |
| E3R | 2VL | 4.25 | 4.0 | 4 | 0.250 | 5000 | 82.35 | 5.15 |
| E4 | 2VL | 4.25 | 4.0 | 8 | 0.163 | 5000 | 129.39 | 4.05 |
| E5 | 2VL | 4.25 | 4.0 | 8 | 0.250 | 4800 | 110.14 | 3.44 |
| E6 | 2VL | 4.50 | 4.0 | 12 | 0.163 | 4900 | 134.26 | 2.80 |
| E7 | 2VL | 4.50 | 4.0 | 12 | 0.250 | 3800 | 129.36 | 2.70 |

The failure modes observed in series E were screw shear, cone pullout and top chord buckling. It should be noted that some specimens in this series exhibited a combination of failure modes, i.e., screw shear followed by screw pullout. In these cases, the first failure mode is primary. Again, as in series C, specimens utilizing the 0.109 in. thick top chord failed primarily in screw shear as opposed to screw pullout. However, some screws in these tests were found to have pulled out of the top chord once one or more screws had failed in shear. Test E1 was the only group where top chord buckling was encountered. Specimens formed with Vulcraft 2VL, 22 ga. deck were found to be susceptible to top chord buckling due to a longer unbraced length resulting from the larger rib spacing in this type of deck, i.e., the distance from the top of the specimen to the first screw or set of screws is greater than in specimens using other deck types. When screws were grouped in relatively dense configurations a cone pullout mode generally controlled. This mode was observed in tests E4-E5 and E6-E7 where screws were placed eight and 12 screws per rib, respectively.

The effects of grouping screws in Vulcraft 2VL, 22 ga. deck are evident from this test series. It can be seen that larger screw densities resulted in lower shear strength per screw while the greatest shear strength per screw values for this series were found in tests having four screws per rib. Tests with eight screws per rib resulted in the shear load per screw falling somewhere in between.

Specimens with 0.187 in. thick top chords realized greater shear loads than those with other top chord thicknesses. As is generally expected, specimens using the 0.109 in. thick top chord resulted in the smallest shear load per screw. Specimens with the 0.163 in. and 0.250 in. top chords reached similar peak shear loads per screw with those of the 0.163 in. thick top chord being slightly greater. This, again, is expected when using these top chord sizes.

The greatest slip values at peak shear load occurred in specimens utilizing the 0.187 in. thick top chord as in previous tests. In tests where 12 screws per rib were used, E6 and E7, slip values at peak shear load were relatively low compared to the rest of the tests in series E. This is a result of the more densely packed screw configuration causing a cone failure which has been proven to result in lower peak shear loads. The slip values of group E3 are abnormally small compared to the rest of the series. This is most likely a result of the high concrete strength in those tests.

### 3.3.4 Series F Test Results

Test series F consisted of six groups totaling 12 individual tests aimed at evaluating the performance of the 5/16 in. diameter Elco Grade 8 standoff screw in solid slab configurations. Screws in this series were placed in dense screw patterns, from 14 screws to 26 screws per half specimen. As stated previously, solid slab configurations can be used to model composite joist girders where deck is placed such that the deck ribs are parallel to the joist girders. All concrete slabs in this series were sufficiently reinforced against longitudinal splitting. A complete discussion and summary of the test parameters for series F is presented in section 2.3.4. The results of each individual test in series F as well as the average results for each test group are presented in Tables 3.9 and 3.10, respectively.

Table 3.9 Series F Results

| Test Number | Deck Type | Slab Depth (in.) | Screw Height (in.) | Screws Per Rib | Total Screws | Top Chord Thickness (in.) | Concrete $f'_c$ (psi) | Peak Shear Load (kips) | Peak Shear Load Per Screw (kips) | Average Slip at Peak Shear Load (in.) | Failure Mode |
|---|---|---|---|---|---|---|---|---|---|---|---|
| F1-1 | none | 2.50 | 2.0 | 2 | 28 | 0.163 | 3800 | 190.20 | 6.79 | 0.696 | screw shear |
| F1-2 | none | 2.50 | 2.0 | 2 | 28 | 0.163 | 3800 | 181.90 | 6.50 | 0.553 | screw shear |
| *F1 Avg.* | | | | | | | *3800* | *186.05* | *6.65* | *0.625* | |
| F2-1 | none | 2.50 | 2.0 | 2 | 28 | 0.250 | 3700 | 213.19 | 7.61 | 0.567 | screw shear |
| F2-2 | none | 2.50 | 2.0 | 2 | 28 | 0.250 | 3700 | 204.14 | 7.29 | 0.576 | screw shear |
| *F2 Avg.* | | | | | | | *3700* | *208.67* | *7.45* | *0.572* | |
| F3-1 | none | 3.00 | 2.5 | 2 | 36 | 0.212 | 3800 | 252.38 | 7.01 | 0.725 | screw shear |
| F3-2 | none | 3.00 | 2.5 | 2 | 36 | 0.212 | 3800 | 223.24 | 6.20 | 0.738 | screw shear |
| *F3 Avg.* | | | | | | | *3800* | *237.81* | *6.61* | *0.732* | |
| F4-1 | none | 3.00 | 2.5 | 2 | 36 | 0.313 | 5100 | 216.58 | 6.02 | 0.243 | screw shear |
| F4-2 | none | 3.00 | 2.5 | 2 | 36 | 0.313 | 5100 | 202.13 | 5.61 | 0.243 | screw shear |
| *F4 Avg.* | | | | | | | *5100* | *209.36* | *5.82* | *0.243* | |
| F5-1 | none | 3.50 | 3.0 | 2 | 52 | 0.227 | 5700 | 300.25 | 5.77 | 0.357 | no failure observed |
| F5-2 | none | 3.50 | 3.0 | 2 | 52 | 0.227 | 5700 | 241.33 | 4.64 | N.A. | concrete (N.A.) |
| *F5 Avg.* | | | | | | | *5700* | *300.25* * | *5.77* * | *0.357* * | |
| F6-1 | none | 3.50 | 3.0 | 2 | 52 | 0.375 | 5600 | 320.60 | 6.17 | 0.346 | screw shear |
| F6-2 | none | 3.50 | 3.0 | 2 | 52 | 0.375 | 5600 | 313.56 | 6.03 | 0.199 | screw shear |
| *F6 Avg.* | | | | | | | *5600* | *317.08* | *6.10* | *0.273* | |

* does not include specimen in which the concrete slab failed

Table 3.10 Series F Average Results

| Test Group | Deck Type | Slab Depth (in.) | Screw Height (in.) | Screws Per Rib | Top Chord Thickness (in.) | Concrete $f'_c$ (psi) | Peak Shear Load (kips) | Peak Shear Load Per Screw (kips) |
|---|---|---|---|---|---|---|---|---|
| F1 | none | 2.5 | 2.0 | 2 | 0.163 | 3800 | 186.05 | 6.65 |
| F2 | none | 2.5 | 2.0 | 2 | 0.250 | 3700 | 208.67 | 7.45 |
| F3 | none | 3.0 | 2.5 | 2 | 0.212 | 3800 | 237.81 | 6.61 |
| F4 | none | 3.0 | 2.5 | 2 | 0.313 | 5100 | 209.36 | 5.82 |
| F5 | none | 3.5 | 3.0 | 2 | 0.227 | 5700 | 300.25* | 5.77* |
| F6 | none | 3.5 | 3.0 | 2 | 0.375 | 5600 | 317.08 | 6.10 |

* does not include specimen in which the concrete slab failed

Screw shear was the only applicable mode of failure observed in series F. This occurred in all tests except F5. Test F5-1 was stopped before a failure mode was observed because the load being applied to the specimen was so large that the test frame began to deform. However, the data from this test is considered valid since the peak shear load had already been achieved before the test was stopped. Upon completion of this test the test frame was checked for capacity and reinforced to sustain the high loads specimens in this series were capable of carrying. Bolts were added to the frame as well as a kicker to prevent any lateral movement. In the case of test F5-2, the interior of slab A failed in a crushing mode rendering the specimen unstable before any screw related failure occurred. Data from this test is not considered applicable since this failure is not one of the primary modes.

The results from series F show that the screw density had little effect on the shear strength per screw. This is most likely due to the solid slab configuration. In a solid slab configuration, there is a much greater amount of concrete surrounding the screw than in cases where deck is used. All specimens in this series exhibited extensive cracking on the exterior sides of the concrete slabs as a result of the large screw densities.

Slip values were noticeably smaller for tests F4 and F6 where the top chords were 0.313 in. thick and 0.375 in. thick, respectively. This, as discussed previously, can be attributed to the fixed support condition induced by the thick top chord which inhibits screw rotation. As in other test series, the greatest shear load per screw values were found in specimens using medium top chord thicknesses, i.e., test F2.

**3.4 Comparison of Results**

A summary of the average standoff screw shear strengths is given in Table 3.11. As in previous sections, results from tests conducted by Alander (1998) are included for comparison purposes.

It can be seen that the 5/16 in. diameter Elco Grade 8 standoff screw performs best in solid slab configurations, series F. This is most attributable to the increased amount of concrete surrounding the screws in solid slab geometries as opposed to specimens formed with steel deck. The greatest shear capacity per screw reported was in test F2, 7.45 kips. This follows the general trend of specimens utilizing medium thickness top chords resulting in better screw performance.

Viewing only results from tests formed with steel deck, it can be seen that the screws performed better in specimens having medium thickness, generally 0.187 in., than any other top chord section. Also, of those tests using the 0.187 in. thick top chord, those with only one screw per rib generally resulted in greater shear loads per screw. This can be best explained by the fact that forces in a concrete rib are increased with the addition of more screws. This increase results in the concrete rib "breaking" and thus leaving the screw shank relatively unsupported.

At low screw densities, one or two screw per rib, it can be seen that screw strengths were the lowest in series B. This can be attributed to the small rib area of the Vulcraft 1.0C, 26 ga. deck used. Due to the small rib height of the Vulcraft 0.6C, 28 ga. deck used in series A, the effect rib area is not as critical as in series B. The rib failures observed in all series B tests, as shown in Figure 3.7, may account for the lower shear strengths. In cases where screws were grouped more than two screws per rib, it can be seen that the effects were most detrimental in series D and were comparable between series C and series E. Looking specifically at tests C7-C10 the effect of embeddment depth in grouped screw configurations can be seen. It is clear that when screws are grouped, an embeddment depth of 2 in. above the deck is more advantageous to the 1.5 in. height above deck that was previously found to be the optimal amount of screw embeddment. The increased embeddment when screws are grouped, especially four screws or more helps to resist the cone pullout failure mode. By resisting a cone pullout failure mode, screws are able to be loaded until a screw related failure mode occurs which generally results in greater shear capacities, refer to Table 3.5.

Table 3.11 Average Shear Strength Summary

| Test Group | Deck Type | Slab Depth (in.) | Screw Height (in.) | Screws Per Rib | Top Chord Thickness (in.) | Concrete f'c (psi) | Peak Shear Load (kips) | Peak Shear Load Per Screw (kips) |
|---|---|---|---|---|---|---|---|---|
| A1 | 0.6C | 2.25 | 2.0 | 0.5 | 0.109 | 5000 | 51.63 | 4.30 |
| A2 | 0.6C | 2.25 | 2.0 | 0.5 | 0.187 | 4800 | 65.20 | 5.43 |
| A3 | 0.6C | 2.75 | 2.5 | 1 | 0.109 | N.A. | N.A. | N.A. |
| A4 | 0.6C | 2.75 | 2.5 | 1 | 0.187 | N.A. | N.A. | N.A. |
| A5 | 0.6C | 2.75 | 2.5 | 1 | 0.250 | 5500 | 95.32 | 4.33 |
| A6 | 0.6C | 2.25 | 2.0 | 1 | 0.109 | 5100 | 90.58 | 4.12 |
| A7 | 0.6C | 2.25 | 2.0 | 1 | 0.187 | 5100 | 116.52 | 5.30 |
| A8 | 0.6C | 2.25 | 2.0 | 1 | 0.250 | 5100 | 113.06 | 5.14 |
| B1 | 1.0C | 2.25 | 2.0 | 1 | 0.109 | 4300 | 50.57 | 3.16 |
| B2 | 1.0C | 2.25 | 2.0 | 1 | 0.187 | 4300 | 57.41 | 3.59 |
| B3 | 1.0C | 2.25 | 2.0 | 1 | 0.250 | 4300 | 52.90 | 3.31 |
| B4 | 1.0C | 2.75 | 2.5 | 1 | 0.109 | 3800 | 60.18 | 3.76 |
| B5 | 1.0C | 2.75 | 2.5 | 1 | 0.187 | 3800 | 73.56 | 4.60 |
| B6 | 1.0C | 2.75 | 2.5 | 1 | 0.250 | 3800 | 63.44 | 3.97 |
| B7 | 1.0C | 3.25 | 3.0 | 1 | 0.109 | 3800 | 59.24 | 3.70 |
| B8 | 1.0C | 3.25 | 3.0 | 1 | 0.187 | 3800 | 77.33 | 4.83 |
| B9 | 1.0C | 3.25 | 3.0 | 1 | 0.250 | 4700 | 70.10 | 4.38 |
| B10 | 1.0C | 3.25 | 3.0 | 2 | 0.163 | 4700 | 110.11 | 3.44 |
| B11 | 1.0C | 3.25 | 3.0 | 2 | 0.313 | 4800 | 98.80 | 3.09 |
| B12 | 1.0C | 2.75 | 2.5 | 1 | 0.109 | 6600 | 61.37 | 3.84 |
| B13 | 1.0C | 2.75 | 2.5 | 1 | 0.187 | 7000 | 83.10 | 5.20 |
| B14 | 1.0C | 2.75 | 2.5 | 2 | 0.109 | 6500 | 117.43 | 3.67 |
| B14R | 1.0C | 2.75 | 2.5 | 2 | 0.109 | 5900 | 119.22 | 3.73 |
| B15 | 1.0C | 2.75 | 2.5 | 2 | 0.187 | 6700 | 155.87 | 4.88 |
| B15R | 1.0C | 3.00 | 2.5 | 2 | 0.187 | 5500 | 164.45 | 5.14 |
| B16 | 1.0C | 2.75 | 2.5 | 2 | 0.250 | 7300 | 108.01 | 3.38 |
| B16R | 1.0C | 3.00 | 2.5 | 2 | 0.250 | 5500 | 99.16 | 3.10 |
| C1 | 1.5C | 3.25 | 3.0 | 1 | 0.109 | 5800 | 40.42 | 4.04 |
| C1R | 1.5C | 3.25 | 3.0 | 1 | 0.109 | 4100 | 50.38 | 5.04 |
| C2 | 1.5C | 3.25 | 3.0 | 1 | 0.187 | 5800 | 52.61 | 5.26 |
| C2R | 1.5C | 3.25 | 3.0 | 1 | 0.187 | 4100 | 57.79 | 5.78 |
| C3 | 1.5C | 3.25 | 3.0 | 1 | 0.250 | 4300 | 44.03 | 4.40 |
| C4 | 1.5C | 3.25 | 3.0 | 2 | 0.109 | 4300 | 88.10 | 4.41 |
| C5 | 1.5C | 3.25 | 3.0 | 2 | 0.187 | 4300 | 111.59 | 5.58 |
| C6 | 1.5C | 3.25 | 3.0 | 2 | 0.250 | 4300 | 86.72 | 4.34 |
| C7 | 1.5C | 3.75 | 3.5 | 4 | 0.163 | 4300 | 173.05 | 4.33 |
| C8 | 1.5C | 3.75 | 3.5 | 4 | 0.250 | 3900 | 154.30 | 3.86 |
| C9 | 1.5C | 3.50 | 3.0 | 4 | 0.163 | 5400 | 130.02 | 3.25 |
| C10 | 1.5C | 3.50 | 3.0 | 4 | 0.250 | 5400 | 143.66 | 3.59 |
| D1 | 1.5VL | 3.25 | 3.0 | 1 | 0.109 | 3600 | 39.86 | 3.99 |
| D2 | 1.5VL | 3.25 | 3.0 | 1 | 0.187 | 3600 | 56.57 | 5.66 |
| D3 | 1.5VL | 3.25 | 3.0 | 1 | 0.250 | 3600 | 51.70 | 5.17 |
| D4 | 1.5VL | 3.25 | 3.0 | 2 | 0.109 | 3600 | 81.00 | 4.05 |
| D5 | 1.5VL | 3.25 | 3.0 | 2 | 0.187 | 5400 | 97.96 | 4.90 |
| D6 | 1.5VL | 3.25 | 3.0 | 2 | 0.250 | 5400 | 82.04 | 4.10 |
| D7 | 1.5VL | 3.75 | 3.0 | 4 | 0.163 | 5400 | 90.52 | 2.26 |
| D8 | 1.5VL | 3.75 | 3.0 | 4 | 0.250 | 5400 | 103.61 | 2.59 |
| D9 | 1.5VL | 3.75 | 3.0 | 4 | 0.163 | 5100 | 83.67 | 2.09 |
| D10 | 1.5VL | 3.75 | 3.0 | 4 | 0.250 | 5100 | 96.33 | 2.41 |
| D11 | 1.5VL | 3.75 | 3.0 | 6 | 0.163 | 5100 | 96.80 | 1.61 |
| D12 | 1.5VL | 3.75 | 3.0 | 6 | 0.250 | 5100 | 106.85 | 1.78 |
| E1 | 2VL | 4.25 | 4.0 | 4 | 0.109 | N.A. | N.A. | N.A. |
| E1R | 2VL | 4.25 | 4.0 | 4 | 0.109 | 4700 | 62.88 | 3.93 |
| E2 | 2VL | 4.25 | 4.0 | 4 | 0.187 | 7200 | 97.52 | 6.10 |
| E2R | 2VL | 4.25 | 4.0 | 4 | 0.187 | 5000 | 91.40 | 5.71 |
| E3 | 2VL | 4.25 | 4.0 | 4 | 0.250 | 7200 | 72.02 | 4.50 |
| E3R | 2VL | 4.25 | 4.0 | 4 | 0.250 | 5000 | 82.35 | 5.15 |
| E4 | 2VL | 4.25 | 4.0 | 8 | 0.163 | 5000 | 129.39 | 4.05 |
| E5 | 2VL | 4.25 | 4.0 | 8 | 0.250 | 4800 | 110.14 | 3.44 |
| E6 | 2VL | 4.50 | 4.0 | 12 | 0.163 | 4900 | 134.26 | 2.80 |
| E7 | 2VL | 4.50 | 4.0 | 12 | 0.250 | 3800 | 129.36 | 2.70 |
| F1 | none | 2.5 | 2.0 | 2 | 0.163 | 3800 | 186.05 | 6.65 |
| F2 | none | 2.5 | 2.0 | 2 | 0.250 | 3700 | 208.67 | 7.45 |
| F3 | none | 3.0 | 2.5 | 2 | 0.212 | 3800 | 237.81 | 6.61 |
| F4 | none | 3.0 | 2.5 | 2 | 0.313 | 5100 | 209.36 | 5.82 |
| F5 | none | 3.5 | 3.0 | 2 | 0.227 | 5700 | 300.25* | 5.77* |
| F6 | none | 3.5 | 3.0 | 2 | 0.375 | 5600 | 317.08 | 6.10 |

* does not include specimen in which the concrete slab failed

# CHAPTER 4
# ANALYTICAL STUDY

## 4.1 General

Analysis of the data collected from the 59 pushout tests conducted in this study as well as relevant test data from Alander's study will be presented in this chapter. Since configurations of one screw per rib have been sufficiently investigated by Alander, the focus of this analytical study will be on the effects of grouping screws in steel deck. Various relationships will be evaluated to determine which variables have an effect on the performance of the 5/16 in. diameter Elco Grade 8 standoff screw when used more than one per rib.

When evaluating the strength of the 5/16 in. diameter Elco Grade 8 standoff screw, the ratio of experimental strength to an existing shear model will be used. This model is as follows:

$$V_u = 0.6 A_s F_u \tag{4.1}$$

where:

$V_u$ = ultimate shear strength per screw, kips
$A_s$ = effective tensile area, in.$^2$
$F_u$ = tensile stress, ksi

This ratio will be referred to as the "shear ratio" herein. The value given by applying the shear rupture equation, $0.6A_sF_u$, represents the greatest shear load the standoff screw can theoretically sustain. By taking this ratio, all comparisons can be made based on an accepted model of shear strength. In order to determine the theoretical shear strength of the screw itself, the effective tensile area and ultimate strength of the screws had to be determined. Elco Textron supplied these values as part of the material tests performed, discussed in Section 3.2. An effective tensile area of 0.058 in.$^2$ and an ultimate strength of 165.4 ksi were used for calculation resulting in a theoretical ultimate shear strength of 5.76 kips. Again, this is the greatest shear load that the standoff screw can theoretically carry assuming the conventional shear rupture model applies.

Once the effects of individual test parameters on the performance of the 5/16 in. diameter Elco Grade 8 standoff screw have been investigated, the existing predictive models will be evaluated. Alander (1998) developed an equation for predicting the strength of the standoff screw when screw related failure modes apply as well as modifying an equation developed by Hankins (1994). The modified Hankins equation was developed to predict the strength of the standoff screws in cases where concrete cone pullout is the controlling failure mode. Both will be applied to test data contained herein and will be modified as needed. The performance of the 5/16 in. diameter Elco Grade 8 standoff screw in solid slab applications will also be evaluated.

### 4.2 Strength of Standoff Screws Used in Steel Deck

This section will examine the performance of the 5/16 in. diameter Elco Grade 8 standoff screw when used with steel deck. Since an in-depth analysis has been done by Alander (1998) on tests having one screw per rib, the focus of this study will be on the effects of grouping screws. Due to the majority of the tests conducted in this study having more than one screw per rib, it is justifiable to concentrate on grouping effects. Any arrangement of more than one screw per rib will be characterized as a screw grouping.

The effect of these different test parameters will be evaluated at both ultimate load and 0.2 in. slip load. The 0.2 in. slip load is the load which causes 0.2 in. of slip between the steel and concrete sections. In cases where failure occurred before 0.2 inches of slip was reached, the ultimate load is used. Due to the great ductility of the standoff screw it is possible to achieve rather large amounts of slip at the steel/concrete interface. Very often, once slips reach approximately 0.5 in., small increases in shear load lead to large increases in relative slip. For this reason, it is not practical to consider the ultimate load when discussing the overall performance of the 5/16 in. diameter Elco Grade 8 standoff screw. However, the behavior of the screws as well as the system as a whole at ultimate load should not be ignored.

Only tests in which the screws were embedded at least 1.5 in. above the top of the deck profile will be included in the analysis. Alander (1998) found that an embedment depth of 1.5 in. above the top of the deck profile is sufficient to fully develop the shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw. It was also noted that increasing screw embedment beyond 1.5 in. had little effect on ultimate strength. These trends were clearly proven for specimens having one screw per rib. In this study, the only series where multiple screw heights were examined in cases of more than one screw per rib was series C, more specifically, tests C7-C10. As illustrated in Figures 4.1 and 4.2, increasing screw embedment in the case of four screws per rib leads to an increase in ultimate strength. It should also be noted that by increasing screw embedment the failure mode changes from concrete cone pullout to screw shear which has been proven to produce greater ultimate strengths. This change in failure modes is expected since increasing the screw embedment increases the effective concrete cone area thereby increasing the load at which the concrete cone pullout failure mode would control. This effective concrete cone area will later be discussed in greater detail.

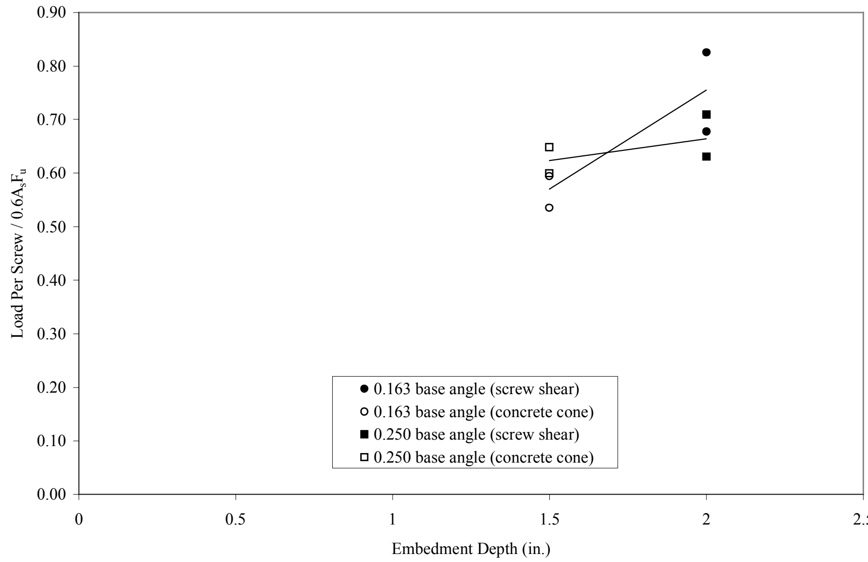



Figure 4.1 Shear Load Per Screw / $0.6A_sF_u$ vs. Embedment Depth Above Top of Deck (Tests C7-C10)

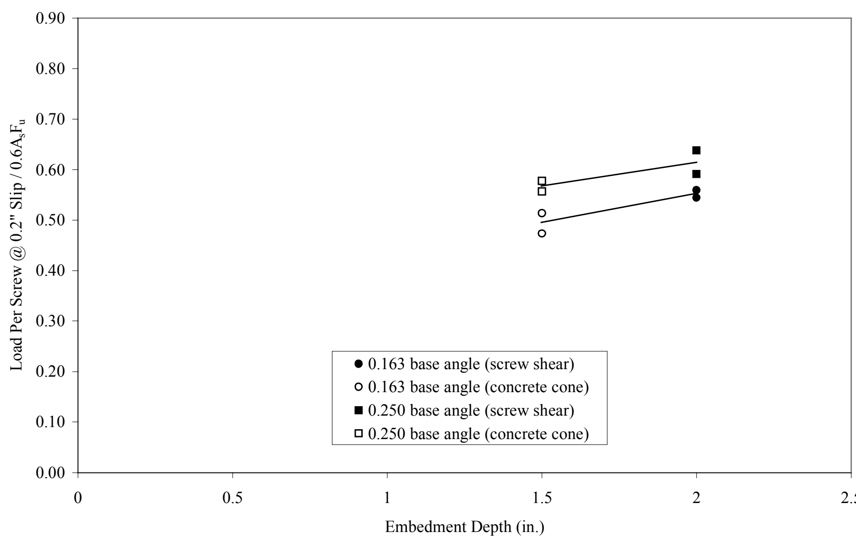



Figure 4.2 Shear Load Per Screw at 0.2 in. Slip / $0.6A_sF_u$ vs. Embedment Depth Above Top of Deck (Tests C7-C10)

As previously mentioned, data from the 106 pushout tests conducted by Alander (1998) will be used in conjunction with the data collected in this study. However, specimens that failed by top chord buckling and tests having less than one screw per rib will not be included in this analysis. Also excluded from analysis will be any tests not having sufficient transverse reinforcement. Tests that will be used in this part of the analysis are summarized in Table 4.1. The results from these tests will be used to develop trends with respect to the effects of grouping screws in steel deck. These results will also be used to evaluate the applicability of existing predictive equations.

Table 4.1 Ultimate and 0.2 in. Slip Loads

| Test Number | Deck Type | Rib Area ($in^2$) | Screw Height (in.) | Screws Per Rib | Top Chord Thickness (in.) | Concrete f'c (psi) | Peak Shear Load Per Screw (kips) | Peak Shear Load/Screw / $0.6A_sF_u$ | Shear Load Per Screw at 0.2" Slip (kips) | Peak Shear Load/Screw / $0.6A_sF_u$ at 0.2" Slip | Failure Mode |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A6-1 | 0.6C | 0.704 | 2 | 1 | 0.109 | 5100 | 4.12 | 0.72 | 2.71 | 0.47 | screw pullout |
| A6-2 | 0.6C | 0.704 | 2 | 1 | 0.109 | 5100 | 4.12 | 0.72 | 2.85 | 0.50 | screw pullout |
| A7-1 | 0.6C | 0.704 | 2 | 1 | 0.187 | 5100 | 5.18 | 0.90 | 3.29 | 0.57 | screw shear |
| A7-2 | 0.6C | 0.704 | 2 | 1 | 0.187 | 5100 | 5.41 | 0.94 | 3.52 | 0.61 | screw shear |
| A8-1 | 0.6C | 0.704 | 2 | 1 | 0.250 | 5100 | 5.06 | 0.88 | 3.96 | 0.69 | screw shear |
| A8-2 | 0.6C | 0.704 | 2 | 1 | 0.250 | 5100 | 5.22 | 0.91 | 3.85 | 0.67 | screw shear |
| B12-1 | 1.0C | 1.875 | 2.5 | 1 | 0.109 | 6600 | 3.58 | 0.62 | 2.55 | 0.44 | screw pullout |
| B12-2 | 1.0C | 1.875 | 2.5 | 1 | 0.109 | 6600 | 4.09 | 0.71 | 2.63 | 0.46 | screw pullout |
| B13-1 | 1.0C | 1.875 | 2.5 | 1 | 0.187 | 7000 | 5.52 | 0.96 | 3.26 | 0.57 | screw shear |
| B13-2 | 1.0C | 1.875 | 2.5 | 1 | 0.187 | 7000 | 4.87 | 0.85 | 2.75 | 0.48 | screw shear |
| B14-1 | 1.0C | 1.875 | 2.5 | 2 | 0.109 | 6500 | 3.64 | 0.63 | 2.27 | 0.39 | screw pullout |
| B14-2 | 1.0C | 1.875 | 2.5 | 2 | 0.109 | 6500 | 3.70 | 0.64 | 2.27 | 0.39 | screw pullout |
| B14R-1 | 1.0C | 1.875 | 2.5 | 2 | 0.109 | 5900 | 3.75 | 0.65 | 2.40 | 0.42 | screw pullout |
| B14R-2 | 1.0C | 1.875 | 2.5 | 2 | 0.109 | 5900 | 3.71 | 0.64 | 2.24 | 0.39 | screw pullout |
| B15-1 | 1.0C | 1.875 | 2.5 | 2 | 0.187 | 6700 | 4.74 | 0.82 | 2.80 | 0.49 | screw shear |
| B15-2 | 1.0C | 1.875 | 2.5 | 2 | 0.187 | 6700 | 5.01 | 0.87 | 2.75 | 0.48 | screw shear |
| B15R-1 | 1.0C | 1.875 | 2.5 | 2 | 0.187 | 5500 | 5.17 | 0.90 | 2.74 | 0.48 | screw shear |
| B15R-2 | 1.0C | 1.875 | 2.5 | 2 | 0.187 | 5500 | 5.11 | 0.89 | 2.71 | 0.47 | screw shear |
| B16-1 | 1.0C | 1.875 | 2.5 | 2 | 0.250 | 7300 | 3.31 | 0.58 | 3.11 | 0.54 | screw shear |
| B16-2 | 1.0C | 1.875 | 2.5 | 2 | 0.250 | 7300 | 3.44 | 0.60 | 3.29 | 0.57 | screw shear |
| B16R-1 | 1.0C | 1.875 | 2.5 | 2 | 0.250 | 5500 | 3.33 | 0.58 | 3.21 | 0.56 | screw shear |
| B16R-2 | 1.0C | 1.875 | 2.5 | 2 | 0.250 | 5500 | 3.05 | 0.53 | 2.97 | 0.52 | screw shear |
| B16R-3 | 1.0C | 1.875 | 2.5 | 2 | 0.250 | 5500 | 2.92 | 0.51 | 2.85 | 0.50 | screw shear |
| C1-1 | 1.5C | 5.813 | 3 | 1 | 0.109 | 5800 | 4.05 | 0.70 | 4.05 | 0.70 | screw shear |
| C1-2 | 1.5C | 5.813 | 3 | 1 | 0.109 | 5800 | 4.04 | 0.70 | 4.04 | 0.70 | screw shear |
| C1R-1 | 1.5C | 5.813 | 3 | 1 | 0.109 | 4100 | 5.40 | 0.94 | 4.33 | 0.75 | screw shear |
| C1R-2 | 1.5C | 5.813 | 3 | 1 | 0.109 | 4100 | 4.65 | 0.81 | 3.89 | 0.68 | screw shear |
| C1R-3 | 1.5C | 5.813 | 3 | 1 | 0.109 | 4100 | 5.06 | 0.88 | 4.32 | 0.75 | screw shear |
| C2-1 | 1.5C | 5.813 | 3 | 1 | 0.187 | 5800 | 5.16 | 0.90 | 4.14 | 0.72 | screw shear |
| C2-2 | 1.5C | 5.813 | 3 | 1 | 0.187 | 5800 | 5.36 | 0.93 | 4.25 | 0.74 | screw shear |
| C2R-1 | 1.5C | 5.813 | 3 | 1 | 0.187 | 4100 | 5.87 | 1.02 | 4.65 | 0.81 | screw shear |
| C2R-2 | 1.5C | 5.813 | 3 | 1 | 0.187 | 4100 | 5.69 | 0.99 | 4.43 | 0.77 | screw shear |
| C3-1 | 1.5C | 5.813 | 3 | 1 | 0.250 | 4300 | 4.70 | 0.82 | 4.24 | 0.74 | screw shear |
| C3-2 | 1.5C | 5.813 | 3 | 1 | 0.250 | 4300 | 4.11 | 0.71 | 3.86 | 0.67 | screw shear |
| C4-1 | 1.5C | 5.813 | 3 | 2 | 0.109 | 4300 | 4.24 | 0.74 | 3.26 | 0.57 | screw shear/pullout |
| C4-2 | 1.5C | 5.813 | 3 | 2 | 0.109 | 4300 | 4.57 | 0.79 | 3.34 | 0.58 | screw pullout |
| C5-1 | 1.5C | 5.813 | 3 | 2 | 0.187 | 4300 | 5.50 | 0.96 | 3.60 | 0.63 | screw shear/cone pullout |
| C5-2 | 1.5C | 5.813 | 3 | 2 | 0.187 | 4300 | 5.66 | 0.98 | 3.55 | 0.62 | screw shear/cone pullout |
| C6-1 | 1.5C | 5.813 | 3 | 2 | 0.250 | 4300 | 4.57 | 0.79 | 3.84 | 0.67 | screw shear/cone pullout |
| C6-2 | 1.5C | 5.813 | 3 | 2 | 0.250 | 4300 | 4.11 | 0.71 | 3.57 | 0.62 | screw shear |
| C7-1 | 1.5C | 5.813 | 3.5 | 4 | 0.163 | 4300 | 3.90 | 0.68 | 3.13 | 0.54 | screw shear/cone pullout |
| C7-2 | 1.5C | 5.813 | 3.5 | 4 | 0.163 | 4300 | 4.75 | 0.83 | 3.22 | 0.56 | screw shear |
| C8-1 | 1.5C | 5.813 | 3.5 | 4 | 0.250 | 3900 | 4.08 | 0.71 | 3.67 | 0.64 | screw shear |
| C8-2 | 1.5C | 5.813 | 3.5 | 4 | 0.250 | 3900 | 3.63 | 0.63 | 3.40 | 0.59 | screw shear |
| C9-1 | 1.5C | 5.813 | 3 | 4 | 0.163 | 5400 | 3.42 | 0.59 | 2.95 | 0.51 | concrete cone pullout |
| C9-2 | 1.5C | 5.813 | 3 | 4 | 0.163 | 5400 | 3.08 | 0.54 | 2.72 | 0.47 | concrete cone pullout |
| C10-1 | 1.5C | 5.813 | 3 | 4 | 0.250 | 5400 | 3.45 | 0.60 | 3.20 | 0.56 | concrete cone pullout |
| C10-2 | 1.5C | 5.813 | 3 | 4 | 0.250 | 5400 | 3.73 | 0.65 | 3.32 | 0.58 | concrete cone pullout |

Table 4.1 Ultimate and 0.2 in. Slip Loads (Continued)

| Test Number | Deck Type | Rib Area ($in^2$) | Screw Height (in.) | Screws Per Rib | Top Chord Thickness (in.) | Concrete f'c (psi) | Peak Shear Load Per Screw (kips) | Peak Shear Load/Screw / $0.6A_sF_u$ | Shear Load Per Screw at 0.2" Slip (kips) | Peak Shear Load/Screw / $0.6A_sF_u$ at 0.2" Slip | Failure Mode |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D1-1 | 1.5VL | 3.188 | 3 | 1 | 0.109 | 3600 | 4.09 | 0.71 | 2.92 | 0.51 | screw pullout |
| D1-2 | 1.5VL | 3.188 | 3 | 1 | 0.109 | 3600 | 3.88 | 0.67 | 2.70 | 0.47 | screw pullout |
| D2-1 | 1.5VL | 3.188 | 3 | 1 | 0.187 | 3600 | 5.80 | 1.01 | 3.25 | 0.56 | screw shear |
| D2-2 | 1.5VL | 3.188 | 3 | 1 | 0.187 | 3600 | 5.51 | 0.96 | 3.10 | 0.54 | screw shear |
| D3-1 | 1.5VL | 3.188 | 3 | 1 | 0.250 | 3600 | 4.72 | 0.82 | 3.34 | 0.58 | screw shear |
| D3-2 | 1.5VL | 3.188 | 3 | 1 | 0.250 | 3600 | 5.62 | 0.98 | 3.29 | 0.57 | screw shear |
| D4-1 | 1.5VL | 3.188 | 3 | 2 | 0.109 | 3600 | 4.12 | 0.72 | 2.95 | 0.51 | screw pullout |
| D4-2 | 1.5VL | 3.188 | 3 | 2 | 0.109 | 3600 | 3.98 | 0.69 | 2.81 | 0.49 | screw pullout |
| D5-1 | 1.5VL | 3.188 | 3 | 2 | 0.187 | 5400 | 5.47 | 0.95 | 3.46 | 0.60 | concrete cone pullout |
| D5-2 | 1.5VL | 3.188 | 3 | 2 | 0.187 | 5400 | 4.32 | 0.75 | 3.24 | 0.56 | concrete cone pullout |
| D6-1 | 1.5VL | 3.188 | 3 | 2 | 0.250 | 5400 | 4.10 | 0.71 | 3.71 | 0.65 | concrete cone pullout |
| D6-2 | 1.5VL | 3.188 | 3 | 2 | 0.250 | 5400 | 4.10 | 0.71 | 3.82 | 0.66 | concrete cone pullout |
| D7-1 | 1.5VL | 3.188 | 3 | 4 | 0.163 | 5400 | 2.37 | 0.41 | 2.37 | 0.41 | concrete cone pullout |
| D7-2 | 1.5VL | 3.188 | 3 | 4 | 0.163 | 5400 | 2.16 | 0.38 | 2.16 | 0.37 | concrete cone pullout |
| D8-1 | 1.5VL | 3.188 | 3 | 4 | 0.250 | 5400 | 2.51 | 0.44 | 2.51 | 0.44 | concrete cone pullout |
| D8-2 | 1.5VL | 3.188 | 3 | 4 | 0.250 | 5400 | 2.67 | 0.46 | 2.67 | 0.46 | concrete cone pullout |
| D9-1 | 1.5VL | 3.188 | 3 | 4 | 0.163 | 5100 | 1.92 | 0.33 | 1.92 | 0.33 | concrete cone pullout |
| D9-2 | 1.5VL | 3.188 | 3 | 4 | 0.163 | 5100 | 2.27 | 0.39 | 2.27 | 0.39 | concrete cone pullout |
| D10-1 | 1.5VL | 3.188 | 3 | 4 | 0.250 | 5100 | 2.30 | 0.40 | 2.30 | 0.40 | concrete cone pullout |
| D10-2 | 1.5VL | 3.188 | 3 | 4 | 0.250 | 5100 | 2.52 | 0.44 | 2.52 | 0.44 | concrete cone pullout |
| D11-1 | 1.5VL | 3.188 | 3 | 6 | 0.163 | 5100 | 1.59 | 0.28 | 1.58 | 0.28 | concrete cone pullout |
| D11-2 | 1.5VL | 3.188 | 3 | 6 | 0.163 | 5100 | 1.64 | 0.28 | 1.64 | 0.29 | concrete cone pullout |
| D12-1 | 1.5VL | 3.188 | 3 | 6 | 0.250 | 5100 | 1.63 | 0.28 | 1.63 | 0.28 | concrete cone pullout |
| D12-2 | 1.5VL | 3.188 | 3 | 6 | 0.250 | 5100 | 1.93 | 0.34 | 1.93 | 0.34 | concrete cone pullout |
| E1R-1 | 2VL | 12.000 | 4 | 4 | 0.109 | 4700 | 3.96 | 0.69 | 3.14 | 0.55 | screw shear/pullout |
| E1R-2 | 2VL | 12.000 | 4 | 4 | 0.109 | 4700 | 3.90 | 0.68 | 3.31 | 0.58 | screw shear/pullout |
| E2-1 | 2VL | 12.000 | 4 | 4 | 0.187 | 7200 | 6.01 | 1.04 | 4.18 | 0.73 | screw shear |
| E2-2 | 2VL | 12.000 | 4 | 4 | 0.187 | 7200 | 6.18 | 1.07 | 4.14 | 0.72 | screw shear |
| E2R-1 | 2VL | 12.000 | 4 | 4 | 0.187 | 5000 | 5.82 | 1.01 | 4.25 | 0.74 | screw shear |
| E2R-2 | 2VL | 12.000 | 4 | 4 | 0.187 | 5000 | 5.60 | 0.97 | 3.83 | 0.67 | screw shear |
| E3-1 | 2VL | 12.000 | 4 | 4 | 0.250 | 7200 | 4.15 | 0.72 | 3.87 | 0.67 | screw shear |
| E3-2 | 2VL | 12.000 | 4 | 4 | 0.250 | 7200 | 4.85 | 0.84 | 4.69 | 0.81 | screw shear |
| E3R-1 | 2VL | 12.000 | 4 | 4 | 0.250 | 5000 | 4.17 | 0.72 | 3.79 | 0.66 | screw shear |
| E3R-2 | 2VL | 12.000 | 4 | 4 | 0.250 | 5000 | 5.23 | 0.91 | 4.01 | 0.70 | screw shear |
| E3R-3 | 2VL | 12.000 | 4 | 4 | 0.250 | 5000 | 5.06 | 0.88 | 4.02 | 0.70 | screw shear |
| E4-1 | 2VL | 12.000 | 4 | 8 | 0.163 | 5000 | 4.29 | 0.75 | 2.83 | 0.49 | concrete cone pullout |
| E4-2 | 2VL | 12.000 | 4 | 8 | 0.163 | 5000 | 3.80 | 0.66 | 2.70 | 0.47 | concrete cone pullout |
| E5-1 | 2VL | 12.000 | 4 | 8 | 0.250 | 4800 | 3.50 | 0.61 | 3.00 | 0.52 | concrete cone pullout |
| E5-2 | 2VL | 12.000 | 4 | 8 | 0.250 | 4800 | 3.38 | 0.59 | 3.06 | 0.53 | concrete cone pullout |
| E6-1 | 2VL | 12.000 | 4 | 12 | 0.163 | 4900 | 2.77 | 0.48 | 2.25 | 0.39 | concrete cone pullout |
| E6-2 | 2VL | 12.000 | 4 | 12 | 0.163 | 4900 | 2.82 | 0.49 | 2.30 | 0.40 | concrete cone pullout |
| E7-1 | 2VL | 12.000 | 4 | 12 | 0.250 | 3800 | 2.62 | 0.46 | 2.49 | 0.43 | cone pullout/shear |
| E7-2 | 2VL | 12.000 | 4 | 12 | 0.250 | 3800 | 2.77 | 0.48 | 2.64 | 0.46 | cone pullout/shear |

### 4.2.1 Effects of Individual Test Parameters on Shear Strength

The first step in evaluating the performance of the 5/16 in. diameter Elco Grade 8 standoff screw is to determine the effects of individual test parameters. The primary variable investigated will be screw density, i.e., the number of screws per rib. Also evaluated will be the effects of top chord thickness, deck geometry and concrete compressive strength. These variables are believed to have the greatest effect on the performance of the standoff screws used in this study. As mentioned previously, the effects of these variables will be evaluated at both ultimate load and 0.2 in. slip load.

#### 4.2.1.1 Effects of Base Angle Thickness

The effects of varying top chord thickness will be examined in this section. In this study, four basic base angle thicknesses were investigated: 0.109 in., 0.163 in., 0.187 in. and 0.250 in. To illustrate any effects, plots of shear ratio vs. top chord thickness were made for configurations of one, two and four screws. In addition, plots were made using both ultimate and 0.2 in. slip loads for each screw configuration. It should be noted that trend lines have been added to the plots to better illustrate the general behavior of the system. However, due to the limited data, these trend lines cannot be assumed to accurately depict the effects of different variables absolutely.

The effect of top chord thickness on specimens having one screw per rib is illustrated in Figures 4.3 and 4.4. It is clear that the medium thickness base angle, 0.187 in., yields the greatest ultimate shear strength per screw. In all cases except series C, the 0.109 in. base angle resulted in the lowest ultimate shear strength per screw. This lower strength can be attributed to the excessive rotation allowed by this relatively thin base angle. Due to this rotation, the standoff screws tend to be loaded more in tension than shear. The failure mode of tests using the 0.109 in. base angle being screw pullout, again excluding series C, further proves the predominately tensile loading. In the case of series C, the 0.109 in. base angle does not yield the lowest ultimate shear strength per screw. Due to the wider rib of the 1.5C deck used in this series, more concrete surrounds the base of the screw and therefore rotation is limited. Screw rotation in all tests in this study was observed, when applicable, at the base of the screw. Therefore, concrete supporting the base of the screw can serve to resist rotation.

At the 0.2 in. slip load, again with the exception of series C, there appears to be a linear relationship between strength and top chord thickness. However, this can only be assumed for series A and series D. Due to limited data, it cannot be said that tests from series B would also follow this linear relationship. From this relationship it is clear that, at low slip, performance increases as top chord thickness increases. Even though this does not hold true in series C, the decrease in strength between tests using the 0.187 in. base angle and those using the 0.250 in. base angle is felt to be nominal. This relationship between shear strength and top chord thickness can be attributed to the absence of any substantial rotation. The thicker base angle reduces rotation and therefore yields greater shear loads at low slip. The result is a stiffer system as illustrated by the slope of the elastic portion of the Load vs. Slip plots for these tests (Alander, et al 1998).

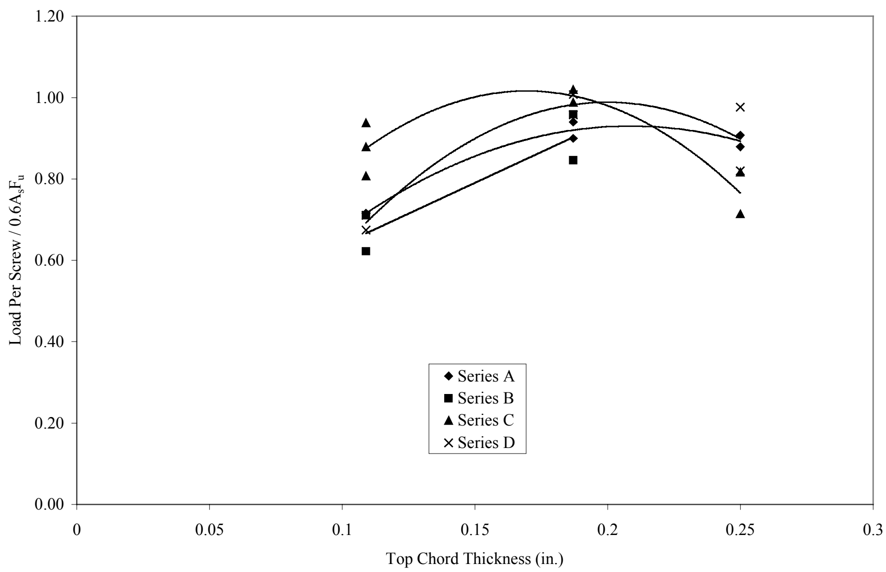



Figure 4.3 Shear Load Per Screw / $0.6A_sF_u$ vs. Top Chord Thickness (1 Screw Per Rib)

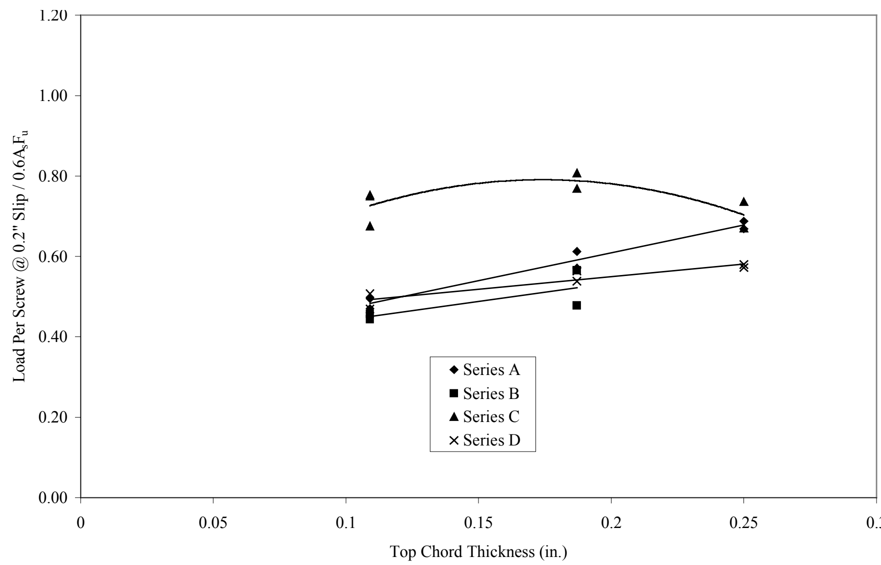



Figure 4.4 Shear Load Per Screw at 0.2 in. Slip / $0.6A_sF_u$ vs. Top Chord Thickness (1 Screw Per Rib)

The effect of top chord thickness on tests having two screws per rib is shown in Figures 4.5 and 4.6. Again, it is clear that the 0.187 in. base angle yields the greatest ultimate shear loads. However, there does not appear to be any substantial difference in ultimate shear load between tests using the 0.109 in. and the 0.250 in. base angles. In the case of the shear strength at low slip, there is a clear linear relationship for all series. From these plots it can be seen that the basic trend found in specimens having one screw per rib holds true for those having two screws per rib.

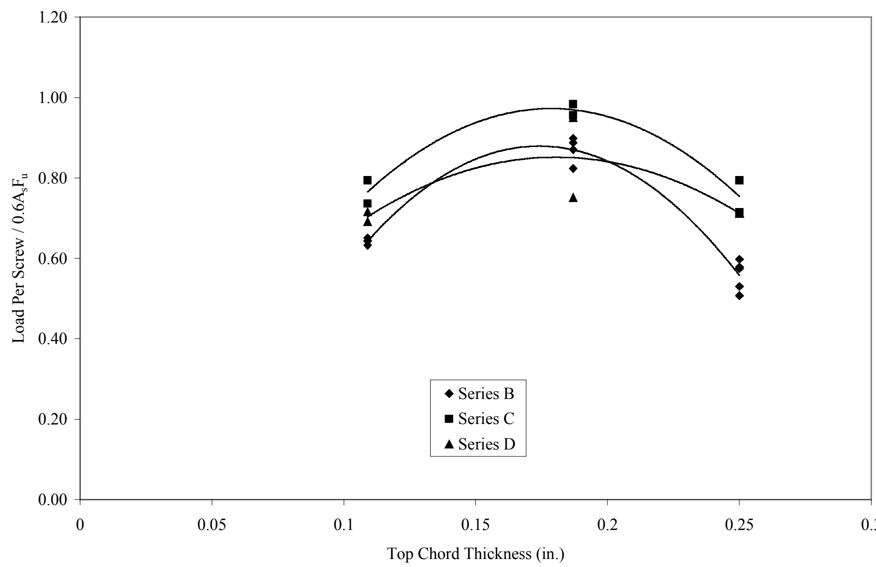



Figure 4.5 Shear Load Per Screw / $0.6A_sF_u$ vs. Top Chord Thickness (2 Screws Per Rib)

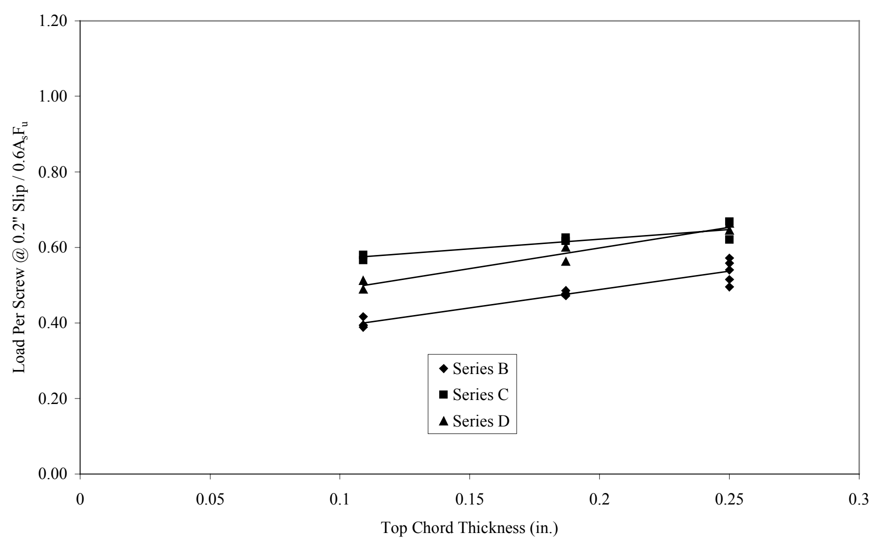



Figure 4.6 Shear Load Per Screw at 0.2 in. Slip / $0.6A_sF_u$ vs. Top Chord Thickness (2 Screws Per Rib)

In the case of four screws per rib it must be noted that both 1.5 in. and 2 in. embedment depths were investigated. A discussion on these embedment depths is provided in Section 4.1. Figures 4.7 and 4.8 illustrate the effect of top chord thickness on tests having four screws per rib. Due to limited data, with the exception of series E, no definitive trend, i.e., parabolic or linear, can be determined. From these plots it cannot be said that one base angle yields the greatest ultimate shear load. This is due to the relatively even mix of screw and concrete related failures. In the case of tests having a 1.5 in. screw embedment the controlling failure mode was concrete cone pullout. From Figure 4.7 it can be seen that, for these tests, a thicker base angle results in a greater ultimate shear load. This can be attributed to the nature of the failure mode and the tendency of the thicker base angle to reduce rotation. By reducing rotation, the concrete surrounding the base of the screws is not subjected to the forces induced by the screws which tend to crush the concrete locally. With the absence of this local crushing of the concrete surrounding the screws, more force is needed to essentially break out the concrete. In the case of tests having a 2 in. screw embedment, it appears that a similar trend is followed to tests having one and two screws per rib. The medium thickness base angle result in the greatest ultimate shear loads. In the case of series E, the same relationship between the 0.109 in. base angle and the 0.250 in. base angle can be found as was evident in previous cases.

At the 0.2 in. slip load a clearly linear relationship is evident as was the case in specimens having two screws per rib. Again, shear strength increases as top chord thickness increases. Due to the absence of any distinct failure mode at the 0.2 in. slip load all series behave in a similar manner. This is evident by the slopes of the trend lines in Figure 4.8.

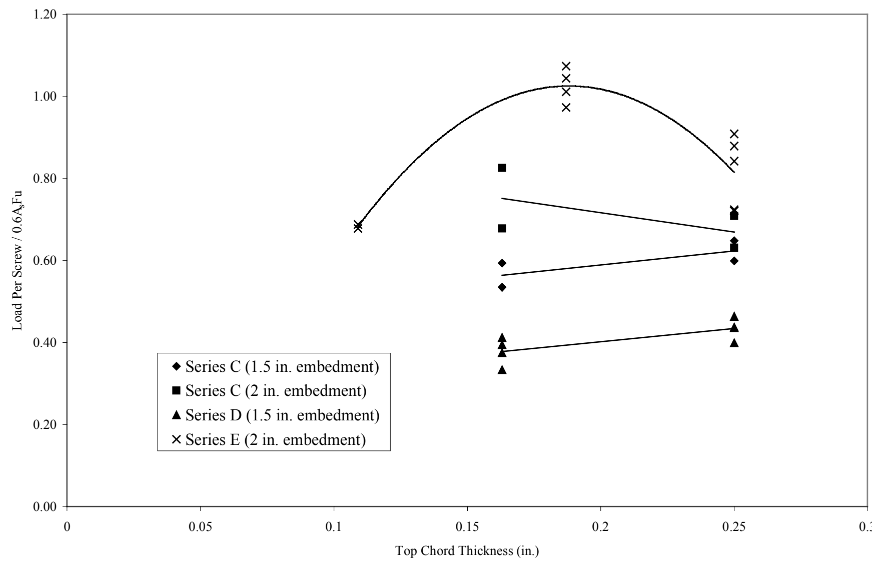



Figure 4.7 Shear Load Per Screw / $0.6A_sF_u$ vs. Top Chord Thickness (4 Screws Per Rib)

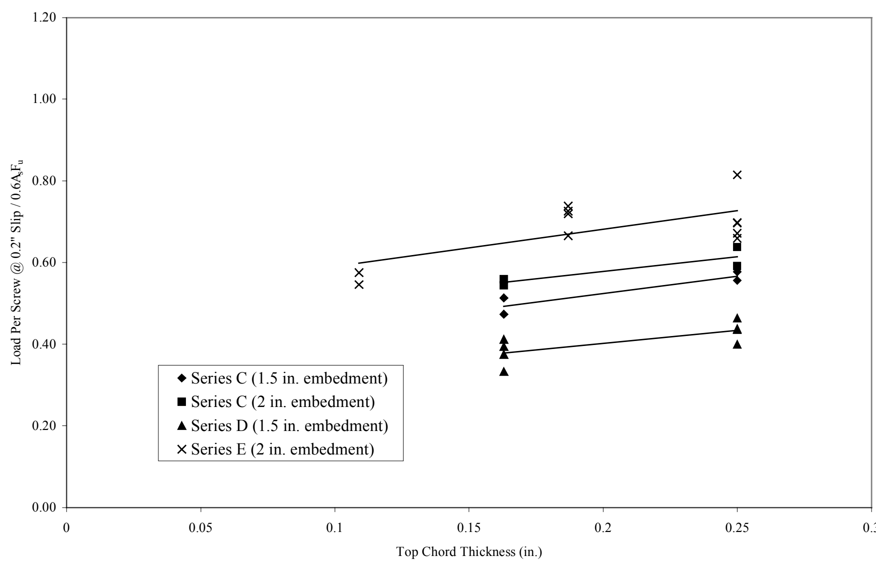



Figure 4.8 Shear Load Per Screw at 0.2 in. Slip / $0.6A_sF_u$ vs. Top Chord Thickness (4 Screws Per Rib)

#### 4.2.1.2 Effects of Deck Geometry

The effects of grouping screws in different deck geometries on the strength of the 5/16 in. diameter Elco Grade 8 standoff screw are discussed in this section. Even though this analytical study includes specimens constructed from five different deck types, those using 0.6C deck (series A) will not be included in this section since none of these tests contained more than one screw per rib. The deck profiles investigated in this section include 1.0C, 1.5C, 1.5VL and 2VL. The dimensions for these deck types can be found in Figures 1.10 and 2.5. In order to determine general trends, the shear ratio was plotted against the number of screws per rib for each deck profile. Plots were made using both ultimate load and 0.2 in. slip load.

The effect of grouping screws on ultimate load and 0.2 in. slip load in 1.0C deck (series B) is shown in Figures 4.9 and 4.10, respectively. Even though a linear relationship is shown, it cannot be assumed that the overall relationship follows a linear trend. Since screw densities in series B were limited to one and two screws per rib, not enough data was available to accurately predict the behavior of this relationship. For this reason, as before, basic trend lines are only added to these plots to better depict the general behavior of the system. It is clear from Figures 4.9 and 4.10 that by increasing the number of screws per rib in 1.0C deck from one to two leads to a decrease in shear strength. However, this decrease is relatively nominal. Also, even though specimens using the 0.187 in. thick base angle achieved greater shear loads, the effect of grouping the screw is similar for both base angle thicknesses.

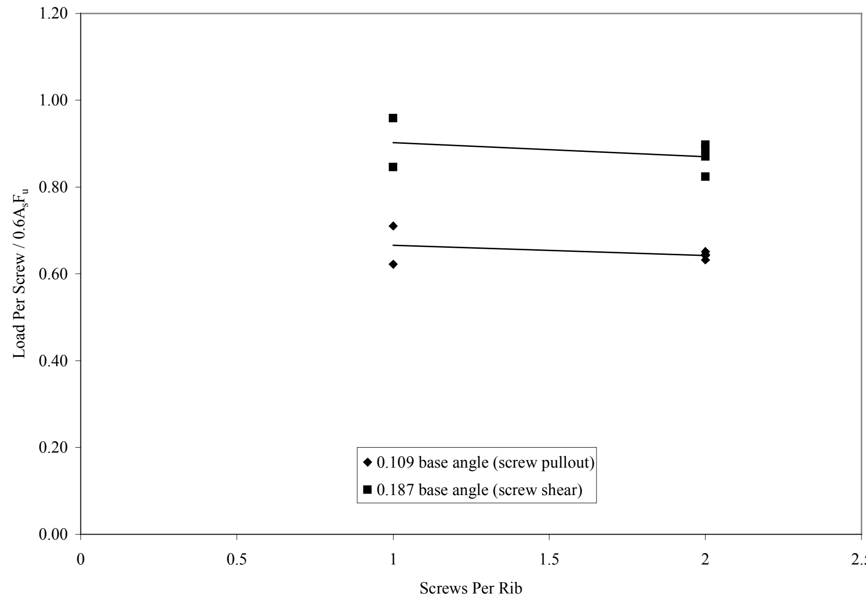



Figure 4.9 Shear Load Per Screw / $0.6A_sF_u$ vs. Screws Per Rib
(Series B – 1.0C Deck)

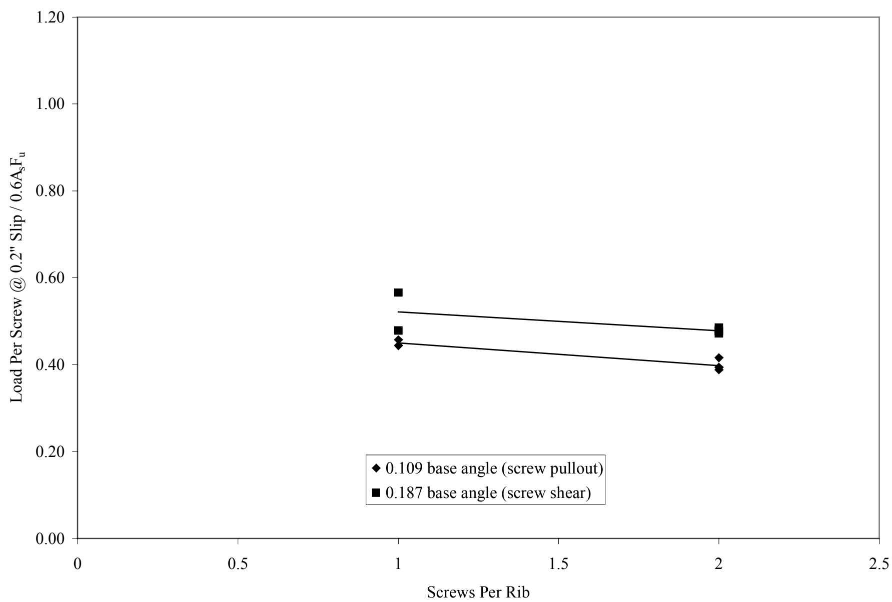



Figure 4.10 Shear Load Per Screw at 0.2 in. Slip / $0.6A_sF_u$ vs. Screws Per Rib
(Series B – 1.0C Deck)

Figures 4.11 and 4.12 show the effect of grouping screws in 1.5C deck (series C). Again, it can be seen that shear load per screw decreases as the number of screws per rib increases. At ultimate load, this decrease is greatest for the 0.109 in. thick base angle. This can be explained by the tendency of this base angle to more readily deform under load. In all tests constructed with the 0.109 in. thick base angle, substantial angle deformation was observed as shown in Figure 1.6. When more than one screw per rib is used in conjunction with this relatively thin base angle the amount of screw rotation increases leading to a decrease in ultimate load. This is evident by the values of ultimate load and average slip at ultimate load presented in Table 3.5. This observation is also supported by the failure modes observed for the tests using the 0.109 in. thick base angle (C1, C1R and C4). By increasing the amount of screw rotation, the failure mode shifts from that of screw shear to screw pullout which consistently yields lower ultimate shear loads. As shown in Figure 4.12, the same basic trends can be found at the 0.2 in. slip load. However, it is important to note that the 0.2 in. slip load is a greater percent of the ultimate load in this series due to the deck type used. The wider rib of the 1.5C deck does not as readily allow the amount of rotation which is found in similar configurations using deck with smaller ribs. Because of this wider rib, there is more concrete surrounding the base of the screw, therefore rotation is limited until a point is reached where the concrete begins to crush locally. Referring to the Load vs. Slip plots for tests in series C, found both in this report and that of Alander (1998b), it is clear by the flattening out of the plot at or slightly beyond 0.2 in. slip, that after 0.2 in., slip increases at a greater rate when subjected to smaller load increments. This suggests that the concrete surrounding the screws has either crushed locally or failed in a cone pullout mode.

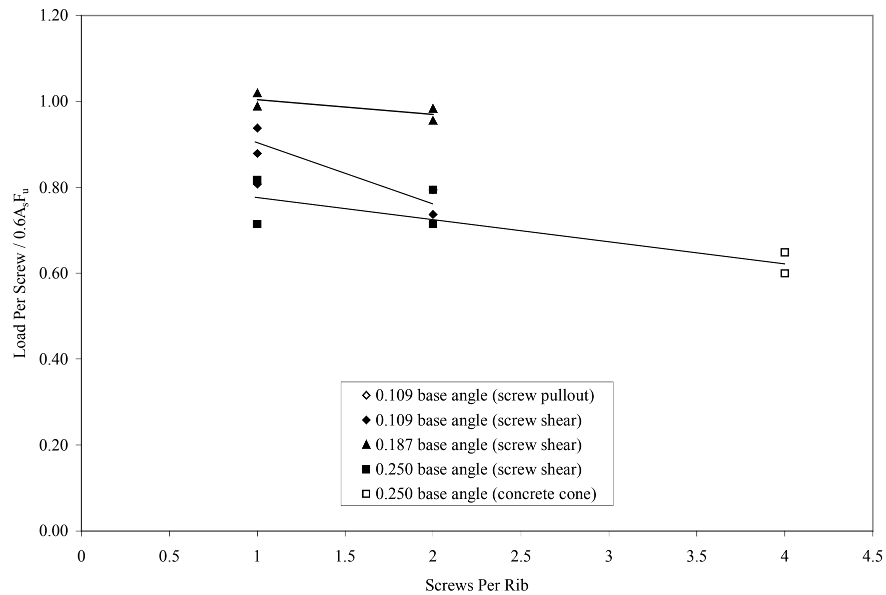



Figure 4.11 Shear Load Per Screw / $0.6A_sF_u$ vs. Screws Per Rib
(Series C – 1.5C Deck)

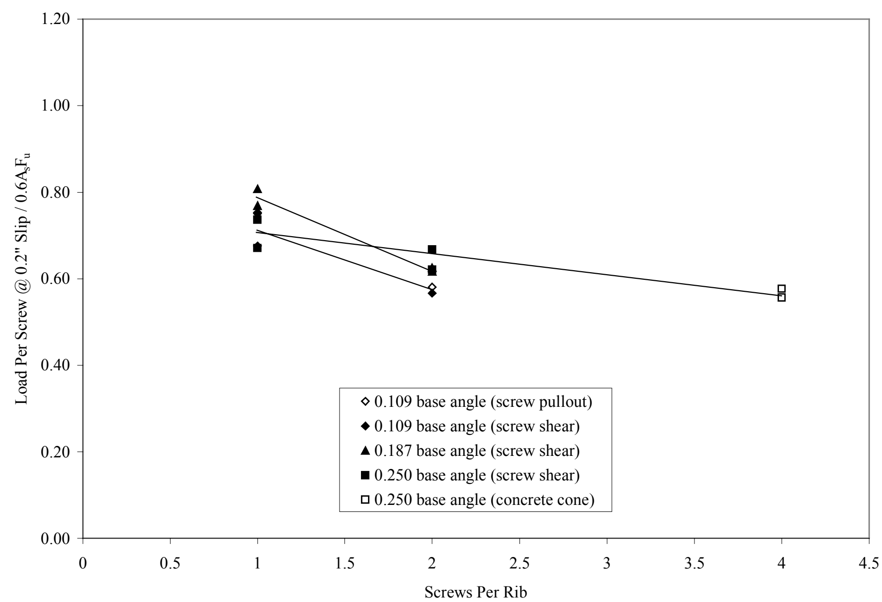



Figure 4.12 Shear Load Per Screw at 0.2 in. Slip / $0.6A_sF_u$ vs. Screws Per Rib
(Series C – 1.5C Deck)

The effect of grouping screws in 1.5VL deck (series D) is illustrated in Figures 4.13 and 4.14. At ultimate load, all configurations exhibit a decrease in strength with the addition of more screws per rib with the exception of those using the 0.109 in. thick base angle. By looking at the different types of failure modes which occurred in these tests, it can be seen that, while tests using all other base angles failed in different modes when screw densities were increased from one to two, those using the 0.109 in. thick base angle failed by screw pullout in both cases. From this, it stands to reason that the ultimate strength would increase due to the addition screws in this case. With respect to the remaining tests, at ultimate load, it can be seen that increasing the number of screws per rib causes a concrete cone pullout failure. From Figure 4.14, it can be seen that, at low slip, increasing the number of screws per rib from one to two results in an increase in shear load. This can be attributed to the absence of any failure at this load. As shown in the load vs. slip plots for these tests (Alander, et al 1998b), at 0.2 in. slip the stiffness of the system is just beginning decrease indicating that little or no degradation of the specimen has occurred. Beyond two screws per rib, the effects are similar to those at ultimate load.

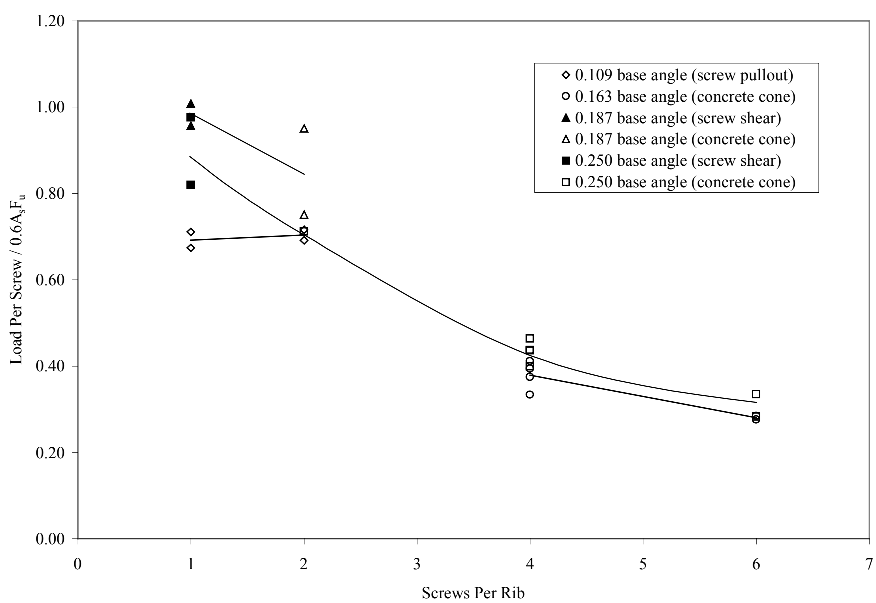



Figure 4.13 Shear Load Per Screw / $0.6A_sF_u$ vs. Screws Per Rib
(Series D – 1.5VL Deck)

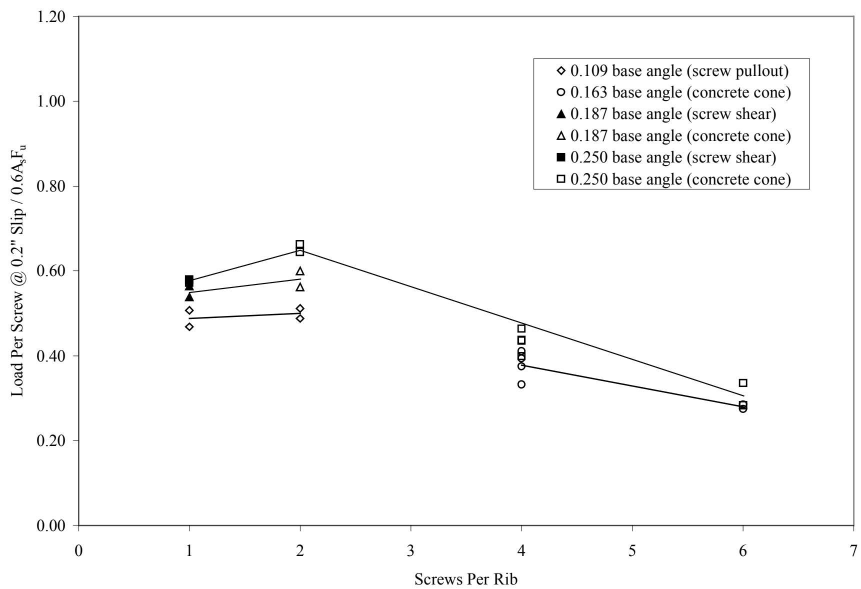



Figure 4.14 Shear Load Per Screw at 0.2 in. Slip / $0.6A_sF_u$ vs. Screws Per Rib (Series C – 1.5C Deck)

The effects of grouping screws in 2VL deck (series E) are presented in Figures 4.15 and 4.16. It is important to note that, unlike previous test series, screws in this series were embedded 2.0 in. above the top of the deck as opposed to the 1.5 in. embeddment generally used. The least screw density for this series was four screws per rib and it is felt that using a larger embeddment depth increases ultimate strength when grouping screws. This belief, discussed in Section 4.2, is based on increasing the effective concrete cone area. Following the trend previously developed, by increasing screw density, shear load per screw decreases and the failure mode changes from that of screw shear to concrete cone pullout. As was the case in series C, it can be seen from the plots that the 0.2 in. slip load is a greater percentage of the ultimate load than in cases where deck with relatively narrow ribs was used. Again, this can be attributed to the larger ribs of the 2VL deck. By increasing the amount of concrete surrounding the base of the screws, slip is restricted until a point is reached when the concrete begins to crush locally or fail in a concrete cone pullout mode. However, since the ribs of 2VL deck are wider than those of the 1.5C deck, it can be seen by looking at the Load vs. Slip plots for series E tests that failure generally occurred near the 0.2 in. slip load. The larger loads needed to crush, or fail, the concrete in 2VL deck are accountable for this relationship between ultimate load and 0.2 in. slip load.

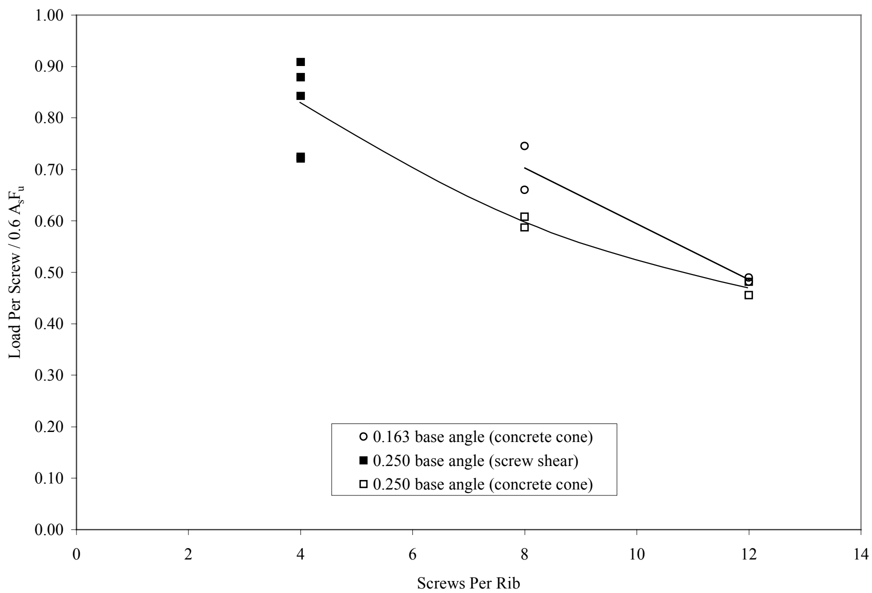



Figure 4.15 Shear Load Per Screw / $0.6A_sF_u$ vs. Screws Per Rib (Series E – 2VL Deck)

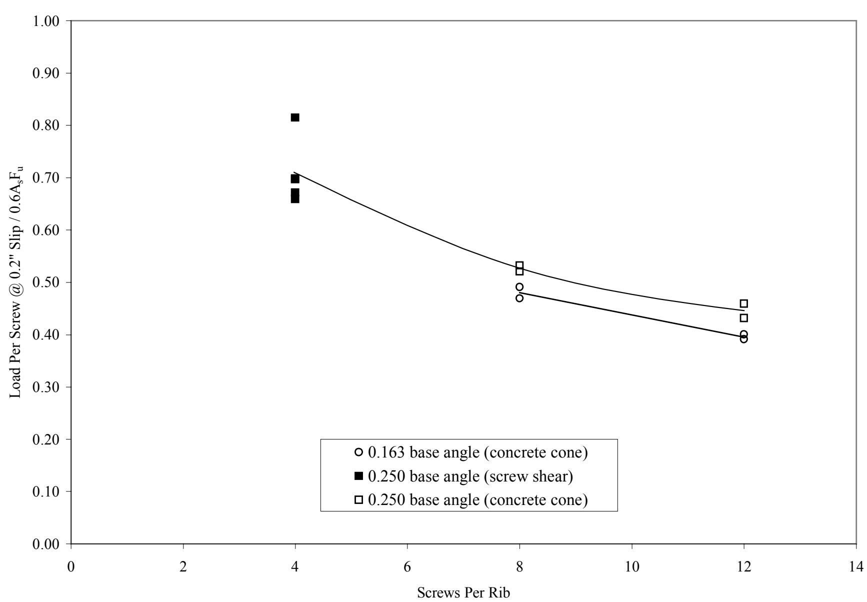



Figure 4.16 Shear Load Per Screw at 0.2 in. Slip / $0.6A_sF_u$ vs. Screws Per Rib (Series E – 2VL Deck)

#### 4.2.1.3 Further Investigation of Deck Geometry Effects

While the previous section investigated the effects of grouping screws in different deck profiles, this section will look explicitly at the effects of rib area on similar screw configurations. By looking at the relationship between these variables, the effects of grouping screws can be more easily compared between different deck profiles. The following plots of the shear ratio vs. rib area were constructed using both ultimate load and the 0.2 in. slip load. The deck types corresponding to the rib areas are shown on the plots.

In order to provide a basis for comparison, the effects of having one screw per rib will be discussed first. These effects are presented in Figures 4.17 and 4.18. As shown in Figure 4.17, it appears that, in the case of one screw per rib, the deck type has little effect on the ultimate strength of the 5/16 in. diameter Elco Grade 8 standoff screw. This is expected since all failures observed for cases of one screw per rib were screw related, i.e., screw pullout and screw shear. Since no concrete failure were observed in these tests, the effective concrete cone area is not as critical as it is in cases of more than one screw per rib. These trends, however, do not hold true at the 0.2 in. slip load. From Figure 4.18 it can be seen that, while the increase in strength is subtle, the screws performed best in 1.5C deck. In spite of this, it cannot be said that larger rib areas yield larger screw strengths since the next highest shear strengths per screw where found in those used with 0.6C deck, the smallest rib area of the group. Also important to note is the separation of different failure modes shown in these plots. It is clear that specimens that failed by screw pullout failed at lower shear loads than those that failed by screw shear.

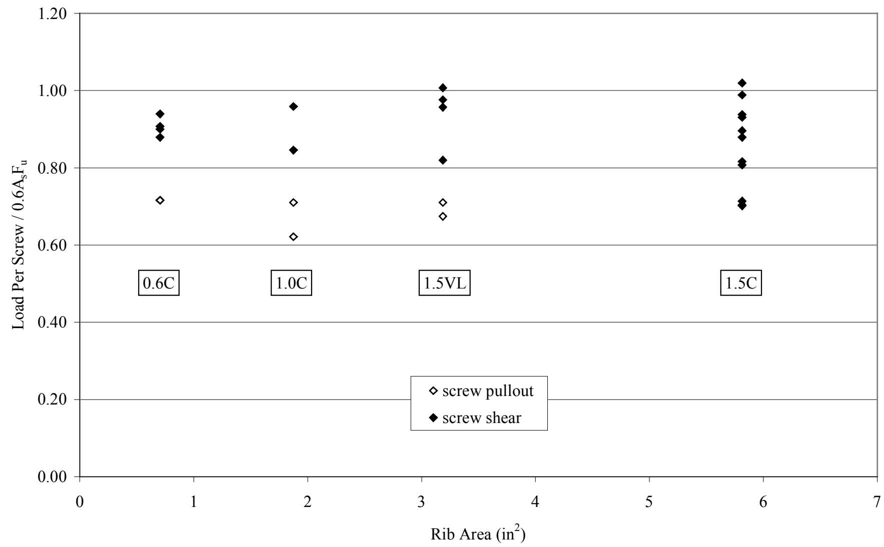



Figure 4.17 Shear Load Per Screw / $0.6A_sF_u$ vs. Rib Area (1 Screw Per Rib)

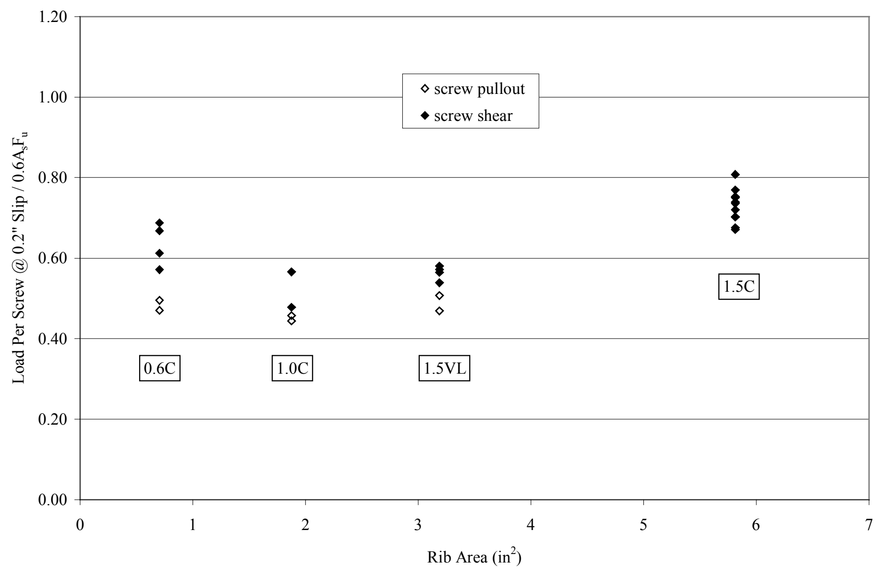



Figure 4.18 Shear Load Per Screw at 0.2 in. Slip / $0.6A_sF_u$ vs. Rib Area
(1 Screw Per Rib)

The effects of having two screws per rib in different deck profiles are illustrated in Figures 4.19 and 4.20. The effect of rib area begins to become more apparent in these plots. It can be seen that there is a slight improvement in both ultimate and 0.2 in. slip strength as rib area increases. However, due to the relatively large amount of scatter in test results at ultimate load, it cannot be said with confidence that increasing rib area leads to a definite increase in strength when using two screws per rib. Also, there is not a clear separation between failure modes at ultimate load as was shown for specimens having one screw per rib. In tests using 1.0C deck, specimens that failed by screw pullout were found to achieve greater ultimate shear loads than approximately half of those failing by screw shear. While this does not support previous beliefs, this occurrence does not necessarily discount the trend that screw pullout occurs at a lower ultimate load than screw shear. At the 0.2 in. slip load a more distinct segregation of failure modes can be observed. In the case of specimens using the 1.5C deck, the only case where the failure modes overlap, the test shown as screw pullout was a combination of both pullout and shear. Another important note is the addition of a concrete cone pullout failure mode in tests utilizing 1.5VL deck and the apparent increased strength of a concrete cone pullout to that of the screw pullout mode.

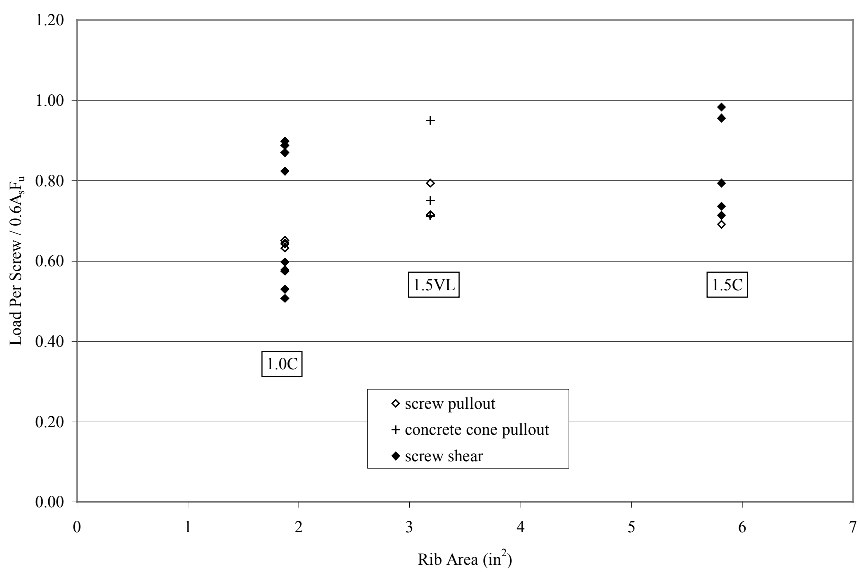



Figure 4.19 Shear Load Per Screw / $0.6A_sF_u$ vs. Rib Area (2 Screws Per Rib)

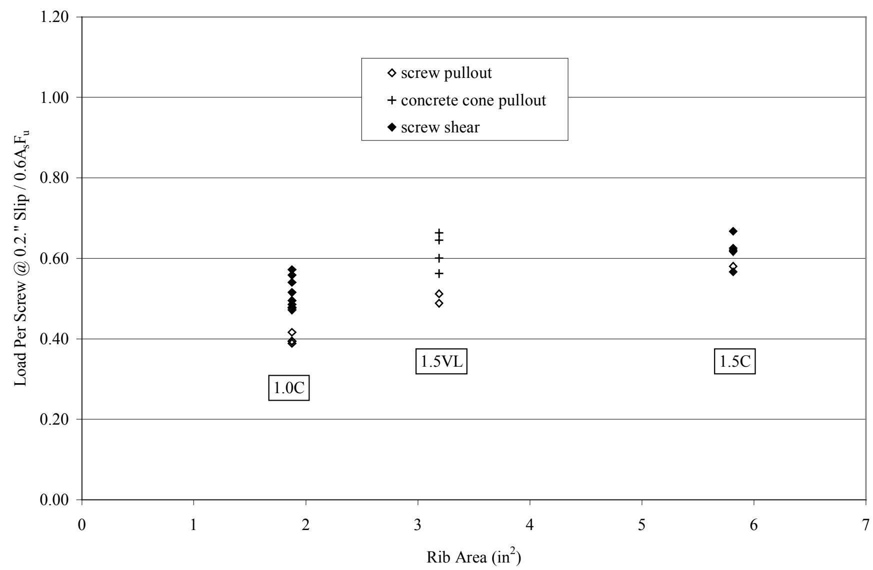



Figure 4.20 Shear Load Per Screw at 0.2 in. Slip / $0.6A_sF_u$ vs. Rib Area (2 Screws Per Rib)

Figures 4.21 and 4.22 illustrate the effects of having four screws per rib in different deck profiles. It should be noted that, in the case of four screws per rib, different embedment depths were investigated. A complete discussion on the effects of embedment depth when grouping screws is presented in Section 4.2. When screws are grouped four per rib, there is a definite correlation between screw strength and rib area. This can be attributed to the increased area of the effective concrete pullout cone as is demonstrated by the even distribution of concrete cone pullout and screw shear failures. Since different embedment depths were used in specimens having four screws per rib, these tests cannot be directly compared. However, it is felt that the trends shown in Figures 4.21 and 4.22, while most likely not as distinct, would still apply if all embedment depths were the same. Also shown in these plots is the common decrease in ultimate strength of a specimen failing by concrete cone pullout compared to those failing by screw shear.

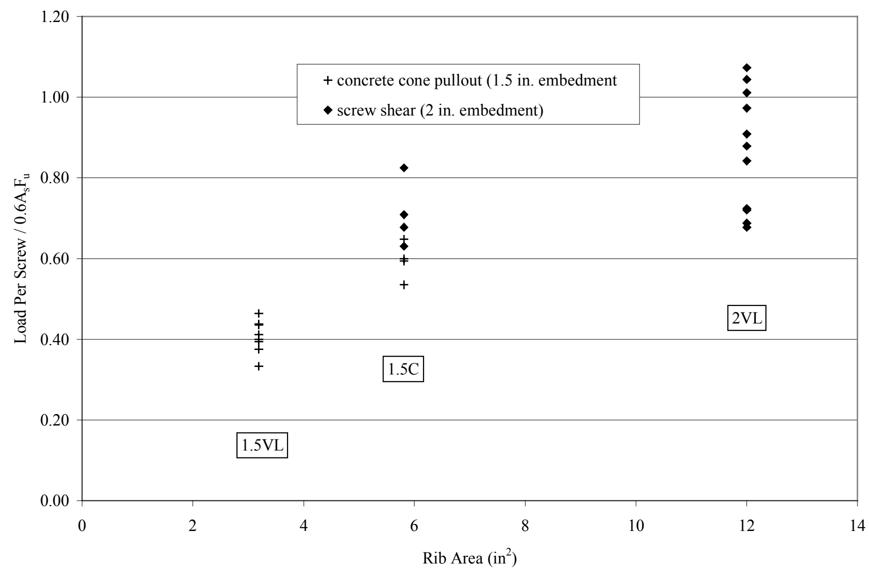



Figure 4.21 Shear Load Per Screw / $0.6A_sF_u$ vs. Rib Area (4 Screws Per Rib)

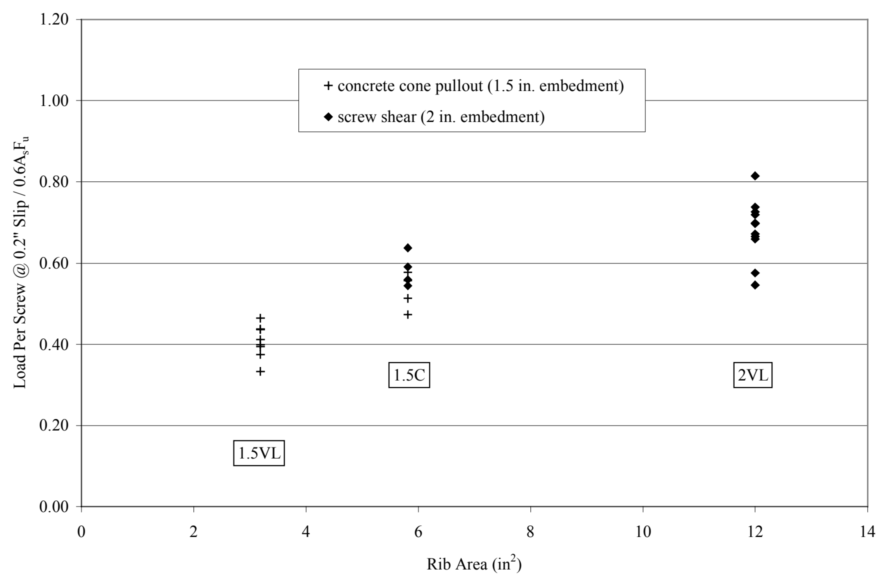



Figure 4.22 Shear Load Per Screw at 0.2 in. Slip / $0.6A_sF_u$ vs. Rib Area
(4 Screws Per Rib)

#### 4.2.1.4 Effects of Concrete Strength

While not one of the variables intentionally investigated, the concrete compressive strength varies from test to test and must be accounted for. The target range concrete strength for all tests in the studies conducted on the 5/16 in. diameter Elco Grade 8 standoff screw at Virginia Tech was between 3 ksi and 5 ksi. Due to inconstancies in concrete mixes, some tests yielded concrete strengths greater than 7 ksi. This relatively large variance further necessitates the investigation of the effects of concrete strength on screw performance. To determine any effects caused by varying concrete strengths, plots of shear ratio vs. concrete compressive strength were constructed for different screw configurations.

The effects of concrete compressive strength on screw strength are illustrated in Figures 4.23 and 4.24 for specimens having one screw per rib. While not representative of the different top chord sections used, it can be seen that the concrete strength has little effect on ultimate strength on specimens having similar failure modes. This is evident since the ratio of ultimate strength to the $0.6A_sF_u$ load for the majority of tests failing by screw shear fall between 1.0 and 0.8. Also important is the consistency of strengths where screw pullout controlled. The screw pullout failure mode is characterized by a relatively large amount of screw rotation. Since this rotation can be resisted by the concrete surrounding the base of the screw, it is unexpected that the concrete strength does not appear to have any effect on the strengths noted in these tests. As shown, screw pullout failures were only observed in tests utilizing 0.6C, 1.0C and 1.5VL deck. The relatively narrow ribs in these deck types can account for the concrete strength having little if no effect on ultimate and 0.2 in. slip loads. Since there is little concrete surrounding the base of the screws, the strength of that concrete becomes less critical, within reason.

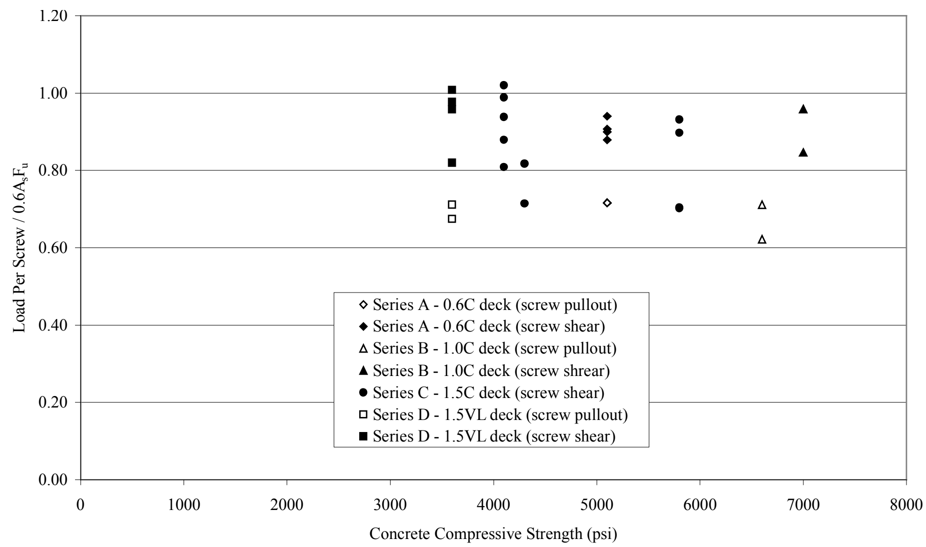



Figure 4.23 Shear Load Per Screw / $0.6A_sF_u$ vs. Concrete Compressive Strength (1 Screw Per Rib)

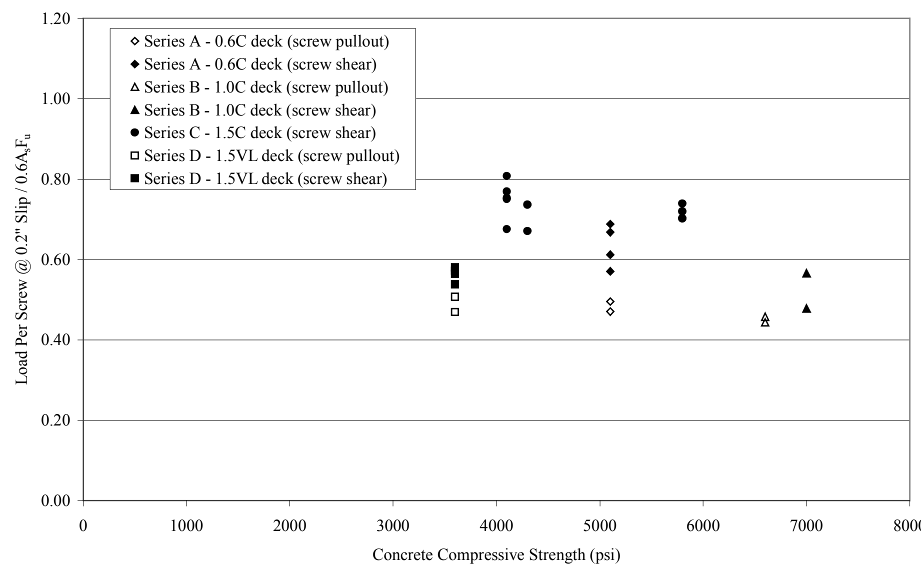



Figure 4.24 Shear Load Per Screw at 0.2 in. Slip / $0.6A_sF_u$ vs. Concrete Compressive Strength (1 Screw Per Rib)

For specimens having two screws per rib, the effects of concrete compressive strength are shown in Figures 4.25 and 4.26. Unlike tests with one screw per rib, there does not seem to be a grouping of the data at ultimate load for tests failing by screw shear. Even though there is a relatively large amount of scatter in Figure 4.25, no distinct trend can be inferred between the concrete strength and screw performance for these tests. This suggests that, as in tests having one screw per rib, the strength of the concrete has little effect. As is generally the case, at 0.2 in. slip load, the data yields much less scatter. In tests having two screws per rib, as before, the concrete strength does not appear to have any significant effect of tests failing by screw pullout. A concrete cone pullout failure is also introduced by having two screws per rib but no relationship between this type of failure and concrete strength can be derived without more test data.

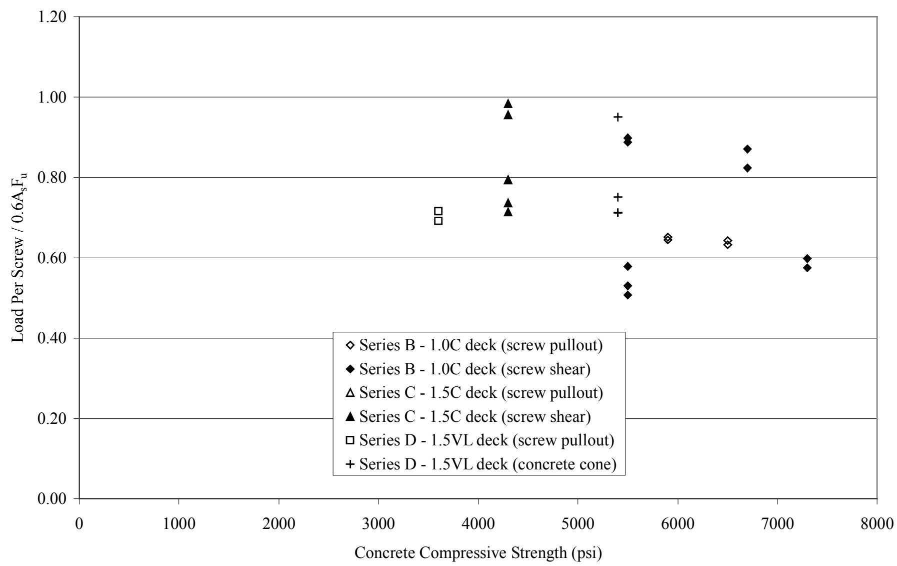



Figure 4.25 Shear Load Per Screw / $0.6A_sF_u$ vs. Concrete Compressive Strength (2 Screws Per Rib)

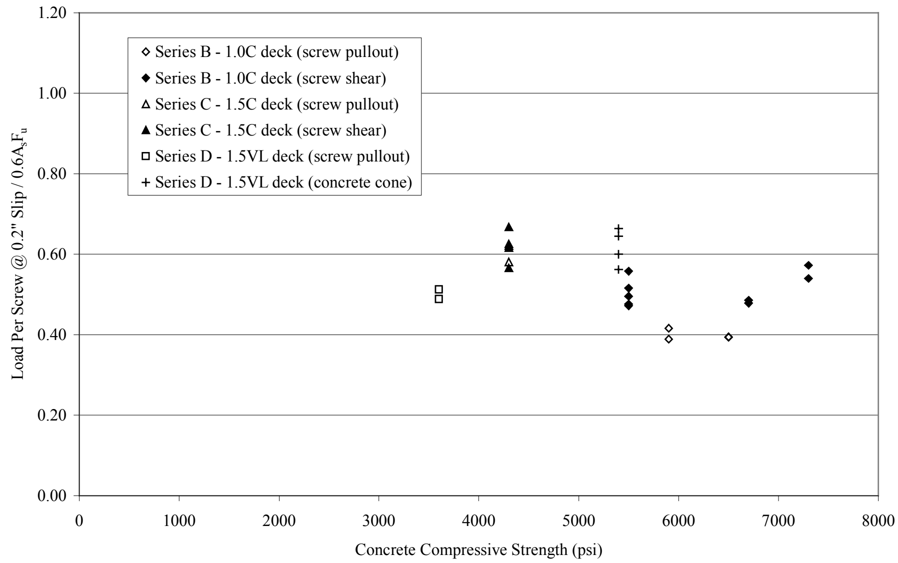



Figure 4.26 Shear Load Per Screw at 0.2 in. Slip / $0.6A_sF_u$ vs. Concrete Compressive Strength (2 Screws Per Rib)

Figures 4.27 and 4.28 show the effects of concrete strength on ultimate and 0.2 in. slip load, respectively, in tests having four screws per rib. It must be noted that screws used with 2VL deck were embedded 2 in. above the top of the deck as discussed previously. Screws in all other tests, with the exception of C7 and C8, had screws embedded 1.5 in. above the top of the deck. Screws in tests C7 and C8 were embedded 2 in. above the top of the deck. In both cases, ultimate and 0.2 in. slip load, the results are very similar to those of tests having two screws per rib. While there is noticeable scatter in the data, it is clear that there is not a distinct relationship between concrete strength and screw performance in the case of tests which failed by screw shear. However, in the case of a concrete cone pullout failure, an increase in concrete strength appears to lead to better screw performance. Even though the data is limited for cases of concrete pullout failures, it is expected that this relationship would exist due to the nature of the failure mode.

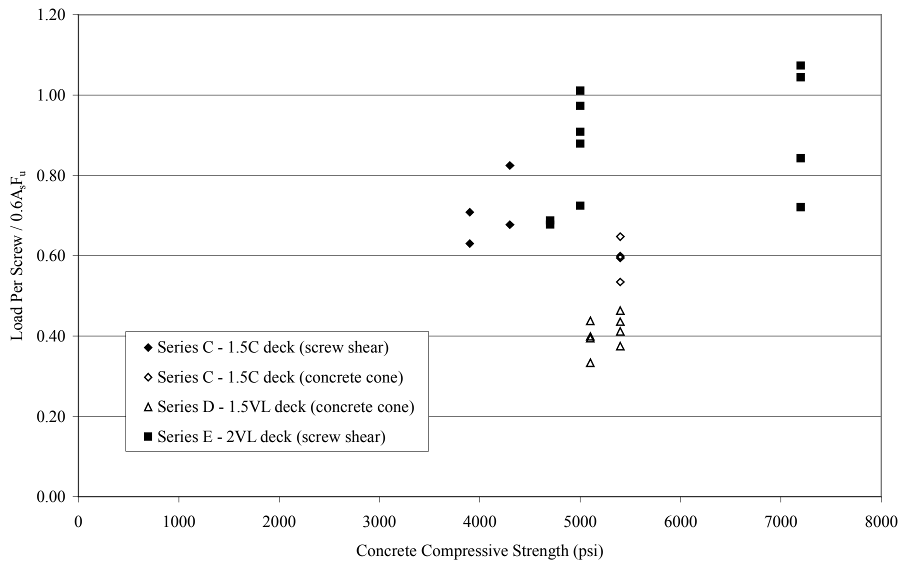



Figure 4.27 Shear Load Per Screw / $0.6A_sF_u$ vs. Concrete Compressive Strength (4 Screws Per Rib)

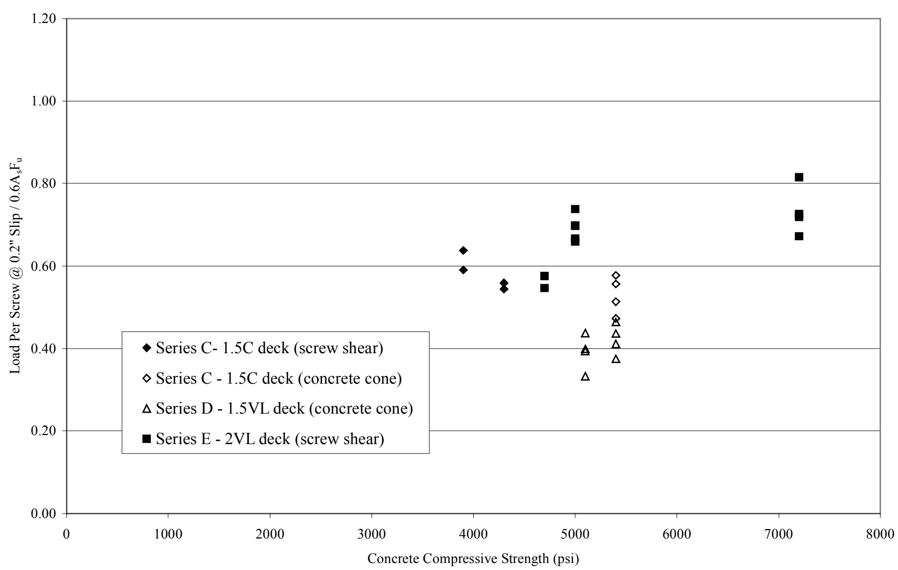



Figure 4.28 Shear Load Per Screw at 0.2 in. Slip / $0.6A_sF_u$ vs. Concrete Compressive Strength (4 Screws Per Rib)

### 4.3 Existing Predictive Equations

Since the use of standoff screws as shear connectors is relatively new, very few equations exist to predict their performance in different configurations. The most recent predictive equation is that of Alander (1998). Alander's equation was developed to determine the strength of the 5/16 in. diameter Elco Grade 8 standoff screw in cases where screw related failure modes control. The applicability and limitations of this equation are discussed at length in Section 1.2. In cases where concrete cone failures control, Alander modified an equation developed by Hankins (1994), also discussed in Section 1.2. For configurations where a solid slab is used, the existing equation developed by The British Steel Construction Institute (Eq. 1.8) will be evaluated.

### 4.3.1 Alander's Proposed Shear Strength Equation

As discussed in Section 1.2, Alander (1998) developed an equation for calculating the shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw when used with steel deck. This equation, shown below, was developed by performing a multiple linear regression analysis on selected data. Of the 106 pushout tests conducted, only those which exhibited a screw related failure were used in developing Equation 1.6.

$$V_s = \sqrt{f_c'}\left(0.034 + 0.0012A_r + 0.068t_{TC}\right) \tag{1.6}$$

where:

$V_s$ = shear strength per screw, kips

$f_c'$ = concrete compressive strength, psi

$A_r$ = rib area, in.$^2$

= average rib width × nominal rib height

$t_{TC}$ = top chord thickness, in.

To determine the validity of Eq. 1.6 it was applied to relevant test data gathered in both this study and that of Alander. Comparison between the predicted values given by this equation and experimental values is shown in Table 4.2. The correlation between experimental values and those predicted using Eq. 1.6 is also illustrated in Figure 4.29. As a means of measuring scatter, lines denoting 15% variation are included in Figure 4.29.

As shown in Table 4.2, there seems to be good correlation between the predicted and experimental values for some of the test series but not all. Alander's equation does an acceptable job predicting the shear strength, at 0.2 inches of slip, for series A, C and D but does not seem to be applicable for tests in series B and E. This is also illustrated in Figure 4.29. However, this result is expected due to the nature of the equation. Series A, C and D were test series originally investigated by Alander and were used to develop the predictive equation. Therefore, it is understandable that Equation 1.6 would accurately predict the shear strength of the 5/16 in. diameter Elco Grade 8 standoff screws for those test series. The inability of Alander's equation to predict the shear strength in series B and E suggests the need for a new predictive equation or a new approach to determining the shear strength of the standoff screws.

# Table 4.2 Evaluation of Alander's Proposed Shear Strength Equation

| Test Number | Deck Type | Rib Area (in2) | Screw Height (in.) | Screws Per Rib | Top Chord Thickness (in.) | Concrete f'c (psi) | Experimental Shear Load Per Screw at 0.2" Slip (kips) | Predicted Shear Strength Per Screw at 0.2" Slip, Alander (kips) | Experimental / Predicted | Failure Mode |
|---|---|---|---|---|---|---|---|---|---|---|
| A6-1 | 0.6C | 0.704 | 2 | 1 | 0.109 | 5100 | 2.71 | 3.02 | 0.90 | screw pullout |
| A6-2 | 0.6C | 0.704 | 2 | 1 | 0.109 | 5100 | 2.85 | 3.02 | 0.95 | screw pullout |
| A7-1 | 0.6C | 0.704 | 2 | 1 | 0.187 | 5100 | 3.29 | 3.40 | 0.97 | screw shear |
| A7-2 | 0.6C | 0.704 | 2 | 1 | 0.187 | 5100 | 3.52 | 3.40 | 1.04 | screw shear |
| A8-1 | 0.6C | 0.704 | 2 | 1 | 0.250 | 5100 | 3.96 | 3.70 | 1.07 | screw shear |
| A8-2 | 0.6C | 0.704 | 2 | 1 | 0.250 | 5100 | 3.85 | 3.70 | 1.04 | screw shear |
| B12-1 | 1.0C | 1.875 | 2.5 | 1 | 0.109 | 6600 | 2.55 | 3.55 | 0.72 | screw pullout |
| B12-2 | 1.0C | 1.875 | 2.5 | 1 | 0.109 | 6600 | 2.63 | 3.55 | 0.74 | screw pullout |
| B13-1 | 1.0C | 1.875 | 2.5 | 1 | 0.187 | 7000 | 3.26 | 4.10 | 0.79 | screw shear |
| B13-2 | 1.0C | 1.875 | 2.5 | 1 | 0.187 | 7000 | 2.75 | 4.10 | 0.67 | screw shear |
| B14-1 | 1.0C | 1.875 | 2.5 | 2 | 0.109 | 6500 | 2.27 | 3.52 | 0.64 | screw pullout |
| B14-2 | 1.0C | 1.875 | 2.5 | 2 | 0.109 | 6500 | 2.27 | 3.52 | 0.65 | screw pullout |
| B14R-1 | 1.0C | 1.875 | 2.5 | 2 | 0.109 | 5900 | 2.40 | 3.35 | 0.71 | screw pullout |
| B14R-2 | 1.0C | 1.875 | 2.5 | 2 | 0.109 | 5900 | 2.24 | 3.35 | 0.67 | screw pullout |
| B15-1 | 1.0C | 1.875 | 2.5 | 2 | 0.187 | 6700 | 2.80 | 4.01 | 0.70 | screw shear |
| B15-2 | 1.0C | 1.875 | 2.5 | 2 | 0.187 | 6700 | 2.75 | 4.01 | 0.69 | screw shear |
| B15R-1 | 1.0C | 1.875 | 2.5 | 2 | 0.187 | 5500 | 2.74 | 3.63 | 0.76 | screw shear |
| B15R-2 | 1.0C | 1.875 | 2.5 | 2 | 0.187 | 5500 | 2.71 | 3.63 | 0.75 | screw shear |
| B16-1 | 1.0C | 1.875 | 2.5 | 2 | 0.250 | 7300 | 3.11 | 4.55 | 0.68 | screw shear |
| B16-2 | 1.0C | 1.875 | 2.5 | 2 | 0.250 | 7300 | 3.29 | 4.55 | 0.72 | screw shear |
| B16R-1 | 1.0C | 1.875 | 2.5 | 2 | 0.250 | 5500 | 3.21 | 3.95 | 0.81 | screw shear |
| B16R-2 | 1.0C | 1.875 | 2.5 | 2 | 0.250 | 5500 | 2.97 | 3.95 | 0.75 | screw shear |
| B16R-3 | 1.0C | 1.875 | 2.5 | 2 | 0.250 | 5500 | 2.85 | 3.95 | 0.72 | screw shear |
| C1-1 | 1.5C | 5.813 | 3 | 1 | 0.109 | 5800 | 4.05 | 3.69 | 1.10 | screw shear |
| C1-2 | 1.5C | 5.813 | 3 | 1 | 0.109 | 5800 | 4.04 | 3.69 | 1.10 | screw shear |
| C1R-1 | 1.5C | 5.813 | 3 | 1 | 0.109 | 4100 | 4.33 | 3.10 | 1.40 | screw shear |
| C1R-2 | 1.5C | 5.813 | 3 | 1 | 0.109 | 4100 | 3.89 | 3.10 | 1.26 | screw shear |
| C1R-3 | 1.5C | 5.813 | 3 | 1 | 0.109 | 4100 | 4.32 | 3.10 | 1.39 | screw shear |
| C2-1 | 1.5C | 5.813 | 3 | 1 | 0.187 | 5800 | 4.14 | 4.09 | 1.01 | screw shear |
| C2-2 | 1.5C | 5.813 | 3 | 1 | 0.187 | 5800 | 4.25 | 4.09 | 1.04 | screw shear |
| C2R-1 | 1.5C | 5.813 | 3 | 1 | 0.187 | 4100 | 4.65 | 3.44 | 1.35 | screw shear |
| C2R-2 | 1.5C | 5.813 | 3 | 1 | 0.187 | 4100 | 4.43 | 3.44 | 1.29 | screw shear |
| C3-1 | 1.5C | 5.813 | 3 | 1 | 0.250 | 4300 | 4.24 | 3.80 | 1.11 | screw shear |
| C3-2 | 1.5C | 5.813 | 3 | 1 | 0.250 | 4300 | 3.86 | 3.80 | 1.02 | screw shear |
| C4-1 | 1.5C | 5.813 | 3 | 2 | 0.109 | 4300 | 3.26 | 3.17 | 1.03 | screw shear/pullout |
| C4-2 | 1.5C | 5.813 | 3 | 2 | 0.109 | 4300 | 3.34 | 3.17 | 1.05 | screw pullout |
| C5-1 | 1.5C | 5.813 | 3 | 2 | 0.187 | 4300 | 3.60 | 3.52 | 1.02 | screw shear/cone pullout |
| C5-2 | 1.5C | 5.813 | 3 | 2 | 0.187 | 4300 | 3.55 | 3.52 | 1.01 | screw shear/cone pullout |
| C6-1 | 1.5C | 5.813 | 3 | 2 | 0.250 | 4300 | 3.84 | 3.80 | 1.01 | screw shear/cone pullout |
| C6-2 | 1.5C | 5.813 | 3 | 2 | 0.250 | 4300 | 3.57 | 3.80 | 0.94 | screw shear |
| C7-1 | 1.5C | 5.813 | 3.5 | 4 | 0.163 | 4300 | 3.13 | 3.41 | 0.92 | screw shear/cone pullout |
| C7-2 | 1.5C | 5.813 | 3.5 | 4 | 0.163 | 4300 | 3.22 | 3.41 | 0.94 | screw shear |
| C8-1 | 1.5C | 5.813 | 3.5 | 4 | 0.250 | 3900 | 3.67 | 3.62 | 1.01 | screw shear |
| C8-2 | 1.5C | 5.813 | 3.5 | 4 | 0.250 | 3900 | 3.40 | 3.62 | 0.94 | screw shear |
| D1-1 | 1.5VL | 3.188 | 3 | 1 | 0.109 | 3600 | 2.92 | 2.71 | 1.08 | screw pullout |
| D1-2 | 1.5VL | 3.188 | 3 | 1 | 0.109 | 3600 | 2.70 | 2.71 | 0.99 | screw pullout |
| D2-1 | 1.5VL | 3.188 | 3 | 1 | 0.187 | 3600 | 3.25 | 3.03 | 1.07 | screw shear |
| D2-2 | 1.5VL | 3.188 | 3 | 1 | 0.187 | 3600 | 3.10 | 3.03 | 1.02 | screw shear |
| D3-1 | 1.5VL | 3.188 | 3 | 1 | 0.250 | 3600 | 3.34 | 3.29 | 1.02 | screw shear |
| D3-2 | 1.5VL | 3.188 | 3 | 1 | 0.250 | 3600 | 3.29 | 3.29 | 1.00 | screw shear |
| D4-1 | 1.5VL | 3.188 | 3 | 2 | 0.109 | 3600 | 2.95 | 2.71 | 1.09 | screw pullout |
| D4-2 | 1.5VL | 3.188 | 3 | 2 | 0.109 | 3600 | 2.81 | 2.71 | 1.04 | screw pullout |
| E1R-1 | 2VL | 12.000 | 4 | 4 | 0.109 | 4700 | 3.14 | 3.83 | 0.82 | screw shear/pullout |
| E1R-2 | 2VL | 12.000 | 4 | 4 | 0.109 | 4700 | 3.31 | 3.83 | 0.87 | screw shear/pullout |
| E2-1 | 2VL | 12.000 | 4 | 4 | 0.187 | 7200 | 4.18 | 5.19 | 0.81 | screw shear |
| E2-2 | 2VL | 12.000 | 4 | 4 | 0.187 | 7200 | 4.14 | 5.19 | 0.80 | screw shear |
| E2R-1 | 2VL | 12.000 | 4 | 4 | 0.187 | 5000 | 4.25 | 4.32 | 0.98 | screw shear |
| E2R-2 | 2VL | 12.000 | 4 | 4 | 0.187 | 5000 | 3.83 | 4.32 | 0.89 | screw shear |
| E3-1 | 2VL | 12.000 | 4 | 4 | 0.250 | 7200 | 3.87 | 5.55 | 0.70 | screw shear |
| E3-2 | 2VL | 12.000 | 4 | 4 | 0.250 | 7200 | 4.69 | 5.55 | 0.85 | screw shear |
| E3R-1 | 2VL | 12.000 | 4 | 4 | 0.250 | 5000 | 3.79 | 4.62 | 0.82 | screw shear |
| E3R-2 | 2VL | 12.000 | 4 | 4 | 0.250 | 5000 | 4.01 | 4.62 | 0.87 | screw shear |
| E3R-3 | 2VL | 12.000 | 4 | 4 | 0.250 | 5000 | 4.02 | 4.62 | 0.87 | screw shear |

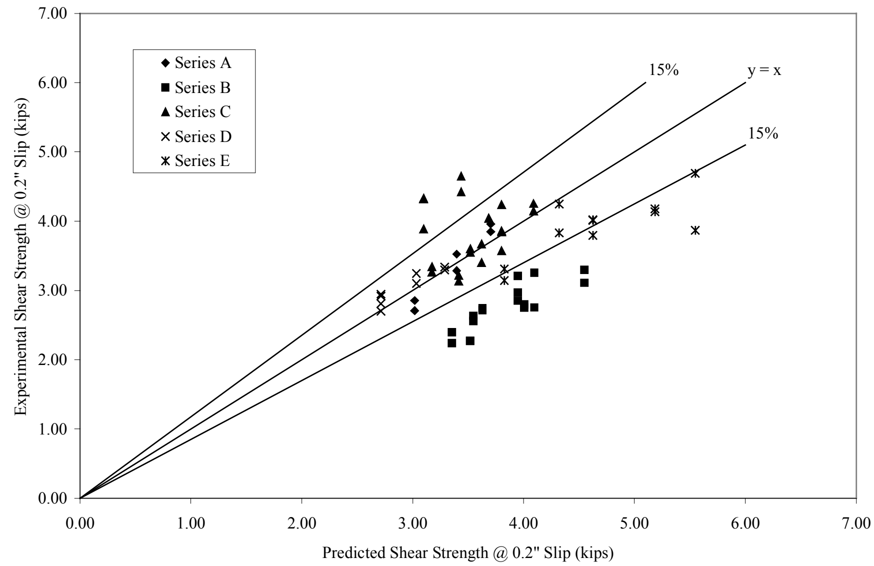



Figure 4.29 Experimental vs. Predicted Shear Strength (using Eq. 1.6)

### 4.3.2 Existing Predictors of Concrete Cone Strength

Previous to research done on standoff screws, the primary existing equation for predicting the load at which a concrete cone failure occurred was that developed by Lloyd and Wright (1990). This equation was developed from data gathered by performing pushout tests constructed with welded shear studs. While other equations were based on theoretical pullout cone areas, Lloyd and Wright's model was based on actual test observations. Lloyd and Wright found that the concrete consistently failed in a similar manner and developed an equation to determine the area of this effective concrete cone. This effective concrete cone area is illustrated in Figure 1.8 and described by the following equation:

$$A_{wc} = 2w_{r2}\sqrt{\frac{w_{r2}^2}{4}+\left(H_s-h_r\right)^2}+w_{r2}\sqrt{w_{r2}^2+2\left(H_s-h_r\right)^2}+2w_{r1}\sqrt{3h_r^2} \qquad (4.2)$$

where:

$A_{wc}$ = surface area of wedge shaped tensile concrete pullout cone, in.$^2$

$h_r$ = nominal rib height of steel deck, in.

$H_s$ = total length of shear connector, in.

$w_{r1}$ = concrete rib width at bottom of flange of steel deck, in.

$w_{r2}$ = concrete rib width at top of flange of steel deck, in.

In cases where two studs are placed in a rib, Lloyd and Wright modified Eq. 4. as follows:

$$A_{wc} = A_{wc}(ss) + 2s\sqrt{\frac{w_{r2}^2}{4} + h_p^2} \tag{4.3}$$

where:

$A_{wc}(ss)$ = surface area of wedge shaped tensile concrete pullout cone for a single stud arrangement (shown above), in.$^2$

With the effective concrete cone pullout area defined, Lloyd and Wright developed the following equation to predict the capacity of tests where cone pullout failures control. This equation, shown below, was found acceptable in predicting stud strength in concrete cone failures and would provide the basis equations developed to predict the strength of standoff screws in similar applications.

$$V_{wc} = 0.92\left(A_{wc}\sqrt{f'_c}\right)^{0.349} \tag{4.4}$$

where:

$V_{wc}$ = connector shear strength, kN

$A_{wc}$ = surface area of wedged shaped tensile concrete pullout cone, mm$^2$

$f'_c$ = concrete compressive strength, N/mm$^2$

Using Eq. 4.4 as a model, Hankins (1994) developed the following equation as a means of predicting the shear capacity of standoff screws:

$$V_{wc} = 0.11\sqrt{A_{wc}\sqrt{f'_c}} \tag{1.4}$$

where:

$V_{wc}$ = connector strength, kips

$A_{wc}$ = surface area of wedge shaped tensile concrete pullout cone, in.$^2$

$f'_c$ = concrete compressive strength, psi

However, Eq. 1.6 was not developed as a means of predicting concrete cone failures but to predict shear capacity of the 5/16 in. diameter Elco Grade 8 standoff screw. Alander (1998) later found this to be an unacceptable predictor and modified Eq. 1.6 to predict connector strength in concrete cone pullout failure modes. This modification, discussed in Section 1.2, is as follows:

$$V_{rs} = 0.11\sqrt{A_{rs}\sqrt{f'_c}} \tag{1.7}$$

where:

$V_{rs}$ = rib shear strength, in.

$A_{rs}$ = rib shear failure surface area, in.$^2$ (Lloyd and Wright 1990)

$$= w_{r2}\sqrt{\frac{b^2}{4}+\left(H_s-h_r\right)^2}+b\sqrt{\frac{w_{r2}^2}{4}+\left(H_s-h_r\right)^2}$$

$b$ = width of concrete rib, in.

$h_r$ = nominal rib height of steel deck, in.

$w_{r2}$ = concrete rib width at top flange of steel deck, in.

$f'_c$ = concrete compressive strength, psi

While all of the preceding equations were found acceptable when applied to the data contained within the reports in which they were developed, when applied to the combined data used in this analytical study all were found to be poor predictors. As was done for existing predictors of shear strength in Section 4.3.1, predicted values obtained from the above equations were compared to those gathered experimentally. From this, an acceptable correlation between predicted and experimental values could not be realized.

Therefore, a new equation must be developed to predict capacity when a concrete cone pullout is the controlling failure mode.

### 4.3.3 The British Steel Construction Institute's Equation for Solid Slab Configurations

While the focus of this study is one standoff screws used in steel deck, solid slab configurations were evaluated in a limited capacity. For this reason, the strength of the 5/16 in. diameter Elco Grade 8 standoff screw in solid slab configurations must be analyzed. To determine the shear strength of standoff screws in solid slabs, The British Steel Construction Institute has adopted the following equation, discussed in detail in Section 1.2:

$$v_r = 0.03\eta f_{cu} A_{cv} + 0.7 A_{sv} f_y \leq 0.8\eta A_{cv} \sqrt{f_{cu}} \qquad (1.8)$$

where:

$v_r$ = shear resistance per unit length of each shear plane, kips/in.

$\eta$ = 1.0 for normal weight concrete

= 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.

$f_y$ = yield strength of steel reinforcement, ksi

The basis of Eq. 1.8 for predicting shear strength is the amount of transverse reinforcement needed to resist longitudinal splitting of the specimen. In this study, the only series where solid slab tests were investigated was series F. While specimens in series F ultimately failed by screw shear, longitudinal splitting was observed to varying extents in all tests. Alander (1998) conducted four groups of solid slab tests. These tests were part of the preliminary series included in his study and have not been discussed to this point. For analysis, results from Alander's solid slab tests will be used in conjunction with results from series F. Longitudinal splitting was found to be the controlling mode of failure in half of the solid slab tests conducted by Alander. Remaining solid slab tests from this preliminary series failed by screw shear with varying amounts of longitudinal splitting observed. Test configurations of solid slab tests conducted by Alander can be found in Standoff Screws Used in Composite Joists (Alander, et al 1998a).

To evaluate the applicability of Eq. 1.8, predicted shear loads were compared to those found experimentally, shown in Table 4.3. As before, these results are also presented graphically. This representation is given in Figure 4.30.

Table 4.3 Predicted Ultimate Shear Strength in Solid Slabs (using Eq. 1.8)

| Test Number | Slab Depth (in.) | Slab Length (in.) | Screw Height (in.) | Total Screws | Concrete $f'_c$ (ksi) | Number of Shear Planes | $A_{cv}$ (in.$^2$) | $A_{sv}$ (in.$^2$) | Experimental Peak Shear Load (kips) | Predicted Peak Shear Load (kips) | Experimental / Predicted | Failure Mode |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P7-1 | 3.0 | 36 | 2.5 | 32 | 5.4 | 4 (2 ea. half) | 108 | 0.000 | 83.92 | 87.48 | 0.96 | longitudinal splitting |
| P7-2 | 3.0 | 36 | 2.5 | 32 | 5.4 | 4 (2 ea. half) | 108 | 0.000 | 77.26 | 87.48 | 0.88 | longitudinal splitting |
| P8-1 | 3.0 | 36 | 2.5 | 32 | 5.4 | 4 (2 ea. half) | 108 | 0.240 | 131.72 | 131.16 | 1.00 | longitudinal splitting |
| P8-2 | 3.0 | 36 | 2.5 | 32 | 5.4 | 4 (2 ea. half) | 108 | 0.240 | 127.07 | 131.16 | 0.97 | long. split./screw shear |
| P9-1 | 3.0 | 36 | 2.5 | 32 | 5.4 | 4 (2 ea. half) | 108 | 0.633 | 204.64 | 202.69 | 1.01 | screw shear |
| P9-2 | 3.0 | 36 | 2.5 | 32 | 5.4 | 4 (2 ea. half) | 108 | 0.633 | 204.64 | 202.69 | 1.01 | screw shear |
| P10-1 | 3.0 | 36 | 2.5 | 32 | 3.2 | 4 (2 ea. half) | 108 | 1.025 | 231.59 | 238.39 | 0.97 | screw shear |
| P10-2 | 3.0 | 36 | 2.5 | 32 | 3.2 | 4 (2 ea. half) | 108 | 1.025 | 233.29 | 238.39 | 0.98 | screw shear |
| F1-1 | 2.5 | 36 | 2.0 | 28 | 3.8 | 4 (2 ea. half) | 90 | 0.981 | 190.20 | 229.84 | 0.83 | screw shear |
| F1-2 | 2.5 | 36 | 2.0 | 28 | 3.8 | 4 (2 ea. half) | 90 | 0.981 | 181.90 | 229.84 | 0.79 | screw shear |
| F2-1 | 2.5 | 36 | 2.0 | 28 | 3.7 | 4 (2 ea. half) | 90 | 0.981 | 213.19 | 228.49 | 0.93 | screw shear |
| F2-2 | 2.5 | 36 | 2.0 | 28 | 3.7 | 4 (2 ea. half) | 90 | 0.981 | 204.14 | 228.49 | 0.89 | screw shear |
| F3-1 | 3.0 | 36 | 2.5 | 36 | 3.8 | 4 (2 ea. half) | 108 | 0.820 | 252.38 | 210.80 | 1.20 | screw shear |
| F3-2 | 3.0 | 36 | 2.5 | 36 | 3.8 | 4 (2 ea. half) | 108 | 0.820 | 223.24 | 210.80 | 1.06 | screw shear |
| F4-1 | 3.0 | 36 | 2.5 | 36 | 5.1 | 4 (2 ea. half) | 108 | 0.820 | 216.58 | 231.86 | 0.93 | screw shear |
| F4-2 | 3.0 | 36 | 2.5 | 36 | 5.1 | 4 (2 ea. half) | 108 | 0.820 | 202.13 | 231.86 | 0.87 | screw shear |
| F5-1 | 3.5 | 36 | 3.0 | 52 | 5.7 | 4 (2 ea. half) | 126 | 1.240 | 300.25 | 333.41 | 0.90 | no failure observed* |
| F5-2 | 3.5 | 36 | 3.0 | 52 | 5.7 | 4 (2 ea. half) | 126 | 1.240 | N.A. | N.A. | N.A. | concrete (N.A.) |
| F6-1 | 3.5 | 36 | 3.0 | 52 | 5.6 | 4 (2 ea. half) | 126 | 1.240 | 320.60 | 331.52 | 0.97 | screw shear |
| F6-2 | 3.5 | 36 | 3.0 | 52 | 5.6 | 4 (2 ea. half) | 126 | 1.240 | 313.56 | 331.52 | 0.95 | screw shear |

* Ultimate load reached before test was stopped

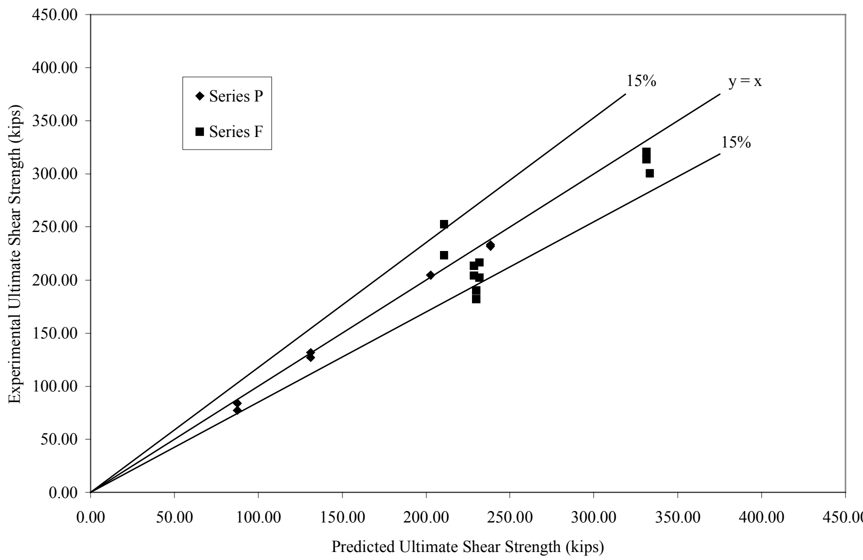



Figure 4.30 Experimental vs. Predicted Ultimate Shear Strength (using Eq. 1.8)

It would appear from the above comparison results that Eq. 1.8 is acceptable in predicting the ultimate shear load a solid slab specimen can sustain. However, due to the nature of the equation, one condition must be met to be applicable. Since Eq. 1.8 assumes that a longitudinal splitting failure mode controls, the shear capacity of the screws must be checked to assure that this is in fact true. If the number of screws in a specimen is not sufficient to induce a longitudinal splitting failure, screw shear would control rendering Eq. 1.8 inapplicable. As illustrated in Figure 4.30, it is clear that the majority of data points from the preliminary series, in which tests failed by longitudinal splitting or exhibited an advanced amount of splitting, lie on or near the *y*=*x* line. In contrast, data points from series F specimens, in which most tests failed in screw shear, are scattered with a few falling outside the 15% barrier. From this it is clear that, while Eq. 1.8 is an acceptable predictor in cases of longitudinal splitting, a new approach must be developed for cases where screw capacity is not sufficient to induce longitudinal splitting. It is felt that the ability of Eq. 4.8 to predict ultimate strength in cases of screw shear is based solely on the advanced splitting observed during testing. However, as approach must still be developed for cases where the only mode of failure observed is screw shear.

## 4.4 New Predictive Equations for the 5/16 in. Diameter Elco Grade 8 Standoff Screw

Due to the inability of existing equations to predict the strength of the 5/16 in. diameter Elco Grade 8 standoff screw, new equations must be developed. Analysis performed in Section 4.2 will be used in developing these equations. As discussed previously, for design purposes the strength of the standoff screw will be limited to the load that causes 0.2 inches of slip. The ultimate strength of the 5/16 in. diameter Elco Grade 8 standoff screw will also be discussed.

### 4.4.1 Shear Strength of the 5/16 in. Diameter Elco Grade 8 Standoff Screw at Low Slip

It is clear from the Figures shown in Section 4.2 that three main variables contribute to the strength of the 5/16 in. diameter Elco Grade 8 standoff screw at low slip. These are number of screws per rib, rib area and top chord thickness. At low slip there is clearly a linear relationship between these variables and the resulting shear strength.

One major difference, other than the addition of the number of screws per rib, between the equation which will be developed here and that of Alander is the absence of the concrete compressive strength. As proven in Section 4.2.1.4, concrete strength does not have a substantial effect on screw performance in cases of screw related failures. Therefore, it will not be included in this portion of the analysis. However, it will be included when concrete cone failures are investigated.

Using these observations, a multiple linear regression analysis will be conducted to develop an equation to predict the shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw at low slip. A summary of the data used in this multiple linear regression analysis is presented in Table 4.4.

Table 4.4 Data Used in First Multiple Linear Regression

| Test Number | Screws Per Rib | Rib Area (in$^2$) | Top Chord Thickness (in.) | Experimental Shear Load Per Screw at 0.2" Slip (kips) | Test Number | Screws Per Rib | Rib Area (in$^2$) | Top Chord Thickness (in.) | Experimental Shear Load Per Screw at 0.2" Slip (kips) |
|---|---|---|---|---|---|---|---|---|---|
| A6-1 | 1 | 0.704 | 0.109 | 2.71 | C3-1 | 1 | 5.813 | 0.250 | 4.24 |
| A6-2 | 1 | 0.704 | 0.109 | 2.85 | C3-2 | 1 | 5.813 | 0.250 | 3.86 |
| A7-1 | 1 | 0.704 | 0.187 | 3.29 | C4-1 | 2 | 5.813 | 0.109 | 3.26 |
| A7-2 | 1 | 0.704 | 0.187 | 3.52 | C4-2 | 2 | 5.813 | 0.109 | 3.34 |
| A8-1 | 1 | 0.704 | 0.250 | 3.96 | C5-1 | 2 | 5.813 | 0.187 | 3.60 |
| A8-2 | 1 | 0.704 | 0.250 | 3.85 | C5-2 | 2 | 5.813 | 0.187 | 3.55 |
| B12-1 | 1 | 1.875 | 0.109 | 2.55 | C6-1 | 2 | 5.813 | 0.250 | 3.84 |
| B12-2 | 1 | 1.875 | 0.109 | 2.63 | C6-2 | 2 | 5.813 | 0.250 | 3.57 |
| B13-1 | 1 | 1.875 | 0.187 | 3.26 | C7-1 | 4 | 5.813 | 0.163 | 3.13 |
| B13-2 | 1 | 1.875 | 0.187 | 2.75 | C7-2 | 4 | 5.813 | 0.163 | 3.22 |
| B14-1 | 2 | 1.875 | 0.109 | 2.27 | C8-1 | 4 | 5.813 | 0.250 | 3.67 |
| B14-2 | 2 | 1.875 | 0.109 | 2.27 | C8-2 | 4 | 5.813 | 0.250 | 3.40 |
| B14R-1 | 2 | 1.875 | 0.109 | 2.40 | D1-1 | 1 | 3.188 | 0.109 | 2.92 |
| B14R-2 | 2 | 1.875 | 0.109 | 2.24 | D1-2 | 1 | 3.188 | 0.109 | 2.70 |
| B15-1 | 2 | 1.875 | 0.187 | 2.80 | D2-1 | 1 | 3.188 | 0.187 | 3.25 |
| B15-2 | 2 | 1.875 | 0.187 | 2.75 | D2-2 | 1 | 3.188 | 0.187 | 3.10 |
| B15R-1 | 2 | 1.875 | 0.187 | 2.74 | D3-1 | 1 | 3.188 | 0.250 | 3.34 |
| B15R-2 | 2 | 1.875 | 0.187 | 2.71 | D3-2 | 1 | 3.188 | 0.250 | 3.29 |
| B16-1 | 2 | 1.875 | 0.250 | 3.11 | D4-1 | 2 | 3.188 | 0.109 | 2.95 |
| B16-2 | 2 | 1.875 | 0.250 | 3.29 | D4-2 | 2 | 3.188 | 0.109 | 2.81 |
| B16R-1 | 2 | 1.875 | 0.250 | 3.21 | E1R-1 | 4 | 12.000 | 0.109 | 3.14 |
| B16R-2 | 2 | 1.875 | 0.250 | 2.97 | E1R-2 | 4 | 12.000 | 0.109 | 3.31 |
| B16R-3 | 2 | 1.875 | 0.250 | 2.85 | E2-1 | 4 | 12.000 | 0.187 | 4.18 |
| C1-1 | 1 | 5.813 | 0.109 | 4.05 | E2-2 | 4 | 12.000 | 0.187 | 4.14 |
| C1-2 | 1 | 5.813 | 0.109 | 4.04 | E2R-1 | 4 | 12.000 | 0.187 | 4.25 |
| C1R-1 | 1 | 5.813 | 0.109 | 4.33 | E2R-2 | 4 | 12.000 | 0.187 | 3.83 |
| C1R-2 | 1 | 5.813 | 0.109 | 3.89 | E3-1 | 4 | 12.000 | 0.250 | 3.87 |
| C1R-3 | 1 | 5.813 | 0.109 | 4.32 | E3-2 | 4 | 12.000 | 0.250 | 4.69 |
| C2-1 | 1 | 5.813 | 0.187 | 4.14 | E3R-1 | 4 | 12.000 | 0.250 | 3.79 |
| C2-2 | 1 | 5.813 | 0.187 | 4.25 | E3R-2 | 4 | 12.000 | 0.250 | 4.01 |
| C2R-1 | 1 | 5.813 | 0.187 | 4.65 | E3R-3 | 4 | 12.000 | 0.250 | 4.02 |
| C2R-2 | 1 | 5.813 | 0.187 | 4.43 | | | | | |

The multiple linear regression analysis performed on the data presented in Table 4.4 resulted in the following equation:

$$V_s = 2.54 - 0.407 N_r + 0.190 A_r + 4.19 t_{tc} \tag{4.5}$$

where:

$V_s$ = shear strength per screw, kips

$N_r$ = Number of screws per rib

$A_r$ = rib area, in.$^2$

= average rib width $\times$ nominal rib height

$t_{tc}$ = top chord thickness, in.

In order to evaluate the accuracy of Eq. 4.5, experimental values were compared to those calculated. These experimental and predicted values are summarized in Table 4.5. As evident by the ratio of experimental shear strength to predicted shear strength, it appears that Eq. 4.5 serves as an acceptable predictor of the shear strength of the 5/16 in. diameter standoff screw at low slip. The coefficient of correlation, R, and the coefficient of determination, $R^2$, are 0.84 and 0.71, respectively. While a coefficient of correlation equal to 1.00 is ideal, considering the variations in the test procedure and the specimens themselves a value of 0.84 is considered acceptable. The coefficient of determination indicates that 71% of the variation in the shear strength per screw can be attributed to variations in the independent variables of Eq. 4.5. Again, for visual reference, experimental values were plotted against predicted. The result is shown in Figure 4.31. Reference lines denoting 15% variation between experimental and predicted values are also included.

Table 4.5 Predicted Shear Strength at 0.2 in. of Slip (using Eq. 4.5)

| Test Number | Deck Type | Screws Per Rib | Rib Area ($in^2$) | Top Chord Thickness (in.) | Experimental Shear Load Per Screw at 0.2" Slip (kips) | Predicted Shear Load Per Screw at 0.2" Slip (kips) | Experimental / Predicted | Failure Mode |
|---|---|---|---|---|---|---|---|---|
| A6-1 | 0.6C | 1 | 0.704 | 0.109 | 2.71 | 2.72 | 0.99 | screw pullout |
| A6-2 | 0.6C | 1 | 0.704 | 0.109 | 2.85 | 2.72 | 1.05 | screw pullout |
| A7-1 | 0.6C | 1 | 0.704 | 0.187 | 3.29 | 3.05 | 1.08 | screw shear |
| A7-2 | 0.6C | 1 | 0.704 | 0.187 | 3.52 | 3.05 | 1.16 | screw shear |
| A8-1 | 0.6C | 1 | 0.704 | 0.250 | 3.96 | 3.31 | 1.19 | screw shear |
| A8-2 | 0.6C | 1 | 0.704 | 0.250 | 3.85 | 3.31 | 1.16 | screw shear |
| B12-1 | 1.0C | 1 | 1.875 | 0.109 | 2.55 | 2.95 | 0.87 | screw pullout |
| B12-2 | 1.0C | 1 | 1.875 | 0.109 | 2.63 | 2.95 | 0.89 | screw pullout |
| B13-1 | 1.0C | 1 | 1.875 | 0.187 | 3.26 | 3.27 | 0.99 | screw shear |
| B13-2 | 1.0C | 1 | 1.875 | 0.187 | 2.75 | 3.27 | 0.84 | screw shear |
| B14-1 | 1.0C | 2 | 1.875 | 0.109 | 2.27 | 2.54 | 0.89 | screw pullout |
| B14-2 | 1.0C | 2 | 1.875 | 0.109 | 2.27 | 2.54 | 0.89 | screw pullout |
| B14R-1 | 1.0C | 2 | 1.875 | 0.109 | 2.40 | 2.54 | 0.94 | screw pullout |
| B14R-2 | 1.0C | 2 | 1.875 | 0.109 | 2.24 | 2.54 | 0.88 | screw pullout |
| B15-1 | 1.0C | 2 | 1.875 | 0.187 | 2.80 | 2.87 | 0.98 | screw shear |
| B15-2 | 1.0C | 2 | 1.875 | 0.187 | 2.75 | 2.87 | 0.96 | screw shear |
| B15R-1 | 1.0C | 2 | 1.875 | 0.187 | 2.74 | 2.87 | 0.96 | screw shear |
| B15R-2 | 1.0C | 2 | 1.875 | 0.187 | 2.71 | 2.87 | 0.95 | screw shear |
| B16-1 | 1.0C | 2 | 1.875 | 0.250 | 3.11 | 3.13 | 0.99 | screw shear |
| B16-2 | 1.0C | 2 | 1.875 | 0.250 | 3.29 | 3.13 | 1.05 | screw shear |
| B16R-1 | 1.0C | 2 | 1.875 | 0.250 | 3.21 | 3.13 | 1.03 | screw shear |
| B16R-2 | 1.0C | 2 | 1.875 | 0.250 | 2.97 | 3.13 | 0.95 | screw shear |
| B16R-3 | 1.0C | 2 | 1.875 | 0.250 | 2.85 | 3.13 | 0.91 | screw shear |
| C1-1 | 1.5C | 1 | 5.813 | 0.109 | 4.05 | 3.69 | 1.09 | screw shear |
| C1-2 | 1.5C | 1 | 5.813 | 0.109 | 4.04 | 3.69 | 1.09 | screw shear |
| C1R-1 | 1.5C | 1 | 5.813 | 0.109 | 4.33 | 3.69 | 1.17 | screw shear |
| C1R-2 | 1.5C | 1 | 5.813 | 0.109 | 3.89 | 3.69 | 1.05 | screw shear |
| C1R-3 | 1.5C | 1 | 5.813 | 0.109 | 4.32 | 3.69 | 1.17 | screw shear |
| C2-1 | 1.5C | 1 | 5.813 | 0.187 | 4.14 | 4.02 | 1.03 | screw shear |
| C2-2 | 1.5C | 1 | 5.813 | 0.187 | 4.25 | 4.02 | 1.06 | screw shear |
| C2R-1 | 1.5C | 1 | 5.813 | 0.187 | 4.65 | 4.02 | 1.16 | screw shear |
| C2R-2 | 1.5C | 1 | 5.813 | 0.187 | 4.43 | 4.02 | 1.10 | screw shear |
| C3-1 | 1.5C | 1 | 5.813 | 0.250 | 4.24 | 4.28 | 0.99 | screw shear |
| C3-2 | 1.5C | 1 | 5.813 | 0.250 | 3.86 | 4.28 | 0.90 | screw shear |
| C4-1 | 1.5C | 2 | 5.813 | 0.109 | 3.26 | 3.29 | 0.99 | screw shear/pullout |
| C4-2 | 1.5C | 2 | 5.813 | 0.109 | 3.34 | 3.29 | 1.02 | screw pullout |
| C5-1 | 1.5C | 2 | 5.813 | 0.187 | 3.60 | 3.61 | 1.00 | screw shear/cone pullout |
| C5-2 | 1.5C | 2 | 5.813 | 0.187 | 3.55 | 3.61 | 0.98 | screw shear/cone pullout |
| C6-1 | 1.5C | 2 | 5.813 | 0.250 | 3.84 | 3.88 | 0.99 | screw shear/cone pullout |
| C6-2 | 1.5C | 2 | 5.813 | 0.250 | 3.57 | 3.88 | 0.92 | screw shear |
| C7-1 | 1.5C | 4 | 5.813 | 0.163 | 3.13 | 2.70 | 1.16 | screw shear/cone pullout |
| C7-2 | 1.5C | 4 | 5.813 | 0.163 | 3.22 | 2.70 | 1.19 | screw shear |
| C8-1 | 1.5C | 4 | 5.813 | 0.250 | 3.67 | 3.06 | 1.20 | screw shear |
| C8-2 | 1.5C | 4 | 5.813 | 0.250 | 3.40 | 3.06 | 1.11 | screw shear |
| D1-1 | 1.5VL | 1 | 3.188 | 0.109 | 2.92 | 3.20 | 0.91 | screw pullout |
| D1-2 | 1.5VL | 1 | 3.188 | 0.109 | 2.70 | 3.20 | 0.84 | screw pullout |
| D2-1 | 1.5VL | 1 | 3.188 | 0.187 | 3.25 | 3.52 | 0.92 | screw shear |
| D2-2 | 1.5VL | 1 | 3.188 | 0.187 | 3.10 | 3.52 | 0.88 | screw shear |
| D3-1 | 1.5VL | 1 | 3.188 | 0.250 | 3.34 | 3.79 | 0.88 | screw shear |
| D3-2 | 1.5VL | 1 | 3.188 | 0.250 | 3.29 | 3.79 | 0.87 | screw shear |
| D4-1 | 1.5VL | 2 | 3.188 | 0.109 | 2.95 | 2.79 | 1.06 | screw pullout |
| D4-2 | 1.5VL | 2 | 3.188 | 0.109 | 2.81 | 2.79 | 1.01 | screw pullout |
| E1R-1 | 2VL | 4 | 12.000 | 0.109 | 3.14 | 3.65 | 0.86 | screw shear/pullout |
| E1R-2 | 2VL | 4 | 12.000 | 0.109 | 3.31 | 3.65 | 0.91 | screw shear/pullout |
| E2-1 | 2VL | 4 | 12.000 | 0.187 | 4.18 | 3.98 | 1.05 | screw shear |
| E2-2 | 2VL | 4 | 12.000 | 0.187 | 4.14 | 3.98 | 1.04 | screw shear |
| E2R-1 | 2VL | 4 | 12.000 | 0.187 | 4.25 | 3.98 | 1.07 | screw shear |
| E2R-2 | 2VL | 4 | 12.000 | 0.187 | 3.83 | 3.98 | 0.96 | screw shear |
| E3-1 | 2VL | 4 | 12.000 | 0.250 | 3.87 | 4.24 | 0.91 | screw shear |
| E3-2 | 2VL | 4 | 12.000 | 0.250 | 4.69 | 4.24 | 1.11 | screw shear |
| E3R-1 | 2VL | 4 | 12.000 | 0.250 | 3.79 | 4.24 | 0.89 | screw shear |
| E3R-2 | 2VL | 4 | 12.000 | 0.250 | 4.01 | 4.24 | 0.95 | screw shear |
| E3R-3 | 2VL | 4 | 12.000 | 0.250 | 4.02 | 4.24 | 0.95 | screw shear |

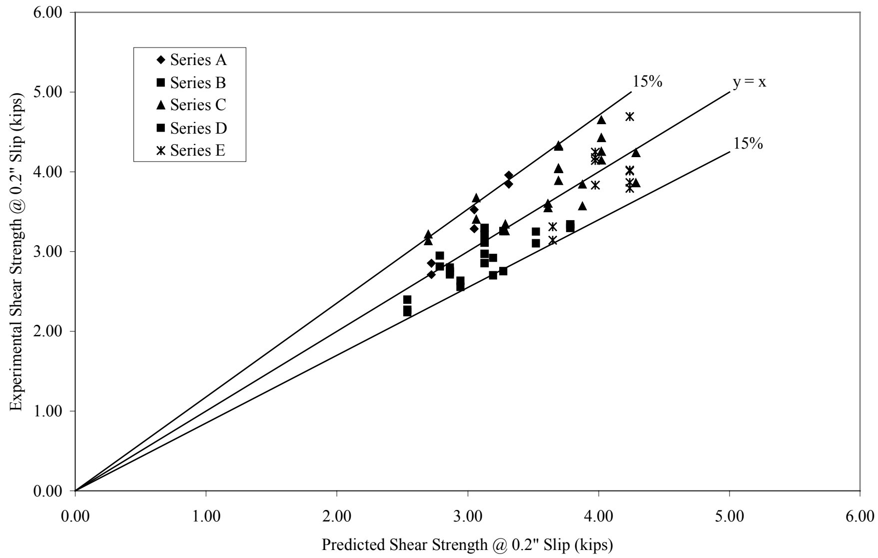



Figure 4.31 Experimental vs. Predicted Shear Strength (using Eq. 4.5)

Figure 4.31 further supports the validity of Eq. 4.5 with all data points lying within, or on, the 15% boundaries. Also, data is clearly distributed evenly above and below the *y=x* line. Data points lying directly on the *y=x* line denote a perfect correlation between experimental and predicted values.

Even though Eq. 4.5 was derived using data from tests ultimately failing in a screw-related mode, it should also be applicable to tests that failed by concrete cone pullout. The 0.2 in. slip load was originally chosen for two main reasons. First, it is not practical to allow for large amounts of slip in design. Second, at 0.2 inches of slip, the majority of these tests still behave elastically. This is evident by the Load vs. Slip plots for all tests in this and Alander's study. The slope of the Load vs. Slip plots were very often found to decrease after 0.2 inches of slip had occurred. For this reason it can be said that little, if any, failure of any type within the specimen occurs before 0.2 inches of slip is achieved. This holds true for the majority of tests conducted. Because of this, at low slip, tests that fail in a concrete related mode perform in a similar manner to those failing in a screw-related mode. Therefore, another multiple linear regression was performed on data from all tests, not just those failing in a screw-related mode. This data is summarized in Table 4.6.

Table 4.6 Data Used in Second Multiple Linear Regression

| Test Number | Rib Area ($in^2$) | Screws Per Rib | Top Chord Thickness (in.) | Experimental Shear Load Per Screw at 0.2" Slip (kips) | Test Number | Rib Area ($in^2$) | Screws Per Rib | Top Chord Thickness (in.) | Experimental Shear Load Per Screw at 0.2" Slip (kips) |
|---|---|---|---|---|---|---|---|---|---|
| A6-1 | 0.704 | 1 | 0.109 | 2.71 | C10-1 | 5.813 | 4 | 0.250 | 3.20 |
| A6-2 | 0.704 | 1 | 0.109 | 2.85 | C10-2 | 5.813 | 4 | 0.250 | 3.32 |
| A7-1 | 0.704 | 1 | 0.187 | 3.29 | D1-1 | 3.188 | 1 | 0.109 | 2.92 |
| A7-2 | 0.704 | 1 | 0.187 | 3.52 | D1-2 | 3.188 | 1 | 0.109 | 2.70 |
| A8-1 | 0.704 | 1 | 0.250 | 3.96 | D2-1 | 3.188 | 1 | 0.187 | 3.25 |
| A8-2 | 0.704 | 1 | 0.250 | 3.85 | D2-2 | 3.188 | 1 | 0.187 | 3.10 |
| B12-1 | 1.875 | 1 | 0.109 | 2.55 | D3-1 | 3.188 | 1 | 0.250 | 3.34 |
| B12-2 | 1.875 | 1 | 0.109 | 2.63 | D3-2 | 3.188 | 1 | 0.250 | 3.29 |
| B13-1 | 1.875 | 1 | 0.187 | 3.26 | D4-1 | 3.188 | 2 | 0.109 | 2.95 |
| B13-2 | 1.875 | 1 | 0.187 | 2.75 | D4-2 | 3.188 | 2 | 0.109 | 2.81 |
| B14-1 | 1.875 | 2 | 0.109 | 2.27 | D5-1 | 3.188 | 2 | 0.187 | 3.46 |
| B14-2 | 1.875 | 2 | 0.109 | 2.27 | D5-2 | 3.188 | 2 | 0.187 | 3.24 |
| B14R-1 | 1.875 | 2 | 0.109 | 2.40 | D6-1 | 3.188 | 2 | 0.250 | 3.71 |
| B14R-2 | 1.875 | 2 | 0.109 | 2.24 | D6-2 | 3.188 | 2 | 0.250 | 3.82 |
| B15-1 | 1.875 | 2 | 0.187 | 2.80 | D7-1 | 3.188 | 4 | 0.163 | 2.37 |
| B15-2 | 1.875 | 2 | 0.187 | 2.75 | D7-2 | 3.188 | 4 | 0.163 | 2.16 |
| B15R-1 | 1.875 | 2 | 0.187 | 2.74 | D8-1 | 3.188 | 4 | 0.250 | 2.51 |
| B15R-2 | 1.875 | 2 | 0.187 | 2.71 | D8-2 | 3.188 | 4 | 0.250 | 2.67 |
| B16-1 | 1.875 | 2 | 0.250 | 3.11 | D9-1 | 3.188 | 4 | 0.163 | 1.92 |
| B16-2 | 1.875 | 2 | 0.250 | 3.29 | D9-2 | 3.188 | 4 | 0.163 | 2.27 |
| B16R-1 | 1.875 | 2 | 0.250 | 3.21 | D10-1 | 3.188 | 4 | 0.250 | 2.30 |
| B16R-2 | 1.875 | 2 | 0.250 | 2.97 | D10-2 | 3.188 | 4 | 0.250 | 2.52 |
| B16R-3 | 1.875 | 2 | 0.250 | 2.85 | D11-1 | 3.188 | 6 | 0.163 | 1.58 |
| C1-1 | 5.813 | 1 | 0.109 | 4.05 | D11-2 | 3.188 | 6 | 0.163 | 1.64 |
| C1-2 | 5.813 | 1 | 0.109 | 4.04 | D12-1 | 3.188 | 6 | 0.250 | 1.63 |
| C1R-1 | 5.813 | 1 | 0.109 | 4.33 | D12-2 | 3.188 | 6 | 0.250 | 1.93 |
| C1R-2 | 5.813 | 1 | 0.109 | 3.89 | E1R-1 | 12.000 | 4 | 0.109 | 3.14 |
| C1R-3 | 5.813 | 1 | 0.109 | 4.32 | E1R-2 | 12.000 | 4 | 0.109 | 3.31 |
| C2-1 | 5.813 | 1 | 0.187 | 4.14 | E2-1 | 12.000 | 4 | 0.187 | 4.18 |
| C2-2 | 5.813 | 1 | 0.187 | 4.25 | E2-2 | 12.000 | 4 | 0.187 | 4.14 |
| C2R-1 | 5.813 | 1 | 0.187 | 4.65 | E2R-1 | 12.000 | 4 | 0.187 | 4.25 |
| C2R-2 | 5.813 | 1 | 0.187 | 4.43 | E2R-2 | 12.000 | 4 | 0.187 | 3.83 |
| C3-1 | 5.813 | 1 | 0.250 | 4.24 | E3-1 | 12.000 | 4 | 0.250 | 3.87 |
| C3-2 | 5.813 | 1 | 0.250 | 3.86 | E3-2 | 12.000 | 4 | 0.250 | 4.69 |
| C4-1 | 5.813 | 2 | 0.109 | 3.26 | E3R-1 | 12.000 | 4 | 0.250 | 3.79 |
| C4-2 | 5.813 | 2 | 0.109 | 3.34 | E3R-2 | 12.000 | 4 | 0.250 | 4.01 |
| C5-1 | 5.813 | 2 | 0.187 | 3.60 | E3R-3 | 12.000 | 4 | 0.250 | 4.02 |
| C5-2 | 5.813 | 2 | 0.187 | 3.55 | E4-1 | 12.000 | 8 | 0.163 | 2.83 |
| C6-1 | 5.813 | 2 | 0.250 | 3.84 | E4-2 | 12.000 | 8 | 0.163 | 2.70 |
| C6-2 | 5.813 | 2 | 0.250 | 3.57 | E5-1 | 12.000 | 8 | 0.250 | 3.00 |
| C7-1 | 5.813 | 4 | 0.163 | 3.13 | E5-2 | 12.000 | 8 | 0.250 | 3.06 |
| C7-2 | 5.813 | 4 | 0.163 | 3.22 | E6-1 | 12.000 | 12 | 0.163 | 2.25 |
| C8-1 | 5.813 | 4 | 0.250 | 3.67 | E6-2 | 12.000 | 12 | 0.163 | 2.30 |
| C8-2 | 5.813 | 4 | 0.250 | 3.40 | E7-1 | 12.000 | 12 | 0.250 | 2.49 |
| C9-1 | 5.813 | 4 | 0.163 | 2.95 | E7-2 | 12.000 | 12 | 0.250 | 2.64 |
| C9-2 | 5.813 | 4 | 0.163 | 2.72 | | | | | |

Using the data in Table 4.6, the following equation for predicting the shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw at low slip was developed.

$$V_s = 2.43 - 0.289N_r + 0.181A_r + 3.69t_{tc} \qquad (4.6)$$

where:

$V_s$ = shear strength per screw, kips

$N_r$ = Number of screws per rib

$A_r$ = rib area, in.$^2$

= average rib width × nominal rib height

$t_{tc}$ = top chord thickness, in.

The validity of Eq. 4.6 was checked in the same manner as Eq. 4.5 and found to be acceptable. The coefficient of correlation and coefficient of determination for Eq. 4.6 are 0.88 and 0.77, respectively. It is clear that Eq. 4.6 predicts the shear strength at low slip more accurately than Eq. 4.5. By simplifying the constants, a suitable design equation is obtained. In simplifying Eq. 4.6, the coefficients were rounded in numerous combinations to determine the best combination. From this, Eq. 4.7 was developed and will be evaluated in greater detail.

$$V_s = 2.5 - 0.3N_r + 0.18A_r + 3.7t_{tc} \qquad (4.7)$$

Comparison of theoretical values obtained from Eq. 4.7 to experimental values are presented in Table 4.7. It is clear that Eq. 4.7 is acceptable for predicting shear strength at low slip for cases of both screw and concrete related failures. This further proves that, before the 0.2 in. slip load is reached, all tests behave in a similar manner regardless of their ultimate failure modes. The largest differences in experimental and predicted shear strengths are found in cases where large numbers of screws per rib are used. However, this is acceptable since it is impractical to have systems with such large screw densities, i.e., 12 screws per rib in 2VL deck.

Table 4.7 Predicted Shear Strength at 0.2 in. of Slip (using Eq. 4.7)

| Test Number | Deck Type | Screws Per Rib | Rib Area ($in^2$) | Top Chord Thickness (in.) | Experimental Shear Load Per Screw at 0.2" Slip (kips) | Predicted Shear Load Per Screw at 0.2" Slip (kips) | Experimental / Predicted | Failure Mode |
|---|---|---|---|---|---|---|---|---|
| A6-1 | 0.6C | 1 | 0.704 | 0.109 | 2.71 | 2.73 | 0.99 | screw pullout |
| A6-2 | 0.6C | 1 | 0.704 | 0.109 | 2.85 | 2.73 | 1.04 | screw pullout |
| A7-1 | 0.6C | 1 | 0.704 | 0.187 | 3.29 | 3.02 | 1.09 | screw shear |
| A7-2 | 0.6C | 1 | 0.704 | 0.187 | 3.52 | 3.02 | 1.17 | screw shear |
| A8-1 | 0.6C | 1 | 0.704 | 0.250 | 3.96 | 3.25 | 1.22 | screw shear |
| A8-2 | 0.6C | 1 | 0.704 | 0.250 | 3.85 | 3.25 | 1.18 | screw shear |
| B12-1 | 1.0C | 1 | 1.875 | 0.109 | 2.55 | 2.94 | 0.87 | screw pullout |
| B12-2 | 1.0C | 1 | 1.875 | 0.109 | 2.63 | 2.94 | 0.90 | screw pullout |
| B13-1 | 1.0C | 1 | 1.875 | 0.187 | 3.26 | 3.23 | 1.01 | screw shear |
| B13-2 | 1.0C | 1 | 1.875 | 0.187 | 2.75 | 3.23 | 0.85 | screw shear |
| B14-1 | 1.0C | 2 | 1.875 | 0.109 | 2.27 | 2.64 | 0.86 | screw pullout |
| B14-2 | 1.0C | 2 | 1.875 | 0.109 | 2.27 | 2.64 | 0.86 | screw pullout |
| B14R-1 | 1.0C | 2 | 1.875 | 0.109 | 2.40 | 2.64 | 0.91 | screw pullout |
| B14R-2 | 1.0C | 2 | 1.875 | 0.109 | 2.24 | 2.64 | 0.85 | screw pullout |
| B15-1 | 1.0C | 2 | 1.875 | 0.187 | 2.80 | 2.93 | 0.95 | screw shear |
| B15-2 | 1.0C | 2 | 1.875 | 0.187 | 2.75 | 2.93 | 0.94 | screw shear |
| B15R-1 | 1.0C | 2 | 1.875 | 0.187 | 2.74 | 2.93 | 0.94 | screw shear |
| B15R-2 | 1.0C | 2 | 1.875 | 0.187 | 2.71 | 2.93 | 0.93 | screw shear |
| B16-1 | 1.0C | 2 | 1.875 | 0.250 | 3.11 | 3.16 | 0.98 | screw shear |
| B16-2 | 1.0C | 2 | 1.875 | 0.250 | 3.29 | 3.16 | 1.04 | screw shear |
| B16R-1 | 1.0C | 2 | 1.875 | 0.250 | 3.21 | 3.16 | 1.02 | screw shear |
| B16R-2 | 1.0C | 2 | 1.875 | 0.250 | 2.97 | 3.16 | 0.94 | screw shear |
| B16R-3 | 1.0C | 2 | 1.875 | 0.250 | 2.85 | 3.16 | 0.90 | screw shear |
| C1-1 | 1.5C | 1 | 5.813 | 0.109 | 4.05 | 3.65 | 1.11 | screw shear |
| C1-2 | 1.5C | 1 | 5.813 | 0.109 | 4.04 | 3.65 | 1.11 | screw shear |
| C1R-1 | 1.5C | 1 | 5.813 | 0.109 | 4.33 | 3.65 | 1.19 | screw shear |
| C1R-2 | 1.5C | 1 | 5.813 | 0.109 | 3.89 | 3.65 | 1.07 | screw shear |
| C1R-3 | 1.5C | 1 | 5.813 | 0.109 | 4.32 | 3.65 | 1.18 | screw shear |
| C2-1 | 1.5C | 1 | 5.813 | 0.187 | 4.14 | 3.94 | 1.05 | screw shear |
| C2-2 | 1.5C | 1 | 5.813 | 0.187 | 4.25 | 3.94 | 1.08 | screw shear |
| C2R-1 | 1.5C | 1 | 5.813 | 0.187 | 4.65 | 3.94 | 1.18 | screw shear |
| C2R-2 | 1.5C | 1 | 5.813 | 0.187 | 4.43 | 3.94 | 1.12 | screw shear |
| C3-1 | 1.5C | 1 | 5.813 | 0.250 | 4.24 | 4.17 | 1.02 | screw shear |
| C3-2 | 1.5C | 1 | 5.813 | 0.250 | 3.86 | 4.17 | 0.93 | screw shear |
| C4-1 | 1.5C | 2 | 5.813 | 0.109 | 3.26 | 3.35 | 0.97 | screw shear/cone pullout |
| C4-2 | 1.5C | 2 | 5.813 | 0.109 | 3.34 | 3.35 | 1.00 | screw pullout |
| C5-1 | 1.5C | 2 | 5.813 | 0.187 | 3.60 | 3.64 | 0.99 | screw shear/cone pullout |
| C5-2 | 1.5C | 2 | 5.813 | 0.187 | 3.55 | 3.64 | 0.98 | screw shear/cone pullout |
| C6-1 | 1.5C | 2 | 5.813 | 0.250 | 3.84 | 3.87 | 0.99 | screw shear/cone pullout |
| C6-2 | 1.5C | 2 | 5.813 | 0.250 | 3.57 | 3.87 | 0.92 | screw shear |
| C7-1 | 1.5C | 4 | 5.813 | 0.163 | 3.13 | 2.95 | 1.06 | screw shear/cone pullout |
| C7-2 | 1.5C | 4 | 5.813 | 0.163 | 3.22 | 2.95 | 1.09 | screw shear |
| C8-1 | 1.5C | 4 | 5.813 | 0.250 | 3.67 | 3.27 | 1.12 | screw shear |
| C8-2 | 1.5C | 4 | 5.813 | 0.250 | 3.40 | 3.27 | 1.04 | screw shear |
| C9-1 | 1.5C | 4 | 5.813 | 0.163 | 2.95 | 2.95 | 1.00 | concrete cone pullout |
| C9-2 | 1.5C | 4 | 5.813 | 0.163 | 2.72 | 2.95 | 0.92 | concrete cone pullout |
| C10-1 | 1.5C | 4 | 5.813 | 0.250 | 3.20 | 3.27 | 0.98 | concrete cone pullout |
| C10-2 | 1.5C | 4 | 5.813 | 0.250 | 3.32 | 3.27 | 1.02 | concrete cone pullout |

Table 4.7 Predicted Shear Strength at 0.2 in. of Slip (using Eq. 4.7) (cont'd)

| Test Number | Deck Type | Screws Per Rib | Rib Area ($in^2$) | Top Chord Thickness (in.) | Experimental Shear Load Per Screw at 0.2" Slip (kips) | Predicted Shear Load Per Screw at 0.2" Slip (kips) | Experimental / Predicted | Failure Mode |
|---|---|---|---|---|---|---|---|---|
| D1-1 | 1.5VL | 1 | 3.188 | 0.109 | 2.92 | 3.18 | 0.92 | screw pullout |
| D1-2 | 1.5VL | 1 | 3.188 | 0.109 | 2.70 | 3.18 | 0.85 | screw pullout |
| D2-1 | 1.5VL | 1 | 3.188 | 0.187 | 3.25 | 3.47 | 0.94 | screw shear |
| D2-2 | 1.5VL | 1 | 3.188 | 0.187 | 3.10 | 3.47 | 0.89 | screw shear |
| D3-1 | 1.5VL | 1 | 3.188 | 0.250 | 3.34 | 3.70 | 0.90 | screw shear |
| D3-2 | 1.5VL | 1 | 3.188 | 0.250 | 3.29 | 3.70 | 0.89 | screw shear |
| D4-1 | 1.5VL | 2 | 3.188 | 0.109 | 2.95 | 2.88 | 1.02 | screw pullout |
| D4-2 | 1.5VL | 2 | 3.188 | 0.109 | 2.81 | 2.88 | 0.98 | screw pullout |
| D5-1 | 1.5VL | 2 | 3.188 | 0.187 | 3.46 | 3.17 | 1.09 | concrete cone pullout |
| D5-2 | 1.5VL | 2 | 3.188 | 0.187 | 3.24 | 3.17 | 1.02 | concrete cone pullout |
| D6-1 | 1.5VL | 2 | 3.188 | 0.250 | 3.71 | 3.40 | 1.09 | concrete cone pullout |
| D6-2 | 1.5VL | 2 | 3.188 | 0.250 | 3.82 | 3.40 | 1.12 | concrete cone pullout |
| D7-1 | 1.5VL | 4 | 3.188 | 0.163 | 2.37 | 2.48 | 0.96 | concrete cone pullout |
| D7-2 | 1.5VL | 4 | 3.188 | 0.163 | 2.16 | 2.48 | 0.87 | concrete cone pullout |
| D8-1 | 1.5VL | 4 | 3.188 | 0.250 | 2.51 | 2.80 | 0.90 | concrete cone pullout |
| D8-2 | 1.5VL | 4 | 3.188 | 0.250 | 2.67 | 2.80 | 0.95 | concrete cone pullout |
| D9-1 | 1.5VL | 4 | 3.188 | 0.163 | 1.92 | 2.48 | 0.77 | concrete cone pullout |
| D9-2 | 1.5VL | 4 | 3.188 | 0.163 | 2.27 | 2.48 | 0.92 | concrete cone pullout |
| D10-1 | 1.5VL | 4 | 3.188 | 0.250 | 2.30 | 2.80 | 0.82 | concrete cone pullout |
| D10-2 | 1.5VL | 4 | 3.188 | 0.250 | 2.52 | 2.80 | 0.90 | concrete cone pullout |
| D11-1 | 1.5VL | 6 | 3.188 | 0.163 | 1.58 | 1.88 | 0.84 | concrete cone pullout |
| D11-2 | 1.5VL | 6 | 3.188 | 0.163 | 1.64 | 1.88 | 0.88 | concrete cone pullout |
| D12-1 | 1.5VL | 6 | 3.188 | 0.250 | 1.63 | 2.20 | 0.74 | concrete cone pullout |
| D12-2 | 1.5VL | 6 | 3.188 | 0.250 | 1.93 | 2.20 | 0.88 | concrete cone pullout |
| E1R-1 | 2VL | 4 | 12.000 | 0.109 | 3.14 | 3.86 | 0.81 | screw shear/pullout |
| E1R-2 | 2VL | 4 | 12.000 | 0.109 | 3.31 | 3.86 | 0.86 | screw shear/pullout |
| E2-1 | 2VL | 4 | 12.000 | 0.187 | 4.18 | 4.15 | 1.01 | screw shear |
| E2-2 | 2VL | 4 | 12.000 | 0.187 | 4.14 | 4.15 | 1.00 | screw shear |
| E2R-1 | 2VL | 4 | 12.000 | 0.187 | 4.25 | 4.15 | 1.02 | screw shear |
| E2R-2 | 2VL | 4 | 12.000 | 0.187 | 3.83 | 4.15 | 0.92 | screw shear |
| E3-1 | 2VL | 4 | 12.000 | 0.250 | 3.87 | 4.39 | 0.88 | screw shear |
| E3-2 | 2VL | 4 | 12.000 | 0.250 | 4.69 | 4.39 | 1.07 | screw shear |
| E3R-1 | 2VL | 4 | 12.000 | 0.250 | 3.79 | 4.39 | 0.87 | screw shear |
| E3R-2 | 2VL | 4 | 12.000 | 0.250 | 4.01 | 4.39 | 0.91 | screw shear |
| E3R-3 | 2VL | 4 | 12.000 | 0.250 | 4.02 | 4.39 | 0.92 | screw shear |
| E4-1 | 2VL | 8 | 12.000 | 0.163 | 2.83 | 2.86 | 0.99 | concrete cone pullout |
| E4-2 | 2VL | 8 | 12.000 | 0.163 | 2.70 | 2.86 | 0.94 | concrete cone pullout |
| E5-1 | 2VL | 8 | 12.000 | 0.250 | 3.00 | 3.19 | 0.94 | concrete cone pullout |
| E5-2 | 2VL | 8 | 12.000 | 0.250 | 3.06 | 3.19 | 0.96 | concrete cone pullout |
| E6-1 | 2VL | 12 | 12.000 | 0.163 | 2.25 | 1.66 | 1.35 | concrete cone pullout |
| E6-2 | 2VL | 12 | 12.000 | 0.163 | 2.30 | 1.66 | 1.38 | concrete cone pullout |
| E7-1 | 2VL | 12 | 12.000 | 0.250 | 2.49 | 1.99 | 1.25 | cone pullout/shear |
| E7-2 | 2VL | 12 | 12.000 | 0.250 | 2.64 | 1.99 | 1.33 | cone pullout/shear |

The plot of experimental shear strength versus predicted shear strength at low slip is presented in Figure 4.32. While there is noticeably more scatter in Figure 4.32 than was present in Figure 4.31, this is considered acceptable due to the amount of data included and the inherent variations in that data. Also, even though not as clear as before, there appears to be an even distribution above and below the *y*=*x* line as expected. It is important to note that the majority of data points falling outside the 15% boundaries denote tests having large screw densities. Since test data has shown that large screw densities do not result in significant increases in shear load, it is justifiable to limit the number of screws that should be placed per rib for each deck type. These limitations are as follows:

- 0.6C deck – no more than one screw per rib
- 1.0C deck – no more than two screws per rib
- 1.5C deck – no more than four screws per rib
- 1.5VL deck – no more than two screws per rib
- 2VL deck – no more than eight screws per rib

By limiting the number of screws allowable per rib, the precision of Eq. 4.7 is enhanced. This is illustrated in Figure 4.33 which plots experimental versus predicted shear strength for all tests excluding those falling outside the screw density limits. It is clear that by limiting the number of screws per rib for each deck profile, there is considerably less scatter in the data. This further supports the use of Eq. 4.7 as a predictor of shear strength at low slip. It should be noted that a multiple linear regression analysis was conducted neglecting data from tests not meeting the screw density restrictions described above and that the resulting equation, when simplified, was the same as shown in Eq. 4.7.

In addition to screw density, there are other limitations to Eq. 4.7. This equation is only applicable when using the 5/16 in. diameter Elco Grade 8 standoff screw embedded at least 1.5 in. above the top of the deck profile and no more than 2.0 in. Also, even though concrete compressive strength was not found to have a significant effect on shear strength at low slip, Eq. 4.7 is limited to configurations having compressive strengths lying within the range of tests contained within this report.

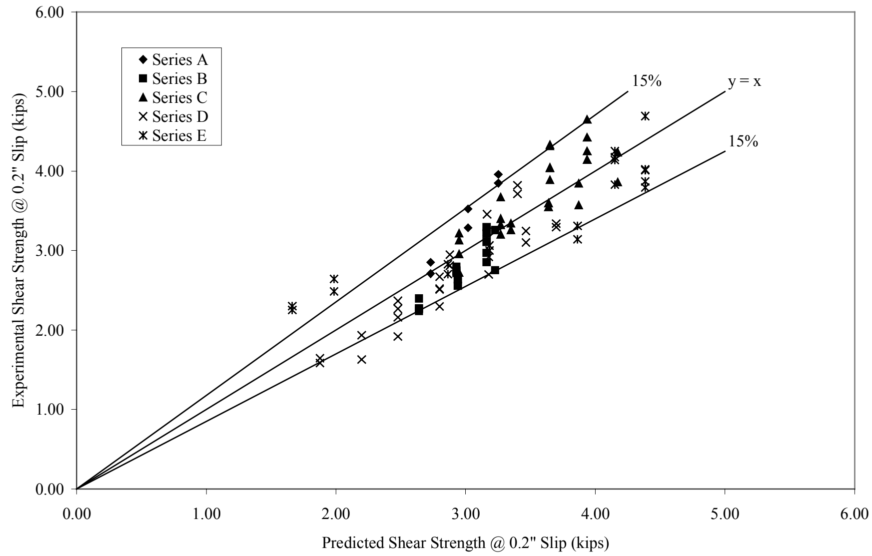



Figure 4.32 Experimental vs. Predicted Shear Strength (using Eq. 4.7)

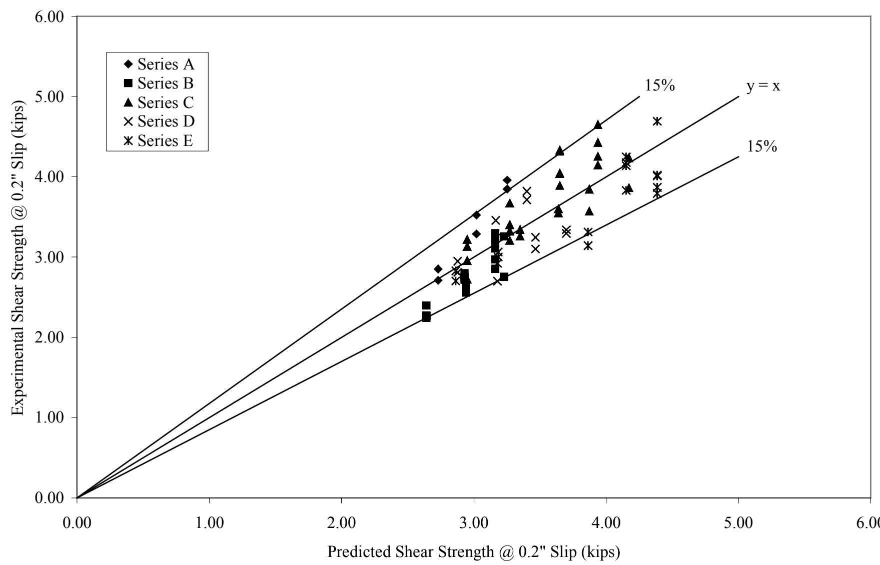



Figure 4.33 Modified Experimental vs. Predicted Shear Strength (using Eq. 4.7)

### 4.4.2 Ultimate Shear Strength of the 5/16 in. Diameter Elco Grade 8 Standoff Screw

While it may not be practical to design for ultimate strength when using the 5/16 in. diameter Elco Grade 8 standoff screw, there are cases where the ultimate strength must be known. The most important of these cases is when ultimate load is reached before 0.2 in. of slip is reached. This occurrence was observed in a few tests contained in this report. In these instances, Eq. 4.7 would not be a predictor of shear load at low slip but one of ultimate strength, for which it is not designed. As a means of predicting the ultimate strength of standoff screws, the shear rupture equation, Eq. 4.1, will be investigated and modified as necessary. Experimental values of ultimate shear load are first compared to the value of 5.76 kips ($0.6A_sF_u$), as discussed in Section 4.1. To evaluate the ability of Eq. 4.1 to predict the ultimate shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw, experimental versus predicted values will be plotted. Since the predicted values will be the same for all tests, the range of values will be the determining criteria for acceptance of this method. As shown in Figure 4.34, a coefficient of 0.6 overestimates ultimate shear strength. From this, other coefficients were investigated until the majority of the data points fell between the 15% boundaries. As shown in Figure 4.35, a coefficient of 0.5 results in the best correlation between experimental and predicted ultimate shear strengths.

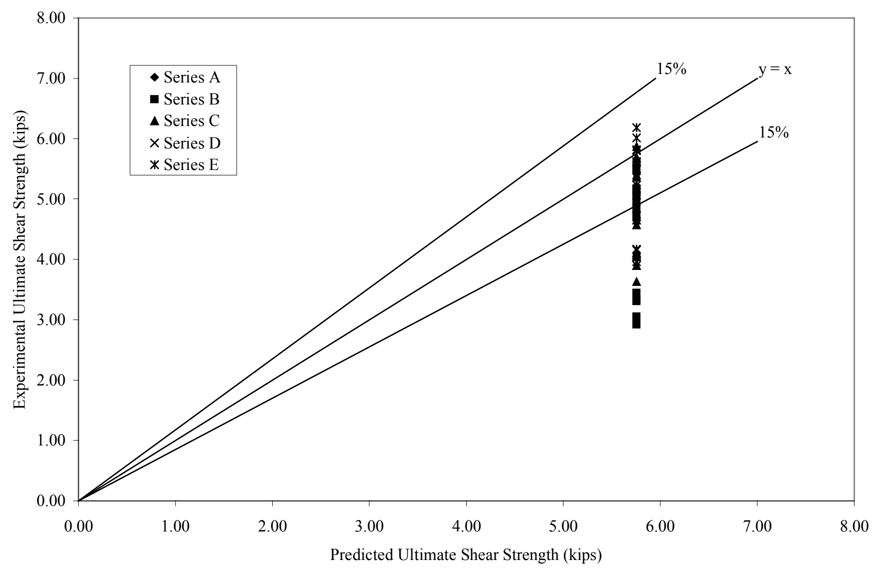



Figure 4.34 Experimental vs. Predicted Ultimate Shear Strength (using Eq. 4.1)

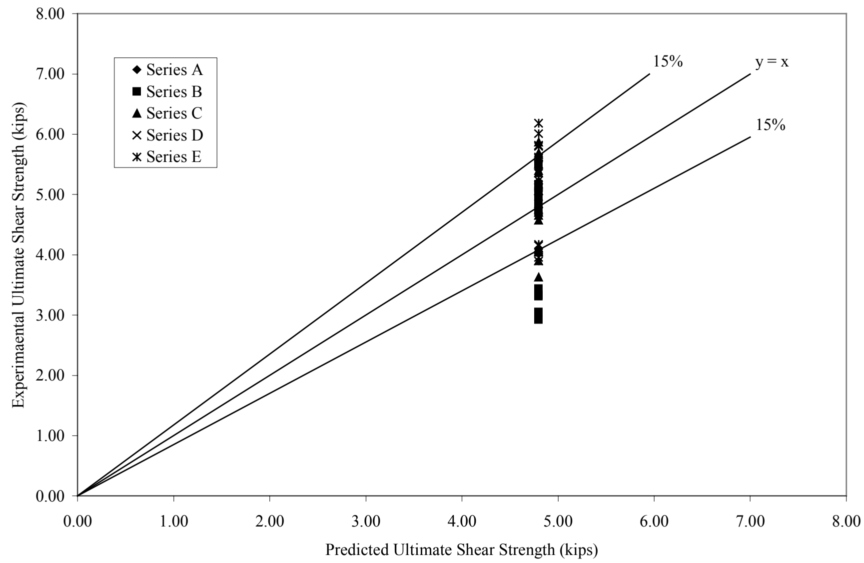



Figure 4.35 Experimental vs. Predicted Ultimate Shear Strength (using Eq. 4.8)

Based on the correlation shown in Figure 4.35, when predicting the ultimate strength of the 5/16 in. diameter Elco Grade 8 standoff screw, the following equation will be used:

$$V_u = 0.5 A_s F_u \qquad (4.8)$$

where:

$V_u$ = ultimate shear strength per screw, kips

$A_s$ = effective tensile area, in.$^2$

$F_u$ = tensile stress, ksi

While Eq. 4.8 is based solely on the ultimate strength of one screw and does not account for any other variables, it is considered acceptable for this application. Also, from test data, it appears that experimental peak shear load per screw values in series B were inconsistent with those from other series for tests of similar configuration. Often, series B tests (1.0C deck) resulted in lower shear load per screw values. While not necessarily the cause for this discrepancy, this group of tests was cured for a significantly longer period than all other tests due to an overlap in research projects. Again, this does not validate these lower screw strengths but is important to take note of. If these tests, series B, are ignored there is clearly less scatter in Figure 4.35.

### 4.4.3 Effects of Concrete Cone Failures on the Strength of Standoff Screws

Concrete cone failures are of special concern. The brittle nature of this type of failure mode is undesirable as opposed to the more ductile failure mode of screw-related failures. For this reason, it is important to be able to predict the susceptibility of a configuration to this failure mode. Due to the inability of existing predictors of concrete cone strength, a new equation must be developed. This new equation will be based on strength per effective rib. An effective rib will be defined as any rib having shear connectors. Data from specimens tested in this study and that of Alander (1998) failing by concrete cone pullout is presented in Table 4.8.

Table 4.8 Summary of Tests Failing by Concrete Cone Pullout

| Test Number | Deck Type | Rib Area (in.$^2$) | Effective Ribs Per Specimen | Screw Height (in.) | Screws Per Rib | Top Chord Thickness (in.) | Concrete f'c (psi) | Peak Shear Load (kips) | Peak Shear Load Per Rib (kips) | Failure Mode |
|---|---|---|---|---|---|---|---|---|---|---|
| C9-1 | 1.5C | 5.813 | 10 | 3 | 4 | 0.163 | 5400 | 136.87 | 13.69 | concrete cone pullout |
| C9-2 | 1.5C | 5.813 | 10 | 3 | 4 | 0.163 | 5400 | 123.17 | 12.32 | concrete cone pullout |
| C10-1 | 1.5C | 5.813 | 10 | 3 | 4 | 0.250 | 5400 | 138.19 | 13.82 | concrete cone pullout |
| C10-2 | 1.5C | 5.813 | 10 | 3 | 4 | 0.250 | 5400 | 149.12 | 14.91 | concrete cone pullout |
| D5-1 | 1.5VL | 3.188 | 10 | 3 | 2 | 0.187 | 5400 | 109.48 | 10.95 | concrete cone pullout |
| D5-2 | 1.5VL | 3.188 | 10 | 3 | 2 | 0.187 | 5400 | 86.43 | 8.64 | concrete cone pullout |
| D6-1 | 1.5VL | 3.188 | 10 | 3 | 2 | 0.250 | 5400 | 82.04 | 8.20 | concrete cone pullout |
| D6-2 | 1.5VL | 3.188 | 10 | 3 | 2 | 0.250 | 5400 | 82.04 | 8.20 | concrete cone pullout |
| D7-1 | 1.5VL | 3.188 | 10 | 3 | 4 | 0.163 | 5400 | 94.72 | 9.47 | concrete cone pullout |
| D7-2 | 1.5VL | 3.188 | 10 | 3 | 4 | 0.163 | 5400 | 86.31 | 8.63 | concrete cone pullout |
| D8-1 | 1.5VL | 3.188 | 10 | 3 | 4 | 0.250 | 5400 | 100.37 | 10.04 | concrete cone pullout |
| D8-2 | 1.5VL | 3.188 | 10 | 3 | 4 | 0.250 | 5400 | 106.84 | 10.68 | concrete cone pullout |
| D9-1 | 1.5VL | 3.188 | 10 | 3 | 4 | 0.163 | 5100 | 76.63 | 7.66 | concrete cone pullout |
| D9-2 | 1.5VL | 3.188 | 10 | 3 | 4 | 0.163 | 5100 | 90.70 | 9.07 | concrete cone pullout |
| D10-1 | 1.5VL | 3.188 | 10 | 3 | 4 | 0.250 | 5100 | 91.90 | 9.19 | concrete cone pullout |
| D10-2 | 1.5VL | 3.188 | 10 | 3 | 4 | 0.250 | 5100 | 100.75 | 10.08 | concrete cone pullout |
| D11-1 | 1.5VL | 3.188 | 10 | 3 | 6 | 0.163 | 5100 | 95.16 | 9.52 | concrete cone pullout |
| D11-2 | 1.5VL | 3.188 | 10 | 3 | 6 | 0.163 | 5100 | 98.43 | 9.84 | concrete cone pullout |
| D12-1 | 1.5VL | 3.188 | 10 | 3 | 6 | 0.250 | 5100 | 97.74 | 9.77 | concrete cone pullout |
| D12-2 | 1.5VL | 3.188 | 10 | 3 | 6 | 0.250 | 5100 | 115.95 | 11.60 | concrete cone pullout |
| E4-1 | 2VL | 12.000 | 4 | 4 | 8 | 0.163 | 5000 | 137.18 | 34.30 | concrete cone pullout |
| E4-2 | 2VL | 12.000 | 4 | 4 | 8 | 0.163 | 5000 | 121.60 | 30.40 | concrete cone pullout |
| E5-1 | 2VL | 12.000 | 4 | 4 | 8 | 0.250 | 4800 | 112.12 | 28.03 | concrete cone pullout |
| E5-2 | 2VL | 12.000 | 4 | 4 | 8 | 0.250 | 4800 | 108.16 | 27.04 | concrete cone pullout |
| E6-1 | 2VL | 12.000 | 4 | 4 | 12 | 0.163 | 4900 | 133.04 | 33.26 | concrete cone pullout |
| E6-2 | 2VL | 12.000 | 4 | 4 | 12 | 0.163 | 4900 | 135.48 | 33.87 | concrete cone pullout |
| E7-1 | 2VL | 12.000 | 4 | 4 | 12 | 0.250 | 3800 | 125.81 | 31.45 | cone pullout/shear |
| E7-2 | 2VL | 12.000 | 4 | 4 | 12 | 0.250 | 3800 | 132.91 | 33.23 | cone pullout/shear |

Even though existing models of concrete cone strength were found to be inaccurate, they will be used as a basis for a new predictive equation. More specifically, the relationship between the effective concrete cone area, $A_{wc}$, and concrete compressive strength will be utilized. The effective concrete cone area, developed by Lloyd and Wright (1990) and illustrated in Figure 1.8, is defined in detail in Section 4.3.2. Lloyd and Wright developed equations for both one and two connector per rib configurations, Eq. 4.2 and Eq. 4.3. While many of the tests failing by concrete cone pullout utilized more than two screws per rib, rendering Lloyd and Wright's equations inapplicable, it is felt that these configurations can be simplified to one having two screws. It is clear from test data presented in Table 4.8 that large screw densities generally do not significantly increase shear strength in tests failing by cone pullout. Also, due to the limitations on screw placement induced by the size of deck ribs and top chords, the resulting effective cone area of a four, or more, screw arrangement would not be significantly greater than that of a two screw arrangement. For these reasons, when calculating effective cone area, all configurations of more than one screw per rib will be generalized to two screws per rib.

Before developing a new equation for predicting capacity in cases of concrete cone failures, a relationship between the independent variables, effective cone area and concrete compressive strength, and the dependent variable, ultimate shear strength per rib, must be established. Based on past studies, the product of effective cone area and the square root of concrete compressive strength, $A_{wc}\sqrt{f'_c}$, was investigated. As illustrated in Figure 4.36, there is a linear relationship between this product and experimental values of shear strength per rib. More data would be necessary to further verify that a truly linear relationship exists. However, based on the data contained within this study, a linear regression analysis can be performed to develop an equation for predicting concrete cone shear strength.

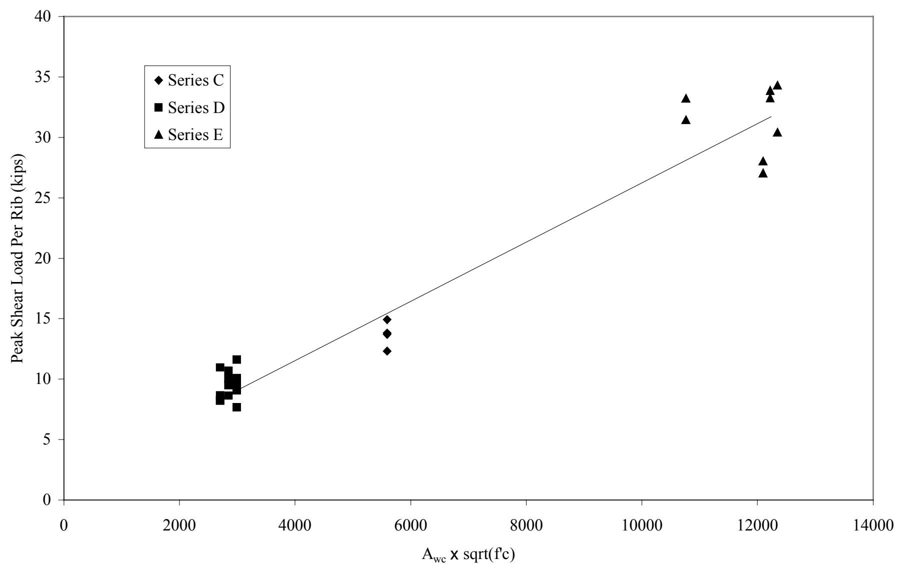



Figure 4.36 Peak Shear Load Per Rib vs. $A_{wc}\sqrt{f'_c}$

Performing a linear regression analysis with the variables discussed above results in the following equation:

$$V_{wc} = 0.0024 A_{wc}\sqrt{f'_c} + 2.16 \qquad (4.9)$$

where:

$V_{wc}$ = shear strength per effective rib, kips

$A_{wc}$ = surface area of wedge shaped tensile concrete pullout cone, in.$^2$

$f'_c$ = concrete compressive strength, psi

The coefficients of correlation, R, and determination, $R^2$, of Eq. 4.9 are 0.98 and 0.96, respectively. This suggests that this is equation is an excellent predictor of cone strength. As done in previous sections, values given by Eq. 4.9 were compared to those obtained experimentally. This comparison is summarized in Table 4.9 and illustrated in Figure 4.37.

Table 4.9 Predicted Concrete Cone Strength (using Eq. 4.9)

| Test Number | Deck Type | Screw Height (in.) | Screws Per Rib | Effective Ribs Per Specimen | Top Chord Thickness (in.) | Concrete f'c (psi) | Area of Tensile Concrete Pullout Cone, $A_{wc}$ (in.$^2$) | Experimental Peak Shear Load (kips) | Experimental Peak Shear Load Per Rib (kips) | Predicted Peak Shear Load Per Rib (kips) | Experimental / Predicted | Failure Mode |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C9-1 | 1.5C | 3 | 4 | 10 | 0.163 | 5400 | 76.09 | 136.87 | 13.69 | 15.58 | 0.88 | concrete cone pullout |
| C9-2 | 1.5C | 3 | 4 | 10 | 0.163 | 5400 | 76.09 | 123.17 | 12.32 | 15.58 | 0.79 | concrete cone pullout |
| C10-1 | 1.5C | 3 | 4 | 10 | 0.250 | 5400 | 76.09 | 138.19 | 13.82 | 15.58 | 0.89 | concrete cone pullout |
| C10-2 | 1.5C | 3 | 4 | 10 | 0.250 | 5400 | 76.09 | 149.12 | 14.91 | 15.58 | 0.96 | concrete cone pullout |
| D5-1 | 1.5VL | 3 | 2 | 10 | 0.187 | 5400 | 36.82 | 109.48 | 10.95 | 8.65 | 1.27 | concrete cone pullout |
| D5-2 | 1.5VL | 3 | 2 | 10 | 0.187 | 5400 | 36.82 | 86.43 | 8.64 | 8.65 | 1.00 | concrete cone pullout |
| D6-1 | 1.5VL | 3 | 2 | 10 | 0.250 | 5400 | 36.82 | 82.04 | 8.20 | 8.65 | 0.95 | concrete cone pullout |
| D6-2 | 1.5VL | 3 | 2 | 10 | 0.250 | 5400 | 36.82 | 82.04 | 8.20 | 8.65 | 0.95 | concrete cone pullout |
| D7-1 | 1.5VL | 3 | 4 | 10 | 0.163 | 5400 | 38.77 | 94.72 | 9.47 | 9.00 | 1.05 | concrete cone pullout |
| D7-2 | 1.5VL | 3 | 4 | 10 | 0.163 | 5400 | 38.77 | 86.31 | 8.63 | 9.00 | 0.96 | concrete cone pullout |
| D8-1 | 1.5VL | 3 | 4 | 10 | 0.250 | 5400 | 38.77 | 100.37 | 10.04 | 9.00 | 1.12 | concrete cone pullout |
| D8-2 | 1.5VL | 3 | 4 | 10 | 0.250 | 5400 | 38.77 | 106.84 | 10.68 | 9.00 | 1.19 | concrete cone pullout |
| D9-1 | 1.5VL | 3 | 4 | 10 | 0.163 | 5100 | 41.89 | 76.63 | 7.66 | 9.34 | 0.82 | concrete cone pullout |
| D9-2 | 1.5VL | 3 | 4 | 10 | 0.163 | 5100 | 41.89 | 90.70 | 9.07 | 9.34 | 0.97 | concrete cone pullout |
| D10-1 | 1.5VL | 3 | 4 | 10 | 0.250 | 5100 | 41.89 | 91.90 | 9.19 | 9.34 | 0.98 | concrete cone pullout |
| D10-2 | 1.5VL | 3 | 4 | 10 | 0.250 | 5100 | 41.89 | 100.75 | 10.08 | 9.34 | 1.08 | concrete cone pullout |
| D11-1 | 1.5VL | 3 | 6 | 10 | 0.163 | 5100 | 41.89 | 95.16 | 9.52 | 9.34 | 1.02 | concrete cone pullout |
| D11-2 | 1.5VL | 3 | 6 | 10 | 0.163 | 5100 | 41.89 | 98.43 | 9.84 | 9.34 | 1.05 | concrete cone pullout |
| D12-1 | 1.5VL | 3 | 6 | 10 | 0.250 | 5100 | 41.89 | 97.74 | 9.77 | 9.34 | 1.05 | concrete cone pullout |
| D12-2 | 1.5VL | 3 | 6 | 10 | 0.250 | 5100 | 41.89 | 115.95 | 11.60 | 9.34 | 1.24 | concrete cone pullout |
| E4-1 | 2VL | 4 | 8 | 4 | 0.163 | 5000 | 174.56 | 137.18 | 34.30 | 31.78 | 1.08 | concrete cone pullout |
| E4-2 | 2VL | 4 | 8 | 4 | 0.163 | 5000 | 174.56 | 121.60 | 30.40 | 31.78 | 0.96 | concrete cone pullout |
| E5-1 | 2VL | 4 | 8 | 4 | 0.250 | 4800 | 174.56 | 112.12 | 28.03 | 31.19 | 0.90 | concrete cone pullout |
| E5-2 | 2VL | 4 | 8 | 4 | 0.250 | 4800 | 174.56 | 108.16 | 27.04 | 31.19 | 0.87 | concrete cone pullout |
| E6-1 | 2VL | 4 | 12 | 4 | 0.163 | 4900 | 174.56 | 133.04 | 33.26 | 31.49 | 1.06 | concrete cone pullout |
| E6-2 | 2VL | 4 | 12 | 4 | 0.163 | 4900 | 174.56 | 135.48 | 33.87 | 31.49 | 1.08 | concrete cone pullout |
| E7-1 | 2VL | 4 | 12 | 4 | 0.250 | 3800 | 174.56 | 125.81 | 31.45 | 27.99 | 1.12 | cone pullout/shear |
| E7-2 | 2VL | 4 | 12 | 4 | 0.250 | 3800 | 174.56 | 132.91 | 33.23 | 27.99 | 1.19 | cone pullout/shear |

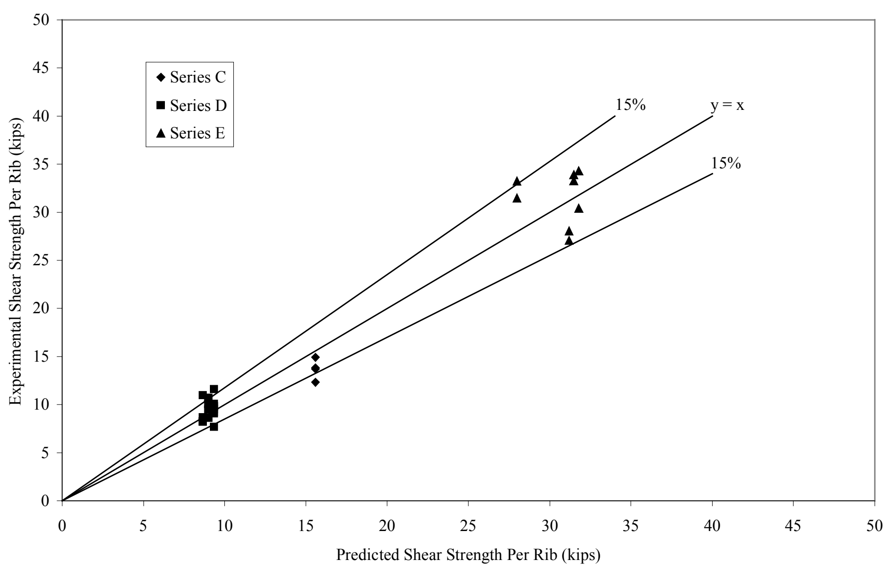



Figure 4.37 Experimental vs. Predicted Shear Strength Per Rib (using Eq. 4.9)

With the majority of data points falling between the 15% boundaries, Figure 4.37 shows that Eq. 4.9 is an acceptable predictor of concrete cone strength. Also, the data is evenly distributed above and below the $y=x$ line. It should be noted that Eq. 4.9 is only valid for predicting concrete cone strength when using the 5/16 in. diameter Elco Grade 8 standoff screw in configurations detailed in this study.

### 4.4.4 Ultimate Shear Strength of Standoff Screws in Solid Slabs

As discussed in Section 4.3.3, the equation developed by the British Steel Construction Institute is an acceptable predictor of the shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw in solid slab configurations when longitudinal spitting is the controlling mode of failure. For cases when screw shear controls, a new approach must be developed. This approach, as used in configurations having steel deck, will be to use the modified shear rupture equation for the 5/16 in. diameter Elco Grade 8 standoff screw, Eq. 4.8. This equation is shown below:

$$V_u = 0.5 A_s F_u \tag{4.8}$$

where:

$V_u$ = ultimate shear strength per screw, kips

$A_s$ = effective tensile area, in.$^2$

$F_u$ = tensile stress, ksi

Predicted values obtained by applying Eq. 4.8 to solid slab tests discussed in Section 4.3.3 were compared to ultimate strengths obtained experimentally. A summary of this comparison is given in Table 4.10. The correlation between experimental and predicted values is also presented graphically in Figure 4.38.

Table 4.10 Predicted Ultimate Shear Strength in Solid Slabs (using Eq. 4.8)

| Test Number | Slab Depth (in.) | Slab Length (in.) | Screw Height (in.) | Total Screws | Concrete $f'_c$ (ksi) | Number of Shear Planes | Experimental Peak Shear Load (kips) | Predicted Peak Shear Load using $0.5A_sF_u$ (kips) | Experimental / Predicted | Failure Mode |
|---|---|---|---|---|---|---|---|---|---|---|
| P7-1 | 3.0 | 36 | 2.5 | 32 | 5.4 | 4 (2 ea. half) | 83.92 | 153.6 | 0.55 | longitudinal splitting |
| P7-2 | 3.0 | 36 | 2.5 | 32 | 5.4 | 4 (2 ea. half) | 77.26 | 153.6 | 0.50 | longitudinal splitting |
| P8-1 | 3.0 | 36 | 2.5 | 32 | 5.4 | 4 (2 ea. half) | 131.72 | 153.6 | 0.86 | longitudinal splitting |
| P8-2 | 3.0 | 36 | 2.5 | 32 | 5.4 | 4 (2 ea. half) | 127.07 | 153.6 | 0.83 | long. split./screw shear |
| P9-1 | 3.0 | 36 | 2.5 | 32 | 5.4 | 4 (2 ea. half) | 204.64 | 153.6 | 1.33 | screw shear |
| P9-2 | 3.0 | 36 | 2.5 | 32 | 5.4 | 4 (2 ea. half) | 204.64 | 153.6 | 1.33 | screw shear |
| P10-1 | 3.0 | 36 | 2.5 | 32 | 3.2 | 4 (2 ea. half) | 231.59 | 153.6 | 1.51 | screw shear |
| P10-2 | 3.0 | 36 | 2.5 | 32 | 3.2 | 4 (2 ea. half) | 233.29 | 153.6 | 1.52 | screw shear |
| F1-1 | 2.5 | 36 | 2.0 | 28 | 3.8 | 4 (2 ea. half) | 190.20 | 134.4 | 1.42 | screw shear |
| F1-2 | 2.5 | 36 | 2.0 | 28 | 3.8 | 4 (2 ea. half) | 181.90 | 134.4 | 1.35 | screw shear |
| F2-1 | 2.5 | 36 | 2.0 | 28 | 3.7 | 4 (2 ea. half) | 213.19 | 134.4 | 1.59 | screw shear |
| F2-2 | 2.5 | 36 | 2.0 | 28 | 3.7 | 4 (2 ea. half) | 204.14 | 134.4 | 1.52 | screw shear |
| F3-1 | 3.0 | 36 | 2.5 | 36 | 3.8 | 4 (2 ea. half) | 252.38 | 172.8 | 1.46 | screw shear |
| F3-2 | 3.0 | 36 | 2.5 | 36 | 3.8 | 4 (2 ea. half) | 223.24 | 172.8 | 1.29 | screw shear |
| F4-1 | 3.0 | 36 | 2.5 | 36 | 5.1 | 4 (2 ea. half) | 216.58 | 172.8 | 1.25 | screw shear |
| F4-2 | 3.0 | 36 | 2.5 | 36 | 5.1 | 4 (2 ea. half) | 202.13 | 172.8 | 1.17 | screw shear |
| F5-1 | 3.5 | 36 | 3.0 | 52 | 5.7 | 4 (2 ea. half) | 300.25 | 249.6 | 1.20 | no failure observed* |
| F5-2 | 3.5 | 36 | 3.0 | 52 | 5.7 | 4 (2 ea. half) | N.A. | N.A. | N.A. | concrete (N.A.) |
| F6-1 | 3.5 | 36 | 3.0 | 52 | 5.6 | 4 (2 ea. half) | 320.60 | 249.6 | 1.28 | screw shear |
| F6-2 | 3.5 | 36 | 3.0 | 52 | 5.6 | 4 (2 ea. half) | 313.56 | 249.6 | 1.26 | screw shear |

* Ultimate load reached before test was stopped

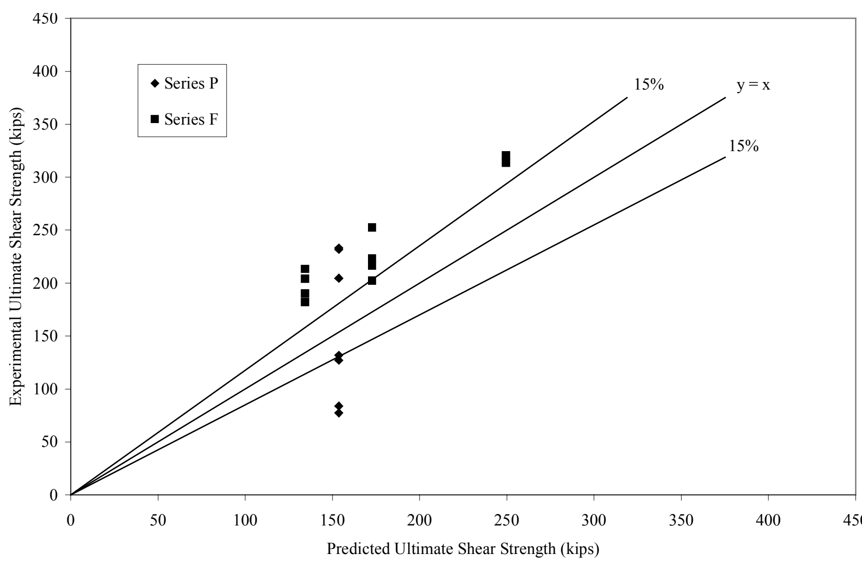



Figure 4.38 Experimental vs. Predicted Ultimate Shear Strength in Solid Slabs (using Eq. 4.8)

Initially, it appears that Eq. 4.8 is not an acceptable predictor of the ultimate shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw in solid slab configurations. However, this is not necessarily the case. First, it should be noted that tests P7 and P8 failed by longitudinal splitting and that Eq. 4.8 is not applicable for these tests. As expected, Eq. 4.8 overestimates shear strength in cases of longitudinal splitting. Therefore, data points representing these tests in Figure 4.38 can be ignored for this discussion. These data points are the only points in Figure 4.38 lying below the $y=x$ reference line. Concentrating on the remaining data, it appears that Eq. 4.8 is a very conservative predictor of ultimate shear strength in solid slab applications. However, the chemical bond and friction that exists between the steel base angle and the concrete slab can easily account for this added shear strength.

It must be reiterated that majority of top chord sections used in solid slab configurations are thicker than those used in specimens formed with steel deck. This is done to more closely model a typical composite joist girder. With the use of top chords having thicker base angles, the gap between the top base angles and the filler plate is increased. This gap, generally 1/8 in., is illustrated in Figure 2.3. Due to the thicker base angles, which generally have longer legs, this gap was measured at up to 3/4 in. for some specimens. Because of the manner in which solid slab specimens are fabricated, discussed in Section 2.2, concrete fills this gap resulting in the formation of a friction key adding to ultimate shear strength. Again, this added shear strength easily accounts for the over-prediction of Eq. 4.8. However, the amount of additional shear strength provided by this friction key can not be known without further testing. In all tests conducted in this study where this key was a factor, at failure, this key sheared off at the plane of the top chords as opposed to simply debonding from the steel section. This sheared off section of concrete is illustrated in Figure 4.39. In this past, sheeting has been placed over this gap prior to pouring concrete to prevent the formation of this key and thereby negating any additive effects. However, this has not been done in tests of similar configuration to those in this study.


Figure 4.39 Typical Fiction Key Observed in Solid Slab Tests

**4.5 Further Evaluation of Proposed Equations for Predicting Ultimate Strength**

In this report, three predictors of ultimate shear strength have been proposed based on different ultimate failure modes: screw shear, concrete cone pullout and longitudinal splitting. These equations are Eq. 4.8, Eq. 4.9 and Eq. 1.8, respectively. While no specimens utilizing steel deck in this study were found to fail by longitudinal splitting, this failure mode must be addressed. In order to further evaluate the ability of these equations to predict ultimate shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw in various configurations, theoretical values given by these equations was used to determine a controlling load. The failure mode corresponding to this controlling load was then compared to that which was obtained experimentally. A summary of this comparison is shown in Table 4.11. The ratio of experimental to predicted ultimate strength is also given. For simplicity, some certain values in Table 4.11 have been generalized. The effects of these generalizations have been deemed nominal.

## Table 4.11 Evaluation of Proposed Predictors of Ultimate Strength

| Test Number* | Slab Depth (in.) | Screw Height (in.) | Screws Per Rib | Total Screws | Effective Ribs Per Specimen | Top Chord Thickness (in.) | $f'_c$ (psi) | Peak Shear Load (kips) | Area of Tensile Concrete Pullout Cone, $A_{wc}$ (in.$^2$) | $A_{cv}$ (in.$^2$) | $A_{sv}$ (in.$^2$) | Predicted Shear Strength (using Eq. 4.8) (kips) | Predicted Shear Strength (using Eq. 4.9) (kips) | Predicted Shear Strength (using Eq. 1.8) (kips) | Experimental Failure Mode | Predicted Failure Mode | Experimental/Predicted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A6-1 | 2.25 | 2 | 1 | 22 | 22 | 0.109 | 5100 | 90.58 | 11.96 | 70.31 | 1.618 | 105.53 | 92.62 | 87.07 | screw pullout | longitudinal splitting | 1.04 |
| A6-2 | 2.25 | 2 | 1 | 22 | 22 | 0.109 | 5100 | 90.58 | 11.96 | 70.31 | 1.618 | 105.53 | 92.62 | 87.07 | screw pullout | longitudinal splitting | 1.04 |
| A7-1 | 2.25 | 2 | 1 | 22 | 22 | 0.187 | 5100 | 114.00 | 11.96 | 70.31 | 1.618 | 105.53 | 92.62 | 87.07 | screw shear | longitudinal splitting | 1.31 |
| A7-2 | 2.25 | 2 | 1 | 22 | 22 | 0.187 | 5100 | 119.03 | 11.96 | 70.31 | 1.618 | 105.53 | 92.62 | 87.07 | screw shear | longitudinal splitting | 1.37 |
| A8-1 | 2.25 | 2 | 1 | 22 | 22 | 0.250 | 5100 | 111.36 | 11.96 | 70.31 | 1.618 | 105.53 | 92.62 | 87.07 | screw shear | longitudinal splitting | 1.28 |
| A8-2 | 2.25 | 2 | 1 | 22 | 22 | 0.250 | 5100 | 114.76 | 11.96 | 70.31 | 1.618 | 105.53 | 92.62 | 87.07 | screw shear | longitudinal splitting | 1.32 |
| B12-1 | 2.75 | 2.5 | 1 | 16 | 16 | 0.109 | 6600 | 57.29 | 24.09 | 99.00 | 1.973 | 76.75 | 109.71 | 114.27 | screw pullout | screw shear | 0.75 |
| B12-2 | 2.75 | 2.5 | 1 | 16 | 16 | 0.109 | 6600 | 65.45 | 24.09 | 99.00 | 1.973 | 76.75 | 109.71 | 114.27 | screw pullout | screw shear | 0.85 |
| B13-1 | 2.75 | 2.5 | 1 | 16 | 16 | 0.187 | 7000 | 88.25 | 24.09 | 99.00 | 1.973 | 76.75 | 111.96 | 115.76 | screw shear | screw shear | 1.15 |
| B13-2 | 2.75 | 2.5 | 1 | 16 | 16 | 0.187 | 7000 | 77.95 | 24.09 | 99.00 | 1.973 | 76.75 | 111.96 | 115.76 | screw shear | screw shear | 1.02 |
| B14-1 | 2.75 | 2.5 | 2 | 32 | 16 | 0.109 | 6500 | 116.45 | 31.24 | 99.00 | 2.561 | 153.49 | 131.28 | 140.66 | screw pullout | concrete cone pullout | 0.89 |
| B14-2 | 2.75 | 2.5 | 2 | 32 | 16 | 0.109 | 6500 | 118.40 | 31.24 | 99.00 | 2.561 | 153.49 | 131.28 | 140.66 | screw pullout | concrete cone pullout | 0.90 |
| B14R-1 | 2.75 | 2.5 | 2 | 32 | 16 | 0.109 | 5900 | 119.84 | 31.24 | 99.00 | 2.561 | 153.49 | 126.70 | 138.43 | screw pullout | concrete cone pullout | 0.95 |
| B14R-2 | 2.75 | 2.5 | 2 | 32 | 16 | 0.109 | 5900 | 118.59 | 31.24 | 99.00 | 2.561 | 153.49 | 126.70 | 138.43 | screw pullout | concrete cone pullout | 0.94 |
| B15-1 | 2.75 | 2.5 | 2 | 32 | 16 | 0.187 | 6700 | 151.57 | 34.30 | 99.00 | 3.345 | 153.49 | 142.37 | 177.07 | screw shear | concrete cone pullout | 1.06 |
| B15-2 | 2.75 | 2.5 | 2 | 32 | 16 | 0.187 | 6700 | 160.17 | 34.30 | 99.00 | 3.345 | 153.49 | 142.37 | 177.07 | screw shear | concrete cone pullout | 1.13 |
| B15R-1 | 3.00 | 2.5 | 2 | 32 | 16 | 0.187 | 5500 | 165.45 | 34.30 | 108.00 | 3.345 | 153.49 | 132.24 | 174.47 | screw shear | concrete cone pullout | 1.25 |
| B15R-2 | 3.00 | 2.5 | 2 | 32 | 16 | 0.187 | 5500 | 163.44 | 34.30 | 108.00 | 3.345 | 153.49 | 132.24 | 174.47 | screw shear | concrete cone pullout | 1.24 |
| B16-1 | 2.75 | 2.5 | 2 | 32 | 16 | 0.250 | 7300 | 106.03 | 34.30 | 99.00 | 3.345 | 153.49 | 147.09 | 179.30 | screw shear | concrete cone pullout | 0.72 |
| B16-2 | 2.75 | 2.5 | 2 | 32 | 16 | 0.250 | 7300 | 109.98 | 34.30 | 99.00 | 3.345 | 153.49 | 147.09 | 179.30 | screw shear | concrete cone pullout | 0.75 |
| B16R-1 | 3.00 | 2.5 | 2 | 32 | 16 | 0.250 | 5500 | 106.53 | 34.30 | 108.00 | 3.345 | 153.49 | 132.24 | 174.47 | screw shear | concrete cone pullout | 0.81 |
| B16R-2 | 3.00 | 2.5 | 2 | 32 | 16 | 0.250 | 5500 | 97.49 | 34.30 | 108.00 | 3.345 | 153.49 | 132.24 | 174.47 | screw shear | concrete cone pullout | 0.74 |
| B16R-3 | 3.00 | 2.5 | 2 | 32 | 16 | 0.250 | 5500 | 93.47 | 34.30 | 108.00 | 3.345 | 153.49 | 132.24 | 174.47 | screw shear | concrete cone pullout | 0.71 |

* See Chapter 2 for deck types

Table 4.11 Evaluation of Proposed Predictors of Ultimate Strength (cont'd)

| Test Number* | Slab Depth (in.) | Screw Height (in.) | Screws Per Rib | Total Screws | Effective Ribs Per Specimen | Top Chord Thickness (in.) | $f'_c$ (psi) | Peak Shear Load (kips) | Area of Tensile Concrete Pullout Cone, $A_{wc}$ (in.$^2$) | $A_{cv}$ (in.$^2$) | $A_{sv}$ (in.$^2$) | Predicted Shear Strength (using Eq. 4.8) (kips) | Predicted Shear Strength (using Eq. 4.9) (kips) | Predicted Shear Strength (using Eq. 1.8) (kips) | Experimental Failure Mode | Predicted Failure Mode | Experimental / Predicted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C1-1 | 3.25 | 3 | 1 | 10 | 10 | 0.109 | 5800 | 40.45 | 60.48 | 117.00 | 2.423 | 47.97 | 132.14 | 135.69 | screw shear | screw shear | 0.84 |
| C1-2 | 3.25 | 3 | 1 | 10 | 10 | 0.109 | 5800 | 40.39 | 60.48 | 117.00 | 2.423 | 47.97 | 132.14 | 135.69 | screw shear | screw shear | 0.84 |
| C1R-1 | 3.25 | 3 | 1 | 10 | 10 | 0.109 | 4100 | 54.02 | 60.48 | 104.00 | 2.423 | 47.97 | 114.54 | 126.24 | screw shear | screw shear | 1.13 |
| C1R-2 | 3.25 | 3 | 1 | 10 | 10 | 0.109 | 4100 | 46.48 | 60.48 | 104.00 | 2.423 | 47.97 | 114.54 | 126.24 | screw shear | screw shear | 0.97 |
| C1R-3 | 3.25 | 3 | 1 | 10 | 10 | 0.109 | 4100 | 50.63 | 60.48 | 104.00 | 2.423 | 47.97 | 114.54 | 126.24 | screw shear | screw shear | 1.06 |
| C2-1 | 3.25 | 3 | 1 | 10 | 10 | 0.187 | 5800 | 51.63 | 60.48 | 117.00 | 2.423 | 47.97 | 132.14 | 135.69 | screw shear | screw shear | 1.08 |
| C2-2 | 3.25 | 3 | 1 | 10 | 10 | 0.187 | 5800 | 53.58 | 60.48 | 117.00 | 2.423 | 47.97 | 132.14 | 135.69 | screw shear | screw shear | 1.12 |
| C2R-1 | 3.25 | 3 | 1 | 10 | 10 | 0.187 | 4100 | 58.67 | 60.48 | 104.00 | 2.423 | 47.97 | 114.54 | 126.24 | screw shear | screw shear | 1.22 |
| C2R-2 | 3.25 | 3 | 1 | 10 | 10 | 0.187 | 4100 | 56.91 | 60.48 | 104.00 | 2.423 | 47.97 | 114.54 | 126.24 | screw shear | screw shear | 1.19 |
| C3-1 | 3.25 | 3 | 1 | 10 | 10 | 0.250 | 4300 | 46.98 | 60.48 | 117.00 | 2.423 | 47.97 | 116.78 | 129.11 | screw shear | screw shear | 0.98 |
| C3-2 | 3.25 | 3 | 1 | 10 | 10 | 0.250 | 4300 | 41.08 | 60.48 | 117.00 | 2.423 | 47.97 | 116.78 | 129.11 | screw shear | screw shear | 0.86 |
| C4-1 | 3.25 | 3 | 2 | 20 | 10 | 0.109 | 4300 | 84.86 | 69.59 | 117.00 | 2.423 | 95.93 | 131.12 | 129.11 | screw shear/pullout | screw shear | 0.88 |
| C4-2 | 3.25 | 3 | 2 | 20 | 10 | 0.109 | 4300 | 91.33 | 69.59 | 117.00 | 2.423 | 95.93 | 131.12 | 129.11 | screw pullout | screw shear | 0.95 |
| C5-1 | 3.25 | 3 | 2 | 20 | 10 | 0.187 | 4300 | 109.98 | 73.49 | 117.00 | 2.423 | 95.93 | 137.26 | 129.11 | screw shear/cone pullout | screw shear | 1.15 |
| C5-2 | 3.25 | 3 | 2 | 20 | 10 | 0.187 | 4300 | 113.19 | 73.49 | 117.00 | 2.423 | 95.93 | 137.26 | 129.11 | screw shear/cone pullout | screw shear | 1.18 |
| C6-1 | 3.25 | 3 | 2 | 20 | 10 | 0.250 | 4300 | 91.33 | 73.49 | 117.00 | 2.423 | 95.93 | 137.26 | 129.11 | screw shear/cone pullout | screw shear | 0.95 |
| C6-2 | 3.25 | 3 | 2 | 20 | 10 | 0.250 | 4300 | 82.10 | 73.49 | 117.00 | 2.423 | 95.93 | 137.26 | 129.11 | screw shear | screw shear | 0.86 |
| C7-1 | 3.75 | 3.5 | 4 | 40 | 10 | 0.163 | 4300 | 156.15 | 79.28 | 135.00 | 2.865 | 191.86 | 146.37 | 152.13 | screw shear/cone pullout | concrete cone pullout | 1.07 |
| C7-2 | 3.75 | 3.5 | 4 | 40 | 10 | 0.163 | 4300 | 189.94 | 79.28 | 135.00 | 2.865 | 191.86 | 146.37 | 152.13 | screw shear | concrete cone pullout | 1.30 |
| C8-1 | 3.75 | 3.5 | 4 | 40 | 10 | 0.250 | 3900 | 163.25 | 79.28 | 135.00 | 2.865 | 191.86 | 140.42 | 150.10 | screw shear | concrete cone pullout | 1.16 |
| C8-2 | 3.75 | 3.5 | 4 | 40 | 10 | 0.250 | 3900 | 145.35 | 79.28 | 135.00 | 2.865 | 191.86 | 140.42 | 150.10 | screw shear | concrete cone pullout | 1.04 |
| C9-1 | 3.50 | 3 | 4 | 40 | 10 | 0.163 | 5400 | 136.87 | 76.09 | 126.00 | 2.815 | 191.86 | 155.79 | 153.60 | concrete cone pullout | longitudinal splitting | 0.89 |
| C9-2 | 3.50 | 3 | 4 | 40 | 10 | 0.163 | 5400 | 123.17 | 76.09 | 126.00 | 2.815 | 191.86 | 155.79 | 153.60 | concrete cone pullout | longitudinal splitting | 0.80 |
| C10-1 | 3.50 | 3 | 4 | 40 | 10 | 0.250 | 5400 | 138.19 | 76.09 | 126.00 | 2.815 | 191.86 | 155.79 | 153.60 | concrete cone pullout | longitudinal splitting | 0.90 |
| C10-2 | 3.50 | 3 | 4 | 40 | 10 | 0.250 | 5400 | 149.12 | 76.09 | 126.00 | 2.815 | 191.86 | 155.79 | 153.60 | concrete cone pullout | longitudinal splitting | 0.97 |

* See Chapter 2 for deck types

Table 4.11 Evaluation of Proposed Predictors of Ultimate Strength (cont'd)

| Test Number* | Slab Depth (in.) | Screw Height (in.) | Screws Per Rib | Total Screws | Effective Ribs Per Specimen | Top Chord Thickness (in.) | $f'_c$ (psi) | Peak Shear Load (kips) | Area of Tensile Concrete Pullout Cone, $A_{wc}$ (in.$^2$) | $A_{cv}$ (in.$^2$) | $A_{sv}$ (in.$^2$) | Predicted Shear Strength (using Eq. 4.8) (kips) | Predicted Shear Strength (using Eq. 4.9) (kips) | Predicted Shear Strength (using Eq. 1.8) (kips) | Experimental Failure Mode | Predicted Failure Mode | Experimental / Predicted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D1-1 | 3.25 | 3 | 1 | 10 | 10 | 0.109 | 3600 | 40.89 | 27.05 | 117.00 | 2.407 | 47.97 | 60.55 | 125.31 | screw pullout | screw shear | 0.85 |
| D1-2 | 3.25 | 3 | 1 | 10 | 10 | 0.109 | 3600 | 38.82 | 27.05 | 117.00 | 2.407 | 47.97 | 60.55 | 125.31 | screw pullout | screw shear | 0.81 |
| D2-1 | 3.25 | 3 | 1 | 10 | 10 | 0.187 | 3600 | 58.04 | 27.05 | 117.00 | 2.407 | 47.97 | 60.55 | 125.31 | screw shear | screw shear | 1.21 |
| D2-2 | 3.25 | 3 | 1 | 10 | 10 | 0.187 | 3600 | 55.10 | 27.05 | 117.00 | 2.407 | 47.97 | 60.55 | 125.31 | screw shear | screw shear | 1.15 |
| D3-1 | 3.25 | 3 | 1 | 10 | 10 | 0.250 | 3600 | 47.23 | 27.05 | 117.00 | 2.407 | 47.97 | 60.55 | 125.31 | screw shear | screw shear | 0.98 |
| D3-2 | 3.25 | 3 | 1 | 10 | 10 | 0.250 | 3600 | 56.16 | 27.05 | 117.00 | 2.407 | 47.97 | 60.55 | 125.31 | screw shear | screw shear | 1.17 |
| D4-1 | 3.25 | 3 | 2 | 20 | 10 | 0.109 | 3600 | 82.35 | 33.89 | 117.00 | 2.407 | 95.93 | 70.40 | 125.31 | screw pullout | concrete cone pullout | 1.17 |
| D4-2 | 3.25 | 3 | 2 | 20 | 10 | 0.109 | 3600 | 79.65 | 33.89 | 117.00 | 2.407 | 95.93 | 70.40 | 125.31 | screw pullout | concrete cone pullout | 1.13 |
| D5-1 | 3.25 | 3 | 2 | 20 | 10 | 0.187 | 5400 | 109.48 | 36.82 | 117.00 | 2.407 | 95.93 | 86.54 | 133.21 | concrete cone pullout | concrete cone pullout | 1.27 |
| D5-2 | 3.25 | 3 | 2 | 20 | 10 | 0.187 | 5400 | 86.43 | 36.82 | 117.00 | 2.407 | 95.93 | 86.54 | 133.21 | concrete cone pullout | concrete cone pullout | 1.00 |
| D6-1 | 3.25 | 3 | 2 | 20 | 10 | 0.250 | 5400 | 82.04 | 36.82 | 117.00 | 2.407 | 95.93 | 86.54 | 133.21 | concrete cone pullout | concrete cone pullout | 0.95 |
| D6-2 | 3.25 | 3 | 2 | 20 | 10 | 0.250 | 5400 | 82.04 | 36.82 | 117.00 | 2.407 | 95.93 | 86.54 | 133.21 | concrete cone pullout | concrete cone pullout | 0.95 |
| D7-1 | 3.75 | 3 | 4 | 40 | 10 | 0.163 | 5400 | 94.72 | 38.77 | 135.00 | 2.815 | 191.86 | 89.98 | 155.42 | concrete cone pullout | concrete cone pullout | 1.05 |
| D7-2 | 3.75 | 3 | 4 | 40 | 10 | 0.163 | 5400 | 86.31 | 38.77 | 135.00 | 2.815 | 191.86 | 89.98 | 155.42 | concrete cone pullout | concrete cone pullout | 0.96 |
| D8-1 | 3.75 | 3 | 4 | 40 | 10 | 0.250 | 5400 | 100.37 | 38.77 | 135.00 | 2.815 | 191.86 | 89.98 | 155.42 | concrete cone pullout | concrete cone pullout | 1.12 |
| D8-2 | 3.75 | 3 | 4 | 40 | 10 | 0.250 | 5400 | 106.84 | 38.77 | 135.00 | 2.815 | 191.86 | 89.98 | 155.42 | concrete cone pullout | concrete cone pullout | 1.19 |
| D9-1 | 3.75 | 3 | 4 | 40 | 10 | 0.163 | 5100 | 76.63 | 41.89 | 135.00 | 2.815 | 191.86 | 93.40 | 153.90 | concrete cone pullout | concrete cone pullout | 0.82 |
| D9-2 | 3.75 | 3 | 4 | 40 | 10 | 0.163 | 5100 | 90.70 | 41.89 | 135.00 | 2.815 | 191.86 | 93.40 | 153.90 | concrete cone pullout | concrete cone pullout | 0.97 |
| D10-1 | 3.75 | 3 | 6 | 60 | 10 | 0.250 | 5100 | 91.90 | 41.89 | 135.00 | 2.815 | 287.80 | 93.40 | 153.90 | concrete cone pullout | concrete cone pullout | 0.98 |
| D10-2 | 3.75 | 3 | 6 | 60 | 10 | 0.250 | 5100 | 100.75 | 41.89 | 135.00 | 2.815 | 287.80 | 93.40 | 153.90 | concrete cone pullout | concrete cone pullout | 1.08 |
| D11-1 | 3.75 | 3 | 6 | 60 | 10 | 0.136 | 5100 | 95.16 | 41.89 | 135.00 | 3.599 | 287.80 | 93.40 | 189.57 | concrete cone pullout | concrete cone pullout | 1.02 |
| D11-2 | 3.75 | 3 | 6 | 60 | 10 | 0.163 | 5100 | 98.43 | 41.89 | 135.00 | 3.599 | 287.80 | 93.40 | 189.57 | concrete cone pullout | concrete cone pullout | 1.05 |
| D12-1 | 3.75 | 3 | 6 | 60 | 10 | 0.250 | 5100 | 97.74 | 41.89 | 135.00 | 3.599 | 287.80 | 93.40 | 189.57 | concrete cone pullout | concrete cone pullout | 1.05 |
| D12-2 | 3.75 | 3 | 6 | 60 | 10 | 0.250 | 5100 | 115.95 | 41.89 | 135.00 | 3.599 | 287.80 | 93.40 | 189.57 | concrete cone pullout | concrete cone pullout | 1.24 |

* See Chapter 2 for deck types

Table 4.11 Evaluation of Proposed Predictors of Ultimate Strength (cont'd)

| Test Number* | Slab Depth (in.) | Screw Height (in.) | Screws Per Rib | Total Screws | Effective Ribs Per Specimen | Top Chord Thickness (in.) | $f'_c$ (psi) | Peak Shear Load (kips) | Area of Tensile Concrete Pullout Cone, $A_{wc}$ (in.$^2$) | $A_{cv}$ (in.$^2$) | $A_{sv}$ (in.$^2$) | Predicted Shear Strength (using Eq. 4.8) (kips) | Predicted Shear Strength (using Eq. 4.9) (kips) | Predicted Shear Strength (using Eq. 1.8) (kips) | Experimental Failure Mode | Predicted Failure Mode | Experimental / Predicted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E1-1 | 4.25 | 4 | 4 | 16 | 4 | 0.109 | 7400 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | top chord buckling | N.A. | N.A. |
| E1-2 | 4.25 | 4 | 4 | 16 | 4 | 0.109 | 7400 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | top chord buckling | N.A. | N.A. |
| E1R-1 | 4.25 | 4 | 4 | 16 | 4 | 0.109 | 4700 | 63.32 | 60.48 | 153.00 | 2.497 | 76.75 | 158.03 | 140.58 | screw shear | screw shear | 0.83 |
| E1R-2 | 4.25 | 4 | 4 | 16 | 4 | 0.109 | 4700 | 62.44 | 60.48 | 153.00 | 2.497 | 76.75 | 158.03 | 140.58 | screw shear | screw shear | 0.81 |
| E2-1 | 4.25 | 4 | 4 | 16 | 4 | 0.187 | 7200 | 96.23 | 60.48 | 153.00 | 2.497 | 76.75 | 164.08 | 154.92 | screw shear | screw shear | 1.25 |
| E2-2 | 4.25 | 4 | 4 | 16 | 4 | 0.187 | 7200 | 98.81 | 60.48 | 153.00 | 2.497 | 76.75 | 164.08 | 154.92 | screw shear | screw shear | 1.29 |
| E2R-1 | 4.25 | 4 | 4 | 16 | 4 | 0.187 | 5000 | 93.09 | 60.48 | 153.00 | 2.497 | 76.75 | 164.08 | 142.30 | screw shear | screw shear | 1.21 |
| E2R-2 | 4.25 | 4 | 4 | 16 | 4 | 0.187 | 5000 | 89.70 | 60.48 | 153.00 | 2.497 | 76.75 | 164.08 | 142.30 | screw shear | screw shear | 1.17 |
| E3-1 | 4.25 | 4 | 4 | 16 | 4 | 0.250 | 7200 | 66.39 | 60.48 | 153.00 | 2.497 | 76.75 | 168.11 | 154.92 | screw shear | screw shear | 0.87 |
| E3-2 | 4.25 | 4 | 4 | 16 | 4 | 0.250 | 7200 | 77.64 | 60.48 | 153.00 | 2.497 | 76.75 | 168.11 | 154.92 | screw shear | screw shear | 1.01 |
| E3R-1 | 4.25 | 4 | 4 | 16 | 4 | 0.250 | 5000 | 66.71 | 60.48 | 153.00 | 2.497 | 76.75 | 168.11 | 142.30 | screw shear | screw shear | 0.87 |
| E3R-2 | 4.25 | 4 | 4 | 16 | 4 | 0.250 | 5000 | 83.67 | 69.59 | 153.00 | 2.497 | 76.75 | 168.11 | 142.30 | screw shear | screw shear | 1.09 |
| E3R-3 | 4.25 | 4 | 4 | 16 | 4 | 0.250 | 5000 | 81.03 | 69.59 | 153.00 | 2.497 | 76.75 | 168.11 | 142.30 | screw shear | screw shear | 1.06 |
| E4-1 | 4.25 | 4 | 8 | 32 | 4 | 0.163 | 5000 | 137.18 | 73.49 | 153.00 | 2.497 | 153.49 | 174.56 | 142.30 | concrete cone pullout | concrete cone pullout | 0.96 |
| E4-2 | 4.25 | 4 | 8 | 32 | 4 | 0.163 | 5000 | 121.60 | 73.49 | 153.00 | 2.497 | 153.49 | 174.56 | 142.30 | concrete cone pullout | concrete cone pullout | 0.85 |
| E5-1 | 4.25 | 4 | 8 | 32 | 4 | 0.250 | 4800 | 112.12 | 73.49 | 153.00 | 2.497 | 153.49 | 174.56 | 141.15 | concrete cone pullout | concrete cone pullout | 0.79 |
| E5-2 | 4.25 | 4 | 8 | 32 | 4 | 0.250 | 4800 | 108.16 | 73.49 | 153.00 | 2.497 | 153.49 | 174.56 | 141.15 | concrete cone pullout | concrete cone pullout | 0.77 |
| E6-1 | 4.50 | 4 | 12 | 48 | 4 | 0.163 | 4900 | 133.04 | 79.28 | 162.00 | 3.281 | 230.24 | 174.56 | 179.05 | concrete cone pullout | concrete cone pullout | 0.76 |
| E6-2 | 4.50 | 4 | 12 | 48 | 4 | 0.163 | 4900 | 135.48 | 79.28 | 162.00 | 3.281 | 230.24 | 174.56 | 179.05 | concrete cone pullout | concrete cone pullout | 0.78 |
| E7-1 | 4.50 | 4 | 12 | 48 | 4 | 0.250 | 3800 | 125.81 | 79.28 | 162.00 | 3.281 | 230.24 | 174.56 | 172.37 | cone pullout/shear | concrete cone pullout | 0.73 |
| E7-2 | 4.50 | 4 | 12 | 48 | 4 | 0.250 | 3800 | 132.91 | 79.28 | 162.00 | 3.281 | 230.24 | 174.56 | 172.37 | cone pullout/shear | concrete cone pullout | 0.77 |

* See Chapter 2 for deck types

In evaluating the validity of these equations it is important to look at more than merely which failure mode is predicted. For instance, even though all tests in Table 4.11 contained sufficient lateral reinforcement, longitudinal splitting was calculated as the controlling mode of failure for all tests in series A. Also, the actual failure mode observed in these tests was that of screw pullout/shear while this failure mode was calculated as being the least controlling. It is felt that the shallow deck ribs of the Vulcraft 0.6C deck in conjunction with the slab thicknesses tested in this series are accountable for these discrepancies. This potential effect of shallow deck ribs is also noted in series B tests which utilized Vulcraft 1.0C deck. In series B the majority of tests were found to theoretically be susceptible to a concrete cone pullout failure. However, as is series A, no concrete cone pullout failures were observed in series B tests. Again, this is felt to be due to the deck geometry used in these series.

Although not proven, embedment depth may also be a contributing factor. While it has been shown that an embedment depth of at least 1.5 in. above the top of the deck profile is ideal, this amount of embedment in shallow deck profiles may have a greater influence on failure mode, and in turn, ultimate strength, than in other deck profiles. In all test series excluding series A and series B, screws were equally embedded both in the deck rib as well as above the top of the deck profile. For example, in series D (1.5VL deck), a 3 in. screw height was used. Therefore, half of the screw was embedded in the deck rib while the other half extended into the slab. However, in series A and series B, due to the screw heights used, more of the screw shank was embedded in the slab than the deck rib. This is believed effect the failure modes in these tests. As was proven by tests C7-C10, by increasing screw embedment, failure modes were effected leading to changes in ultimate strength. In the case of series B, the majority of tests are predicted to fail by concrete cone pullout, however, due to more of the screw shank being embedded in the slab than in the deck rib, a screw shear failure is actually realized. Again, this is a theory that has been extrapolated from the results of another series. Tests would have to been conducted to prove that this is, in fact, what occurs.

There appears to be a strong correlation between predicted and experimental load cases with the exception of tests C9 and C10 in which longitudinal splitting is predicted. However, the difference between the predicted concrete cone pullout load, the actual failure mode observed, and the predicted splitting load is less than a kip. Since it is not practical to predict ultimate loads with the precision shown in Table 4.11, this difference irrelevant and it can be said that the ultimate failure is accurately predicted. It is clear in series C that there is an overlap of failure modes in some tests. Since it is impossible to observe what occurs within a specimen during testing, in cases where combinations of failure modes are noted, it is often unknown which failure mode was primary. Also, the process by which specimens are disassembled for documentation can often be damaging making it difficult to know what occurred during the test and what was a result of disassembling the specimen.

Results in series D and series E are similar to those observed in series C. There is a strong correlation between the predicted and experimental controlling load case, even more so than was observed in series C. The results presented in Table 4.11 validate the use of these proposed equations to predict ultimate failure modes. However, as stated before, the ability to predict the ultimate load itself is much more important. Referring to the ratio of experimental peak shear load to predicted presented in Table 4.11, it can be seen that these predictors are not always acceptable. With the exception of series A, where predicted values are very conservative, there appears to be a mix within each series of conservative and unconservative predictions. As of August 1998, an in depth analytical study is underway at Virginia Tech on the performance of the 5/16 in. diameter Elco Grade 8 standoff screw, part of which will include the further evaluation of the predictive equations proposed in this study.

# CHAPTER 5
# SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Summary

Test data and results from 59 pushout tests conducted to further evaluate the performance of 5/16 in. diameter Elco Grade 8 standoff screws, as well as subsequent analysis, are presented in this report. This study is a direct continuation of research performed by Alander (1998). Selected test data from Alander's study was used in conjunction with results gathered in this study in performing various analyses. Findings are intended to supplement previous research performed by Alander (1998), Hankins (1994) and Lauer (1994) at Virginia Tech.

Tests in this study utilized standoff screws varying in length from 2.5 in. to 4 in. Screws were placed in steel sections fabricated from equal-leg double angles designed to simulate the top chord of a typical steel joist. The angle thicknesses of these top chord sections ranged from 0.109 in. to 0.375 in. These double angle sections were separated by a 0.5 in. or 1 in. filler plate depending on the configuration. Tests were performed using different types of steel deck. Solid slab tests were also conducted.

Four series of tests were performed on the 5/16 in. diameter Elco Grade 8 standoff screw: series B, series C, series E and series F. Both series B and series C were originally conducted by Alander (1998), who conducted tests comprising series A through D, and tests performed in this study are either continuations of these series or retests of specimens in those series. Retests were deemed necessary in cases where test data from specimens of the same configuration did not agree with acceptable accuracy. Concrete strengths falling outside the targeted range of 3-5 ksi for test groups also warranted retests. Each of the test series conducted in this study utilized a different deck type. Series B tests were formed with Vulcraft 1.0C deck, series C tests used Vulcraft

1.5C deck and series E tests utilized Vulcraft 2VL deck. Series F investigated screw performance in solid slab configurations. Various screw densities and arrangements were investigated within each series and sufficient steel reinforcement was used to resist longitudinal splitting. This reinforcement was supplied by No. 4 reinforcing bars used in conjunction with varying sizes of welded wire fabric for control of temperature and shrinkage effects. Specimen configurations for tests performed by Alander can be found in Standoff Screws Used in Composite Joists (Alander, et al 1998a).

Analysis of the test data gathered in this study as well as selected data from Alander's study, consisted of evaluating the applicability of existing predictive equations; examining the effects of various test parameters on shear strength for various screw configurations; developing new predictive equations, or procedures, when necessary; and evaluating the ability of these new equations to predict the shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw. Equations were developed to predict ultimate shear strength as well as shear strength at low slip. These equations are based on predicting shear strength in cases where failure modes of screw shear, concrete cone pullout and longitudinal splitting control.

**5.2 Conclusions**

Based on the results from the pushout tests investigated in this study as well as analysis performed on these results, several conclusions can be drawn regarding the performance of the 5/16 in. diameter Elco Grade 8 standoff screw:

1. The 5/16 in. diameter Elco Grade 8 standoff screw is a viable alternative to conventional means of shear connection in short-span composite joists.
2. By sufficiently reinforcing slabs against longitudinal splitting, greater shear loads per screw can be realized. In the few cases where similar configurations were investigated with and without transverse reinforcement, results consistently showed an increase in shear strength per screw for sufficiently reinforced specimens. The amount of this increase varied depending on the specific configuration. One major observation in these tests was the reduction in average slip. By reinforcing slabs

against longitudinal splitting, screws were better supported by the concrete surrounding them resulting in greater shear strengths. By limiting slip, there is a more balanced loading of both direct shear and tension. This balance between shear and tension in screw loading has been proven to result in the greatest screw capacities.

3. In general, specimens using medium thickness base angles (0.163 in. and 0.187 in.) yielded the greatest shear loads per screw. This is because the medium thickness base angle is flexible enough to allow some rotation but rigid enough not to allow excessive rotation. By allowing some rotation, screws are subjected to a combined shear and tensile loading. Again, this balance between shear and tension results in the greatest shear loads per screw.
4. Very thin angles (0.109 in.) allow excessive screw rotation resulting in screws being loaded primarily in tension. This most commonly resulted in the screws pulling out of the top chord sections. However, this can be avoided by increasing the amount of concrete surrounding the screws. In series C and series E, tests were constructed with Vulcraft 1.5C and 2VL deck, respectively. These deck profiles had the largest rib width of all the deck types investigated in this study, refer to Figure 2.5. By increasing the amount of concrete surrounding the screws, screw rotation is decreased and therefore a strictly tensile loading is avoided. Screw shear was the primary mode of failure observed in the majority of specimens from these two test series where the 0.109 in. base angle was used.
5. Certain combinations of test parameters make specimens susceptible to top chord buckling. First, the use of a 0.5 in. filler plate often does not provide enough resistance to this particular failure mode. Second, in cases where thin base angles are used, the excessive deformation of the top chord due to screw rotation decreases stiffness. Finally, specimens fabricated with the 0.5 in. filler plate do not provide a stable loading surface which can often lead to an eccentricity in the applied shear load. Top chord buckling is particularly difficult to avoid in specimens constructed with Vulcraft 2VL deck, series E. Due to the geometry of this type of deck, the

unbraced length, i.e., the distance from the top of the specimen to the first set of screws, is greater than in other series configurations. Even with the use of a 1 in. filler plate and lateral bracing, small amounts of top chord buckling were observed in some tests in series E. However, this was only found to be substantial in one set of tests, E1.

6. An embedment depth of 1.5 in. above the top of the deck profile is sufficient to develop the full shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw. Increasing the embedment depth has been proven to increase shear strength in specimens having one screw per rib, however, this increase nominal. In specimens where screws are grouped, increasing embedment depth was found to substantially increase shear strength, as evident by results from tests C7 through C10. By increasing embedment depth, the failure mode was changed from that of concrete cone pullout to screw shear.
7. Of the failure modes observed in this study, screw related failure modes consistently yielded the greatest shear loads while concrete related failure yielded the smallest in specimens having steel deck.
8. Solid slab tests yielded the greatest shear load per screw values. This can be attributed to the amount of concrete surrounding the screws in a solid slab configuration.
9. Generally, grouping screws decreases shear loads per screw. While larger specimen shear loads can often be realized, strength per screw decreases as screw density increases. However, there is a point at which increasing the number of screws per rib does not increase ultimate shear load.
10. Configurations of grouped screws performed best in Vulcraft 2VL deck when compared to other types of deck investigated in this study. This can be attributed to the wider rib width of the Vulcraft 2VL deck. Grouped screws also performed well in specimens fabricated with Vulcraft 1.5C deck. Again, this is due to the wider rib width of these types of deck.

11. Grouping screws had the most detrimental effect in specimens formed with Vulcraft 1.5VL deck. Due to the rib height to average rib width ratio, specimens using 1.5VL deck are very susceptible to the brittle concrete cone failures. This type of failure was observed in the majority of series D tests where screws were placed more than one per rib.
12. In any deck type there is a limit to the number of screws that should be placed per rib to avoid a concrete cone failure. The brittle nature of this type of failure is undesirable as opposed the more ductile screw-related failures. The limits on the number of screws that should be placed per rib in each type of deck to avoid a concrete cone pullout failure are as follows:
    - 0.6C deck – no more than one screw per rib
    - 1.0C deck – no more than two screws per rib
    - 1.5C deck – no more than four screws per rib
    - 1.5VL deck – no more than two screws per rib
    - 2VL deck – no more than eight screws per rib
13. While large amounts of slip observed in most tests demonstrates the great ductility of the 5/16 in. diameter Elco Grade 8 standoff screw, these large slips are impractical. At high slips, i.e., between 0.6 in. and 1.0 in., small increases in load result in large increases in slip at the steel-concrete interface. When slips reach these ranges, the deformation in the specimen is permanent. For these reasons, in design, strength of the 5/16 in. diameter Elco Grade 8 standoff screw should be based on a controlled amount of slip.
14. Limiting the amount of acceptable slip to 0.2 in. is felt to be practical for design purposes. First, inelastic behavior was observed to set in just after 0.2 in. of slip was reached in most tests. This is evident by the nonlinear behavior exhibited in the Load vs. Slip plots for these tests. When large slips are involved, small load increases can result in large amounts of damage to the system. By limiting the amount of slip, the integrity of the system can be more closely controlled. Finally, the maximum shear load of a typical welded shear stud occurs at approximately 0.2. in. of slip (TRW Nelson 1977). To be comparable with welded shear studs, the ultimate design

strength of the 5/16 in. diameter Elco Grade 8 standoff screw should likewise be assumed to occur at 0.2 in. of slip.

15. Alander's proposed equation (Eq. 1.6) for predicting the shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw at low slip was found to be inaccurate when applied to test data gathered in this study. As stated previously, tests in this study were fabricated from similar materials and in the same manner as those conducted by Alander. The only differences lie in the configurations of the tests, i.e., deck type, screw densities, etc. Because of this, Eq. 1.6 should be able to predict shear strength for configurations in this study and not only those from which it was derived. While Eq. 1.6 was found to predict the shear strength of tests conducted by Alander with acceptable accuracy, it's inability to predict shear strength for configurations investigated in this study warranted the need for a new predictive equation.
16. Existing predictors of concrete cone strength were not found to be good predictors of shear strength applied to data gathered in this study. As in the case of Alander's proposed equation for predicting shear strength at low slip, existing predictors of concrete cone strength were found to be acceptable when applied to the data contained within the reports in which they were developed. Again, the inability of existing equations to predict concrete cone strengths of tests in this study necessitates the development of a new predictive equation.
17. Three independent variables were found to have the most influence on the shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw at low slip: the number of screws per rib, top chord thickness and rib area. These test parameters have different effects on shear strength at low slip than they do on ultimate shear strength. For instance, while medium thickness base angles were found to yield the greatest ultimate shear load per screw, at low slip, thicker base angles yield the largest screw strengths. This is illustrated by the steep slope of the elastic region of the Load vs. Slip plots for tests with thicker base angles. This also holds true for rib area. However, increasing the number of screws placed per rib has a detrimental effect

shear strength per screw. This effect is not as pronounced at low slip as it is at ultimate load.

18. Using multiple linear regression analysis techniques, an equation was developed to accurately predict the shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw at 0.2 in. of slip. This equation predicts shear strength as a function of the number of screws per rib, top chord thickness and rib area and assumes that slabs are sufficiently reinforced. This equation, shown below, is not based on a specific failure mode. It is believed that at low slip, strength is independent on the ultimate mode of failure.

$$V_s = 2.5 - 0.3N_r + 0.18A_r + 3.7t_{tc} \tag{4.7}$$

where:

$V_s$ = shear strength per screw, kips

$N_r$ = Number of screws per rib

$A_r$ = rib area, in.$^2$

= average rib width × nominal rib height

$t_{tc}$ = top chord thickness, in.

Equation 4.7 is only applicable to the 5/16 in. diameter Elco Grade 8 standoff screw embedded at least 1.5 in. above the top to the deck profile. It is also limited to screw densities as described previously (#12).

19. In predicting ultimate shear strength, assuming slabs are sufficiently reinforced, two modes of failure must be accounted for. In cases where screw shear is the ultimate mode of failure, a modification of the shear rupture equation (Eq. 4.1) was developed to predict the ultimate shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw. This equation is as follows:

$$V_u = 0.5A_sF_u \tag{4.8}$$

where:

$V_u$ = ultimate shear strength per screw, kips

$A_s$ = effective tensile area, in.$^2$

$F_u$ = tensile stress, ksi

In cases where concrete cone pullout is the failure mode at ultimate load, existing predictive equations do not predict cone strength with acceptable accuracy. In developing a new equation for predicting cone shear strength, relationships developed in existing models were used. The effective concrete cone area as developed by Lloyd and Wright (1990) and concrete compressive strength were found to be the two independent variables influencing concrete cone strength. The effective concrete tensile pullout cone area is described by the following equation:

$$A_{wc} = 2w_{r2}\sqrt{\frac{w_{r2}^2}{4} + \left(H_s - h_r\right)^2} + w_{r2}\sqrt{w_{r2}^2 + 2\left(H_s - h_r\right)^2} + 2w_{r1}\sqrt{3h_r^2} \tag{4.2}$$

where:

$A_{wc}$ = surface area of wedge shaped tensile concrete pullout cone, in.$^2$

$h_r$ = nominal rib height of steel deck, in.

$H_s$ = total length of shear connector, in.

$w_{r1}$ = concrete rib width at bottom of flange of steel deck, in.

$w_{r2}$ = concrete rib width at top of flange of steel deck, in.

In cases where two studs are placed in a rib, Eq. 4.2 can be modified as follows:

$$A_{wc} = A_{wc}(ss) + 2s\sqrt{\frac{w_{r2}^2}{4} + h_p^2} \tag{4.3}$$

where:

$A_{wc}(ss)$ = surface area of wedge shaped tensile concrete pullout cone for a single stud arrangement (shown above), in.$^2$

Using regression techniques, the following equation was developed which accurately predicts ultimate shear strength in cases where concrete cone pullout controls:

$$V_{wc} = 0.0024 A_{wc} \sqrt{f'_c} + 2.16 \quad (4.9)$$

where:

$V_{wc}$ = shear strength per effective rib, kips

$A_{wc}$ = surface area of wedge shaped tensile concrete pullout cone, in.$^2$

$f'_c$ = concrete compressive strength, psi

These equations are only valid for the 5/16 in. diameter Elco Grade 8 standoff screw. In cases where steel deck is used, screws must be embedded at least 1.5 in. above the top of the deck profile for these equations to be valid.

20. For solid slab configurations, there are two controlling modes of failure, screw shear and longitudinal splitting. In cases of longitudinal splitting, The British Steel Construction Institute's equation, shown below, is an excellent predictor of shear strength:

$$v_r = 0.03 \eta f_{cu} A_{cv} + 0.7 A_{sv} f_y \le 0.8 \eta A_{cv} \sqrt{f_{cu}} \quad (1.8)$$

where:

$v_r$ = shear resistance per unit length of each shear plane, kips/in.

$\eta$ = 1.0 for normal weight concrete

= 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.

$f_y$ = yield strength of steel reinforcement, ksi

When applied to test results, Eq 1.8 was found to predict ultimate shear strength for not only solid slab tests failing by longitudinal splitting but those failing by screw shear as well. However, this can be attributed to the presence of varying extents of longitudinal splitting observed in all solid slab tests. It should be noted that all solid slab tests conducted in this study and that of Alander (1998) had relatively large screw densities, the lowest being 28 screws per specimen. In order to induce a purely screw shear failure, a configuration of fewer screws would have to be used. In a configuration having fewer screws where the resistance of the screws would not be sufficient to split the concrete to any significant extent, a true screw shear failure would occur. For cases where this criterion is met, Eq. 4.8 will be used to predict ultimate shear strength. In evaluating the ability of Eq. 4.8 to predict ultimate shear strength in cases of screw shear it was found that this equation is very conservative. However, this can be substantiated by the added shear strength provided by the friction between the concrete slab and the steel top chord section. Due to the method of solid slab fabrication a friction key, discussed in Section 4.4.4, is formed and contributes an unknown amount of shear resistance.

## 5.3 Limitations

The data and results gathered in this study apply only to the 5/16 in. diameter Elco Grade 8 standoff screw and are not representative of other shear connectors. Predictive equations developed in this study are only applicable to configurations similar to those contained within this report. When steel deck is used, only screw heights resulting an embedment depth of 1.5 in. to 2 in. above the top of the deck profile are applicable with these predictive equations. Configurations not consistent with those investigated in this study and that of Alander (1998) may result in different failure modes not investigated here. In cases where screw densities exceed the limitations set previously, specific test data should be utilized to evaluate performance.

## 5.4 Suggestions for Further Research

Based on observations and findings noted throughout this study the following recommendations are made:

1. Full-scale tests should be performed substantiate pushout test results. The ability of the equations developed in this report to predict shear strength in full-scale tests should be evaluated. Special attention should be paid to the failure modes of these full-scale tests and whether or not they are consistent with those observed in pushout tests. In some instances, it is felt that the configuration of the pushout test itself may tend to induce forces which would not be present in a full-scale composite joist. This could lead to different failure modes and therefore render pushout data invalid.
2. Embedment depth in configurations where screws are grouped should be investigated further. There is limited test data in this report proving that, when screws are grouped, a greater embedment depth results in larger shear strengths. This has been proven for configurations of four screws per rib placed in Vulcraft 1.5C deck. Other combinations of screw density, embedment depth and deck type should be investigated.
3. While an embedment depth of 1.5 in. above the top of the deck profile has been proven to fully develop the shear strength of the 5/16 in. diameter Elco Grade 8 standoff screw, in cases where decks having ribs heights less than 1.5 in. are used, the effect of embedment depth should be investigated further. This was investigated in some tests conducted by Alander, however, these tests were not transversely reinforced which has been proven to have an effect on screw strength. As discussed in Section 4.5, decreasing embedment depth in these cases may lead to a different controlling failure mode than that observed in tests conducted in this study. By changing the ultimate failure mode, a change in screw performance would also be realized. This may prove to account for discrepancies in the predictive equations proposed in this report.
4. Additional pushout tests using different types of steel deck should be conducted to further evaluate the performance of the 5/16 in. diameter Elco Grade 8 standoff screw. Results from these tests should be used to evaluate the validity of predictive equations developed in this report.

5. An exhaustive analytical study should be conducted using the data gathered in all studies conducted at Virginia Tech on the 5/16 in. diameter Elco Grade 8 standoff screw. Special attention should be paid to the validity of equations developed in this report. Reduction factors should be derived for all predictive equations. Also, a design procedure for the use of the 5/16 in. diameter Elco Grade 8 standoff screw must be developed and evaluated.
6. The use of the 0.109 in. base angle should be avoided. The majority of specimens constructed with this top chord section failed by screw pullout, a failure mode not addressed in detail. Also, the flexibility of this top chord makes specimens susceptible to top chord buckling.
7. Retests should be conducted for all test groups where results do not agree, within 10%, between tests within those groups. One specific group which should be retested is C1. A previous retest of this group yielded screw strengths significantly greater than those originally reported. It is currently believed that these two groups of C1 tests were loaded under different protocols resulting in the large difference in screw strengths. It is left up to the project sponsor to decide which test groups should be retested
8. In the future, the use of the 0.5 in. filler plate should be eliminated in favor of a 1 in. filler plate. A 1 in. filler plate offers more resistance to top chord buckling as well as a more stable loading surface. For configurations that are known not to be susceptible to top chord buckling, the use of a 0.5 in. plate may be justified as a means of cost reduction.
9. A new procedure for fabricating solid slab specimens must be implemented. The current method makes it difficult to produce specimens with similar dimensions and characteristics. Also, special efforts should be made in eliminating concrete from being poured into the gap between the double angle sections of the top chords. This would eliminate any additive effects caused by the friction key formed when solid slab specimens are fabricated using the procedure detailed in this report.

10. A new method of screw attachment must be implemented. The conventional method of using an electric screw gun is time consuming and laborious. Accuracy of screw placement is also decreased with the use of a hand-held electric screw gun. In an attempt to alleviate these problems, a drill press fitted with the proper bit was used to attach screws in some tests. However, due to the torque of the drill press, often screws were stripped in the top chord and were unable to be recovered. The effects of stripping screws are unknown. A stand-up electric screw gun is the means by which these screws are intended to be attached. This type of screw gun should be used when attaching screws for pushout tests.

# REFERENCES

*Acceptance Criteria for Tapping Screw Fasteners, AC118* (1996). International Conference of Building Officials, Whittier, California.

Alander, C.C., Easterling, W.S., and Murray, T.M. (1998a). "Standoff Screws Used in Composite Joists." Report No. CE/VPI-ST-98/02, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Alander, C.C., Easterling, W.S., and Murray, T.M. (1998b). "Data Report for Standoff Screws Used in Composite Joists." Report No. CE/VPI-ST-98/03, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

ASTM. *1993 ASTM Standards in Building Codes*, C192-90a. Philadelphia, PA: American Society for Testing Materials, 1993.

ASTM. *1993 ASTM Standards in Building Codes*, A370-92. Philadelphia, PA: American Society for Testing Materials, 1993.

*Building Code Requirements for Structural Concrete* (1996). American Concrete Institute, Farmington Hills, Michigan.

*Commentary on BS 5950: Part 3: Section 3.1 "Composite Beams"* (1990). The Steel Construction Institute, Berkshire, England.

Hankins, S.C., Easterling, W.S., and Murray, T.M. (1994). "Standoff Screws Functioning as Mechanical Shear Connectors in Composite Joists." Report No. CE/VPI-ST-91/16, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Hawkins, N.M. and Mitchell, D.M. (1984). "Seismic Response of Composite Shear Connections." *Journal of Structural Engineering*, ASCE, 110(9), 2120-2136.

Lauer, D.F., Easterling, W.S., and Murray, T.M. (1994). "Ultimate Strength Analysis of Partially Composite and Fully Composite Open-Web Steel Joists." Report No. CE/VPI-ST-94/06, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Lloyd, R.M. and Wright, H.D. (1990). "Shear Connection Between Composite Slabs and Steel Beams." *Journal of Construction and Steel Research*, 15, 255-285.

*Load and Resistance Factor Design Specifications for Structural Steel Buildings* (1993). American Institute of Steel Construction, Chicago.

Ollgaard, J.G., Slutter, R.G., and Fisher, J.W. (1971). "Shear Strength of Stud Connectors in Lightweight and Normal-weight Concrete." *Engineering Journal*, AISC, 55-64.

Salmon, C.G. and Johnson, J.E. (1996). *Steel Structures: Design and Behavior*, Fourth Edition. Harper and Row, New York.

Samuelson, D. (1999a). Nucor Research and Development, Norfolk, Nebraska. Personal Communication, March 3, 1999.

Samuelson, D. (1999b). Nucor Research and Development, Norfolk, Nebraska. Personal Communication, March 4, 1999.

Strocchia, L.D., Easterling, W.S., and Murray, T.M. (1990). "Evaluation of Deck Fasteners Functioning as Shear Connectors for Composite Steel Joists." Report No. CE/VPI-ST-90/01, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

TRW Nelson (1977). "Design Data 10: Embedment Properties of Headed Studs." TRW Nelson Stud Welding Division, Elyria, Ohio.

Viest, I.M, et al (1997). *Composite Construction Design for Buildings*. McGraw-Hill, New York.

# APPENDIX

# DATA PACKS

**PUSHOUT TEST SUMMARY SHEET**

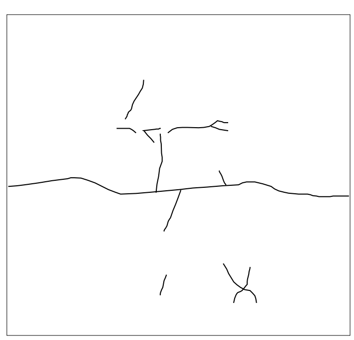
Test: B12-1 Test Date: 31-Jul-98

Test Designation: SC-8-2.5-0.109-1.0C-2.75-1

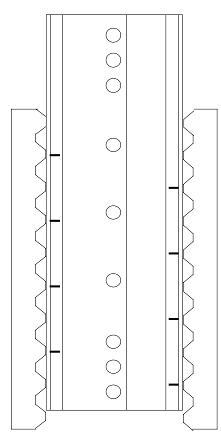
| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.5 in. | No. Per Specimen: | 16 | | |
| **Deck:** | Type: | 1.0C, 26 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 103.8 ksi | $F_u$: | 104.9 ksi | | |
| **Base Member:** | Section: | 2L 1.25x1.25x0.109 | | | | |
| | $F_y$: | 55.6 ksi | $F_u$: | 76.8 ksi | | |
| **Slab:** | Thickness: | 2.75 in. | $f'_c$: | 6566 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 10 | | |
| | | | Height Above Deck: | 0.75 in. | | |
| **Mesh:** | Type: | WWF 6x6-W2.9xW2.9 | | | | |

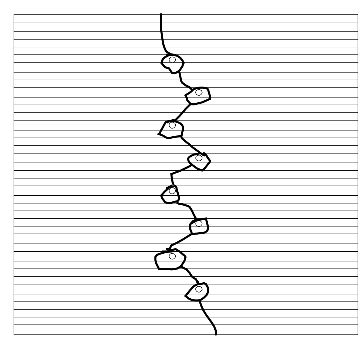
| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 57.29 kips | | | |
| **Peak Shear Load Per Screw:** | 3.58 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.6292 in. | SC5: | 0.8246 in. |
| | SC2: | 0.7638 in. | SC6: | 0.6988 in. |
| | SC3: | 0.5970 in. | SC7: | 0.7142 in. |
| | SC4: | 0.6878 in. | SC8: | 0.7406 in. |

**DAMAGE**



exterior, Slab A





interior, Slab B

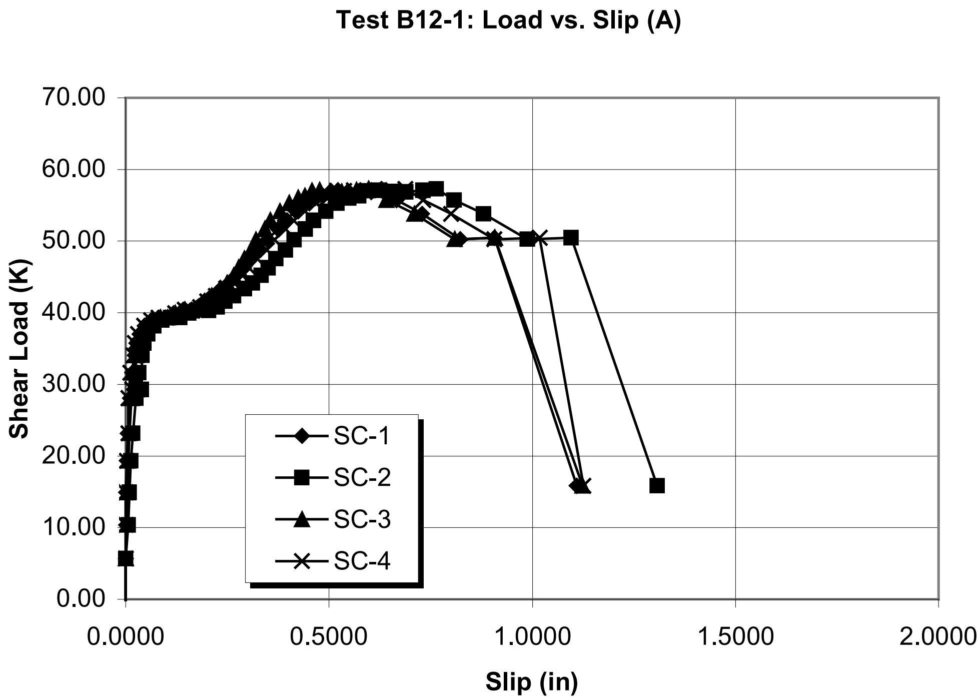
**COMMENTS**

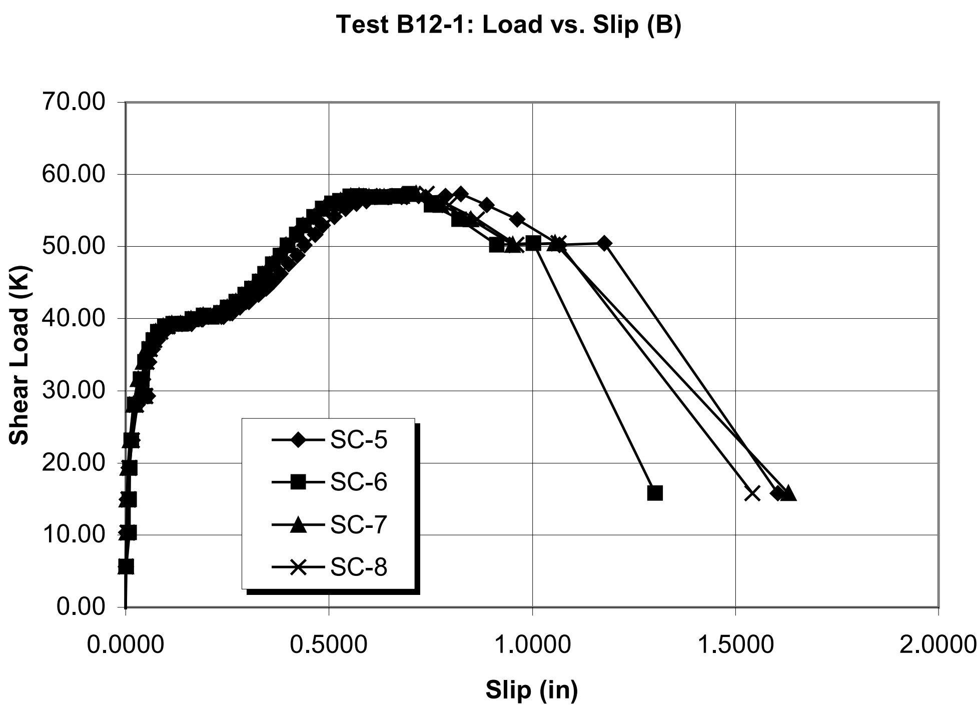
Failure Mode: Concrete rib failure followed by screw pullout from angles at ultimate load

Screw Rotation ≈ 60° - 70°

Deck debonded

Angles slightly deformed at screw locations due to rotation of screws


Test B12-1: Load vs. Slip (A)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Shear Load (K)
0.0000
0.5000
1.0000
1.5000
2.0000
Slip (in)
SC-1
SC-2
SC-3
SC-4


Test B12-1: Load vs. Slip (B)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Shear Load (K)
0.0000
0.5000
1.0000
1.5000
2.0000
Slip (in)
SC-5
SC-6
SC-7
SC-8

## TEST B12-1 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| -0.06 | 0.00 | 0.0002 | -0.0002 | -0.0002 | -0.0004 | 0.0000 | -0.0002 | -0.0002 | 0.0002 |
| 5.65 | 0.48 | -0.0004 | 0.0002 | 0.0004 | 0.0000 | -0.0002 | 0.0013 | -0.0004 | 0.0000 |
| 10.36 | 0.89 | 0.0016 | 0.0064 | 0.0042 | 0.0002 | 0.0009 | 0.0092 | 0.0027 | 0.0038 |
| 14.95 | 1.44 | 0.0018 | 0.0088 | 0.0046 | 0.0002 | 0.0022 | 0.0092 | 0.0027 | 0.0060 |
| 19.35 | 1.89 | 0.0027 | 0.0128 | 0.0059 | 0.0027 | 0.0073 | 0.0106 | 0.0053 | 0.0084 |
| 23.18 | 2.30 | 0.0053 | 0.0172 | 0.0092 | 0.0062 | 0.0163 | 0.0141 | 0.0103 | 0.0148 |
| 28.08 | 2.75 | 0.0104 | 0.0255 | 0.0139 | 0.0064 | 0.0282 | 0.0225 | 0.0194 | 0.0245 |
| 31.60 | 3.15 | 0.0163 | 0.0324 | 0.0201 | 0.0112 | 0.0423 | 0.0363 | 0.0306 | 0.0383 |
| 29.27 | 3.12 | 0.0205 | 0.0392 | 0.0247 | 0.0168 | 0.0535 | 0.0465 | 0.0399 | 0.0478 |
| 34.05 | 3.38 | 0.0223 | 0.0399 | 0.0255 | 0.0194 | 0.0573 | 0.0482 | 0.0425 | 0.0511 |
| 35.74 | 3.58 | 0.0260 | 0.0447 | 0.0304 | 0.0220 | 0.0667 | 0.0575 | 0.0500 | 0.0592 |
| 37.06 | 3.77 | 0.0339 | 0.0537 | 0.0383 | 0.0295 | 0.0793 | 0.0672 | 0.0610 | 0.0701 |
| 38.19 | 3.90 | 0.0460 | 0.0689 | 0.0505 | 0.0450 | 0.0952 | 0.0793 | 0.0742 | 0.0852 |
| 38.94 | 4.10 | 0.0621 | 0.0894 | 0.0668 | 0.0621 | 0.1150 | 0.0963 | 0.0910 | 0.1027 |
| 39.32 | 4.20 | 0.0808 | 0.1097 | 0.0846 | 0.0804 | 0.1377 | 0.1161 | 0.1123 | 0.1227 |
| 39.32 | 4.29 | 0.0976 | 0.1324 | 0.1022 | 0.1004 | 0.1617 | 0.1386 | 0.1346 | 0.1458 |
| 39.95 | 4.35 | 0.1172 | 0.1557 | 0.1218 | 0.1210 | 0.1890 | 0.1635 | 0.1608 | 0.1705 |
| 40.45 | 4.36 | 0.1412 | 0.1846 | 0.1456 | 0.1450 | 0.2192 | 0.1921 | 0.1899 | 0.1994 |
| 40.33 | 4.33 | 0.1582 | 0.2046 | 0.1617 | 0.1635 | 0.2399 | 0.2115 | 0.2097 | 0.2187 |
| 40.77 | 4.23 | 0.1767 | 0.2254 | 0.1796 | 0.1828 | 0.2622 | 0.2342 | 0.2318 | 0.2401 |
| 41.58 | 4.27 | 0.1928 | 0.2439 | 0.1941 | 0.2000 | 0.2802 | 0.2511 | 0.2494 | 0.2578 |
| 42.34 | 4.36 | 0.2122 | 0.2661 | 0.2119 | 0.2216 | 0.3027 | 0.2721 | 0.2699 | 0.2789 |
| 43.34 | 4.46 | 0.2340 | 0.2923 | 0.2326 | 0.2463 | 0.3267 | 0.2947 | 0.2941 | 0.3012 |
| 44.16 | 4.49 | 0.2531 | 0.3124 | 0.2492 | 0.2666 | 0.3454 | 0.3108 | 0.3100 | 0.3181 |
| 45.16 | 4.58 | 0.2723 | 0.3327 | 0.2650 | 0.2871 | 0.3630 | 0.3289 | 0.3267 | 0.3359 |
| 46.23 | 4.66 | 0.2903 | 0.3503 | 0.2784 | 0.3036 | 0.3804 | 0.3432 | 0.3424 | 0.3516 |
| 47.55 | 4.82 | 0.3084 | 0.3696 | 0.2919 | 0.3232 | 0.4007 | 0.3613 | 0.3600 | 0.3707 |
| 48.74 | 4.89 | 0.3304 | 0.3937 | 0.3082 | 0.3467 | 0.4216 | 0.3804 | 0.3787 | 0.3902 |
| 50.19 | 5.05 | 0.3485 | 0.4142 | 0.3212 | 0.3657 | 0.4399 | 0.3985 | 0.3950 | 0.4076 |
| 51.63 | 5.20 | 0.3741 | 0.4424 | 0.3415 | 0.3934 | 0.4661 | 0.4210 | 0.4177 | 0.4325 |
| 52.89 | 5.43 | 0.3924 | 0.4626 | 0.3562 | 0.4131 | 0.4844 | 0.4382 | 0.4353 | 0.4496 |
| 54.15 | 5.55 | 0.4186 | 0.4921 | 0.3798 | 0.4412 | 0.5140 | 0.4629 | 0.4628 | 0.4783 |
| 55.28 | 5.65 | 0.4413 | 0.5195 | 0.4014 | 0.4679 | 0.5410 | 0.4853 | 0.4869 | 0.5036 |
| 55.97 | 5.79 | 0.4657 | 0.5488 | 0.4249 | 0.4944 | 0.5670 | 0.5071 | 0.5091 | 0.5254 |
| 56.28 | 5.88 | 0.4860 | 0.5734 | 0.4410 | 0.5161 | 0.5928 | 0.5267 | 0.5283 | 0.5477 |
| 56.97 | 5.87 | 0.5043 | 0.5964 | 0.4584 | 0.5378 | 0.6252 | 0.5523 | 0.5534 | 0.5765 |
| 57.04 | 5.97 | 0.5228 | 0.6219 | 0.4770 | 0.5607 | 0.6552 | 0.5732 | 0.5736 | 0.6007 |
| 56.91 | 5.96 | 0.5463 | 0.6550 | 0.5025 | 0.5886 | 0.6913 | 0.5992 | 0.5992 | 0.6285 |
| 56.85 | 6.00 | 0.5714 | 0.6886 | 0.5307 | 0.6193 | 0.7373 | 0.6311 | 0.6345 | 0.6627 |
| 57.04 | 6.06 | 0.6036 | 0.7310 | 0.5677 | 0.6572 | 0.7871 | 0.6677 | 0.6789 | 0.7036 |
| 57.29 | 6.11 | 0.6292 | 0.7638 | 0.5970 | 0.6878 | 0.8246 | 0.6988 | 0.7142 | 0.7406 |
| 55.72 | 6.18 | 0.6660 | 0.8081 | 0.6406 | 0.7316 | 0.8880 | 0.7532 | 0.7750 | 0.7955 |
| 53.77 | 6.32 | 0.7288 | 0.8805 | 0.7105 | 0.8005 | 0.9631 | 0.8197 | 0.8492 | 0.8636 |
| 50.25 | 5.67 | 0.8224 | 0.9887 | 0.8085 | 0.9072 | 1.0665 | 0.9134 | 0.9523 | 0.9611 |
| 50.44 | 6.22 | 0.9067 | 1.0952 | 0.9074 | 1.0178 | 1.1769 | 1.0037 | 1.0560 | 1.0641 |
| 15.83 | 6.77 | 1.1090 | 1.3069 | 1.1238 | 1.1260 | 1.6047 | 1.3022 | 1.6305 | 1.5419 |

## PUSHOUT TEST SUMMARY SHEET

Test: B12-2     Test Date: 3-Aug-98

Test Designation: SC-8-2.5-0.109-1.0C-2.75-2

### SPECIMEN DESCRIPTION

| | | | | |
|---|---|---|---|---|
| **Screw:** | Height: 2.5 in. | No. Per Specimen: 16 | | |
| **Deck:** | Type: 1.0C, 26 ga | Width: 36 in. | Length: 36 in. | |
| | $F_y$: 103.8 ksi | $F_u$: 104.9 ksi | | |
| **Base Member:** | Section: 2L 1.25x1.25x0.109 | | | |
| | $F_y$: 55.6 ksi | $F_u$: 76.8 ksi | | |
| **Slab:** | Thickness: 2.75 in. | $f'_c$: 6566 psi | | |
| **Rebar:** | Size: No. 4 | No. Per Specimen: 10 | | |
| | | Height Above Deck: 0.75 in. | | |
| **Mesh:** | Type: WWF 6x6-W2.9xW2.9 | | | |

### TEST RESULTS

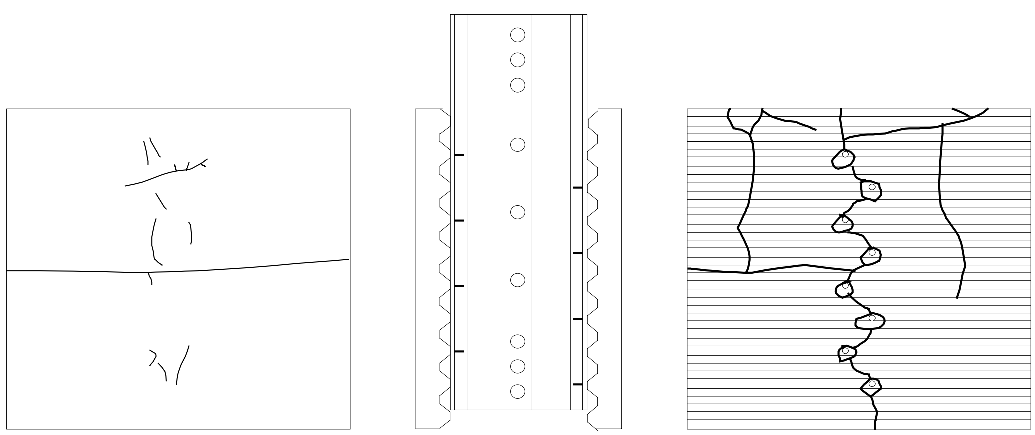
**Peak Shear Load:** 65.45 kips

**Peak Shear Load Per Screw:** 4.09 kips

**Slip at Peak Shear Load:**

| | |
|---|---|
| SC1: 0.6422 in. | SC5: 0.7668 in. |
| SC2: 0.6380 in. | SC6: 0.7501 in. |
| SC3: 0.6201 in. | SC7: 0.6322 in. |
| SC4: 0.6763 in. | SC8: 0.7701 in. |

### DAMAGE



exterior, Slab A     interior, Slab B

### COMMENTS

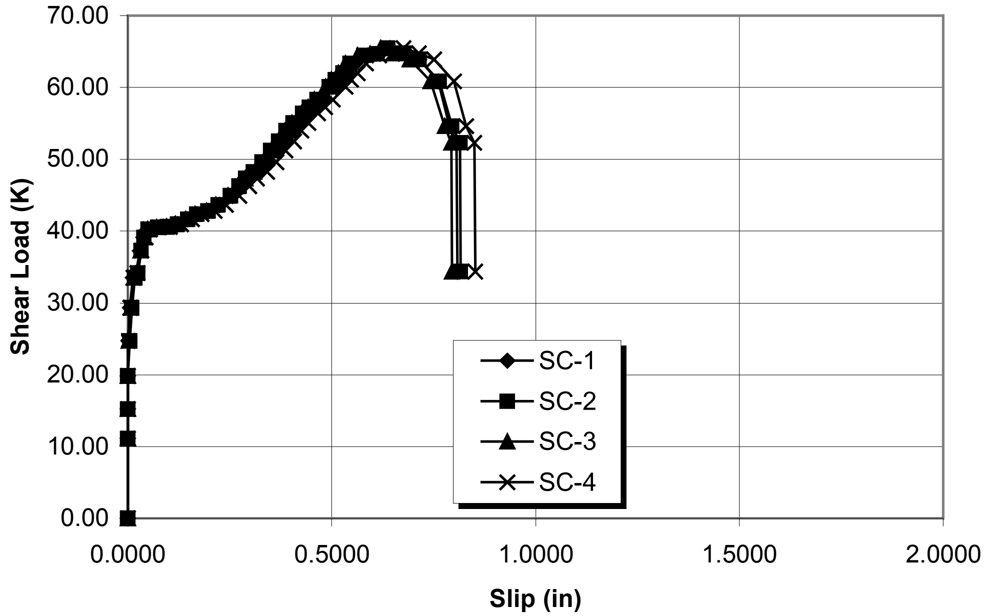
Failure Mode: Concrete rib failure followed by screw pullout from angles at ultimate load

Screw Rotation ≈ 60° - 70°

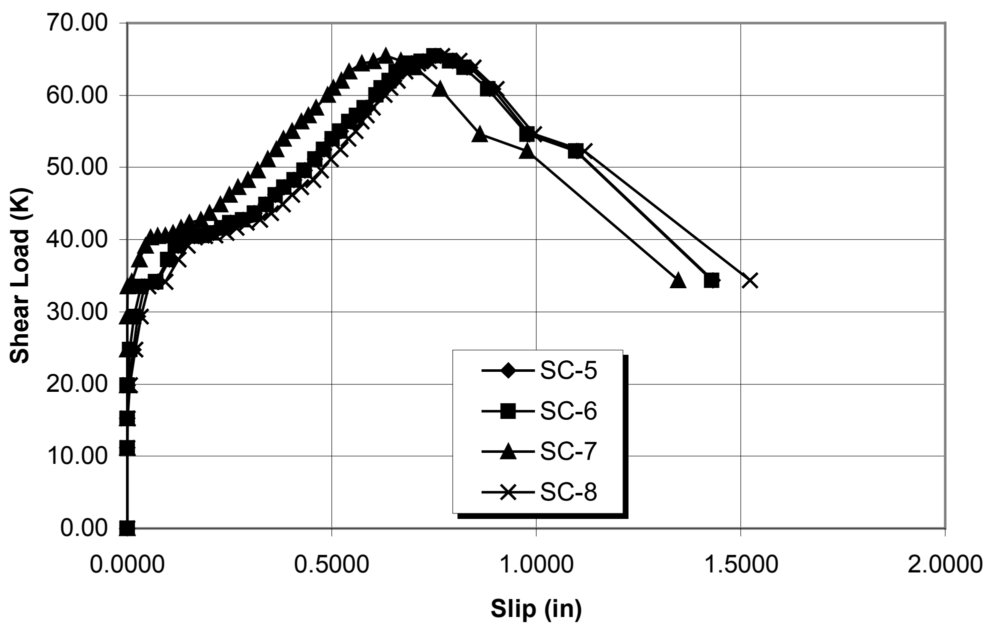
Deck debonded

Angles slightly deformed at screw locations due to rotation of screws

**Test B12-2: Load vs. Slip (A)**




**Test B12-2: Load vs. Slip (B)**



**TEST B12-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0002 | 0.0000 | 0.0002 | 0.0000 | 0.0000 | 0.0000 | -0.0004 | -0.0002 |
| 11.12 | 0.96 | 0.0000 | 0.0000 | 0.0002 | 0.0000 | 0.0000 | 0.0000 | -0.0002 | -0.0002 |
| 15.26 | 1.47 | -0.0004 | 0.0004 | 0.0000 | -0.0002 | 0.0002 | -0.0002 | 0.0000 | 0.0007 |
| 19.85 | 1.88 | 0.0000 | 0.0005 | 0.0005 | 0.0002 | 0.0007 | 0.0002 | -0.0002 | 0.0066 |
| 24.75 | 2.32 | 0.0009 | 0.0044 | 0.0029 | 0.0002 | 0.0147 | 0.0060 | 0.0002 | 0.0203 |
| 29.33 | 2.81 | 0.0048 | 0.0099 | 0.0077 | 0.0059 | 0.0262 | 0.0165 | 0.0005 | 0.0333 |
| 33.54 | 3.39 | 0.0128 | 0.0168 | 0.0148 | 0.0139 | 0.0429 | 0.0330 | 0.0007 | 0.0516 |
| 34.17 | 3.44 | 0.0205 | 0.0251 | 0.0225 | 0.0236 | 0.0743 | 0.0690 | 0.0110 | 0.0930 |
| 37.25 | 3.95 | 0.0302 | 0.0328 | 0.0311 | 0.0335 | 0.1037 | 0.0991 | 0.0304 | 0.1258 |
| 39.13 | 4.12 | 0.0392 | 0.0403 | 0.0401 | 0.0432 | 0.1242 | 0.1187 | 0.0447 | 0.1474 |
| 40.26 | 4.25 | 0.0491 | 0.0502 | 0.0493 | 0.0544 | 0.1406 | 0.1348 | 0.0568 | 0.1652 |
| 40.52 | 4.49 | 0.0705 | 0.0736 | 0.0709 | 0.0760 | 0.1641 | 0.1582 | 0.0745 | 0.1906 |
| 40.58 | 4.52 | 0.0952 | 0.0974 | 0.0945 | 0.1035 | 0.1872 | 0.1811 | 0.0938 | 0.2157 |
| 40.95 | 4.59 | 0.1218 | 0.1229 | 0.1178 | 0.1311 | 0.2108 | 0.2058 | 0.1119 | 0.2423 |
| 41.65 | 4.58 | 0.1471 | 0.1467 | 0.1419 | 0.1569 | 0.2317 | 0.2307 | 0.1315 | 0.2675 |
| 42.34 | 4.54 | 0.1703 | 0.1699 | 0.1641 | 0.1813 | 0.2531 | 0.2514 | 0.1516 | 0.2917 |
| 42.78 | 4.45 | 0.1994 | 0.1972 | 0.1936 | 0.2128 | 0.2833 | 0.2829 | 0.1798 | 0.3245 |
| 43.66 | 4.46 | 0.2262 | 0.2225 | 0.2159 | 0.2408 | 0.3108 | 0.3108 | 0.2020 | 0.3523 |
| 44.91 | 4.52 | 0.2575 | 0.2514 | 0.2459 | 0.2734 | 0.3384 | 0.3392 | 0.2271 | 0.3809 |
| 46.23 | 4.68 | 0.2809 | 0.2738 | 0.2692 | 0.2987 | 0.3620 | 0.3620 | 0.2502 | 0.4032 |
| 47.30 | 4.76 | 0.3003 | 0.2892 | 0.2884 | 0.3172 | 0.3833 | 0.3833 | 0.2707 | 0.4252 |
| 48.24 | 4.87 | 0.3240 | 0.3082 | 0.3108 | 0.3421 | 0.4086 | 0.4082 | 0.2954 | 0.4549 |
| 49.62 | 4.96 | 0.3459 | 0.3293 | 0.3316 | 0.3648 | 0.4335 | 0.4327 | 0.3181 | 0.4745 |
| 51.19 | 5.12 | 0.3674 | 0.3511 | 0.3518 | 0.3869 | 0.4593 | 0.4595 | 0.3432 | 0.4981 |
| 52.51 | 5.30 | 0.3877 | 0.3701 | 0.3699 | 0.4075 | 0.4816 | 0.4798 | 0.3639 | 0.5215 |
| 53.96 | 5.39 | 0.4051 | 0.3879 | 0.3859 | 0.4256 | 0.5009 | 0.5007 | 0.3824 | 0.5408 |
| 55.03 | 5.61 | 0.4228 | 0.4053 | 0.4036 | 0.4430 | 0.5221 | 0.5194 | 0.4027 | 0.5587 |
| 56.41 | 5.77 | 0.4450 | 0.4287 | 0.4256 | 0.4662 | 0.5477 | 0.5426 | 0.4256 | 0.5737 |
| 57.22 | 5.89 | 0.4613 | 0.4455 | 0.4412 | 0.4840 | 0.5666 | 0.5611 | 0.4426 | 0.5860 |
| 58.29 | 6.01 | 0.4798 | 0.4639 | 0.4575 | 0.5029 | 0.5882 | 0.5794 | 0.4613 | 0.6008 |
| 60.05 | 5.97 | 0.5087 | 0.4944 | 0.4855 | 0.5336 | 0.6173 | 0.6085 | 0.4906 | 0.6290 |
| 61.06 | 6.27 | 0.5223 | 0.5089 | 0.4987 | 0.5476 | 0.6329 | 0.6203 | 0.5040 | 0.6428 |
| 62.00 | 6.42 | 0.5395 | 0.5280 | 0.5166 | 0.5642 | 0.6536 | 0.6402 | 0.5241 | 0.6616 |
| 63.32 | 6.56 | 0.5574 | 0.5455 | 0.5340 | 0.5840 | 0.6726 | 0.6585 | 0.5424 | 0.6803 |
| 64.45 | 6.67 | 0.5884 | 0.5789 | 0.5642 | 0.6164 | 0.7050 | 0.6887 | 0.5730 | 0.7109 |
| 64.70 | 6.66 | 0.6182 | 0.6113 | 0.5933 | 0.6483 | 0.7356 | 0.7184 | 0.6019 | 0.7393 |
| 65.45 | 6.87 | 0.6422 | 0.6380 | 0.6201 | 0.6763 | 0.7668 | 0.7501 | 0.6322 | 0.7701 |
| 64.76 | 6.93 | 0.6787 | 0.6772 | 0.6556 | 0.7131 | 0.8041 | 0.7880 | 0.6690 | 0.8118 |
| 63.88 | 6.91 | 0.7146 | 0.7155 | 0.6915 | 0.7508 | 0.8384 | 0.8239 | 0.7045 | 0.8464 |
| 60.87 | 7.16 | 0.7607 | 0.7640 | 0.7424 | 0.7994 | 0.8938 | 0.8819 | 0.7644 | 0.9034 |
| 54.65 | 6.27 | 0.7891 | 0.7948 | 0.7768 | 0.8299 | 0.9843 | 0.9777 | 0.8614 | 0.9953 |
| 52.26 | 5.01 | 0.8056 | 0.8146 | 0.7940 | 0.8492 | 1.0985 | 1.0974 | 0.9779 | 1.1185 |
| 34.36 | 4.68 | 0.8085 | 0.8162 | 0.7953 | 0.8517 | 1.4316 | 1.4294 | 1.3476 | 1.5223 |

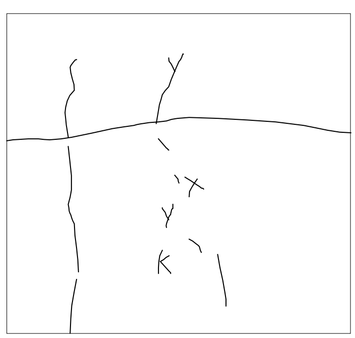
## PUSHOUT TEST SUMMARY SHEET

Test: B13-1 Test Date: 7-Aug-98
Test Designation: SC-8-2.5-0.187-1.0C-2.75-1

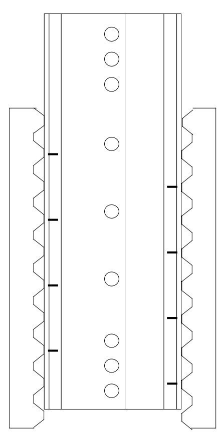
| SPECIMEN DESCRIPTION | | | | |
|---|---|---|---|---|
| **Screw:** | Height: 2.5 in. | No. Per Specimen: 16 | | |
| **Deck:** | Type: 1.0C, 26 ga | Width: 36 in. | Length: 36 in. | |
| | $F_y$: 103.8 ksi | $F_u$: 104.9 ksi | | |
| **Base Member:** | Section: 2L 2x2x0.187 | | | |
| | $F_y$: 61.9 ksi | $F_u$: 85.6 ksi | | |
| **Slab:** | Thickness: 2.75 in. | $f'_c$: 7003 psi | | |
| **Rebar:** | Size: No. 4 | No. Per Specimen: 10 | | |
| | | Height Above Deck: 0.75 in. | | |
| **Mesh:** | Type: WWF 6x6-W2.9xW2.9 | | | |

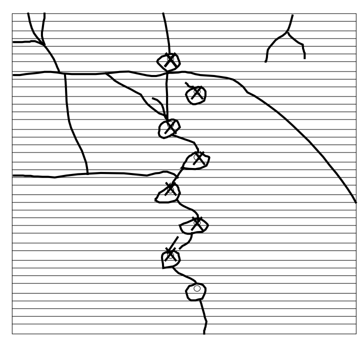
| TEST RESULTS | | |
|---|---|---|
| **Peak Shear Load:** 88.25 kips | | |
| **Peak Shear Load Per Screw:** 5.52 kips | | |
| **Slip at Peak Shear Load:** | SC1: 0.8019 in. | SC5: 0.8140 in. |
| | SC2: 0.8856 in. | SC6: 0.8710 in. |
| | SC3: 0.7972 in. | SC7: 0.8244 in. |
| | SC4: 0.8232 in. | SC8: 0.8808 in. |

### DAMAGE



exterior, Slab A

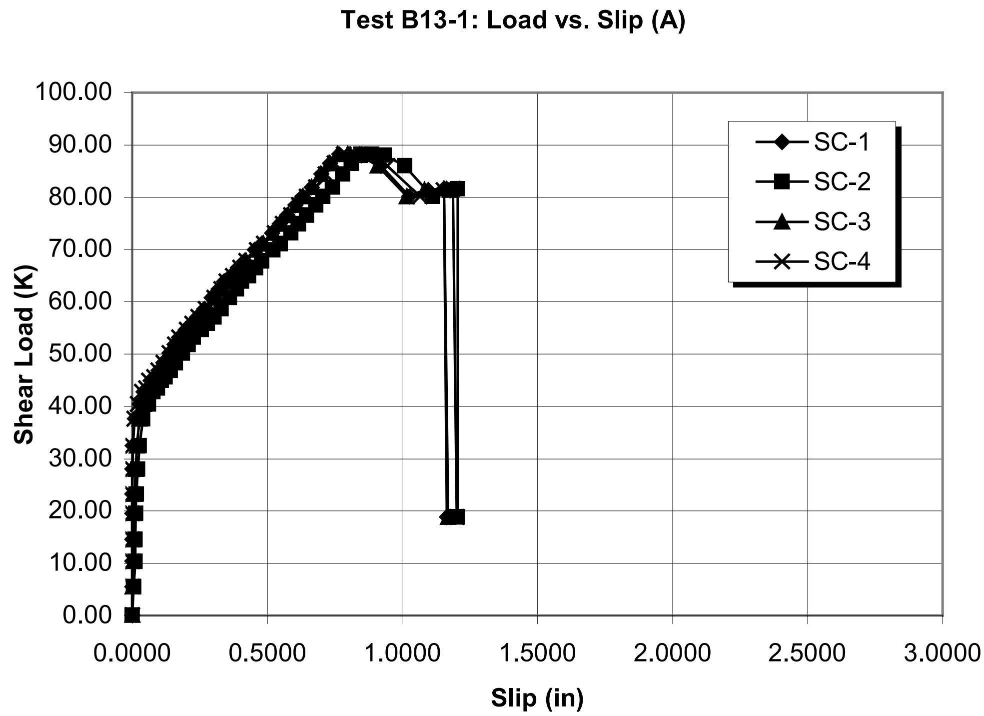




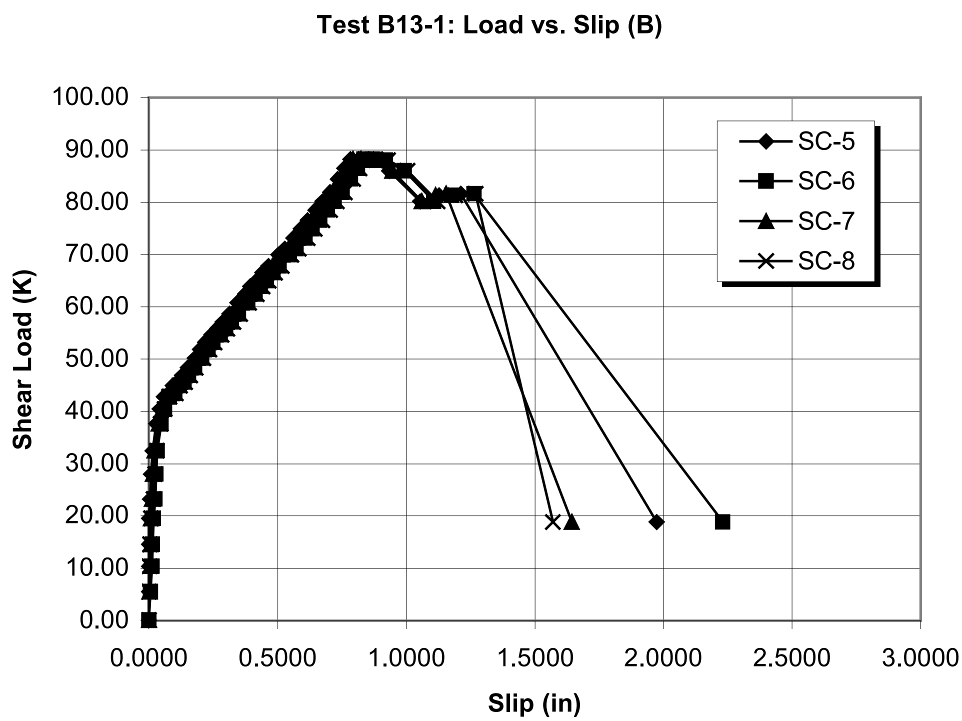
interior, Slab B

### COMMENTS

Failure Mode: Concrete rib failure followed by screw shear at ultimate load
Screw Rotation ≈ 40° - 50°
Deck debonded
Slight bulging of deck below screws
X = screw sheared off



Test B13-1: Load vs. Slip (A)
Shear Load (K)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
3.0000
Slip (in)
SC-1
SC-2
SC-3
SC-4

Test B13-1: Load vs. Slip (B)
Shear Load (K)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
3.0000
Slip (in)
SC-5
SC-6
SC-7
SC-8

## TEST B13-1 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.06 | 0.00 | 0.0005 | -0.0002 | -0.0002 | 0.0002 | -0.0004 | 0.0000 | 0.0000 | 0.0002 |
| 5.59 | 0.46 | 0.0002 | 0.0048 | 0.0016 | 0.0002 | -0.0004 | 0.0053 | 0.0016 | -0.0002 |
| 10.36 | 0.89 | 0.0002 | 0.0104 | 0.0055 | 0.0007 | -0.0005 | 0.0121 | 0.0066 | 0.0016 |
| 14.57 | 1.47 | 0.0000 | 0.0104 | 0.0053 | 0.0005 | -0.0007 | 0.0136 | 0.0068 | 0.0042 |
| 19.60 | 1.94 | 0.0000 | 0.0132 | 0.0066 | 0.0007 | -0.0007 | 0.0174 | 0.0071 | 0.0086 |
| 23.24 | 2.28 | 0.0004 | 0.0159 | 0.0086 | 0.0007 | 0.0033 | 0.0234 | 0.0125 | 0.0176 |
| 28.02 | 2.82 | 0.0005 | 0.0203 | 0.0125 | 0.0011 | 0.0071 | 0.0271 | 0.0163 | 0.0229 |
| 32.47 | 3.30 | 0.0020 | 0.0262 | 0.0170 | 0.0013 | 0.0137 | 0.0322 | 0.0227 | 0.0302 |
| 37.69 | 3.93 | 0.0097 | 0.0390 | 0.0271 | 0.0081 | 0.0277 | 0.0469 | 0.0377 | 0.0450 |
| 40.45 | 4.24 | 0.0275 | 0.0597 | 0.0434 | 0.0214 | 0.0414 | 0.0619 | 0.0515 | 0.0606 |
| 42.78 | 4.52 | 0.0408 | 0.0767 | 0.0577 | 0.0359 | 0.0571 | 0.0798 | 0.0672 | 0.0798 |
| 43.53 | 4.64 | 0.0566 | 0.0945 | 0.0722 | 0.0515 | 0.0776 | 0.1018 | 0.0874 | 0.1046 |
| 44.91 | 4.74 | 0.0676 | 0.1069 | 0.0833 | 0.0623 | 0.0927 | 0.1178 | 0.1016 | 0.1216 |
| 45.67 | 4.84 | 0.0837 | 0.1232 | 0.0994 | 0.0802 | 0.1101 | 0.1355 | 0.1192 | 0.1412 |
| 46.92 | 4.91 | 0.0985 | 0.1405 | 0.1154 | 0.0960 | 0.1293 | 0.1544 | 0.1386 | 0.1604 |
| 48.30 | 4.97 | 0.1148 | 0.1595 | 0.1331 | 0.1154 | 0.1496 | 0.1771 | 0.1610 | 0.1826 |
| 50.19 | 5.45 | 0.1372 | 0.1857 | 0.1557 | 0.1377 | 0.1782 | 0.2060 | 0.1883 | 0.2117 |
| 51.88 | 5.38 | 0.1562 | 0.2077 | 0.1743 | 0.1577 | 0.1981 | 0.2287 | 0.2108 | 0.2344 |
| 53.20 | 5.51 | 0.1723 | 0.2265 | 0.1912 | 0.1740 | 0.2179 | 0.2485 | 0.2304 | 0.2545 |
| 54.71 | 5.57 | 0.1981 | 0.2555 | 0.2179 | 0.2020 | 0.2437 | 0.2767 | 0.2577 | 0.2833 |
| 55.84 | 5.46 | 0.2192 | 0.2793 | 0.2395 | 0.2229 | 0.2655 | 0.2992 | 0.2791 | 0.3049 |
| 57.10 | 5.78 | 0.2412 | 0.3027 | 0.2613 | 0.2447 | 0.2866 | 0.3210 | 0.3012 | 0.3274 |
| 58.67 | 5.97 | 0.2665 | 0.3291 | 0.2851 | 0.2719 | 0.3128 | 0.3489 | 0.3272 | 0.3545 |
| 60.80 | 6.17 | 0.2943 | 0.3595 | 0.3128 | 0.3023 | 0.3439 | 0.3829 | 0.3591 | 0.3899 |
| 62.50 | 6.37 | 0.3207 | 0.3862 | 0.3373 | 0.3296 | 0.3741 | 0.4128 | 0.3884 | 0.4201 |
| 63.88 | 6.55 | 0.3399 | 0.4053 | 0.3549 | 0.3490 | 0.3934 | 0.4327 | 0.4075 | 0.4413 |
| 65.01 | 6.69 | 0.3648 | 0.4307 | 0.3772 | 0.3721 | 0.4170 | 0.4571 | 0.4311 | 0.4655 |
| 66.52 | 6.89 | 0.3919 | 0.4571 | 0.4009 | 0.3989 | 0.4404 | 0.4829 | 0.4554 | 0.4908 |
| 67.84 | 6.94 | 0.4157 | 0.4805 | 0.4223 | 0.4217 | 0.4642 | 0.5065 | 0.4796 | 0.5155 |
| 69.91 | 7.13 | 0.4543 | 0.5204 | 0.4602 | 0.4602 | 0.5025 | 0.5457 | 0.5175 | 0.5541 |
| 71.11 | 7.23 | 0.4798 | 0.5476 | 0.4851 | 0.4871 | 0.5272 | 0.5715 | 0.5413 | 0.5805 |
| 73.18 | 7.43 | 0.5183 | 0.5867 | 0.5215 | 0.5272 | 0.5620 | 0.6076 | 0.5761 | 0.6164 |
| 74.87 | 7.60 | 0.5454 | 0.6155 | 0.5487 | 0.5565 | 0.5899 | 0.6353 | 0.6030 | 0.6441 |
| 76.57 | 7.79 | 0.5748 | 0.6464 | 0.5770 | 0.5871 | 0.6173 | 0.6644 | 0.6300 | 0.6735 |
| 78.45 | 7.96 | 0.6051 | 0.6787 | 0.6069 | 0.6181 | 0.6472 | 0.6937 | 0.6589 | 0.7032 |
| 80.15 | 8.19 | 0.6312 | 0.7056 | 0.6323 | 0.6452 | 0.6739 | 0.7208 | 0.6843 | 0.7301 |
| 81.91 | 8.48 | 0.6646 | 0.7419 | 0.6653 | 0.6803 | 0.7043 | 0.7516 | 0.7133 | 0.7618 |
| 84.42 | 8.83 | 0.7001 | 0.7788 | 0.6988 | 0.7158 | 0.7338 | 0.7829 | 0.7417 | 0.7928 |
| 86.49 | 8.89 | 0.7318 | 0.8120 | 0.7292 | 0.7488 | 0.7589 | 0.8100 | 0.7671 | 0.8193 |
| 88.19 | 9.09 | 0.7658 | 0.8466 | 0.7613 | 0.7838 | 0.7834 | 0.8373 | 0.7928 | 0.8471 |
| 88.25 | 9.34 | 0.8019 | 0.8856 | 0.7972 | 0.8232 | 0.8140 | 0.8710 | 0.8244 | 0.8808 |
| 88.00 | 9.43 | 0.8482 | 0.9340 | 0.8407 | 0.8719 | 0.8580 | 0.9195 | 0.8722 | 0.9297 |
| 85.99 | 9.34 | 0.9199 | 1.0084 | 0.9087 | 0.9451 | 0.9327 | 0.9922 | 0.9455 | 1.0053 |
| 80.15 | 8.26 | 1.0262 | 1.1101 | 1.0167 | 1.0645 | 1.0535 | 1.1071 | 1.0599 | 1.1205 |
| 81.34 | 8.29 | 1.0952 | 1.1747 | 1.0830 | 1.1527 | 1.1282 | 1.1773 | 1.1139 | 1.1914 |
| 81.60 | 8.32 | 1.1537 | 1.2044 | 1.1533 | 1.1879 | 1.2124 | 1.2628 | 1.1540 | 1.2688 |
| 18.84 | 8.60 | 1.1645 | 1.2053 | 1.1685 | 1.2011 | 1.9741 | 2.2304 | 1.6430 | 1.5705 |

**PUSHOUT TEST SUMMARY SHEET**

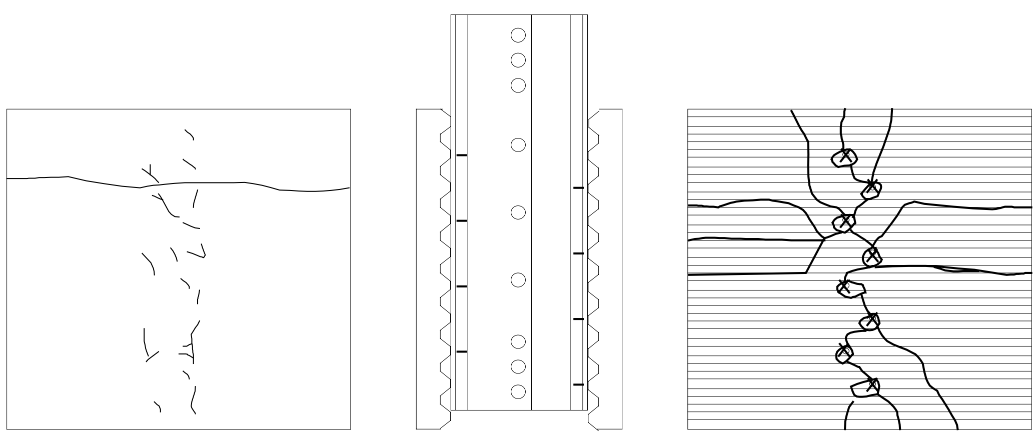
Test: B13-2 — Test Date: 11-Aug-98

Test Designation: SC-8-2.5-0.187-1.0C-2.75-2

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.5 in. | No. Per Specimen: | 16 | | |
| **Deck:** | Type: | 1.0C, 26 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 103.8 ksi | $F_u$: | 104.9 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.187 | | | | |
| | $F_y$: | 61.9 ksi | $F_u$: | 85.6 ksi | | |
| **Slab:** | Thickness: | 2.75 in. | $f'_c$: | 7003 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 10 | | |
| | | | Height Above Deck: | 0.75 in. | | |
| **Mesh:** | Type: | WWF 6x6-W2.9xW2.9 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 77.95 kips | | | |
| **Peak Shear Load Per Screw:** | 4.87 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.8265 in. | SC5: | 0.8774 in. |
| | SC2: | 0.9072 in. | SC6: | 0.8902 in. |
| | SC3: | 0.8266 in. | SC7: | 0.8041 in. |
| | SC4: | 0.8625 in. | SC8: | 0.9023 in. |

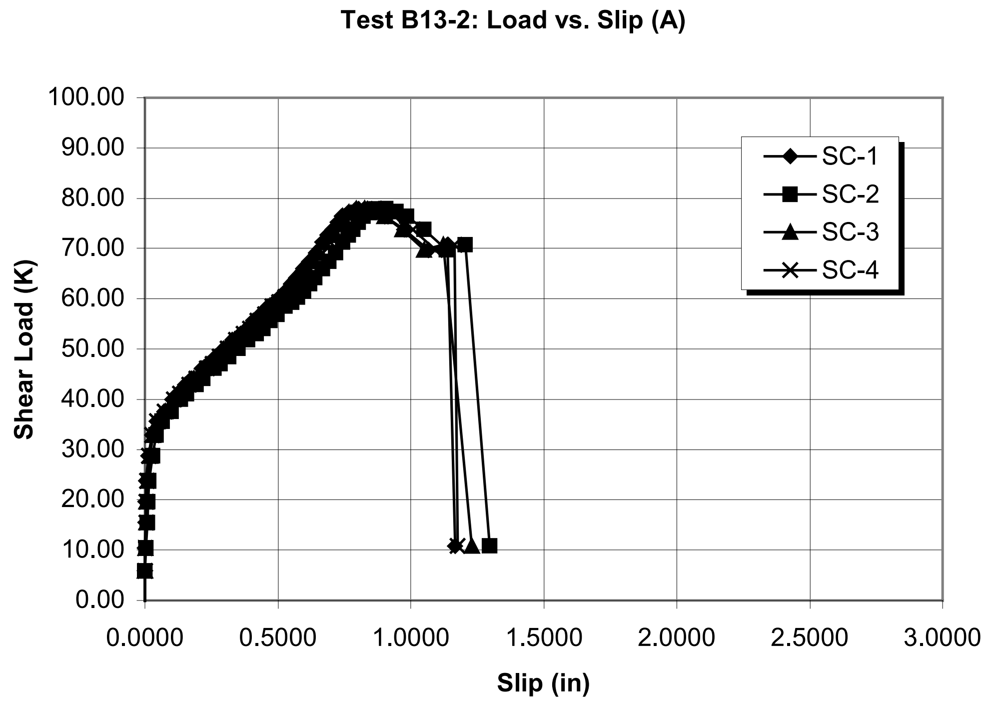
**DAMAGE**

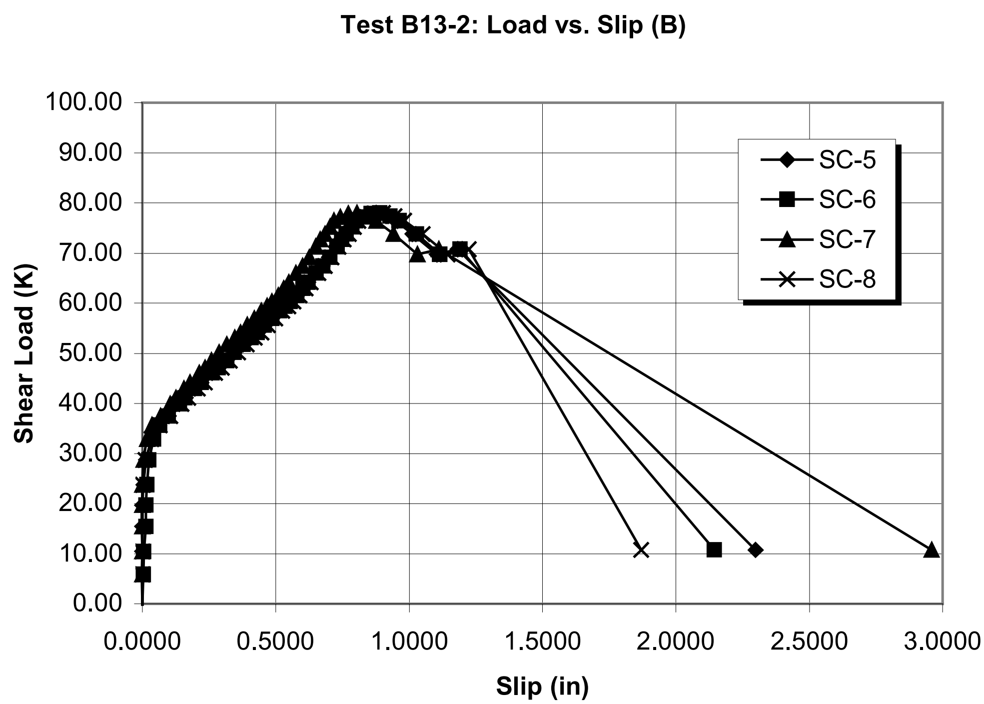


exterior, Slab A — interior, Slab B

**COMMENTS**

Failure Mode: Concrete rib failure followed by screw shear at ultimate load
Screw Rotation ≈ 40° - 50°
Deck debonded
Slight bulging of deck below screws
X = screw sheared off


Test B13-2: Load vs. Slip (A)
Shear Load (K)
Slip (in)
SC-1
SC-2
SC-3
SC-4
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
3.0000


Test B13-2: Load vs. Slip (B)
Shear Load (K)
Slip (in)
SC-5
SC-6
SC-7
SC-8
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
3.0000

## TEST B13-2 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
|---|---|---|---|---|---|---|---|---|---|
| -0.06 | 0.00 | 0.0002 | -0.0002 | 0.0000 | 0.0000 | -0.0002 | 0.0002 | -0.0005 | -0.0002 |
| 5.84 | 0.51 | 0.0000 | 0.0009 | 0.0009 | -0.0002 | -0.0018 | 0.0037 | -0.0004 | 0.0000 |
| 10.43 | 0.98 | 0.0004 | 0.0037 | 0.0022 | 0.0004 | -0.0004 | 0.0059 | -0.0004 | -0.0002 |
| 15.45 | 1.42 | 0.0016 | 0.0088 | 0.0053 | 0.0062 | -0.0004 | 0.0130 | -0.0004 | -0.0015 |
| 19.66 | 1.93 | 0.0016 | 0.0108 | 0.0064 | 0.0060 | -0.0004 | 0.0130 | -0.0005 | -0.0013 |
| 23.81 | 2.44 | 0.0037 | 0.0159 | 0.0106 | 0.0068 | 0.0033 | 0.0163 | -0.0007 | 0.0016 |
| 28.71 | 2.85 | 0.0141 | 0.0295 | 0.0196 | 0.0156 | 0.0126 | 0.0244 | 0.0040 | 0.0110 |
| 32.91 | 3.27 | 0.0258 | 0.0429 | 0.0308 | 0.0267 | 0.0337 | 0.0419 | 0.0163 | 0.0339 |
| 35.68 | 3.50 | 0.0445 | 0.0646 | 0.0483 | 0.0463 | 0.0624 | 0.0641 | 0.0370 | 0.0643 |
| 37.50 | 4.03 | 0.0734 | 0.0989 | 0.0767 | 0.0745 | 0.1000 | 0.0982 | 0.0685 | 0.1044 |
| 39.95 | 4.25 | 0.1029 | 0.1340 | 0.1075 | 0.1088 | 0.1397 | 0.1384 | 0.1044 | 0.1467 |
| 41.08 | 4.36 | 0.1218 | 0.1564 | 0.1280 | 0.1311 | 0.1615 | 0.1604 | 0.1251 | 0.1710 |
| 42.90 | 4.57 | 0.1516 | 0.1927 | 0.1606 | 0.1666 | 0.1958 | 0.1959 | 0.1558 | 0.2075 |
| 44.16 | 4.68 | 0.1753 | 0.2179 | 0.1837 | 0.1925 | 0.2210 | 0.2205 | 0.1791 | 0.2337 |
| 46.11 | 4.77 | 0.2139 | 0.2593 | 0.2220 | 0.2329 | 0.2606 | 0.2621 | 0.2130 | 0.2730 |
| 47.11 | 4.94 | 0.2372 | 0.2833 | 0.2445 | 0.2545 | 0.2833 | 0.2849 | 0.2346 | 0.2976 |
| 48.49 | 5.03 | 0.2665 | 0.3159 | 0.2738 | 0.2820 | 0.3131 | 0.3159 | 0.2593 | 0.3272 |
| 50.13 | 5.15 | 0.2961 | 0.3492 | 0.3044 | 0.3111 | 0.3456 | 0.3452 | 0.2873 | 0.3591 |
| 51.82 | 5.29 | 0.3291 | 0.3853 | 0.3370 | 0.3414 | 0.3778 | 0.3782 | 0.3163 | 0.3915 |
| 53.08 | 5.47 | 0.3597 | 0.4183 | 0.3663 | 0.3717 | 0.4086 | 0.4082 | 0.3461 | 0.4216 |
| 54.08 | 5.56 | 0.3833 | 0.4434 | 0.3895 | 0.3965 | 0.4325 | 0.4314 | 0.3686 | 0.4457 |
| 55.65 | 5.67 | 0.4076 | 0.4701 | 0.4148 | 0.4223 | 0.4587 | 0.4582 | 0.3935 | 0.4716 |
| 56.91 | 5.90 | 0.4344 | 0.4977 | 0.4412 | 0.4512 | 0.4869 | 0.4860 | 0.4186 | 0.4979 |
| 58.48 | 5.98 | 0.4618 | 0.5269 | 0.4683 | 0.4800 | 0.5140 | 0.5140 | 0.4455 | 0.5250 |
| 59.36 | 6.24 | 0.4853 | 0.5518 | 0.4921 | 0.5056 | 0.5362 | 0.5353 | 0.4670 | 0.5465 |
| 60.30 | 6.20 | 0.5058 | 0.5734 | 0.5115 | 0.5269 | 0.5567 | 0.5543 | 0.4853 | 0.5653 |
| 61.49 | 6.41 | 0.5289 | 0.5974 | 0.5338 | 0.5503 | 0.5789 | 0.5798 | 0.5087 | 0.5889 |
| 62.94 | 6.44 | 0.5492 | 0.6193 | 0.5541 | 0.5725 | 0.6023 | 0.6016 | 0.5303 | 0.6113 |
| 64.20 | 6.59 | 0.5682 | 0.6391 | 0.5732 | 0.5919 | 0.6214 | 0.6212 | 0.5487 | 0.6311 |
| 66.02 | 6.70 | 0.5955 | 0.6675 | 0.6003 | 0.6197 | 0.6479 | 0.6516 | 0.5756 | 0.6587 |
| 67.40 | 6.93 | 0.6170 | 0.6919 | 0.6221 | 0.6428 | 0.6743 | 0.6757 | 0.6001 | 0.6834 |
| 69.16 | 7.16 | 0.6424 | 0.7177 | 0.6466 | 0.6691 | 0.6999 | 0.7030 | 0.6257 | 0.7093 |
| 71.23 | 7.50 | 0.6677 | 0.7440 | 0.6723 | 0.6957 | 0.7248 | 0.7299 | 0.6497 | 0.7356 |
| 72.68 | 7.55 | 0.6865 | 0.7640 | 0.6902 | 0.7158 | 0.7440 | 0.7477 | 0.6670 | 0.7549 |
| 73.81 | 7.68 | 0.7052 | 0.7825 | 0.7083 | 0.7351 | 0.7611 | 0.7649 | 0.6847 | 0.7730 |
| 75.25 | 7.70 | 0.7245 | 0.8039 | 0.7287 | 0.7571 | 0.7790 | 0.7845 | 0.7034 | 0.7924 |
| 76.44 | 7.87 | 0.7397 | 0.8208 | 0.7444 | 0.7735 | 0.7950 | 0.8014 | 0.7190 | 0.8092 |
| 77.14 | 8.00 | 0.7647 | 0.8446 | 0.7669 | 0.7986 | 0.8169 | 0.8250 | 0.7409 | 0.8334 |
| 77.83 | 8.19 | 0.7937 | 0.8728 | 0.7950 | 0.8283 | 0.8459 | 0.8569 | 0.7719 | 0.8675 |
| 77.95 | 8.31 | 0.8265 | 0.9072 | 0.8266 | 0.8625 | 0.8774 | 0.8902 | 0.8041 | 0.9023 |
| 77.32 | 8.43 | 0.8627 | 0.9437 | 0.8625 | 0.8993 | 0.9123 | 0.9286 | 0.8426 | 0.9448 |
| 76.44 | 8.38 | 0.9030 | 0.9838 | 0.8999 | 0.9394 | 0.9484 | 0.9634 | 0.8772 | 0.9817 |
| 73.81 | 8.41 | 0.9755 | 1.0491 | 0.9669 | 1.0072 | 1.0126 | 1.0280 | 0.9418 | 1.0506 |
| 69.72 | 7.51 | 1.0648 | 1.1335 | 1.0493 | 1.0918 | 1.1031 | 1.1156 | 1.0313 | 1.1438 |
| 70.73 | 7.55 | 1.1368 | 1.2044 | 1.1227 | 1.1652 | 1.1817 | 1.1910 | 1.1115 | 1.2240 |
| 10.80 | 8.40 | 1.1659 | 1.2958 | 1.2302 | 1.1756 | 2.2984 | 2.1436 | 2.9584 | 1.8691 |

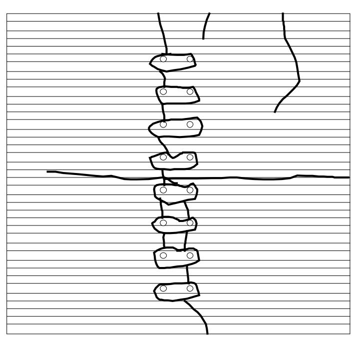
**PUSHOUT TEST SUMMARY SHEET**

Test: B14-1 Test Date: 17-Aug-98
Test Designation: SC-8-2.5-0.109-1.0C-2.75-1

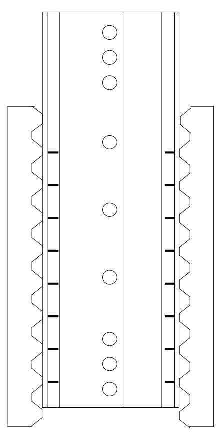
| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.5 in. | No. Per Specimen: | 32 | | |
| **Deck:** | Type: | 1.0C, 26 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 103.8 ksi | $F_u$: | 104.9 ksi | | |
| **Base Member:** | Section: | 2L 1.25x1.25x0.109 | | | | |
| | $F_y$: | 55.6 ksi | $F_u$: | 76.8 ksi | | |
| **Slab:** | Thickness: | 2.75 in. | $f'_c$: | 6526 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 16 | | |
| | | | Height Above Deck: | 0.75 in. | | |
| **Mesh:** | Type: | WWF 6x6-W2.9xW2.9 | | | | |

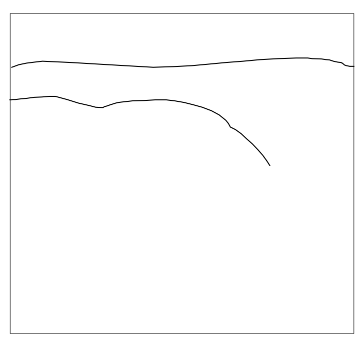
| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 116.45 kips | | | |
| **Peak Shear Load Per Screw:** | 3.64 kips | | | |
| **Slip at Peak Shear Load:** | SC1: 0.6884 in. | | SC5: 0.7296 in. | |
| | SC2: 0.7325 in. | | SC6: 0.6102 in. | |
| | SC3: N.A. | | SC7: 0.6422 in. | |
| | SC4: N.A. | | SC8: 0.6853 in. | |

**DAMAGE**



interior, Slab A



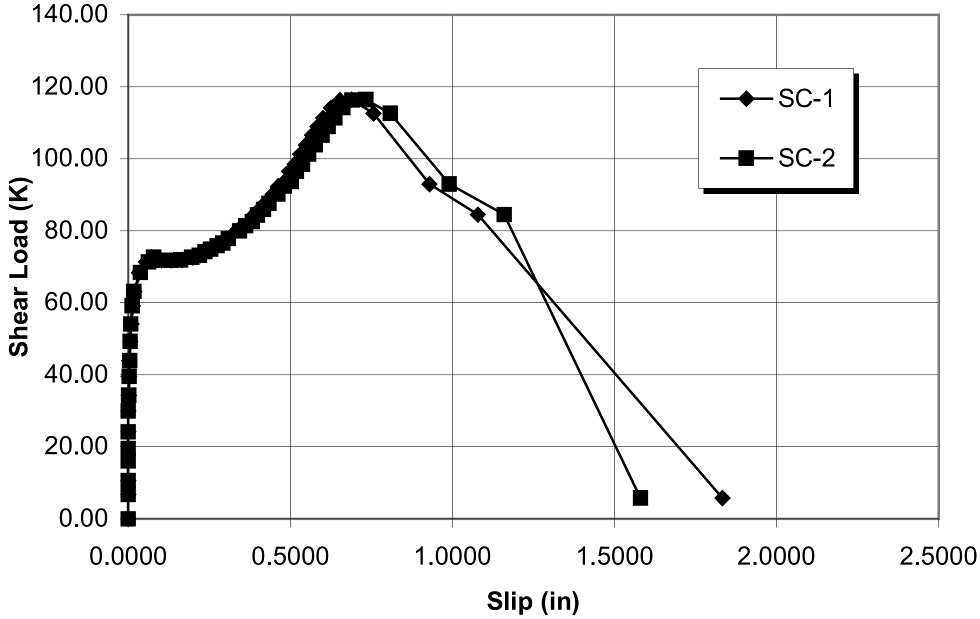


exterior, Slab B

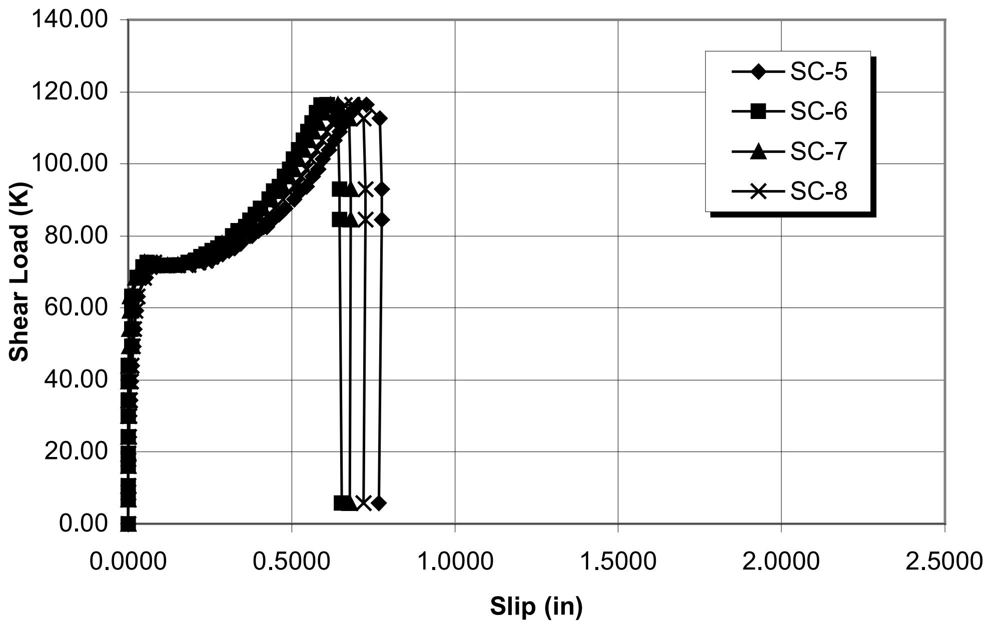
**COMMENTS**

Failure Mode: Concrete rib failure followed by screw pullout from angles at ultimate load
Screw Rotation ≈ 40° - 50°
Deck debonded
Slight bulging of deck below screws

Test B14-1: Load vs. Slip (A)




Test B14-1: Load vs. Slip (B)



**TEST B14-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | -0.0002 | 0.0000 | -0.0002 | -0.0004 | 0.0000 | -0.0002 | -0.0002 | 0.0000 |
| 6.78 | 0.49 | -0.0002 | 0.0000 | -0.0002 | -0.0004 | 0.0000 | 0.0000 | 0.0000 | -0.0002 |
| 10.62 | 0.84 | -0.0005 | -0.0004 | 0.0002 | -0.0005 | -0.0005 | -0.0004 | 0.0002 | 0.0000 |
| 16.08 | 1.32 | -0.0009 | 0.0000 | 0.0002 | -0.0005 | -0.0007 | 0.0000 | -0.0002 | 0.0000 |
| 19.54 | 1.88 | -0.0011 | 0.0000 | -0.0002 | -0.0004 | 0.0000 | -0.0002 | 0.0000 | 0.0004 |
| 24.12 | 2.35 | -0.0005 | 0.0002 | 0.0002 | -0.0004 | 0.0013 | 0.0004 | 0.0002 | 0.0009 |
| 29.96 | 2.86 | 0.0004 | -0.0004 | 0.0000 | -0.0004 | 0.0035 | -0.0002 | 0.0000 | 0.0029 |
| 34.36 | 3.40 | 0.0015 | 0.0011 | 0.0000 | -0.0005 | 0.0055 | 0.0000 | -0.0002 | 0.0049 |
| 39.57 | 3.94 | 0.0020 | 0.0026 | -0.0002 | -0.0002 | 0.0073 | 0.0000 | 0.0002 | 0.0071 |
| 43.97 | 4.30 | 0.0038 | 0.0040 | -0.0002 | -0.0005 | 0.0110 | 0.0000 | 0.0005 | 0.0101 |
| 49.37 | 4.89 | 0.0066 | 0.0068 | 0.0000 | -0.0002 | 0.0159 | 0.0106 | 0.0038 | 0.0136 |
| 54.08 | 5.28 | 0.0097 | 0.0081 | 0.0000 | -0.0004 | 0.0179 | 0.0104 | 0.0035 | 0.0165 |
| 59.23 | 5.87 | 0.0141 | 0.0123 | 0.0002 | -0.0002 | 0.0233 | 0.0108 | 0.0042 | 0.0214 |
| 63.13 | 6.33 | 0.0190 | 0.0179 | 0.0002 | -0.0004 | 0.0280 | 0.0110 | 0.0053 | 0.0273 |
| 68.34 | 6.80 | 0.0328 | 0.0374 | 0.7657 | 1.4609 | 0.0535 | 0.0275 | 0.0225 | 0.0482 |
| 71.36 | 7.25 | 0.0555 | 0.0626 | 0.7869 | 1.4864 | 0.0723 | 0.0447 | 0.0386 | 0.0659 |
| 72.55 | 7.49 | 0.0716 | 0.0780 | 0.8032 | 1.5043 | 0.0870 | 0.0575 | 0.0498 | 0.0800 |
| 71.80 | 7.66 | 0.1026 | 0.1049 | 0.8362 | 1.5410 | 0.1269 | 0.0950 | 0.0863 | 0.1179 |
| 71.73 | 7.74 | 0.1320 | 0.1297 | 0.8666 | 1.5736 | 0.1626 | 0.1236 | 0.1198 | 0.1518 |
| 71.86 | 7.72 | 0.1663 | 0.1612 | 0.8997 | 1.6096 | 0.1967 | 0.1544 | 0.1507 | 0.1842 |
| 72.61 | 7.56 | 0.1987 | 0.1963 | 0.9316 | 1.6444 | 0.2300 | 0.1846 | 0.1829 | 0.2150 |
| 73.12 | 7.52 | 0.2216 | 0.2196 | 0.9557 | 1.6679 | 0.2538 | 0.2077 | 0.2058 | 0.2362 |
| 74.12 | 7.63 | 0.2373 | 0.2373 | 0.9735 | 1.6847 | 0.2718 | 0.2229 | 0.2214 | 0.2534 |
| 74.87 | 7.65 | 0.2534 | 0.2542 | 0.9898 | 1.7019 | 0.2886 | 0.2379 | 0.2375 | 0.2688 |
| 75.82 | 7.79 | 0.2725 | 0.2740 | 1.0070 | 1.7210 | 0.3091 | 0.2567 | 0.2562 | 0.2882 |
| 76.63 | 7.87 | 0.2870 | 0.2917 | 1.0231 | 1.7382 | 0.3262 | 0.2740 | 0.2718 | 0.3033 |
| 77.89 | 7.86 | 0.3022 | 0.3091 | 1.0376 | 1.7550 | 0.3452 | 0.2884 | 0.2875 | 0.3205 |
| 79.90 | 8.00 | 0.3326 | 0.3434 | 1.0658 | 1.7876 | 0.3794 | 0.3196 | 0.3194 | 0.3529 |
| 81.34 | 8.16 | 0.3511 | 0.3628 | 1.0826 | 1.8058 | 0.3985 | 0.3371 | 0.3373 | 0.3712 |
| 82.54 | 8.36 | 0.3714 | 0.3829 | 1.1002 | 1.8256 | 0.4239 | 0.3593 | 0.3600 | 0.3950 |
| 84.36 | 8.36 | 0.3864 | 0.3987 | 1.1137 | 1.8411 | 0.4408 | 0.3732 | 0.3758 | 0.4109 |
| 85.87 | 8.56 | 0.4034 | 0.4181 | 1.1278 | 1.8587 | 0.4618 | 0.3897 | 0.3948 | 0.4300 |
| 87.56 | 8.71 | 0.4208 | 0.4355 | 1.1434 | 1.8759 | 0.4800 | 0.4051 | 0.4111 | 0.4470 |
| 90.14 | 8.95 | 0.4455 | 0.4613 | 1.1656 | 1.9019 | 0.5082 | 0.4313 | 0.4379 | 0.4734 |
| 92.40 | 9.20 | 0.4631 | 0.4816 | 1.1813 | 1.9208 | 0.5270 | 0.4459 | 0.4551 | 0.4911 |
| 93.72 | 9.59 | 0.4814 | 0.5031 | 1.1976 | 1.9420 | 0.5463 | 0.4624 | 0.4730 | 0.5111 |
| 96.42 | 9.63 | 0.4963 | 0.5190 | 1.2115 | 1.9569 | 0.5648 | 0.4785 | 0.4915 | 0.5300 |
| 98.43 | 9.88 | 0.5129 | 0.5386 | 1.2315 | 1.9755 | 0.5818 | 0.4946 | 0.5078 | 0.5463 |
| 101.25 | 10.12 | 0.5300 | 0.5573 | 1.2494 | 1.9938 | 0.5957 | 0.5060 | 0.5212 | 0.5602 |
| 103.89 | 10.42 | 0.5485 | 0.5781 | 1.2696 | 2.0138 | 0.6137 | 0.5223 | 0.5371 | 0.5772 |
| 106.53 | 10.65 | 0.5659 | 0.5974 | 1.2870 | 2.0323 | 0.6305 | 0.5364 | 0.5532 | 0.5933 |
| 108.85 | 10.97 | 0.5836 | 0.6164 | 1.3046 | 2.0502 | 0.6461 | 0.5497 | 0.5666 | 0.6080 |
| 111.36 | 11.29 | 0.6010 | 0.6367 | 1.3252 | 2.0700 | 0.6622 | 0.5620 | 0.5825 | 0.6232 |
| 114.19 | 11.65 | 0.6250 | 0.6620 | 1.3516 | 2.0946 | 0.6829 | 0.5765 | 0.6007 | 0.6430 |
| 116.20 | 11.94 | 0.6521 | 0.6909 | 1.3798 | 2.1242 | 0.7034 | 0.5908 | 0.6190 | 0.6618 |
| 116.45 | 12.08 | 0.6884 | 0.7325 | 1.4172 | 2.1616 | 0.7296 | 0.6102 | 0.6422 | 0.6853 |
| 112.56 | 12.29 | 0.7569 | 0.8081 | 1.4926 | 2.2354 | 0.7695 | 0.6415 | 0.6765 | 0.7201 |
| 92.96 | 12.74 | 0.9292 | 0.9907 | 1.6807 | 2.4255 | 0.7766 | 0.6468 | 0.6814 | 0.7259 |
| 84.55 | 9.58 | 1.0780 | 1.1604 | 1.8455 | 2.5745 | 0.7768 | 0.6468 | 0.6816 | 0.7261 |
| 5.84 | 15.63 | 1.8338 | 1.5796 | 2.3990 | 2.9633 | 0.7673 | 0.6523 | 0.6785 | 0.7206 |

Note: SC-3 and SC-4 readings not included due to operational error

**PUSHOUT TEST SUMMARY SHEET**

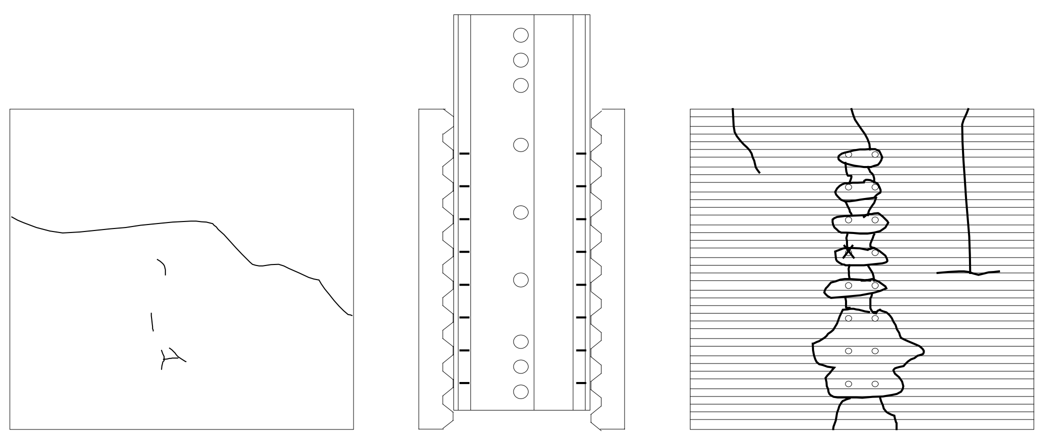
Test: B14-2 Test Date: 19-Aug-98

Test Designation: SC-8-2.5-0.109-1.0C-2.75-2

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.5 in. | No. Per Specimen: | 32 | | |
| **Deck:** | Type: | 1.0C, 26 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 103.8 ksi | $F_u$: | 104.9 ksi | | |
| **Base Member:** | Section: | 2L 1.25x1.25x0.109 | | | | |
| | $F_y$: | 55.6 ksi | $F_u$: | 76.8 ksi | | |
| **Slab:** | Thickness: | 2.75 in. | $f'_c$: | 6526 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 16 | | |
| | | | Height Above Deck: | 0.75 in. | | |
| **Mesh:** | Type: | WWF 6x6-W2.9xW2.9 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 118.40 kips | | | |
| **Peak Shear Load Per Screw:** | 3.70 kips | | | |
| **Slip at Peak Shear Load:** | SC1: 0.6342 in. | | SC5: 0.8274 in. | |
| | SC2: 0.7517 in. | | SC6: 0.6455 in. | |
| | SC3: 0.7592 in. | | SC7: 0.6479 in. | |
| | SC4: 0.7162 in. | | SC8: 0.7803 in. | |

**DAMAGE**

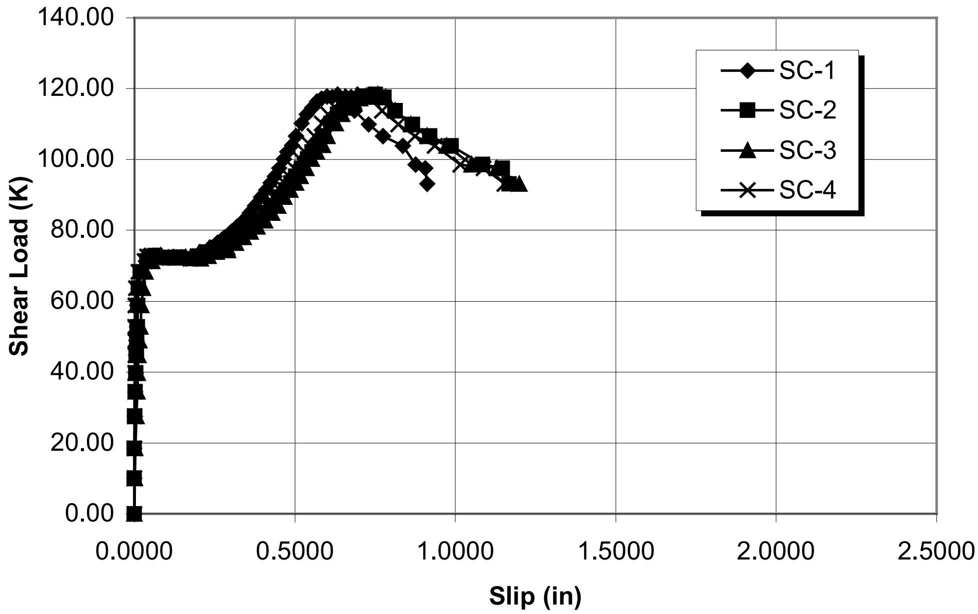


exterior, Slab A interior, Slab B

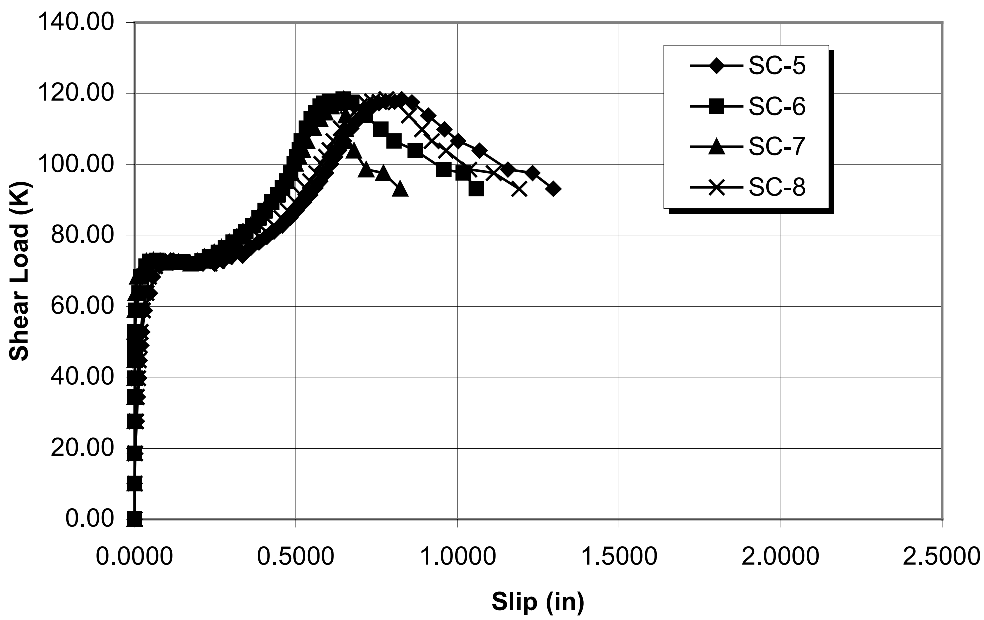
**COMMENTS**

Failure Mode: Concrete rib failure followed by screw pullout from angles at ultimate load
Screw Rotation ≈ 50° - 60°
Bottom six screws of slab B pulled out of concrete
Deck debonded; Slight bulging of deck below screws
X = Screw sheared off

Test B14-2: Load vs. Slip (A)




Test B14-2: Load vs. Slip (B)



**TEST B14-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| -0.06 | -0.01 | 0.0004 | -0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0000 | 0.0002 |
| 9.99 | 0.88 | 0.0005 | 0.0000 | 0.0016 | -0.0004 | 0.0000 | 0.0002 | 0.0000 | 0.0005 |
| 18.53 | 1.85 | 0.0000 | 0.0002 | 0.0038 | 0.0002 | 0.0016 | 0.0004 | -0.0002 | 0.0020 |
| 27.51 | 2.66 | 0.0015 | 0.0018 | 0.0066 | -0.0002 | 0.0066 | 0.0004 | 0.0000 | 0.0044 |
| 34.36 | 3.40 | 0.0027 | 0.0027 | 0.0092 | -0.0002 | 0.0090 | 0.0004 | 0.0000 | 0.0070 |
| 39.76 | 3.93 | 0.0046 | 0.0044 | 0.0115 | 0.0020 | 0.0137 | 0.0009 | -0.0007 | 0.0117 |
| 44.72 | 4.48 | 0.0046 | 0.0057 | 0.0132 | 0.0024 | 0.0157 | 0.0009 | -0.0007 | 0.0134 |
| 48.93 | 4.93 | 0.0060 | 0.0073 | 0.0159 | 0.0020 | 0.0200 | 0.0016 | -0.0009 | 0.0163 |
| 52.83 | 5.30 | 0.0079 | 0.0090 | 0.0185 | 0.0022 | 0.0242 | 0.0015 | 0.0005 | 0.0194 |
| 58.86 | 5.94 | 0.0099 | 0.0106 | 0.0227 | 0.0024 | 0.0311 | 0.0038 | 0.0005 | 0.0251 |
| 63.69 | 6.27 | 0.0134 | 0.0128 | 0.0271 | 0.0049 | 0.0472 | 0.0145 | 0.0024 | 0.0361 |
| 68.28 | 6.83 | 0.0196 | 0.0192 | 0.0348 | 0.0121 | 0.0560 | 0.0196 | 0.0077 | 0.0434 |
| 71.36 | 7.24 | 0.0368 | 0.0401 | 0.0559 | 0.0309 | 0.0769 | 0.0366 | 0.0262 | 0.0634 |
| 72.61 | 7.57 | 0.0440 | 0.0485 | 0.0646 | 0.0388 | 0.0890 | 0.0467 | 0.0363 | 0.0758 |
| 72.80 | 7.75 | 0.0588 | 0.0648 | 0.0828 | 0.0538 | 0.1119 | 0.0687 | 0.0584 | 0.1000 |
| 72.30 | 8.03 | 0.0888 | 0.1013 | 0.1212 | 0.0879 | 0.1520 | 0.1029 | 0.0910 | 0.1379 |
| 72.42 | 8.11 | 0.1212 | 0.1397 | 0.1602 | 0.1267 | 0.2035 | 0.1472 | 0.1350 | 0.1883 |
| 72.05 | 7.95 | 0.1613 | 0.1846 | 0.2079 | 0.1743 | 0.2474 | 0.1870 | 0.1734 | 0.2309 |
| 72.74 | 7.76 | 0.1818 | 0.2068 | 0.2306 | 0.1970 | 0.2725 | 0.2089 | 0.1945 | 0.2553 |
| 73.81 | 7.55 | 0.2053 | 0.2322 | 0.2573 | 0.2230 | 0.2994 | 0.2315 | 0.2161 | 0.2796 |
| 75.19 | 7.15 | 0.2361 | 0.2633 | 0.2906 | 0.2555 | 0.3327 | 0.2600 | 0.2463 | 0.3111 |
| 74.31 | 7.12 | 0.2375 | 0.2643 | 0.2917 | 0.2558 | 0.3348 | 0.2599 | 0.2461 | 0.3128 |
| 76.51 | 7.70 | 0.2586 | 0.2871 | 0.3163 | 0.2800 | 0.3595 | 0.2818 | 0.2694 | 0.3375 |
| 78.08 | 7.93 | 0.2809 | 0.3131 | 0.3401 | 0.3064 | 0.3857 | 0.3049 | 0.2923 | 0.3617 |
| 79.65 | 8.03 | 0.3023 | 0.3364 | 0.3635 | 0.3304 | 0.4100 | 0.3276 | 0.3159 | 0.3862 |
| 81.03 | 8.20 | 0.3207 | 0.3595 | 0.3838 | 0.3503 | 0.4318 | 0.3443 | 0.3355 | 0.4067 |
| 82.73 | 8.31 | 0.3408 | 0.3844 | 0.4076 | 0.3728 | 0.4575 | 0.3666 | 0.3598 | 0.4309 |
| 84.86 | 8.44 | 0.3595 | 0.4080 | 0.4287 | 0.3941 | 0.4814 | 0.3862 | 0.3815 | 0.4538 |
| 87.00 | 8.82 | 0.3761 | 0.4280 | 0.4477 | 0.4124 | 0.5016 | 0.4056 | 0.4005 | 0.4745 |
| 89.32 | 9.04 | 0.3937 | 0.4498 | 0.4681 | 0.4329 | 0.5241 | 0.4256 | 0.4219 | 0.4959 |
| 91.33 | 9.24 | 0.4111 | 0.4717 | 0.4871 | 0.4525 | 0.5443 | 0.4435 | 0.4399 | 0.5150 |
| 93.34 | 9.40 | 0.4243 | 0.4882 | 0.5034 | 0.4673 | 0.5593 | 0.4580 | 0.4532 | 0.5296 |
| 95.23 | 9.65 | 0.4373 | 0.5042 | 0.5183 | 0.4822 | 0.5748 | 0.4708 | 0.4677 | 0.5443 |
| 97.55 | 9.77 | 0.4510 | 0.5214 | 0.5355 | 0.4979 | 0.5926 | 0.4836 | 0.4846 | 0.5626 |
| 100.18 | 9.80 | 0.4659 | 0.5400 | 0.5536 | 0.5159 | 0.6087 | 0.4952 | 0.4981 | 0.5781 |
| 102.07 | 10.23 | 0.4772 | 0.5551 | 0.5693 | 0.5303 | 0.6206 | 0.5023 | 0.5095 | 0.5917 |
| 103.95 | 10.50 | 0.4919 | 0.5743 | 0.5878 | 0.5479 | 0.6338 | 0.5098 | 0.5219 | 0.6038 |
| 106.59 | 10.84 | 0.5031 | 0.5893 | 0.6027 | 0.5613 | 0.6468 | 0.5164 | 0.5338 | 0.6164 |
| 110.17 | 11.18 | 0.5208 | 0.6131 | 0.6279 | 0.5845 | 0.6706 | 0.5324 | 0.5549 | 0.6387 |
| 112.68 | 11.59 | 0.5373 | 0.6338 | 0.6481 | 0.6041 | 0.6935 | 0.5463 | 0.5743 | 0.6598 |
| 114.63 | 11.99 | 0.5538 | 0.6529 | 0.6681 | 0.6257 | 0.7144 | 0.5602 | 0.5913 | 0.6801 |
| 116.33 | 12.18 | 0.5681 | 0.6712 | 0.6851 | 0.6402 | 0.7360 | 0.5745 | 0.6091 | 0.6983 |
| 117.14 | 12.31 | 0.5836 | 0.6906 | 0.7030 | 0.6583 | 0.7565 | 0.5867 | 0.6256 | 0.7164 |
| 117.77 | 12.01 | 0.6007 | 0.7116 | 0.7219 | 0.6778 | 0.7774 | 0.6030 | 0.6415 | 0.7349 |
| 117.58 | 11.84 | 0.6166 | 0.7301 | 0.7398 | 0.6961 | 0.8043 | 0.6246 | 0.6442 | 0.7576 |
| 118.40 | 12.07 | 0.6342 | 0.7517 | 0.7592 | 0.7162 | 0.8274 | 0.6455 | 0.6479 | 0.7803 |
| 117.52 | 12.04 | 0.6567 | 0.7781 | 0.7821 | 0.7398 | 0.8591 | 0.6734 | 0.6534 | 0.8083 |
| 113.69 | 12.25 | 0.6856 | 0.8127 | 0.8135 | 0.7717 | 0.9089 | 0.7151 | 0.6530 | 0.8493 |
| 109.86 | 12.53 | 0.7298 | 0.8660 | 0.8620 | 0.8222 | 0.9600 | 0.7625 | 0.6530 | 0.8906 |
| 106.53 | 12.68 | 0.7752 | 0.9211 | 0.9122 | 0.8741 | 1.0026 | 0.8039 | 0.6532 | 0.9202 |
| 103.83 | 12.91 | 0.8369 | 0.9872 | 0.9735 | 0.9361 | 1.0683 | 0.8697 | 0.6794 | 0.9638 |
| 98.56 | 10.33 | 0.8755 | 1.0848 | 1.0502 | 1.0152 | 1.1564 | 0.9572 | 0.7171 | 1.0368 |
| 97.55 | 10.95 | 0.9063 | 1.1472 | 1.1293 | 1.0888 | 1.2319 | 1.0183 | 0.7697 | 1.1128 |
| 93.03 | 9.63 | 0.9125 | 1.1679 | 1.1993 | 1.1538 | 1.2969 | 1.0581 | 0.8219 | 1.1908 |

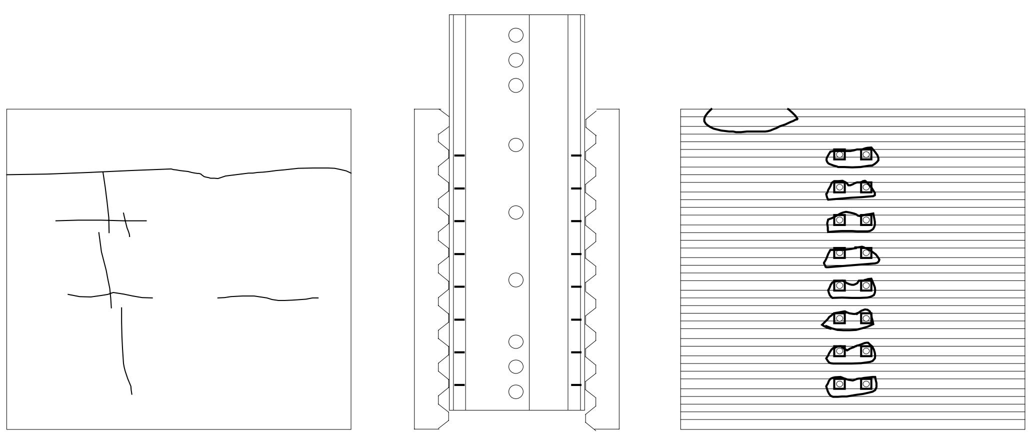
**PUSHOUT TEST SUMMARY SHEET**

Test: B14R-1 Test Date: 29-Jan-99
Test Designation: SC-8-2.5-0.109-1.0C-2.75-1R

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.5 in. | No. Per Specimen: | 32 | | |
| **Deck:** | Type: | 1.0C, 26 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 103.8 ksi | $F_u$: | 104.9 ksi | | |
| **Base Member:** | Section: | 2L 1.25x1.25x0.109 | | | | |
| | $F_y$: | 55.6 ksi | $F_u$: | 76.8 ksi | | |
| **Slab:** | Thickness: | 2.75 in. | $f'_c$: | 5869 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 16 | | |
| | | | Height Above Deck: | 0.75 in. | | |
| **Mesh:** | Type: | WWF 6x6-W2.9xW2.9 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 119.84 kips | | | |
| **Peak Shear Load Per Screw:** | 3.75 kips | | | |
| **Slip at Peak Shear Load:** | SC1: 0.6525 in. | | SC5: 0.7648 in. | |
| | SC2: 0.6653 in. | | SC6: 0.7159 in. | |
| | SC3: 0.6396 in. | | SC7: 0.7349 in. | |
| | SC4: 0.6573 in. | | SC8: 0.7153 in. | |

**DAMAGE**

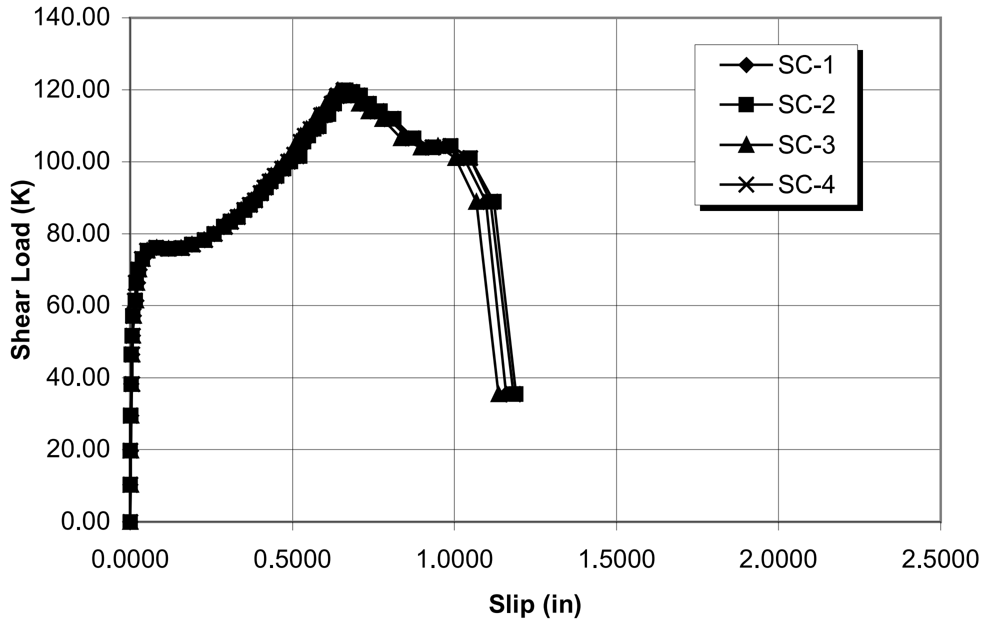


exterior, Slab A interior, Slab B

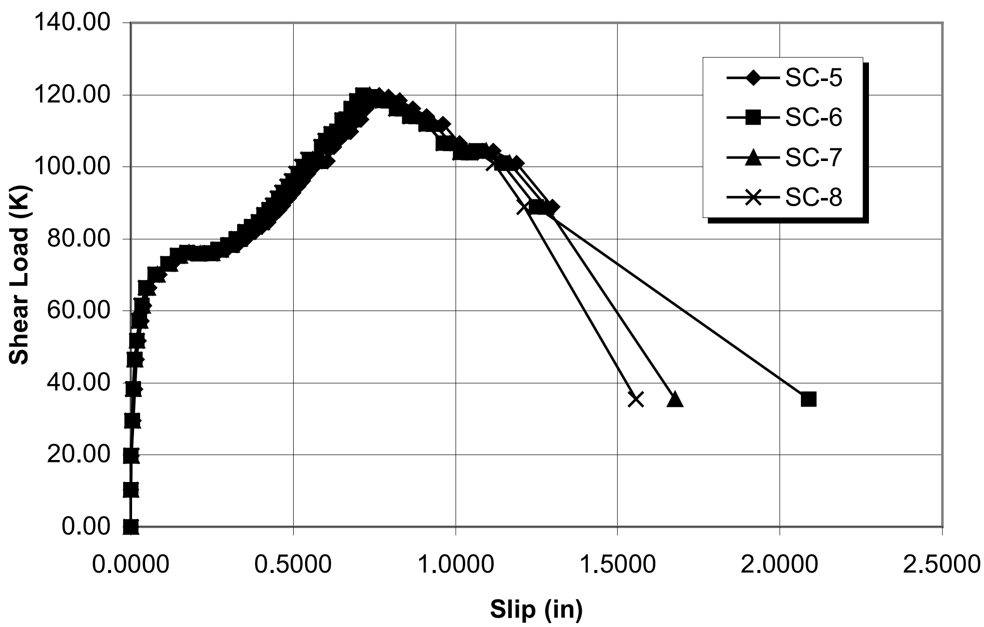
**COMMENTS**

Failure Mode: Concrete rib failure followed by screw pullout from angles at ultimate load
Screw Rotation ≈ 70° - 80°
Deck debonded; Slight bulging of deck below screws
Angles deformed at screw locations due to rotation of screws
□= Screw pulled out of angle

**Test B14R-1: Load vs. Slip (A)**




**Test B14R-1: Load vs. Slip (B)**



## TEST B14R-1 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | -0.0006 | 0.0000 |
| 10.30 | 1.10 | 0.0006 | 0.0006 | 0.0012 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0006 |
| 19.72 | 1.87 | 0.0012 | 0.0006 | 0.0018 | 0.0006 | 0.0012 | 0.0000 | 0.0018 | 0.0012 |
| 29.52 | 2.87 | 0.0031 | 0.0012 | 0.0024 | 0.0006 | 0.0085 | 0.0049 | 0.0055 | 0.0037 |
| 38.32 | 3.95 | 0.0037 | 0.0031 | 0.0043 | 0.0067 | 0.0122 | 0.0079 | 0.0079 | 0.0067 |
| 46.48 | 4.66 | 0.0061 | 0.0037 | 0.0067 | 0.0067 | 0.0171 | 0.0128 | 0.0128 | 0.0116 |
| 51.76 | 5.06 | 0.0085 | 0.0055 | 0.0085 | 0.0073 | 0.0238 | 0.0189 | 0.0195 | 0.0189 |
| 57.16 | 5.66 | 0.0104 | 0.0079 | 0.0116 | 0.0092 | 0.0323 | 0.0262 | 0.0275 | 0.0250 |
| 61.43 | 6.11 | 0.0189 | 0.0153 | 0.0177 | 0.0140 | 0.0403 | 0.0342 | 0.0354 | 0.0317 |
| 66.46 | 6.87 | 0.0232 | 0.0189 | 0.0208 | 0.0177 | 0.0562 | 0.0464 | 0.0513 | 0.0452 |
| 70.10 | 7.61 | 0.0287 | 0.0256 | 0.0269 | 0.0250 | 0.0873 | 0.0757 | 0.0812 | 0.0757 |
| 72.99 | 8.02 | 0.0397 | 0.0372 | 0.0372 | 0.0354 | 0.1270 | 0.1141 | 0.1202 | 0.1141 |
| 75.25 | 8.16 | 0.0543 | 0.0531 | 0.0525 | 0.0525 | 0.1587 | 0.1440 | 0.1501 | 0.1447 |
| 76.13 | 8.30 | 0.0806 | 0.0800 | 0.0812 | 0.0806 | 0.1910 | 0.1721 | 0.1782 | 0.1746 |
| 75.88 | 8.39 | 0.1184 | 0.1166 | 0.1184 | 0.1178 | 0.2271 | 0.2051 | 0.2136 | 0.2094 |
| 76.01 | 8.29 | 0.1581 | 0.1569 | 0.1575 | 0.1593 | 0.2655 | 0.2417 | 0.2502 | 0.2460 |
| 77.01 | 8.08 | 0.1904 | 0.1898 | 0.1898 | 0.1929 | 0.2948 | 0.2679 | 0.2783 | 0.2734 |
| 78.27 | 8.13 | 0.2289 | 0.2289 | 0.2271 | 0.2307 | 0.3284 | 0.2991 | 0.3101 | 0.3046 |
| 79.90 | 8.23 | 0.2588 | 0.2588 | 0.2557 | 0.2612 | 0.3546 | 0.3241 | 0.3351 | 0.3296 |
| 81.91 | 8.30 | 0.2887 | 0.2881 | 0.2844 | 0.2911 | 0.3827 | 0.3516 | 0.3607 | 0.3552 |
| 83.42 | 8.38 | 0.3082 | 0.3094 | 0.3033 | 0.3113 | 0.4034 | 0.3717 | 0.3815 | 0.3748 |
| 84.67 | 8.63 | 0.3296 | 0.3320 | 0.3223 | 0.3314 | 0.4242 | 0.3937 | 0.4034 | 0.3943 |
| 86.56 | 8.68 | 0.3491 | 0.3528 | 0.3418 | 0.3522 | 0.4413 | 0.4114 | 0.4205 | 0.4108 |
| 88.07 | 8.83 | 0.3668 | 0.3711 | 0.3595 | 0.3693 | 0.4565 | 0.4272 | 0.4352 | 0.4260 |
| 89.32 | 9.38 | 0.3815 | 0.3864 | 0.3729 | 0.3839 | 0.4694 | 0.4407 | 0.4474 | 0.4370 |
| 91.33 | 9.29 | 0.3992 | 0.4047 | 0.3906 | 0.4010 | 0.4858 | 0.4572 | 0.4639 | 0.4523 |
| 92.84 | 9.48 | 0.4126 | 0.4187 | 0.4028 | 0.4144 | 0.4999 | 0.4712 | 0.4773 | 0.4657 |
| 94.47 | 9.59 | 0.4272 | 0.4352 | 0.4181 | 0.4297 | 0.5151 | 0.4858 | 0.4926 | 0.4810 |
| 96.11 | 9.65 | 0.4437 | 0.4523 | 0.4340 | 0.4456 | 0.5298 | 0.5011 | 0.5072 | 0.4950 |
| 97.99 | 9.99 | 0.4645 | 0.4736 | 0.4547 | 0.4669 | 0.5463 | 0.5164 | 0.5231 | 0.5103 |
| 100.00 | 10.16 | 0.4852 | 0.4950 | 0.4736 | 0.4865 | 0.5640 | 0.5334 | 0.5414 | 0.5273 |
| 102.01 | 10.12 | 0.5042 | 0.5133 | 0.4932 | 0.5048 | 0.5829 | 0.5505 | 0.5603 | 0.5450 |
| 101.63 | 10.87 | 0.5115 | 0.5219 | 0.5005 | 0.5133 | 0.6055 | 0.5701 | 0.5817 | 0.5676 |
| 105.52 | 10.64 | 0.5243 | 0.5353 | 0.5127 | 0.5255 | 0.6256 | 0.5878 | 0.6012 | 0.5865 |
| 107.28 | 10.74 | 0.5371 | 0.5487 | 0.5261 | 0.5389 | 0.6384 | 0.6006 | 0.6140 | 0.5994 |
| 109.04 | 11.00 | 0.5542 | 0.5658 | 0.5432 | 0.5560 | 0.6586 | 0.6183 | 0.6329 | 0.6177 |
| 109.79 | 11.27 | 0.5713 | 0.5829 | 0.5603 | 0.5737 | 0.6775 | 0.6354 | 0.6519 | 0.6354 |
| 112.81 | 11.52 | 0.5853 | 0.5981 | 0.5737 | 0.5884 | 0.6952 | 0.6512 | 0.6689 | 0.6512 |
| 113.19 | 11.45 | 0.5994 | 0.6122 | 0.5878 | 0.6024 | 0.7092 | 0.6635 | 0.6824 | 0.6647 |
| 116.08 | 11.54 | 0.6165 | 0.6293 | 0.6042 | 0.6213 | 0.7251 | 0.6787 | 0.6976 | 0.6799 |
| 118.21 | 11.78 | 0.6323 | 0.6445 | 0.6201 | 0.6366 | 0.7434 | 0.6958 | 0.7141 | 0.6958 |
| 119.84 | 12.10 | 0.6525 | 0.6653 | 0.6396 | 0.6573 | 0.7648 | 0.7159 | 0.7349 | 0.7153 |
| 119.34 | 12.57 | 0.6720 | 0.6854 | 0.6586 | 0.6781 | 0.7935 | 0.7440 | 0.7617 | 0.7416 |
| 118.34 | 12.43 | 0.6946 | 0.7092 | 0.6805 | 0.7013 | 0.8276 | 0.7776 | 0.7971 | 0.7751 |
| 116.08 | 12.37 | 0.7214 | 0.7379 | 0.7062 | 0.7294 | 0.8691 | 0.8191 | 0.8398 | 0.8167 |
| 114.07 | 12.38 | 0.7538 | 0.7709 | 0.7367 | 0.7611 | 0.9113 | 0.8600 | 0.8820 | 0.8606 |
| 111.93 | 12.58 | 0.7965 | 0.8130 | 0.7782 | 0.8057 | 0.9613 | 0.9094 | 0.9338 | 0.9113 |
| 106.53 | 11.92 | 0.8582 | 0.8746 | 0.8356 | 0.8698 | 1.0137 | 0.9637 | 0.9882 | 0.9625 |
| 104.02 | 12.22 | 0.9198 | 0.9351 | 0.8966 | 0.9326 | 1.0675 | 1.0168 | 1.0424 | 1.0150 |
| 104.39 | 11.06 | 0.9717 | 0.9882 | 0.9491 | 0.9869 | 1.1169 | 1.0675 | 1.0943 | 1.0638 |
| 101.00 | 11.63 | 1.0290 | 1.0491 | 1.0034 | 1.0485 | 1.1883 | 1.1437 | 1.1663 | 1.1187 |
| 88.82 | 9.67 | 1.0974 | 1.1218 | 1.0668 | 1.1114 | 1.2994 | 1.2493 | 1.2792 | 1.2121 |
| 35.43 | 15.62 | 1.1602 | 1.1895 | 1.1364 | 1.1810 | | 2.0892 | 1.6772 | 1.5557 |

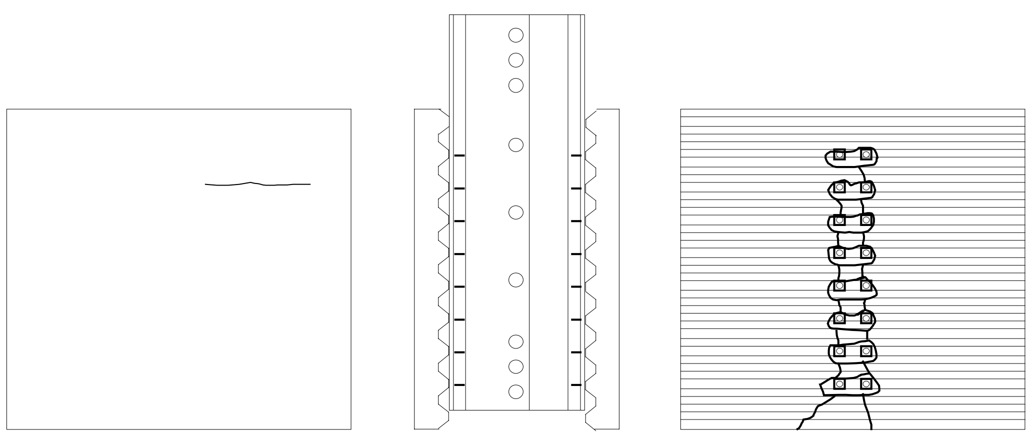
**PUSHOUT TEST SUMMARY SHEET**

Test: B14R-2 Test Date: 29-Jan-99
Test Designation: SC-8-2.5-0.109-1.0C-2.75-2R

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.5 in. | No. Per Specimen: | 32 | | |
| **Deck:** | Type: | 1.0C, 26 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 103.8 ksi | $F_u$: | 104.9 ksi | | |
| **Base Member:** | Section: | 2L 1.25x1.25x0.109 | | | | |
| | $F_y$: | 55.6 ksi | $F_u$: | 76.8 ksi | | |
| **Slab:** | Thickness: | 2.75 in. | $f'_c$: | 5869 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 16 | | |
| | | | Height Above Deck: | 0.75 in. | | |
| **Mesh:** | Type: | WWF 6x6-W2.9xW2.9 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 118.59 kips | | | |
| **Peak Shear Load Per Screw:** | 3.71 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.7178 in. | SC5: | 0.7532 in. |
| | SC2: | 0.7196 in. | SC6: | 0.7275 in. |
| | SC3: | 0.7324 in. | SC7: | 0.7483 in. |
| | SC4: | 0.7147 in. | SC8: | 0.7227 in. |

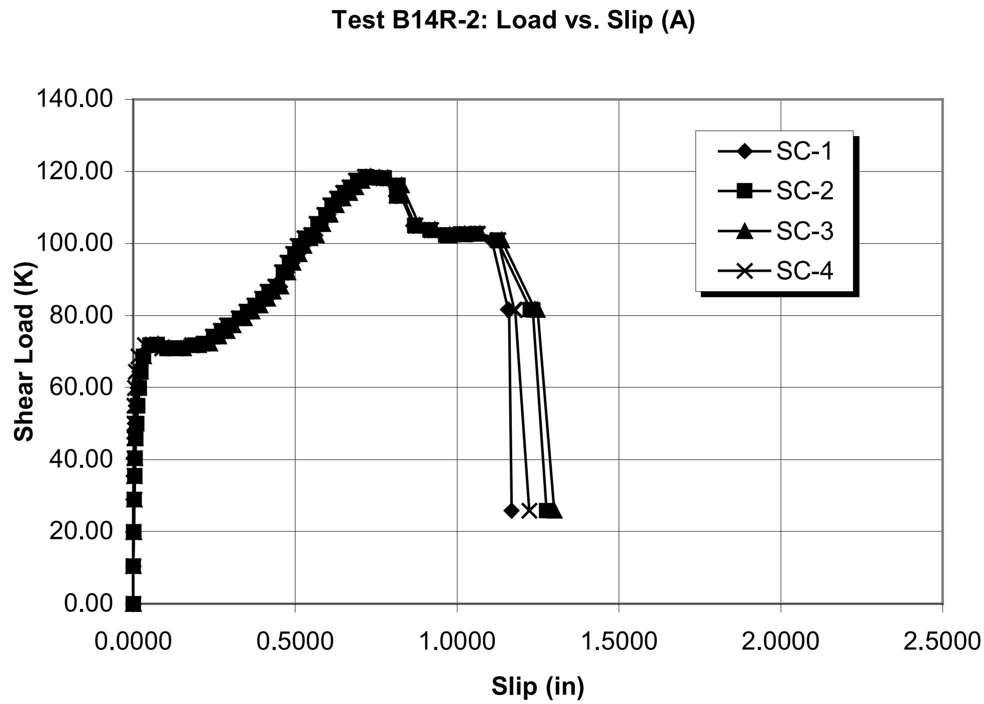
**DAMAGE**

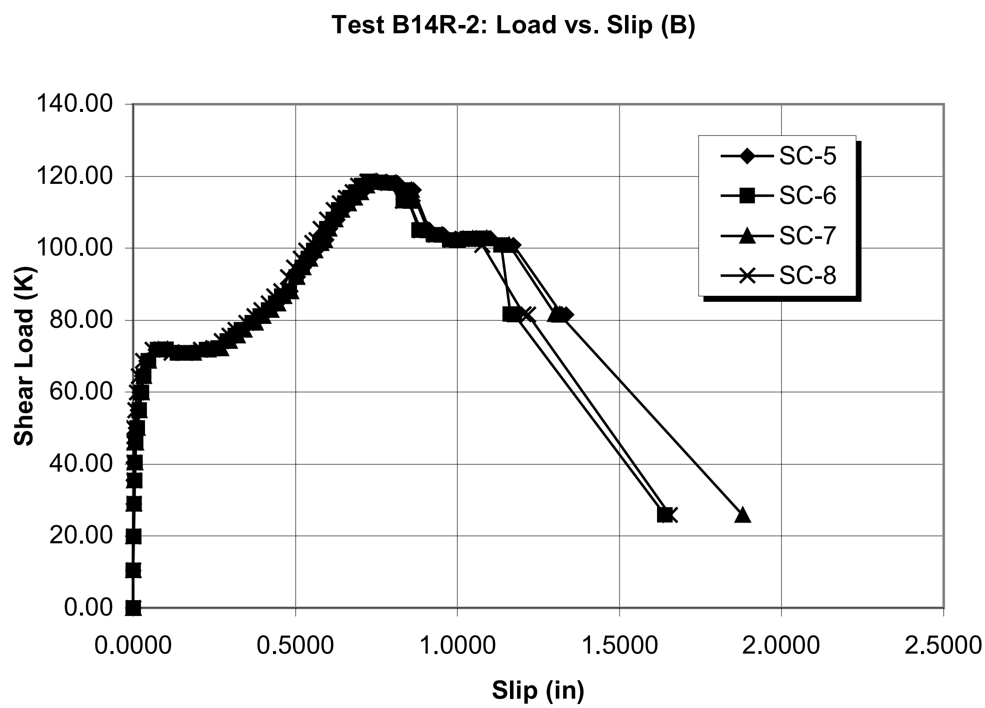


exterior, Slab A interior, Slab B

**COMMENTS**

Failure Mode: Concrete rib failure followed by screw pullout from angles at ultimate load
Screw Rotation ≈ 70° - 80°
Deck debonded; Slight bulging of deck below screws
Angles deformed at screw locations due to rotation of screws
☐= Screw pulled out of angle


Test B14R-2: Load vs. Slip (A)
Shear Load (K)
Slip (in)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
SC-1
SC-2
SC-3
SC-4


Test B14R-2: Load vs. Slip (B)
Shear Load (K)
Slip (in)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
SC-5
SC-6
SC-7
SC-8

**TEST B14R-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | -0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10.43 | 1.06 | 0.0000 | 0.0006 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 19.97 | 1.99 | 0.0006 | 0.0018 | 0.0012 | 0.0000 | 0.0000 | 0.0018 | 0.0006 | 0.0006 |
| 28.89 | 2.88 | 0.0006 | 0.0031 | 0.0024 | 0.0037 | 0.0012 | 0.0024 | 0.0012 | 0.0012 |
| 35.43 | 3.65 | 0.0012 | 0.0049 | 0.0031 | 0.0037 | 0.0012 | 0.0043 | 0.0031 | 0.0012 |
| 40.45 | 4.04 | 0.0018 | 0.0067 | 0.0043 | 0.0037 | 0.0012 | 0.0055 | 0.0055 | 0.0012 |
| 45.98 | 4.59 | 0.0037 | 0.0085 | 0.0061 | 0.0037 | 0.0037 | 0.0085 | 0.0079 | 0.0018 |
| 50.00 | 5.14 | 0.0055 | 0.0116 | 0.0079 | 0.0037 | 0.0079 | 0.0128 | 0.0128 | 0.0018 |
| 55.03 | 5.69 | 0.0085 | 0.0146 | 0.0116 | 0.0037 | 0.0134 | 0.0195 | 0.0189 | 0.0061 |
| 59.92 | 6.30 | 0.0134 | 0.0183 | 0.0153 | 0.0043 | 0.0201 | 0.0256 | 0.0250 | 0.0110 |
| 64.45 | 6.57 | 0.0195 | 0.0238 | 0.0220 | 0.0079 | 0.0281 | 0.0336 | 0.0336 | 0.0177 |
| 68.59 | 7.16 | 0.0293 | 0.0311 | 0.0311 | 0.0159 | 0.0415 | 0.0470 | 0.0476 | 0.0305 |
| 71.73 | 7.68 | 0.0494 | 0.0519 | 0.0525 | 0.0354 | 0.0696 | 0.0751 | 0.0769 | 0.0592 |
| 71.86 | 8.07 | 0.0732 | 0.0739 | 0.0763 | 0.0586 | 0.0970 | 0.1013 | 0.1050 | 0.0848 |
| 70.85 | 8.20 | 0.1056 | 0.1044 | 0.1093 | 0.0897 | 0.1312 | 0.1361 | 0.1398 | 0.1184 |
| 70.98 | 8.21 | 0.1501 | 0.1483 | 0.1562 | 0.1349 | 0.1770 | 0.1813 | 0.1862 | 0.1630 |
| 71.73 | 7.90 | 0.1965 | 0.1904 | 0.2014 | 0.1813 | 0.2240 | 0.2258 | 0.2325 | 0.2094 |
| 72.24 | 7.62 | 0.2307 | 0.2234 | 0.2356 | 0.2173 | 0.2618 | 0.2618 | 0.2698 | 0.2466 |
| 74.12 | 7.73 | 0.2594 | 0.2490 | 0.2637 | 0.2454 | 0.2905 | 0.2899 | 0.2972 | 0.2734 |
| 75.75 | 7.63 | 0.2844 | 0.2740 | 0.2893 | 0.2704 | 0.3156 | 0.3149 | 0.3223 | 0.2966 |
| 77.26 | 7.79 | 0.3033 | 0.2936 | 0.3088 | 0.2899 | 0.3357 | 0.3339 | 0.3418 | 0.3156 |
| 79.27 | 8.08 | 0.3381 | 0.3284 | 0.3424 | 0.3247 | 0.3705 | 0.3674 | 0.3766 | 0.3491 |
| 81.03 | 8.11 | 0.3625 | 0.3534 | 0.3668 | 0.3485 | 0.3955 | 0.3931 | 0.4004 | 0.3729 |
| 82.79 | 8.11 | 0.3888 | 0.3778 | 0.3912 | 0.3741 | 0.4211 | 0.4181 | 0.4248 | 0.3961 |
| 84.67 | 8.14 | 0.4120 | 0.4010 | 0.4144 | 0.3973 | 0.4443 | 0.4401 | 0.4462 | 0.4169 |
| 86.56 | 8.31 | 0.4291 | 0.4193 | 0.4321 | 0.4150 | 0.4626 | 0.4584 | 0.4639 | 0.4340 |
| 88.07 | 9.28 | 0.4535 | 0.4443 | 0.4565 | 0.4382 | 0.4852 | 0.4822 | 0.4858 | 0.4572 |
| 91.96 | 9.32 | 0.4742 | 0.4645 | 0.4773 | 0.4584 | 0.5066 | 0.5023 | 0.5060 | 0.4773 |
| 94.60 | 9.53 | 0.4913 | 0.4822 | 0.4944 | 0.4761 | 0.5255 | 0.5206 | 0.5243 | 0.4956 |
| 96.98 | 9.61 | 0.5084 | 0.4993 | 0.5121 | 0.4938 | 0.5457 | 0.5402 | 0.5438 | 0.5164 |
| 99.25 | 9.90 | 0.5237 | 0.5139 | 0.5273 | 0.5084 | 0.5634 | 0.5573 | 0.5609 | 0.5341 |
| 101.38 | 10.14 | 0.5426 | 0.5328 | 0.5463 | 0.5280 | 0.5835 | 0.5756 | 0.5798 | 0.5530 |
| 102.26 | 10.46 | 0.5615 | 0.5524 | 0.5664 | 0.5481 | 0.5945 | 0.5859 | 0.5908 | 0.5646 |
| 105.40 | 10.65 | 0.5792 | 0.5713 | 0.5847 | 0.5664 | 0.6079 | 0.5981 | 0.6036 | 0.5774 |
| 107.91 | 10.79 | 0.6018 | 0.5963 | 0.6079 | 0.5896 | 0.6287 | 0.6165 | 0.6232 | 0.5981 |
| 110.55 | 11.16 | 0.6201 | 0.6152 | 0.6281 | 0.6091 | 0.6488 | 0.6348 | 0.6439 | 0.6177 |
| 112.43 | 11.27 | 0.6384 | 0.6348 | 0.6476 | 0.6287 | 0.6677 | 0.6525 | 0.6635 | 0.6372 |
| 114.07 | 11.59 | 0.6567 | 0.6537 | 0.6677 | 0.6476 | 0.6860 | 0.6689 | 0.6824 | 0.6561 |
| 115.57 | 11.76 | 0.6744 | 0.6720 | 0.6866 | 0.6677 | 0.7062 | 0.6873 | 0.7019 | 0.6757 |
| 117.33 | 12.01 | 0.6927 | 0.6927 | 0.7062 | 0.6873 | 0.7269 | 0.7043 | 0.7208 | 0.6940 |
| 118.59 | 12.48 | 0.7178 | 0.7196 | 0.7324 | 0.7147 | 0.7532 | 0.7275 | 0.7483 | 0.7227 |
| 118.21 | 12.54 | 0.7434 | 0.7458 | 0.7587 | 0.7422 | 0.7849 | 0.7574 | 0.7800 | 0.7550 |
| 118.09 | 12.57 | 0.7715 | 0.7751 | 0.7867 | 0.7721 | 0.8148 | 0.7861 | 0.8099 | 0.7843 |
| 113.19 | 13.04 | 0.8105 | 0.8148 | 0.8264 | 0.8130 | 0.8612 | 0.8331 | 0.8563 | 0.8325 |
| 116.08 | 10.42 | 0.8124 | 0.8173 | 0.8282 | 0.8154 | 0.8643 | 0.8362 | 0.8588 | 0.8356 |
| 105.02 | 11.83 | 0.8649 | 0.8698 | 0.8832 | 0.8710 | 0.9131 | 0.8826 | 0.9082 | 0.8875 |
| 103.76 | 12.00 | 0.9125 | 0.9174 | 0.9308 | 0.9192 | 0.9570 | 0.9253 | 0.9528 | 0.9326 |
| 102.26 | 10.99 | 0.9619 | 0.9650 | 0.9772 | 0.9698 | 1.0058 | 0.9766 | 0.9998 | 0.9802 |
| 102.63 | 11.21 | 1.0083 | 1.0107 | 1.0241 | 1.0198 | 1.0552 | 1.0308 | 1.0473 | 1.0137 |
| 102.76 | 11.42 | 1.0534 | 1.0589 | 1.0705 | 1.0650 | 1.1016 | 1.0766 | 1.0913 | 1.0369 |
| 100.87 | 11.82 | 1.1065 | 1.1248 | 1.1376 | 1.1267 | 1.1730 | 1.1352 | 1.1596 | 1.0766 |
| 81.66 | 8.63 | 1.1572 | 1.2268 | 1.2402 | 1.1755 | 1.3220 | 1.1633 | 1.3012 | 1.2042 |
| 81.53 | 9.13 | 1.1596 | 1.2347 | 1.2487 | 1.1785 | 1.3360 | 1.1761 | 1.3146 | 1.2182 |
| 25.88 | 13.58 | 1.1676 | 1.2774 | 1.3000 | 1.2231 | | 1.6406 | 1.8798 | 1.6558 |

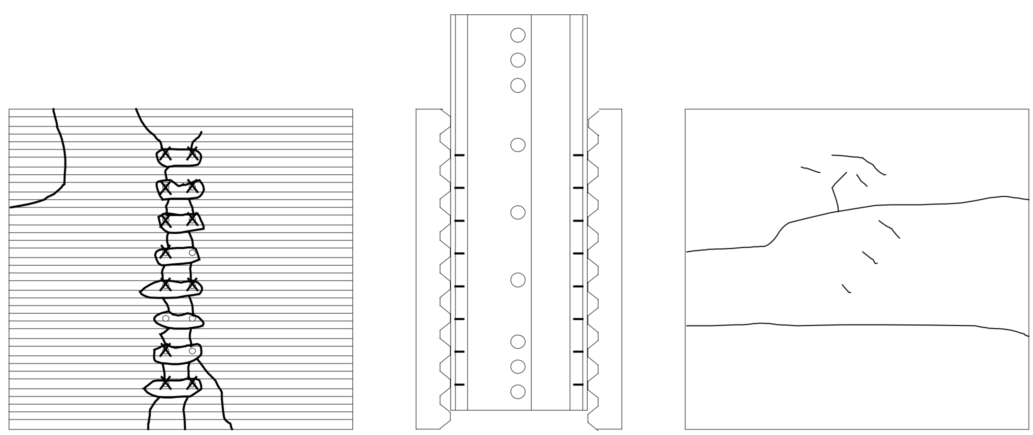
## PUSHOUT TEST SUMMARY SHEET

Test: B15-1 Test Date: 21-Aug-98
Test Designation: SC-8-2.5-0.187-1.0C-2.75-1

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.5 in. | No. Per Specimen: | 32 | | |
| **Deck:** | Type: | 1.0C, 26 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 103.8 ksi | $F_u$: | 104.9 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.187 | | | | |
| | $F_y$: | 61.9 ksi | $F_u$: | 85.6 ksi | | |
| **Slab:** | Thickness: | 2.75 in. | $f'_c$: | 6665 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 24 | | |
| | | | Height Above Deck: | 0.75 in. | | |
| **Mesh:** | Type: | WWF 6x6-W2.9xW2.9 | | | | |

| TEST RESULTS | | | | | |
|---|---|---|---|---|---|
| **Peak Shear Load:** | 151.57 kips | | | | |
| **Peak Shear Load Per Screw:** | 4.74 kips | | | | |
| **Slip at Peak Shear Load:** | | SC1: | 0.7951 in. | SC5: | 0.7116 in. |
| | | SC2: | 0.9345 in. | SC6: | 0.6816 in. |
| | | SC3: | 0.8457 in. | SC7: | 0.6812 in. |
| | | SC4: | 0.8973 in. | SC8: | 0.7303 in. |

### DAMAGE

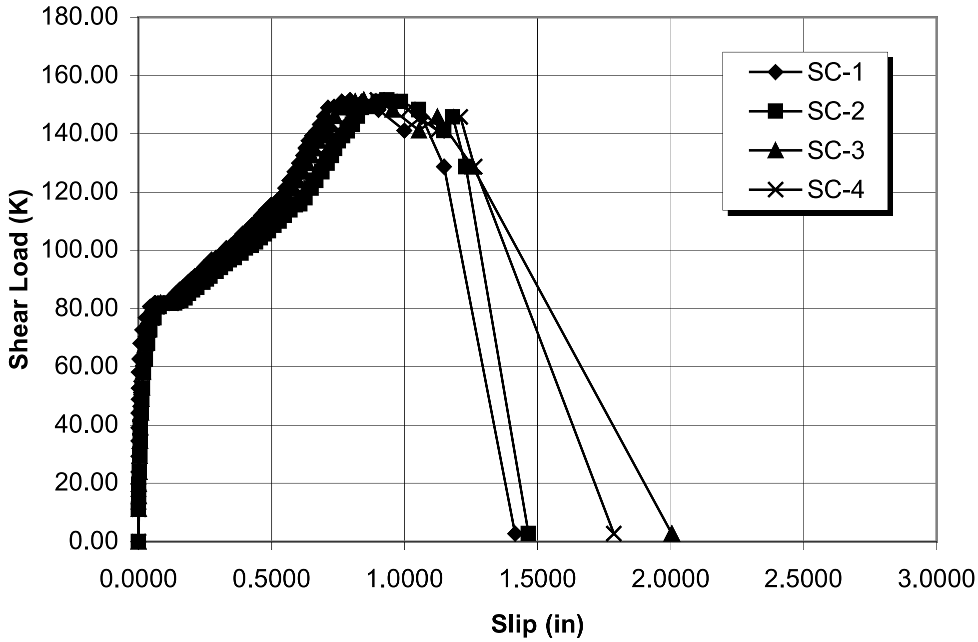


interior, Slab A exterior, Slab B

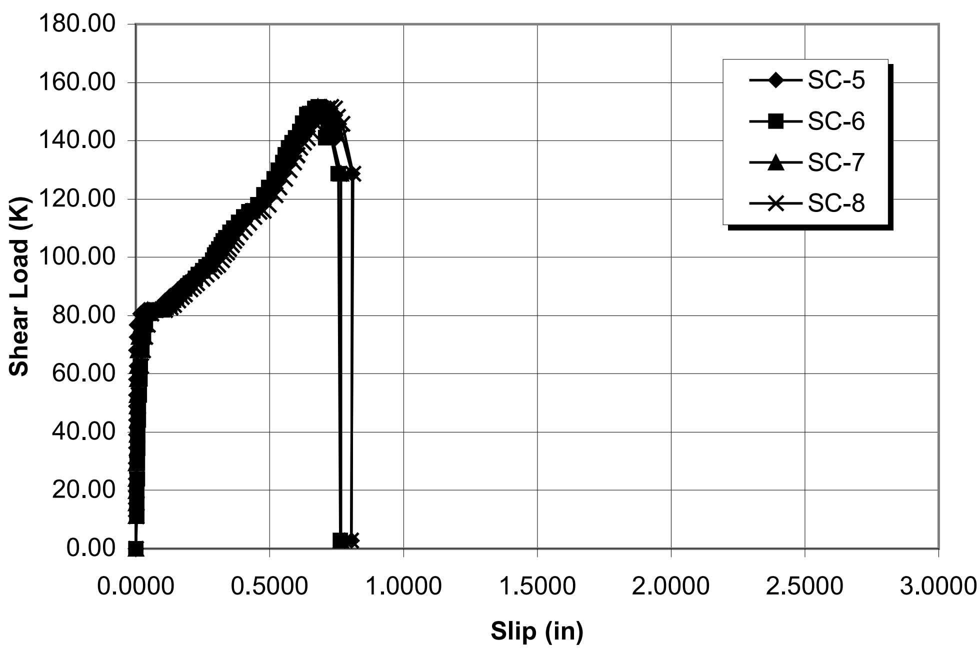
### COMMENTS

Failure Mode: Concrete rib failure followed by screw shear at ultimate load
Screw Rotation ≈ 25° - 35°
Deck debonded
X = Screw sheared off

**Test B15-1: Load vs. Slip (A)**




**Test B15-1: Load vs. Slip (B)**



**TEST B15-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | -0.0002 | -0.0002 | -0.0002 | -0.0002 | 0.0002 | -0.0004 | 0.0002 |
| 11.24 | 1.02 | 0.0004 | 0.0004 | 0.0016 | 0.0004 | -0.0004 | 0.0031 | -0.0004 | 0.0011 |
| 15.52 | 1.54 | 0.0000 | 0.0013 | 0.0024 | 0.0007 | -0.0004 | 0.0040 | 0.0000 | 0.0015 |
| 19.72 | 1.99 | 0.0002 | 0.0022 | 0.0026 | 0.0009 | -0.0002 | 0.0040 | -0.0004 | 0.0016 |
| 23.87 | 2.53 | 0.0002 | 0.0033 | 0.0029 | 0.0016 | -0.0004 | 0.0053 | -0.0002 | 0.0027 |
| 29.40 | 3.09 | 0.0000 | 0.0053 | 0.0044 | 0.0022 | 0.0000 | 0.0066 | -0.0005 | 0.0026 |
| 34.61 | 3.57 | 0.0002 | 0.0071 | 0.0060 | 0.0040 | 0.0018 | 0.0070 | 0.0033 | 0.0029 |
| 39.07 | 3.99 | 0.0002 | 0.0082 | 0.0070 | 0.0053 | 0.0018 | 0.0081 | 0.0035 | 0.0044 |
| 44.10 | 4.49 | 0.0002 | 0.0115 | 0.0090 | 0.0075 | 0.0016 | 0.0092 | 0.0037 | 0.0057 |
| 48.87 | 4.95 | 0.0011 | 0.0132 | 0.0106 | 0.0095 | 0.0018 | 0.0104 | 0.0033 | 0.0075 |
| 52.70 | 5.38 | 0.0013 | 0.0156 | 0.0125 | 0.0121 | 0.0018 | 0.0128 | 0.0031 | 0.0101 |
| 58.10 | 5.93 | 0.0015 | 0.0198 | 0.0163 | 0.0163 | 0.0027 | 0.0143 | 0.0053 | 0.0128 |
| 62.69 | 6.32 | 0.0040 | 0.0262 | 0.0211 | 0.0223 | 0.0029 | 0.0174 | 0.0055 | 0.0183 |
| 68.09 | 6.94 | 0.0079 | 0.0337 | 0.0271 | 0.0286 | 0.0027 | 0.0236 | 0.0075 | 0.0267 |
| 72.61 | 7.34 | 0.0156 | 0.0430 | 0.0352 | 0.0370 | 0.0029 | 0.0288 | 0.0123 | 0.0339 |
| 76.88 | 7.86 | 0.0282 | 0.0593 | 0.0491 | 0.0522 | 0.0038 | 0.0361 | 0.0181 | 0.0429 |
| 80.65 | 8.22 | 0.0441 | 0.0787 | 0.0672 | 0.0703 | 0.0163 | 0.0491 | 0.0302 | 0.0571 |
| 81.91 | 8.52 | 0.0621 | 0.0989 | 0.0848 | 0.0895 | 0.0317 | 0.0661 | 0.0443 | 0.0745 |
| 81.85 | 8.82 | 0.0938 | 0.1375 | 0.1183 | 0.1236 | 0.0648 | 0.0982 | 0.0720 | 0.1088 |
| 82.79 | 8.89 | 0.1145 | 0.1599 | 0.1368 | 0.1449 | 0.0830 | 0.1150 | 0.0890 | 0.1289 |
| 83.61 | 8.91 | 0.1278 | 0.1749 | 0.1502 | 0.1584 | 0.0978 | 0.1273 | 0.1018 | 0.1428 |
| 85.24 | 8.91 | 0.1406 | 0.1901 | 0.1630 | 0.1727 | 0.1097 | 0.1401 | 0.1152 | 0.1569 |
| 86.37 | 8.94 | 0.1544 | 0.2049 | 0.1769 | 0.1850 | 0.1253 | 0.1518 | 0.1287 | 0.1705 |
| 87.31 | 8.90 | 0.1659 | 0.2192 | 0.1892 | 0.1981 | 0.1388 | 0.1644 | 0.1421 | 0.1833 |
| 89.07 | 9.12 | 0.1864 | 0.2421 | 0.2102 | 0.2194 | 0.1584 | 0.1824 | 0.1617 | 0.2042 |
| 90.08 | 9.27 | 0.1994 | 0.2569 | 0.2241 | 0.2337 | 0.1716 | 0.1930 | 0.1749 | 0.2165 |
| 91.08 | 9.39 | 0.2122 | 0.2701 | 0.2368 | 0.2470 | 0.1839 | 0.2036 | 0.1870 | 0.2285 |
| 92.65 | 9.46 | 0.2322 | 0.2930 | 0.2567 | 0.2686 | 0.2049 | 0.2221 | 0.2066 | 0.2491 |
| 94.10 | 9.49 | 0.2472 | 0.3091 | 0.2707 | 0.2844 | 0.2205 | 0.2348 | 0.2212 | 0.2639 |
| 95.35 | 9.59 | 0.2626 | 0.3272 | 0.2875 | 0.3031 | 0.2393 | 0.2516 | 0.2384 | 0.2826 |
| 96.73 | 9.82 | 0.2756 | 0.3414 | 0.2989 | 0.3164 | 0.2522 | 0.2632 | 0.2500 | 0.2947 |
| 97.42 | 9.87 | 0.2915 | 0.3608 | 0.3175 | 0.3335 | 0.2663 | 0.2758 | 0.2632 | 0.3082 |
| 99.06 | 10.03 | 0.3130 | 0.3855 | 0.3397 | 0.3576 | 0.2791 | 0.2873 | 0.2749 | 0.3218 |
| 100.75 | 10.34 | 0.3296 | 0.4023 | 0.3562 | 0.3747 | 0.2882 | 0.2943 | 0.2831 | 0.3296 |
| 101.57 | 10.44 | 0.3483 | 0.4236 | 0.3754 | 0.3950 | 0.2976 | 0.3031 | 0.2932 | 0.3403 |
| 102.88 | 10.54 | 0.3631 | 0.4410 | 0.3910 | 0.4113 | 0.3066 | 0.3102 | 0.3014 | 0.3481 |
| 104.27 | 10.65 | 0.3776 | 0.4582 | 0.4069 | 0.4276 | 0.3155 | 0.3194 | 0.3106 | 0.3584 |
| 105.59 | 10.80 | 0.3919 | 0.4734 | 0.4197 | 0.4415 | 0.3247 | 0.3278 | 0.3190 | 0.3672 |
| 106.65 | 10.97 | 0.4062 | 0.4891 | 0.4338 | 0.4565 | 0.3346 | 0.3371 | 0.3285 | 0.3765 |
| 108.54 | 11.04 | 0.4258 | 0.5102 | 0.4531 | 0.4774 | 0.3503 | 0.3523 | 0.3443 | 0.3917 |
| 109.98 | 11.23 | 0.4437 | 0.5302 | 0.4714 | 0.4968 | 0.3666 | 0.3661 | 0.3598 | 0.4073 |
| 111.87 | 11.41 | 0.4609 | 0.5492 | 0.4891 | 0.5162 | 0.3831 | 0.3838 | 0.3760 | 0.4232 |
| 113.88 | 11.62 | 0.4800 | 0.5699 | 0.5089 | 0.5377 | 0.4036 | 0.4031 | 0.3959 | 0.4424 |
| 115.57 | 11.85 | 0.4988 | 0.5913 | 0.5280 | 0.5593 | 0.4256 | 0.4228 | 0.4172 | 0.4626 |
| 115.89 | 11.92 | 0.5155 | 0.6085 | 0.5444 | 0.5783 | 0.4402 | 0.4364 | 0.4336 | 0.4763 |
| 118.09 | 12.04 | 0.5327 | 0.6272 | 0.5622 | 0.5972 | 0.4604 | 0.4556 | 0.4516 | 0.4955 |
| 121.35 | 12.27 | 0.5521 | 0.6505 | 0.5834 | 0.6204 | 0.4851 | 0.4794 | 0.4763 | 0.5201 |
| 123.93 | 12.50 | 0.5670 | 0.6668 | 0.5990 | 0.6371 | 0.5027 | 0.4954 | 0.4932 | 0.5364 |
| 126.94 | 12.80 | 0.5873 | 0.6900 | 0.6193 | 0.6596 | 0.5263 | 0.5168 | 0.5131 | 0.5573 |
| 129.83 | 13.15 | 0.6032 | 0.7083 | 0.6345 | 0.6783 | 0.5448 | 0.5318 | 0.5294 | 0.5743 |
| 132.53 | 13.42 | 0.6186 | 0.7256 | 0.6499 | 0.6957 | 0.5618 | 0.5487 | 0.5455 | 0.5908 |
| 135.17 | 13.68 | 0.6287 | 0.7365 | 0.6596 | 0.7071 | 0.5737 | 0.5595 | 0.5562 | 0.6019 |
| 134.98 | 13.67 | 0.6289 | 0.7369 | 0.6602 | 0.7072 | 0.5736 | 0.5596 | 0.5563 | 0.6021 |
| 137.50 | 13.94 | 0.6409 | 0.7514 | 0.6732 | 0.7213 | 0.5869 | 0.5710 | 0.5693 | 0.6146 |
| 139.38 | 14.14 | 0.6543 | 0.7684 | 0.6873 | 0.7380 | 0.6018 | 0.5842 | 0.5814 | 0.6281 |
| 140.95 | 14.44 | 0.6686 | 0.7858 | 0.7032 | 0.7552 | 0.6171 | 0.5977 | 0.5961 | 0.6426 |
| 143.21 | 14.74 | 0.6825 | 0.8039 | 0.7186 | 0.7715 | 0.6318 | 0.6113 | 0.6089 | 0.6565 |
| 145.91 | 15.04 | 0.6977 | 0.8228 | 0.7367 | 0.7889 | 0.6472 | 0.6241 | 0.6226 | 0.6712 |
| 148.99 | 15.33 | 0.7118 | 0.8393 | 0.7521 | 0.8054 | 0.6633 | 0.6380 | 0.6356 | 0.6843 |
| 149.24 | 15.53 | 0.7351 | 0.8671 | 0.7834 | 0.8316 | 0.6779 | 0.6508 | 0.6497 | 0.6986 |
| 150.94 | 15.47 | 0.7646 | 0.9010 | 0.8144 | 0.8634 | 0.6968 | 0.6684 | 0.6681 | 0.7171 |
| 151.57 | 16.06 | 0.7951 | 0.9345 | 0.8457 | 0.8973 | 0.7116 | 0.6816 | 0.6812 | 0.7303 |
| 151.00 | 15.94 | 0.8398 | 0.9858 | 0.8920 | 0.9470 | 0.7270 | 0.6937 | 0.6950 | 0.7437 |
| 148.30 | 15.95 | 0.9019 | 1.0520 | 0.9552 | 1.0145 | 0.7391 | 0.7036 | 0.7050 | 0.7541 |
| 141.01 | 16.15 | 0.9988 | 1.1487 | 1.0544 | 1.1231 | 0.7462 | 0.7094 | 0.7120 | 0.7598 |
| 145.79 | 15.02 | 1.0639 | 1.1813 | 1.1234 | 1.2090 | 0.7589 | 0.7179 | 0.7226 | 0.7715 |
| 128.64 | 15.61 | 1.1493 | 1.2306 | 1.2553 | 1.2633 | 0.8085 | 0.7567 | 0.7658 | 0.8127 |
| 2.83 | 17.29 | 1.4153 | 1.4653 | 2.0036 | 1.7864 | 0.8061 | 0.7651 | 0.7666 | 0.8050 |

**PUSHOUT TEST SUMMARY SHEET**

Test: B15-2 Test Date: 31-Aug-98
Test Designation: SC-8-2.5-0.187-1.0C-2.75-2

**SPECIMEN DESCRIPTION**

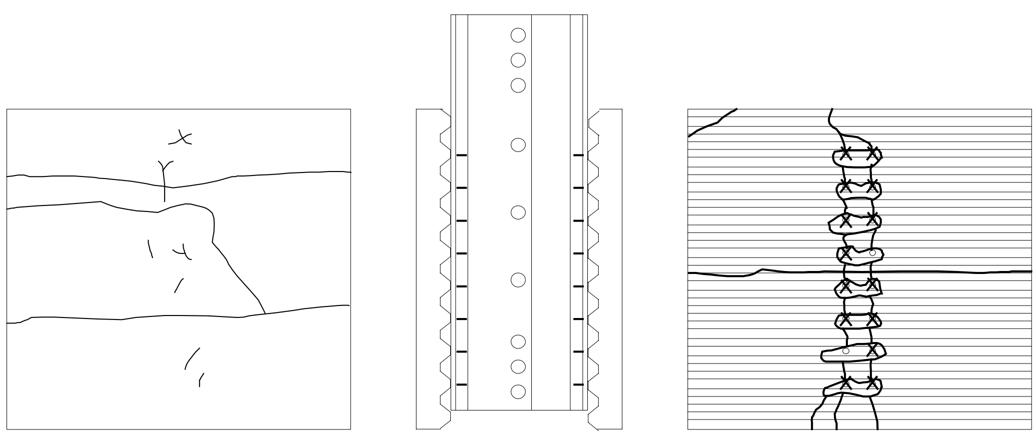
**Screw:** Height: 2.5 in. No. Per Specimen: 32
**Deck:** Type: 1.0C, 26 ga Width: 36 in. Length: 36 in.
$F_y$: 103.8 ksi $F_u$: 104.9 ksi
**Base Member:** Section: 2L 2x2x0.187
$F_y$: 61.9 ksi $F_u$: 85.6 ksi
**Slab:** Thickness: 2.75 in. $f'_c$: 6665 psi
**Rebar:** Size: No. 4 No. Per Specimen: 24
Height Above Deck: 0.75 in.
**Mesh:** Type: WWF 6x6-W2.9xW2.9

**TEST RESULTS**

**Peak Shear Load:** 160.17 kips
**Peak Shear Load Per Screw:** 5.01 kips
**Slip at Peak Shear Load:**

| | | | |
|---|---|---|---|
| SC1: | 0.8287 in. | SC5: | 0.9614 in. |
| SC2: | 0.9693 in. | SC6: | N.A. |
| SC3: | 0.9226 in. | SC7: | 0.8622 in. |
| SC4: | 0.9134 in. | SC8: | 0.8689 in. |

**DAMAGE**

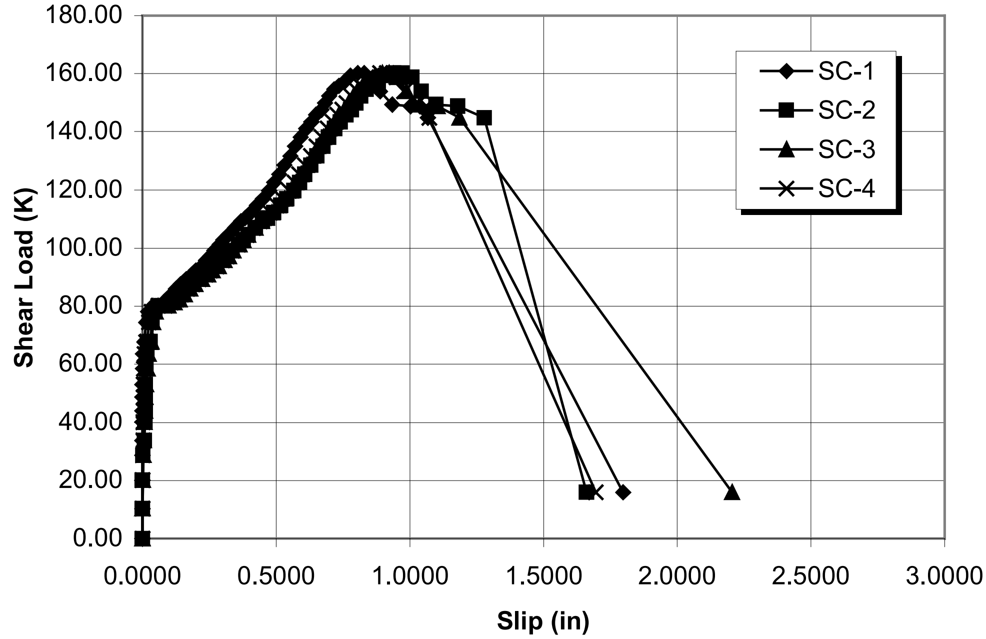


exterior, Slab A interior, Slab B

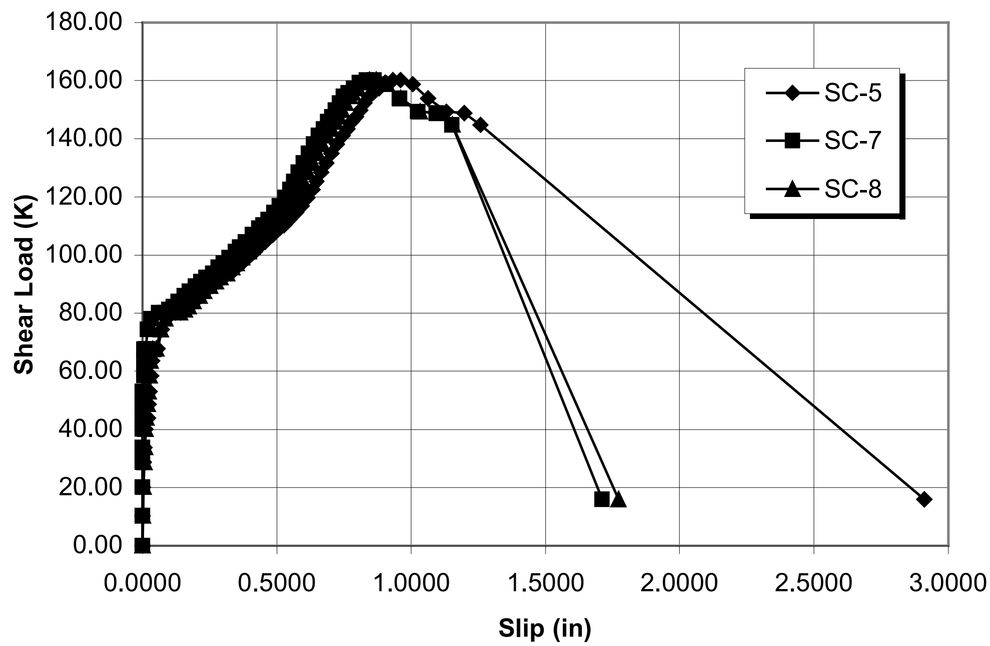
**COMMENTS**

Failure Mode: Concrete rib failure followed by screw shear at ultimate load
Screw Rotation ≈ 60° - 70°
Deck debonded
X = Screw sheared off

**Test B15-2: Load vs. Slip (A)**




**Test B15-2: Load vs. Slip (B)**



**TEST B15-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | -0.0002 | 0.0002 | -0.0005 | -0.0002 | 0.0004 | -0.0002 | 0.0000 | 0.0000 |
| 10.36 | 0.87 | 0.0000 | -0.0004 | 0.0002 | 0.0000 | 0.0004 | -0.0004 | -0.0004 | 0.0011 |
| 20.10 | 1.87 | -0.0002 | 0.0000 | 0.0026 | 0.0002 | 0.0027 | 0.0002 | 0.0000 | 0.0037 |
| 28.64 | 2.83 | -0.0002 | 0.0024 | 0.0042 | 0.0002 | 0.0060 | 0.0004 | -0.0002 | 0.0071 |
| 33.73 | 3.40 | 0.0000 | 0.0081 | 0.0053 | 0.0015 | 0.0081 | 0.0000 | 0.0004 | 0.0086 |
| 40.08 | 3.94 | 0.0004 | 0.0086 | 0.0073 | 0.0016 | 0.0108 | 0.0005 | 0.0004 | 0.0112 |
| 44.03 | 4.44 | 0.0004 | 0.0110 | 0.0097 | 0.0040 | 0.0207 | 0.0002 | 0.0004 | 0.0159 |
| 48.74 | 4.93 | 0.0005 | 0.0119 | 0.0115 | 0.0037 | 0.0233 | 0.0007 | 0.0000 | 0.0198 |
| 53.08 | 5.31 | 0.0005 | 0.0117 | 0.0134 | 0.0038 | 0.0264 | 0.0007 | 0.0004 | 0.0227 |
| 58.42 | 5.67 | 0.0016 | 0.0136 | 0.0183 | 0.0060 | 0.0330 | 0.0005 | 0.0048 | 0.0275 |
| 63.57 | 6.25 | 0.0026 | 0.0174 | 0.0227 | 0.0075 | 0.0368 | 0.0005 | 0.0048 | 0.0309 |
| 67.59 | 6.73 | 0.0068 | 0.0242 | 0.0297 | 0.0134 | 0.0440 | 0.0005 | 0.0048 | 0.0372 |
| 67.71 | 7.04 | 0.0084 | 0.0291 | 0.0335 | 0.0170 | 0.0571 | 0.0007 | 0.0108 | 0.0507 |
| 74.50 | 7.55 | 0.0126 | 0.0364 | 0.0408 | 0.0238 | 0.0729 | 0.0009 | 0.0196 | 0.0678 |
| 78.08 | 8.08 | 0.0201 | 0.0472 | 0.0502 | 0.0348 | 0.0883 | 0.0005 | 0.0331 | 0.0846 |
| 80.21 | 8.63 | 0.0397 | 0.0727 | 0.0747 | 0.0599 | 0.1232 | 0.0007 | 0.0612 | 0.1212 |
| 80.28 | 8.70 | 0.0588 | 0.0949 | 0.0974 | 0.0828 | 0.1419 | 0.0007 | 0.0806 | 0.1410 |
| 81.22 | 8.80 | 0.0776 | 0.1161 | 0.1203 | 0.1071 | 0.1612 | 0.0007 | 0.0994 | 0.1579 |
| 82.35 | 8.83 | 0.0928 | 0.1348 | 0.1394 | 0.1275 | 0.1764 | 0.0007 | 0.1165 | 0.1723 |
| 84.11 | 8.83 | 0.1080 | 0.1513 | 0.1586 | 0.1452 | 0.1943 | 0.0007 | 0.1328 | 0.1895 |
| 85.93 | 8.99 | 0.1258 | 0.1718 | 0.1796 | 0.1670 | 0.2170 | 0.0005 | 0.1557 | 0.2119 |
| 87.63 | 9.04 | 0.1421 | 0.1886 | 0.1981 | 0.1862 | 0.2357 | 0.0013 | 0.1734 | 0.2295 |
| 89.26 | 9.31 | 0.1635 | 0.2106 | 0.2218 | 0.2113 | 0.2599 | 0.0009 | 0.1969 | 0.2524 |
| 90.95 | 9.51 | 0.1837 | 0.2331 | 0.2450 | 0.2357 | 0.2824 | 0.0013 | 0.2185 | 0.2738 |
| 92.34 | 9.80 | 0.2002 | 0.2513 | 0.2622 | 0.2538 | 0.3025 | 0.0007 | 0.2372 | 0.2904 |
| 93.72 | 9.68 | 0.2205 | 0.2782 | 0.2857 | 0.2784 | 0.3285 | 0.0013 | 0.2621 | 0.3144 |
| 95.73 | 9.72 | 0.2382 | 0.2983 | 0.3055 | 0.2990 | 0.3501 | 0.0011 | 0.2827 | 0.3327 |
| 97.24 | 9.88 | 0.2533 | 0.3168 | 0.3238 | 0.3166 | 0.3705 | 0.0007 | 0.3011 | 0.3511 |
| 99.12 | 10.01 | 0.2688 | 0.3351 | 0.3414 | 0.3342 | 0.3932 | 0.0009 | 0.3225 | 0.3716 |
| 101.19 | 10.21 | 0.2893 | 0.3600 | 0.3628 | 0.3569 | 0.4190 | 0.0009 | 0.3470 | 0.3954 |
| 102.70 | 10.50 | 0.3031 | 0.3760 | 0.3772 | 0.3714 | 0.4346 | 0.0016 | 0.3615 | 0.4095 |
| 104.45 | 10.55 | 0.3216 | 0.3959 | 0.3963 | 0.3899 | 0.4558 | 0.0013 | 0.3820 | 0.4282 |
| 107.03 | 10.79 | 0.3459 | 0.4228 | 0.4217 | 0.4152 | 0.4849 | 0.0013 | 0.4098 | 0.4536 |
| 109.29 | 10.92 | 0.3692 | 0.4498 | 0.4476 | 0.4401 | 0.5120 | 0.0009 | 0.4344 | 0.4780 |
| 110.30 | 11.13 | 0.3851 | 0.4686 | 0.4642 | 0.4569 | 0.5278 | 0.0009 | 0.4496 | 0.4922 |
| 112.31 | 11.24 | 0.4047 | 0.4915 | 0.4855 | 0.4781 | 0.5479 | 0.0013 | 0.4683 | 0.5106 |
| 114.69 | 11.53 | 0.4282 | 0.5172 | 0.5102 | 0.5014 | 0.5719 | 0.0015 | 0.4899 | 0.5316 |
| 116.89 | 11.73 | 0.4499 | 0.5402 | 0.5325 | 0.5232 | 0.5922 | 0.0013 | 0.5095 | 0.5488 |
| 119.72 | 12.08 | 0.4728 | 0.5660 | 0.5551 | 0.5485 | 0.6144 | 0.0013 | 0.5309 | 0.5695 |
| 122.55 | 12.26 | 0.4932 | 0.5869 | 0.5752 | 0.5684 | 0.6329 | 0.0013 | 0.5492 | 0.5856 |
| 125.37 | 12.81 | 0.5111 | 0.6074 | 0.5942 | 0.5866 | 0.6474 | 0.0013 | 0.5622 | 0.5996 |
| 128.51 | 12.81 | 0.5313 | 0.6300 | 0.6151 | 0.6076 | 0.6655 | 0.0013 | 0.5800 | 0.6162 |
| 131.59 | 13.28 | 0.5529 | 0.6530 | 0.6366 | 0.6298 | 0.6851 | 0.0018 | 0.5986 | 0.6351 |
| 135.05 | 13.87 | 0.5715 | 0.6752 | 0.6565 | 0.6508 | 0.7038 | 0.0020 | 0.6171 | 0.6510 |
| 138.12 | 13.97 | 0.5913 | 0.6957 | 0.6768 | 0.6702 | 0.7241 | 0.0018 | 0.6360 | 0.6691 |
| 141.08 | 14.29 | 0.6118 | 0.7193 | 0.6974 | 0.6922 | 0.7448 | 0.0016 | 0.6549 | 0.6871 |
| 143.34 | 14.71 | 0.6312 | 0.7404 | 0.7182 | 0.7111 | 0.7635 | 0.0016 | 0.6739 | 0.7034 |
| 145.91 | 15.00 | 0.6481 | 0.7602 | 0.7351 | 0.7279 | 0.7796 | 0.0018 | 0.6902 | 0.7173 |
| 147.67 | 15.16 | 0.6688 | 0.7818 | 0.7549 | 0.7477 | 0.7961 | 0.0020 | 0.7058 | 0.7309 |
| 149.81 | 15.39 | 0.6832 | 0.7988 | 0.7713 | 0.7636 | 0.8107 | 0.0018 | 0.7188 | 0.7433 |
| 152.32 | 15.69 | 0.6986 | 0.8169 | 0.7887 | 0.7794 | 0.8259 | 0.0020 | 0.7332 | 0.7563 |
| 154.64 | 15.88 | 0.7164 | 0.8376 | 0.8067 | 0.7972 | 0.8431 | 0.0016 | 0.7490 | 0.7712 |
| 155.77 | 15.93 | 0.7351 | 0.8574 | 0.8246 | 0.8164 | 0.8578 | 0.0018 | 0.7657 | 0.7832 |
| 157.34 | 16.33 | 0.7563 | 0.8821 | 0.8470 | 0.8373 | 0.8807 | 0.0016 | 0.7860 | 0.8014 |
| 159.42 | 16.66 | 0.7776 | 0.9089 | 0.8710 | 0.8605 | 0.9043 | 0.0024 | 0.8078 | 0.8204 |
| 160.17 | 16.99 | 0.8039 | 0.9400 | 0.8973 | 0.8876 | 0.9321 | 0.0020 | 0.8347 | 0.8446 |
| 160.17 | 16.85 | 0.8287 | 0.9693 | 0.9226 | 0.9134 | 0.9614 | 0.0020 | 0.8622 | 0.8689 |
| 158.79 | 16.71 | 0.8614 | 1.0081 | 0.9565 | 0.9493 | 1.0068 | 0.0020 | 0.9052 | 0.9096 |
| 153.89 | 16.56 | 0.8891 | 1.0430 | 0.9874 | 0.9786 | 1.0628 | 0.0018 | 0.9576 | 0.9614 |
| 149.43 | 16.48 | 0.9347 | 1.0980 | 1.0366 | 1.0249 | 1.1306 | 0.0016 | 1.0258 | 1.0337 |
| 148.86 | 16.49 | 1.0026 | 1.1789 | 1.1038 | 1.0610 | 1.1969 | 0.0016 | 1.0929 | 1.0967 |
| 144.84 | 16.72 | 1.0665 | 1.2780 | 1.1850 | 1.0723 | 1.2575 | 0.0020 | 1.1513 | 1.1537 |
| 16.02 | 17.06 | 1.7986 | 1.6600 | 2.2048 | 1.6946 | 2.9117 | 0.0020 | 1.7109 | 1.7713 |

Note: SC-6 readings not included due to operational error

**PUSHOUT TEST SUMMARY SHEET**

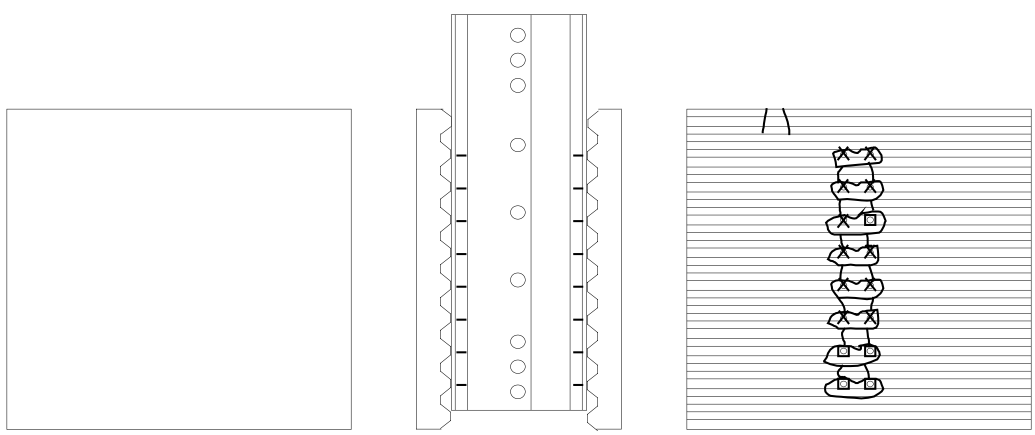
Test: B15R-1 | Test Date: 3-Feb-99

Test Designation: SC-8-2.5-0.187-1.0C-3.0-1R

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.5 in. | No. Per Specimen: | 32 | | |
| **Deck:** | Type: | 1.0C, 26 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 103.8 ksi | $F_u$: | 104.9 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.187 | | | | |
| | $F_y$: | 61.9 ksi | $F_u$: | 85.6 ksi | | |
| **Slab:** | Thickness: | 3.0 in. | $f'_c$: | 5451 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 24 | | |
| | | | Height Above Deck: | 0.75 in. | | |
| **Mesh:** | Type: | WWF 6x6-W2.9xW2.9 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 165.45 kips | | | |
| **Peak Shear Load Per Screw:** | 5.17 kips | | | |
| **Slip at Peak Shear Load:** | SC1: 0.8838 in. | | SC5: 1.0162 in. | |
| | SC2: 0.8954 in. | | SC6: 0.9277 in. | |
| | SC3: 0.8795 in. | | SC7: 0.9802 in. | |
| | SC4: 0.8954 in. | | SC8: 0.9991 in. | |

**DAMAGE**



exterior, Slab A

interior, Slab B

**COMMENTS**

Failure Mode: Concrete rib failure followed by screw shear at ultimate load

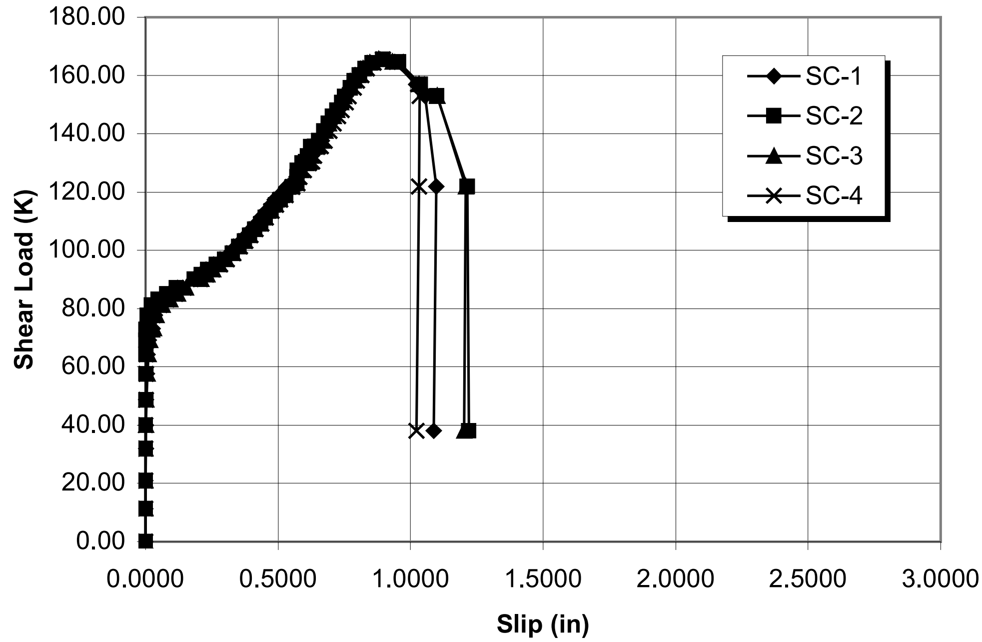
Screw Rotation ≈ 50° - 60°

Deck debonded; Slight bulging of deck below screws

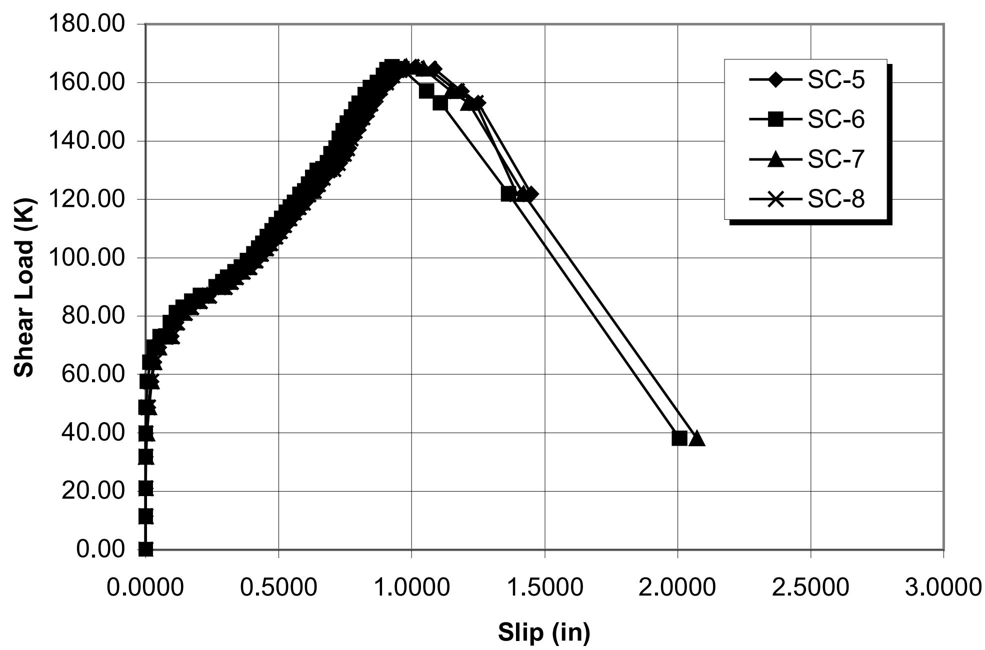
X = Screw sheared off

☐= Screw pulled out of angle

**Test B15R-1: Load vs. Slip (A)**




**Test B15R-1: Load vs. Slip (B)**



**TEST B15R-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11.43 | 1.04 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20.98 | 2.01 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0000 |
| 31.91 | 3.20 | 0.0012 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0024 | 0.0000 |
| 39.95 | 4.10 | 0.0018 | 0.0000 | 0.0018 | 0.0000 | 0.0000 | 0.0006 | 0.0055 | 0.0000 |
| 48.74 | 4.51 | 0.0018 | 0.0024 | 0.0037 | 0.0018 | 0.0104 | 0.0012 | 0.0128 | 0.0092 |
| 57.54 | 5.75 | 0.0049 | 0.0024 | 0.0067 | 0.0018 | 0.0214 | 0.0067 | 0.0226 | 0.0208 |
| 64.20 | 6.36 | 0.0085 | 0.0024 | 0.0116 | 0.0018 | 0.0317 | 0.0165 | 0.0323 | 0.0311 |
| 69.22 | 7.10 | 0.0128 | 0.0024 | 0.0177 | 0.0049 | 0.0488 | 0.0330 | 0.0488 | 0.0488 |
| 72.86 | 7.70 | 0.0189 | 0.0018 | 0.0244 | 0.0122 | 0.0739 | 0.0562 | 0.0732 | 0.0757 |
| 73.12 | 7.09 | 0.0269 | 0.0073 | 0.0323 | 0.0177 | 0.0970 | 0.0757 | 0.0952 | 0.0989 |
| 77.76 | 8.25 | 0.0360 | 0.0073 | 0.0427 | 0.0281 | 0.1154 | 0.0928 | 0.1129 | 0.1178 |
| 81.16 | 9.14 | 0.0555 | 0.0232 | 0.0659 | 0.0531 | 0.1434 | 0.1172 | 0.1410 | 0.1465 |
| 83.04 | 9.50 | 0.0818 | 0.0482 | 0.0934 | 0.0812 | 0.1697 | 0.1416 | 0.1654 | 0.1721 |
| 85.05 | 9.64 | 0.1099 | 0.0812 | 0.1233 | 0.1135 | 0.2039 | 0.1733 | 0.1984 | 0.2051 |
| 87.06 | 9.63 | 0.1404 | 0.1166 | 0.1544 | 0.1459 | 0.2374 | 0.2057 | 0.2313 | 0.2386 |
| 90.08 | 9.31 | 0.1978 | 0.1837 | 0.2112 | 0.2063 | 0.2979 | 0.2655 | 0.2893 | 0.2979 |
| 91.71 | 9.40 | 0.2216 | 0.2118 | 0.2344 | 0.2307 | 0.3217 | 0.2899 | 0.3131 | 0.3210 |
| 93.34 | 9.63 | 0.2435 | 0.2368 | 0.2545 | 0.2533 | 0.3424 | 0.3107 | 0.3326 | 0.3412 |
| 95.23 | 9.77 | 0.2698 | 0.2692 | 0.2808 | 0.2820 | 0.3687 | 0.3363 | 0.3577 | 0.3656 |
| 96.86 | 9.82 | 0.2948 | 0.2985 | 0.3058 | 0.3076 | 0.3931 | 0.3607 | 0.3815 | 0.3900 |
| 98.99 | 10.04 | 0.3186 | 0.3278 | 0.3302 | 0.3326 | 0.4169 | 0.3845 | 0.4034 | 0.4126 |
| 101.25 | 10.29 | 0.3418 | 0.3534 | 0.3522 | 0.3564 | 0.4395 | 0.4065 | 0.4242 | 0.4340 |
| 103.26 | 10.39 | 0.3619 | 0.3748 | 0.3711 | 0.3784 | 0.4602 | 0.4260 | 0.4437 | 0.4529 |
| 105.02 | 10.68 | 0.3796 | 0.3925 | 0.3882 | 0.3961 | 0.4761 | 0.4413 | 0.4590 | 0.4687 |
| 107.28 | 10.87 | 0.3992 | 0.4132 | 0.4071 | 0.4169 | 0.4962 | 0.4596 | 0.4779 | 0.4877 |
| 109.17 | 10.91 | 0.4187 | 0.4346 | 0.4266 | 0.4376 | 0.5127 | 0.4761 | 0.4950 | 0.5048 |
| 111.18 | 11.09 | 0.4352 | 0.4523 | 0.4431 | 0.4541 | 0.5292 | 0.4919 | 0.5103 | 0.5206 |
| 113.56 | 11.43 | 0.4559 | 0.4742 | 0.4626 | 0.4755 | 0.5511 | 0.5133 | 0.5316 | 0.5420 |
| 115.57 | 11.64 | 0.4730 | 0.4919 | 0.4785 | 0.4932 | 0.5695 | 0.5304 | 0.5493 | 0.5591 |
| 117.33 | 11.91 | 0.4877 | 0.5078 | 0.4938 | 0.5084 | 0.5859 | 0.5457 | 0.5652 | 0.5750 |
| 118.96 | 12.29 | 0.5072 | 0.5298 | 0.5133 | 0.5292 | 0.6000 | 0.5597 | 0.5798 | 0.5908 |
| 121.73 | 12.32 | 0.5310 | 0.5548 | 0.5365 | 0.5542 | 0.6226 | 0.5804 | 0.6024 | 0.6122 |
| 122.98 | 12.29 | 0.5511 | 0.5725 | 0.5554 | 0.5743 | 0.6427 | 0.5988 | 0.6213 | 0.6329 |
| 125.25 | 12.45 | 0.5695 | 0.5725 | 0.5725 | 0.5817 | 0.6586 | 0.6146 | 0.6366 | 0.6488 |
| 127.38 | 12.77 | 0.5853 | 0.5743 | 0.5878 | 0.5975 | 0.6732 | 0.6287 | 0.6512 | 0.6647 |
| 129.89 | 13.08 | 0.6049 | 0.5914 | 0.6067 | 0.6171 | 0.6927 | 0.6470 | 0.6696 | 0.6836 |
| 130.40 | 13.20 | 0.6183 | 0.6049 | 0.6189 | 0.6299 | 0.7129 | 0.6665 | 0.6903 | 0.7056 |
| 132.41 | 13.35 | 0.6244 | 0.6116 | 0.6256 | 0.6366 | 0.7300 | 0.6842 | 0.7074 | 0.7227 |
| 135.55 | 13.54 | 0.6360 | 0.6226 | 0.6360 | 0.6482 | 0.7446 | 0.6982 | 0.7214 | 0.7373 |
| 135.67 | 14.00 | 0.6512 | 0.6378 | 0.6506 | 0.6622 | 0.7532 | 0.7062 | 0.7294 | 0.7458 |
| 137.56 | 14.03 | 0.6659 | 0.6549 | 0.6653 | 0.6769 | 0.7648 | 0.7166 | 0.7404 | 0.7568 |
| 140.82 | 14.20 | 0.6812 | 0.6726 | 0.6799 | 0.6940 | 0.7788 | 0.7288 | 0.7532 | 0.7697 |
| 143.46 | 14.35 | 0.6952 | 0.6897 | 0.6934 | 0.7092 | 0.7947 | 0.7434 | 0.7678 | 0.7849 |
| 145.97 | 14.71 | 0.7117 | 0.7068 | 0.7098 | 0.7269 | 0.8112 | 0.7593 | 0.7843 | 0.8014 |
| 148.11 | 14.90 | 0.7263 | 0.7233 | 0.7233 | 0.7410 | 0.8264 | 0.7739 | 0.7983 | 0.8148 |
| 150.75 | 15.20 | 0.7422 | 0.7397 | 0.7385 | 0.7562 | 0.8441 | 0.7910 | 0.8154 | 0.8325 |
| 152.76 | 15.66 | 0.7538 | 0.7520 | 0.7495 | 0.7666 | 0.8569 | 0.8038 | 0.8276 | 0.8453 |
| 155.77 | 15.55 | 0.7715 | 0.7727 | 0.7684 | 0.7855 | 0.8783 | 0.8264 | 0.8472 | 0.8649 |
| 158.16 | 15.88 | 0.7867 | 0.7880 | 0.7837 | 0.7983 | 0.8942 | 0.8453 | 0.8636 | 0.8820 |
| 160.05 | 16.22 | 0.8057 | 0.8081 | 0.8026 | 0.8160 | 0.9174 | 0.8722 | 0.8862 | 0.9045 |
| 162.43 | 16.38 | 0.8246 | 0.8289 | 0.8215 | 0.8362 | 0.9399 | 0.8954 | 0.9076 | 0.9265 |
| 164.32 | 16.79 | 0.8496 | 0.8557 | 0.8459 | 0.8612 | 0.9698 | 0.9088 | 0.9363 | 0.9546 |
| 165.45 | 16.77 | 0.8838 | 0.8954 | 0.8795 | 0.8954 | 1.0162 | 0.9277 | 0.9802 | 0.9991 |
| 164.69 | 17.21 | 0.9399 | 0.9552 | 0.9326 | 0.9485 | 1.0852 | 0.9644 | 1.0467 | 1.0656 |
| 157.03 | 17.21 | 1.0205 | 1.0382 | 1.0321 | 1.0290 | 1.1883 | 1.0583 | 1.1499 | 1.1694 |
| 153.01 | 17.26 | 1.0546 | 1.0998 | 1.1016 | 1.0339 | 1.2512 | 1.1096 | 1.2145 | 1.2414 |
| 121.85 | 12.64 | 1.0974 | 1.2145 | 1.2084 | 1.0327 | 1.4495 | 1.3659 | 1.4215 | 1.3952 |
| 38.07 | 16.12 | 1.0882 | 1.2200 | 1.2030 | 1.0229 | | 2.0068 | 2.0727 | |

## PUSHOUT TEST SUMMARY SHEET

Test: B15R-2 Test Date: 4-Feb-99
Test Designation: SC-8-2.5-0.187-1.0C-3.0-2R

### SPECIMEN DESCRIPTION

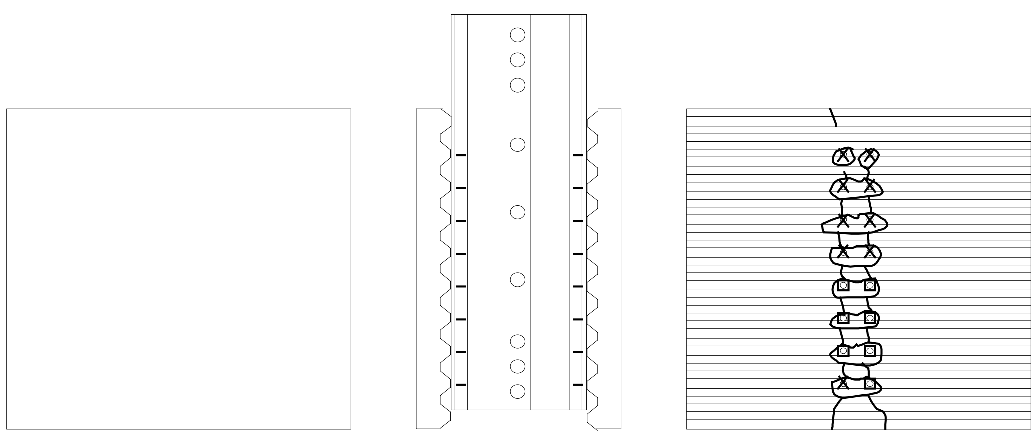
| | | | | |
|---|---|---|---|---|
| **Screw:** | Height: 2.5 in. | No. Per Specimen: 32 | | |
| **Deck:** | Type: 1.0C, 26 ga | Width: 36 in. | Length: 36 in. | |
| | $F_y$: 103.8 ksi | $F_u$: 104.9 ksi | | |
| **Base Member:** | Section: 2L 2x2x0.187 | | | |
| | $F_y$: 61.9 ksi | $F_u$: 85.6 ksi | | |
| **Slab:** | Thickness: 3.0 in. | $f'_c$: 5451 psi | | |
| **Rebar:** | Size: No. 4 | No. Per Specimen: 24 | | |
| | | Height Above Deck: 0.75 in. | | |
| **Mesh:** | Type: WWF 6x6-W2.9xW2.9 | | | |

### TEST RESULTS

**Peak Shear Load:** 163.44 kips
**Peak Shear Load Per Screw:** 5.11 kips
**Slip at Peak Shear Load:**

| | |
|---|---|
| SC1: 0.8911 in. | SC5: 1.0241 in. |
| SC2: 0.9015 in. | SC6: 0.9338 in. |
| SC3: 0.9058 in. | SC7: 0.9906 in. |
| SC4: 0.9015 in. | SC8: 1.0076 in. |

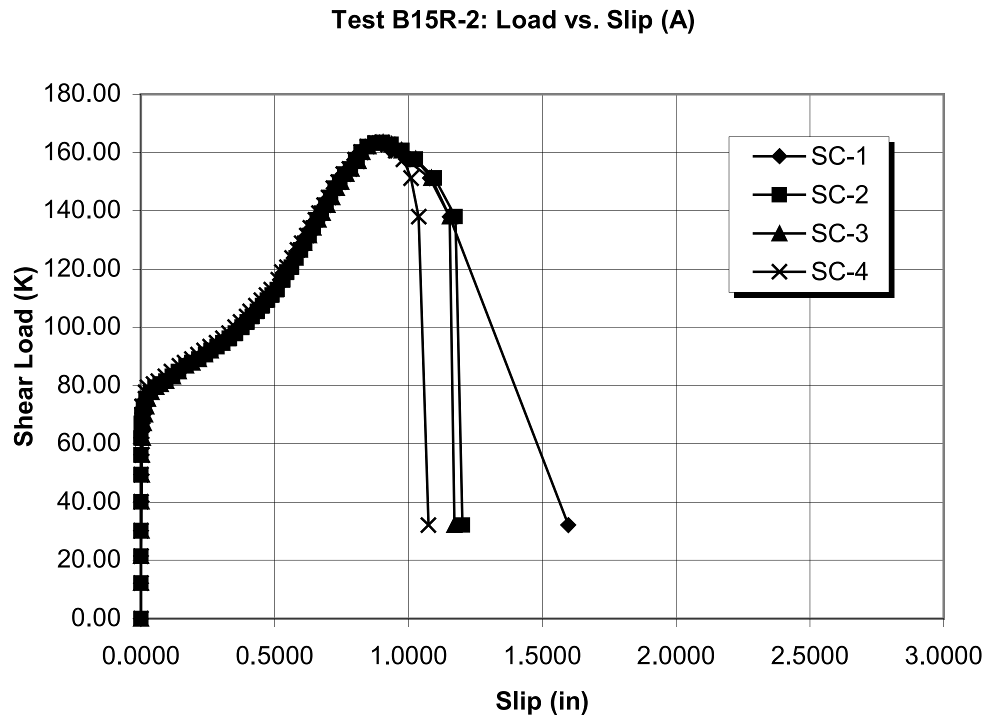
### DAMAGE

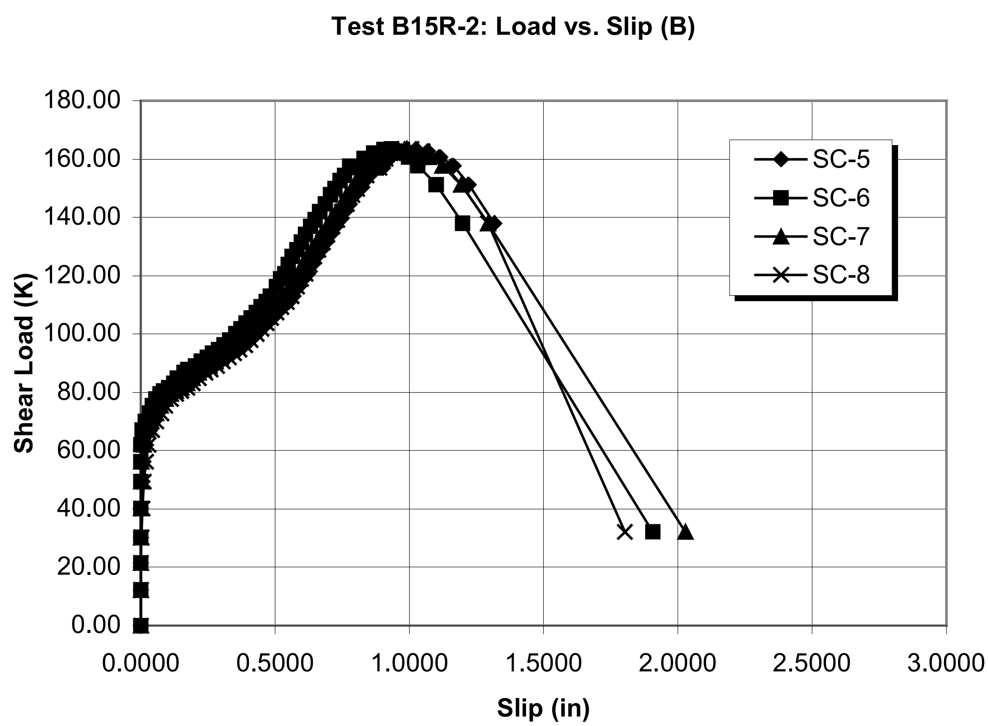


exterior, Slab A interior, Slab B

### COMMENTS

Failure Mode: Concrete rib failure followed by screw shear at ultimate load
Screw Rotation ≈ 50° - 60°
Deck debonded; Slight bulging of deck below screws
X = Screw sheared off
☐ = Screw pulled out of angle


Test B15R-2: Load vs. Slip (A)
Shear Load (K)
Slip (in)
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
3.0000
SC-1
SC-2
SC-3
SC-4


Test B15R-2: Load vs. Slip (B)
Shear Load (K)
Slip (in)
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
3.0000
SC-5
SC-6
SC-7
SC-8

**TEST B15R-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | 0.0000 |
| 12.19 | 1.10 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | 0.0000 |
| 21.48 | 2.44 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | 0.0000 |
| 30.15 | 3.00 | 0.0006 | 0.0006 | 0.0018 | 0.0000 | 0.0006 | 0.0006 | 0.0006 | 0.0024 |
| 40.08 | 3.93 | 0.0012 | 0.0006 | 0.0018 | 0.0000 | 0.0006 | 0.0006 | 0.0006 | 0.0055 |
| 49.37 | 5.00 | 0.0012 | 0.0006 | 0.0031 | 0.0000 | 0.0055 | 0.0006 | 0.0012 | 0.0122 |
| 56.28 | 6.06 | 0.0012 | 0.0006 | 0.0043 | 0.0031 | 0.0104 | 0.0006 | 0.0024 | 0.0189 |
| 62.06 | 6.51 | 0.0024 | 0.0006 | 0.0085 | 0.0031 | 0.0195 | 0.0006 | 0.0110 | 0.0281 |
| 67.09 | 6.91 | 0.0061 | 0.0012 | 0.0122 | 0.0031 | 0.0342 | 0.0055 | 0.0244 | 0.0421 |
| 69.97 | 7.30 | 0.0092 | 0.0043 | 0.0153 | 0.0031 | 0.0476 | 0.0171 | 0.0397 | 0.0562 |
| 72.74 | 7.65 | 0.0128 | 0.0104 | 0.0208 | 0.0031 | 0.0647 | 0.0317 | 0.0574 | 0.0751 |
| 75.38 | 8.00 | 0.0201 | 0.0195 | 0.0275 | 0.0171 | 0.0818 | 0.0439 | 0.0732 | 0.0909 |
| 77.76 | 8.38 | 0.0323 | 0.0354 | 0.0397 | 0.0165 | 0.1025 | 0.0562 | 0.0928 | 0.1117 |
| 79.52 | 8.78 | 0.0500 | 0.0525 | 0.0562 | 0.0238 | 0.1233 | 0.0726 | 0.1117 | 0.1312 |
| 80.53 | 8.98 | 0.0677 | 0.0726 | 0.0751 | 0.0470 | 0.1434 | 0.0854 | 0.1306 | 0.1501 |
| 81.53 | 9.18 | 0.0891 | 0.0940 | 0.0958 | 0.0653 | 0.1654 | 0.1050 | 0.1508 | 0.1721 |
| 83.17 | 9.34 | 0.1105 | 0.1178 | 0.1190 | 0.0922 | 0.1880 | 0.1233 | 0.1727 | 0.1941 |
| 84.80 | 9.42 | 0.1324 | 0.1404 | 0.1416 | 0.1147 | 0.2087 | 0.1361 | 0.1935 | 0.2155 |
| 86.68 | 9.43 | 0.1593 | 0.1685 | 0.1697 | 0.1453 | 0.2338 | 0.1605 | 0.2167 | 0.2405 |
| 87.81 | 9.37 | 0.1801 | 0.1910 | 0.1917 | 0.1642 | 0.2533 | 0.1770 | 0.2344 | 0.2594 |
| 89.07 | 9.23 | 0.2045 | 0.2173 | 0.2167 | 0.1898 | 0.2771 | 0.2045 | 0.2563 | 0.2838 |
| 90.58 | 9.41 | 0.2277 | 0.2411 | 0.2399 | 0.2136 | 0.2997 | 0.2246 | 0.2777 | 0.3052 |
| 92.09 | 9.35 | 0.2496 | 0.2631 | 0.2606 | 0.2362 | 0.3229 | 0.2484 | 0.2972 | 0.3271 |
| 93.34 | 9.43 | 0.2710 | 0.2844 | 0.2820 | 0.2594 | 0.3430 | 0.2667 | 0.3168 | 0.3461 |
| 94.60 | 9.64 | 0.2930 | 0.3070 | 0.3040 | 0.2832 | 0.3650 | 0.2899 | 0.3363 | 0.3668 |
| 96.23 | 9.76 | 0.3162 | 0.3302 | 0.3259 | 0.3070 | 0.3864 | 0.3101 | 0.3571 | 0.3876 |
| 97.99 | 9.96 | 0.3375 | 0.3534 | 0.3479 | 0.3296 | 0.4089 | 0.3314 | 0.3772 | 0.4083 |
| 100.00 | 10.01 | 0.3619 | 0.3778 | 0.3717 | 0.3510 | 0.4327 | 0.3546 | 0.3998 | 0.4309 |
| 101.75 | 10.48 | 0.3809 | 0.3967 | 0.3900 | 0.3717 | 0.4510 | 0.3729 | 0.4175 | 0.4486 |
| 103.64 | 10.62 | 0.4022 | 0.4169 | 0.4102 | 0.3949 | 0.4718 | 0.3918 | 0.4376 | 0.4681 |
| 105.52 | 10.69 | 0.4205 | 0.4352 | 0.4272 | 0.4095 | 0.4901 | 0.4108 | 0.4559 | 0.4852 |
| 107.41 | 10.52 | 0.4413 | 0.4547 | 0.4462 | 0.4291 | 0.5103 | 0.4303 | 0.4755 | 0.5054 |
| 109.29 | 10.98 | 0.4584 | 0.4730 | 0.4645 | 0.4498 | 0.5298 | 0.4480 | 0.4938 | 0.5225 |
| 111.05 | 11.16 | 0.4773 | 0.4901 | 0.4822 | 0.4687 | 0.5511 | 0.4669 | 0.5157 | 0.5438 |
| 112.93 | 11.43 | 0.4968 | 0.5090 | 0.5017 | 0.4858 | 0.5682 | 0.4828 | 0.5334 | 0.5603 |
| 116.33 | 11.86 | 0.5194 | 0.5304 | 0.5243 | 0.5133 | 0.5896 | 0.5048 | 0.5542 | 0.5817 |
| 118.96 | 12.16 | 0.5347 | 0.5463 | 0.5402 | 0.5273 | 0.6067 | 0.5200 | 0.5701 | 0.5975 |
| 120.60 | 12.29 | 0.5524 | 0.5634 | 0.5579 | 0.5450 | 0.6226 | 0.5359 | 0.5872 | 0.6134 |
| 123.86 | 12.64 | 0.5701 | 0.5798 | 0.5768 | 0.5640 | 0.6390 | 0.5493 | 0.6030 | 0.6293 |
| 126.50 | 12.77 | 0.5878 | 0.5975 | 0.5933 | 0.5847 | 0.6555 | 0.5652 | 0.6201 | 0.6451 |
| 128.89 | 13.09 | 0.6030 | 0.6116 | 0.6104 | 0.6006 | 0.6720 | 0.5811 | 0.6372 | 0.6610 |
| 131.53 | 13.39 | 0.6207 | 0.6287 | 0.6281 | 0.6189 | 0.6891 | 0.5981 | 0.6561 | 0.6787 |
| 134.04 | 13.71 | 0.6372 | 0.6439 | 0.6451 | 0.6323 | 0.7062 | 0.6134 | 0.6732 | 0.6952 |
| 136.80 | 13.93 | 0.6537 | 0.6604 | 0.6635 | 0.6519 | 0.7257 | 0.6329 | 0.6927 | 0.7147 |
| 139.19 | 14.19 | 0.6677 | 0.6750 | 0.6781 | 0.6653 | 0.7416 | 0.6500 | 0.7086 | 0.7306 |
| 141.95 | 14.66 | 0.6860 | 0.6927 | 0.6976 | 0.6836 | 0.7599 | 0.6665 | 0.7269 | 0.7483 |
| 144.59 | 14.67 | 0.7031 | 0.7086 | 0.7153 | 0.7013 | 0.7788 | 0.6873 | 0.7477 | 0.7678 |
| 147.73 | 14.98 | 0.7196 | 0.7257 | 0.7318 | 0.7190 | 0.7977 | 0.7056 | 0.7672 | 0.7874 |
| 149.87 | 15.39 | 0.7373 | 0.7434 | 0.7483 | 0.7379 | 0.8173 | 0.7239 | 0.7867 | 0.8057 |
| 152.51 | 15.73 | 0.7550 | 0.7617 | 0.7672 | 0.7568 | 0.8350 | 0.7428 | 0.8038 | 0.8240 |
| 154.39 | 15.78 | 0.7770 | 0.7837 | 0.7880 | 0.7800 | 0.8514 | 0.7587 | 0.8203 | 0.8405 |
| 157.53 | 16.09 | 0.7959 | 0.8020 | 0.8063 | 0.7996 | 0.8704 | 0.7776 | 0.8386 | 0.8582 |
| 157.03 | 16.16 | 0.8026 | 0.8087 | 0.8136 | 0.8087 | 0.9021 | 0.8075 | 0.8698 | 0.8881 |
| 160.17 | 16.49 | 0.8167 | 0.8228 | 0.8276 | 0.8228 | 0.9259 | 0.8307 | 0.8942 | 0.9106 |
| 162.06 | 16.78 | 0.8380 | 0.8453 | 0.8502 | 0.8466 | 0.9564 | 0.8667 | 0.9235 | 0.9393 |
| 163.31 | 16.91 | 0.8673 | 0.8746 | 0.8789 | 0.8759 | 0.9924 | 0.9052 | 0.9589 | 0.9729 |
| 163.44 | 17.20 | 0.8911 | 0.9015 | 0.9058 | 0.9015 | 1.0241 | 0.9338 | 0.9906 | 1.0076 |
| 162.68 | 17.14 | 0.9125 | 0.9344 | 0.9381 | 0.9247 | 1.0675 | 0.9698 | 1.0308 | 1.0485 |
| 160.67 | 17.30 | 0.9357 | 0.9747 | 0.9741 | 0.9534 | 1.1157 | 0.9979 | 1.0711 | 1.0852 |
| 157.66 | 17.26 | 0.9906 | 1.0266 | 1.0260 | 0.9814 | 1.1651 | 1.0321 | 1.1230 | 1.1328 |
| 151.13 | 16.33 | 1.0803 | 1.0961 | 1.0864 | 1.0101 | 1.2213 | 1.1010 | 1.1932 | 1.1938 |
| 137.93 | 14.61 | 1.1541 | 1.1755 | 1.1541 | 1.0375 | 1.3171 | 1.1993 | 1.2933 | 1.2927 |
| 32.16 | 18.43 | 1.5972 | 1.2011 | 1.1718 | 1.0748 | | 1.9067 | 2.0288 | 1.8023 |

**PUSHOUT TEST SUMMARY SHEET**

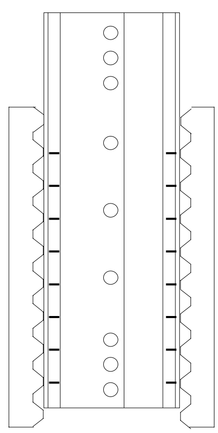
Test: B16-1 Test Date: 4-Sep-98
Test Designation: SC-8-2.5-0.250-1.0C-2.75-1

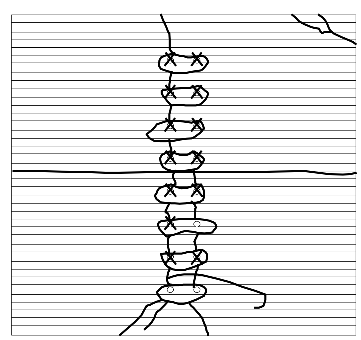
| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.5 in. | No. Per Specimen: | 32 | | |
| **Deck:** | Type: | 1.0C, 26 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 103.8 ksi | $F_u$: | 104.9 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.250 | | | | |
| | $F_y$: | 56.4 ksi | $F_u$: | 77.0 ksi | | |
| **Slab:** | Thickness: | 2.75 in. | $f'_c$: | 7262 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 24 | | |
| | | | Height Above Deck: | 0.75 in. | | |
| **Mesh:** | Type: | WWF 6x6-W2.9xW2.9 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 106.03 kips | | | |
| **Peak Shear Load Per Screw:** | 3.31 kips | | | |
| **Slip at Peak Shear Load:** | SC1: 0.4047 in. | | SC5: 0.4972 in. | |
| | SC2: 0.4653 in. | | SC6: 0.5020 in. | |
| | SC3: 0.4109 in. | | SC7: 0.3893 in. | |
| | SC4: 0.4344 in. | | SC8: 0.5005 in. | |

**DAMAGE**


exterior, Slab A

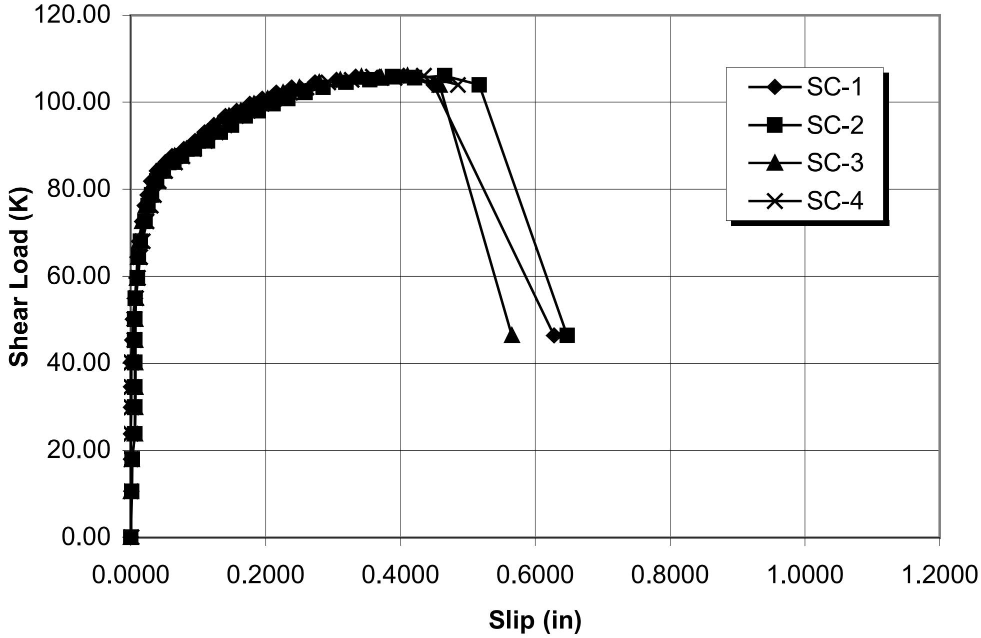



interior, Slab B

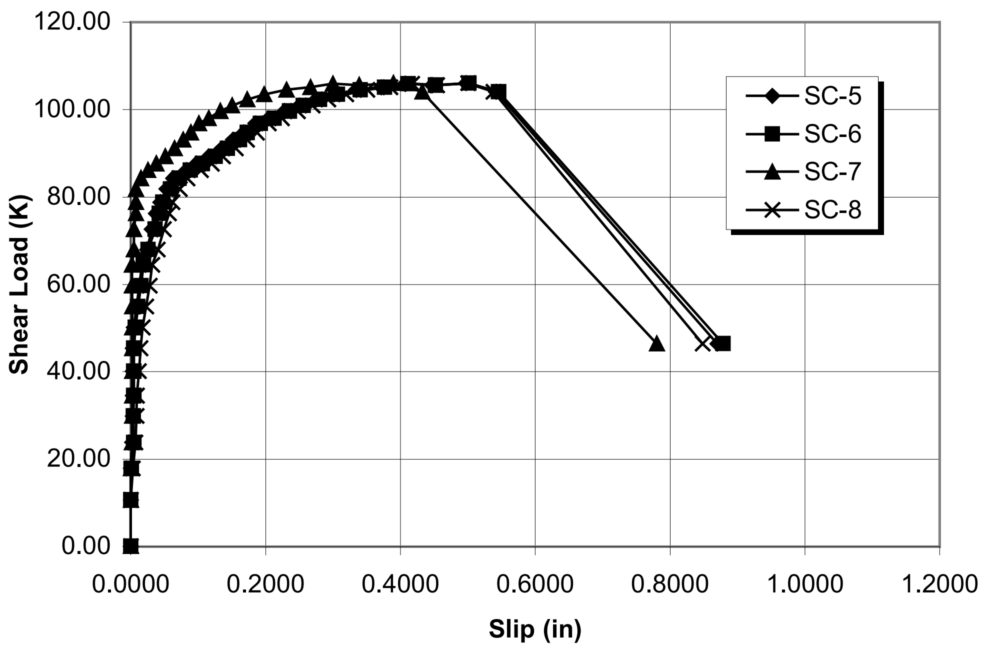
**COMMENTS**

Failure Mode: Concrete rib failure followed by screw shear at ultimate load
Screw Rotation ≈ 10° - 20°
Deck debonded
X = Screw sheared off

**Test B16-1: Load vs. Slip (A)**




**Test B16-1: Load vs. Slip (B)**



**TEST B16-1**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.06 | 0.00 | 0.0002 | 0.0002 | -0.0002 | 0.0005 | -0.0002 | 0.0000 | 0.0002 | 0.0002 |
| 10.68 | 1.07 | 0.0005 | 0.0018 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0004 |
| 17.96 | 1.85 | 0.0004 | 0.0026 | 0.0016 | -0.0002 | 0.0004 | 0.0005 | 0.0000 | 0.0029 |
| 23.81 | 2.47 | -0.0002 | 0.0060 | 0.0064 | 0.0000 | 0.0026 | 0.0044 | 0.0018 | 0.0071 |
| 29.90 | 3.13 | 0.0002 | 0.0059 | 0.0068 | 0.0007 | 0.0027 | 0.0040 | 0.0020 | 0.0081 |
| 34.61 | 3.51 | -0.0004 | 0.0059 | 0.0068 | 0.0009 | 0.0027 | 0.0044 | 0.0022 | 0.0092 |
| 40.20 | 3.99 | -0.0002 | 0.0060 | 0.0066 | 0.0007 | 0.0029 | 0.0046 | 0.0020 | 0.0121 |
| 45.41 | 4.44 | 0.0020 | 0.0060 | 0.0070 | 0.0051 | 0.0029 | 0.0048 | 0.0020 | 0.0143 |
| 50.19 | 4.58 | 0.0033 | 0.0064 | 0.0070 | 0.0053 | 0.0046 | 0.0068 | 0.0020 | 0.0174 |
| 54.96 | 5.47 | 0.0059 | 0.0070 | 0.0075 | 0.0077 | 0.0086 | 0.0103 | 0.0020 | 0.0229 |
| 59.67 | 5.93 | 0.0081 | 0.0095 | 0.0090 | 0.0108 | 0.0132 | 0.0150 | 0.0016 | 0.0282 |
| 64.45 | 6.45 | 0.0099 | 0.0115 | 0.0106 | 0.0137 | 0.0165 | 0.0185 | 0.0013 | 0.0319 |
| 68.03 | 6.99 | 0.0123 | 0.0147 | 0.0121 | 0.0170 | 0.0238 | 0.0260 | 0.0042 | 0.0403 |
| 72.61 | 7.48 | 0.0165 | 0.0209 | 0.0168 | 0.0236 | 0.0308 | 0.0359 | 0.0042 | 0.0493 |
| 76.26 | 7.54 | 0.0205 | 0.0260 | 0.0218 | 0.0291 | 0.0372 | 0.0421 | 0.0079 | 0.0564 |
| 78.77 | 7.88 | 0.0249 | 0.0306 | 0.0260 | 0.0337 | 0.0436 | 0.0478 | 0.0075 | 0.0623 |
| 81.85 | 8.31 | 0.0298 | 0.0385 | 0.0331 | 0.0418 | 0.0527 | 0.0586 | 0.0079 | 0.0725 |
| 84.23 | 8.82 | 0.0383 | 0.0485 | 0.0418 | 0.0509 | 0.0624 | 0.0716 | 0.0148 | 0.0839 |
| 86.18 | 9.21 | 0.0513 | 0.0643 | 0.0551 | 0.0657 | 0.0822 | 0.0881 | 0.0260 | 0.1038 |
| 87.63 | 9.31 | 0.0610 | 0.0758 | 0.0646 | 0.0760 | 0.0976 | 0.1064 | 0.0375 | 0.1198 |
| 89.26 | 9.42 | 0.0784 | 0.0943 | 0.0822 | 0.0939 | 0.1154 | 0.1254 | 0.0511 | 0.1370 |
| 91.08 | 9.52 | 0.0952 | 0.1139 | 0.0987 | 0.1102 | 0.1353 | 0.1436 | 0.0646 | 0.1551 |
| 93.15 | 9.68 | 0.1091 | 0.1330 | 0.1135 | 0.1264 | 0.1518 | 0.1615 | 0.0780 | 0.1721 |
| 94.72 | 9.69 | 0.1229 | 0.1496 | 0.1282 | 0.1390 | 0.1672 | 0.1725 | 0.0888 | 0.1870 |
| 96.80 | 9.96 | 0.1403 | 0.1698 | 0.1454 | 0.1564 | 0.1850 | 0.1928 | 0.1013 | 0.2046 |
| 98.05 | 10.03 | 0.1571 | 0.1890 | 0.1628 | 0.1738 | 0.2044 | 0.2126 | 0.1157 | 0.2241 |
| 99.62 | 10.24 | 0.1769 | 0.2113 | 0.1824 | 0.1937 | 0.2280 | 0.2351 | 0.1328 | 0.2476 |
| 100.87 | 10.41 | 0.1948 | 0.2333 | 0.2027 | 0.2132 | 0.2496 | 0.2556 | 0.1502 | 0.2697 |
| 102.26 | 10.59 | 0.2157 | 0.2589 | 0.2256 | 0.2366 | 0.2749 | 0.2802 | 0.1727 | 0.2932 |
| 103.45 | 10.67 | 0.2384 | 0.2855 | 0.2496 | 0.2602 | 0.3011 | 0.3064 | 0.1978 | 0.3192 |
| 104.52 | 10.84 | 0.2732 | 0.3190 | 0.2789 | 0.2926 | 0.3346 | 0.3403 | 0.2307 | 0.3509 |
| 105.15 | 10.83 | 0.3053 | 0.3551 | 0.3113 | 0.3278 | 0.3716 | 0.3765 | 0.2666 | 0.3851 |
| 105.90 | 10.95 | 0.3335 | 0.3884 | 0.3415 | 0.3589 | 0.4071 | 0.4117 | 0.2998 | 0.4172 |
| 105.59 | 10.91 | 0.3655 | 0.4214 | 0.3714 | 0.3912 | 0.4470 | 0.4520 | 0.3388 | 0.4547 |
| 106.03 | 11.16 | 0.4047 | 0.4653 | 0.4109 | 0.4344 | 0.4972 | 0.5020 | 0.3893 | 0.5005 |
| 104.02 | 10.38 | 0.4494 | 0.5172 | 0.4578 | 0.4851 | 0.5417 | 0.5457 | 0.4322 | 0.5380 |
| 46.42 | 10.47 | 0.6278 | 0.6475 | 0.5651 | | 0.8704 | 0.8785 | 0.7801 | 0.8484 |

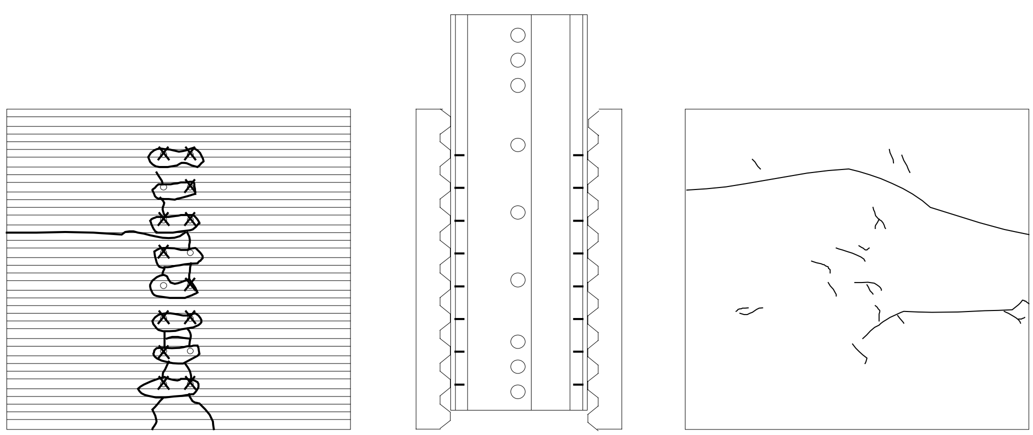
**PUSHOUT TEST SUMMARY SHEET**

Test: B16-2 Test Date: 10-Sep-98
Test Designation: SC-8-2.5-0.250-1.0C-2.75-2

| SPECIMEN DESCRIPTION | | | | | |
|---|---|---|---|---|---|
| **Screw:** | Height: 2.5 in. | No. Per Specimen: 32 | | | |
| **Deck:** | Type: 1.0C, 26 ga | Width: 36 in. | Length: 36 in. | | |
| | $F_y$: 103.8 ksi | $F_u$: 104.9 ksi | | | |
| **Base Member:** | Section: 2L 2x2x0.250 | | | | |
| | $F_y$: 56.4 ksi | $F_u$: 77.0 ksi | | | |
| **Slab:** | Thickness: 2.75 in. | $f'_c$: 7262 psi | | | |
| **Rebar:** | Size: No. 4 | No. Per Specimen: 24 | | | |
| | | Height Above Deck: 0.75 in. | | | |
| **Mesh:** | Type: WWF 6x6-W2.9xW2.9 | | | | |

| TEST RESULTS | | |
|---|---|---|
| **Peak Shear Load:** | 109.98 kips | |
| **Peak Shear Load Per Screw:** | 3.44 kips | |
| **Slip at Peak Shear Load:** | SC1: 0.3545 in. | SC5: 0.2895 in. |
| | SC2: 0.3569 in. | SC6: 0.3382 in. |
| | SC3: 0.3421 in. | SC7: 0.2762 in. |
| | SC4: 0.4075 in. | SC8: 0.3205 in. |

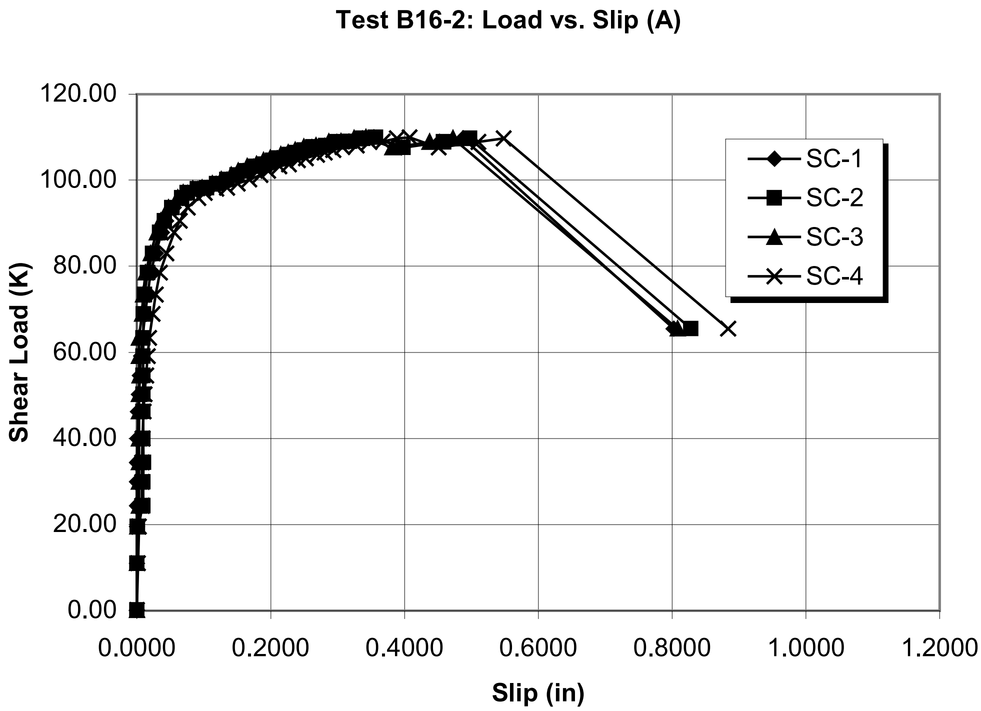
**DAMAGE**

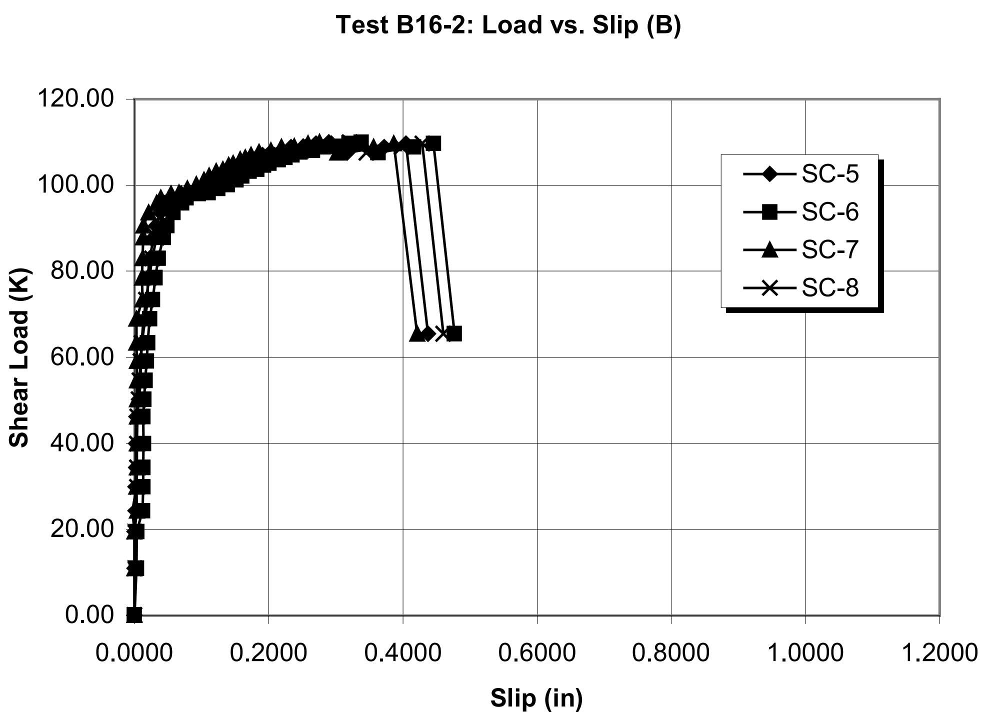


interior, Slab A exterior, Slab B

**COMMENTS**

Failure Mode: Concrete rib failure followed by screw shear at ultimate load
Screw Rotation ≈ 10° - 20°
Deck debonded
X = Screw sheared off


Test B16-2: Load vs. Slip (A)
Shear Load (K)
Slip (in)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0000
0.2000
0.4000
0.6000
0.8000
1.0000
1.2000
SC-1
SC-2
SC-3
SC-4


Test B16-2: Load vs. Slip (B)
Shear Load (K)
Slip (in)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0000
0.2000
0.4000
0.6000
0.8000
1.0000
1.2000
SC-5
SC-6
SC-7
SC-8

**TEST B16-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.06 | 0.00 | 0.0000 | 0.0002 | -0.0002 | -0.0002 | -0.0002 | 0.0002 | 0.0002 | 0.0000 |
| 10.99 | 0.98 | 0.0000 | 0.0004 | 0.0000 | 0.0016 | -0.0004 | 0.0029 | -0.0002 | -0.0004 |
| 19.47 | 2.01 | 0.0000 | 0.0007 | 0.0005 | 0.0027 | 0.0002 | 0.0038 | -0.0002 | -0.0004 |
| 24.37 | 2.40 | 0.0002 | 0.0092 | 0.0027 | 0.0077 | 0.0016 | 0.0125 | 0.0035 | -0.0027 |
| 29.90 | 2.97 | 0.0002 | 0.0088 | 0.0029 | 0.0077 | 0.0016 | 0.0128 | 0.0033 | 0.0038 |
| 34.36 | 3.40 | -0.0002 | 0.0095 | 0.0033 | 0.0079 | 0.0020 | 0.0132 | 0.0037 | 0.0038 |
| 40.01 | 3.98 | 0.0009 | 0.0093 | 0.0031 | 0.0081 | 0.0020 | 0.0134 | 0.0035 | 0.0040 |
| 46.17 | 4.53 | 0.0018 | 0.0093 | 0.0031 | 0.0099 | 0.0033 | 0.0132 | 0.0035 | 0.0046 |
| 50.19 | 5.08 | 0.0033 | 0.0093 | 0.0033 | 0.0115 | 0.0066 | 0.0147 | 0.0037 | 0.0062 |
| 54.59 | 5.52 | 0.0048 | 0.0092 | 0.0035 | 0.0136 | 0.0088 | 0.0161 | 0.0035 | 0.0073 |
| 59.17 | 5.92 | 0.0060 | 0.0093 | 0.0031 | 0.0163 | 0.0101 | 0.0183 | 0.0035 | 0.0090 |
| 63.38 | 6.37 | 0.0084 | 0.0092 | 0.0033 | 0.0183 | 0.0117 | 0.0196 | 0.0033 | 0.0110 |
| 68.91 | 6.88 | 0.0123 | 0.0099 | 0.0073 | 0.0234 | 0.0161 | 0.0231 | 0.0031 | 0.0136 |
| 73.37 | 7.43 | 0.0163 | 0.0114 | 0.0092 | 0.0280 | 0.0198 | 0.0269 | 0.0123 | 0.0172 |
| 78.45 | 7.93 | 0.0209 | 0.0157 | 0.0130 | 0.0342 | 0.0196 | 0.0309 | 0.0117 | 0.0222 |
| 83.04 | 8.41 | 0.0282 | 0.0236 | 0.0207 | 0.0440 | 0.0225 | 0.0359 | 0.0119 | 0.0262 |
| 87.81 | 9.06 | 0.0370 | 0.0339 | 0.0300 | 0.0553 | 0.0286 | 0.0429 | 0.0126 | 0.0333 |
| 90.58 | 9.24 | 0.0432 | 0.0412 | 0.0359 | 0.0635 | 0.0320 | 0.0485 | 0.0134 | 0.0379 |
| 93.66 | 9.60 | 0.0551 | 0.0524 | 0.0471 | 0.0760 | 0.0386 | 0.0579 | 0.0214 | 0.0447 |
| 95.85 | 10.17 | 0.0683 | 0.0670 | 0.0608 | 0.0923 | 0.0485 | 0.0701 | 0.0331 | 0.0551 |
| 97.11 | 10.20 | 0.0758 | 0.0753 | 0.0692 | 0.1013 | 0.0548 | 0.0773 | 0.0397 | 0.0615 |
| 97.99 | 10.30 | 0.0912 | 0.0903 | 0.0835 | 0.1183 | 0.0698 | 0.0952 | 0.0542 | 0.0775 |
| 98.30 | 10.40 | 0.1053 | 0.1044 | 0.0972 | 0.1344 | 0.0817 | 0.1101 | 0.0667 | 0.0921 |
| 99.18 | 10.47 | 0.1188 | 0.1194 | 0.1123 | 0.1503 | 0.0934 | 0.1240 | 0.0791 | 0.1062 |
| 100.12 | 10.51 | 0.1346 | 0.1346 | 0.1264 | 0.1681 | 0.1068 | 0.1386 | 0.0928 | 0.1209 |
| 101.25 | 10.49 | 0.1483 | 0.1496 | 0.1410 | 0.1846 | 0.1179 | 0.1514 | 0.1038 | 0.1337 |
| 102.19 | 10.46 | 0.1588 | 0.1623 | 0.1511 | 0.1959 | 0.1253 | 0.1601 | 0.1115 | 0.1421 |
| 103.20 | 10.41 | 0.1738 | 0.1764 | 0.1648 | 0.2128 | 0.1353 | 0.1712 | 0.1220 | 0.1536 |
| 103.70 | 10.31 | 0.1881 | 0.1910 | 0.1785 | 0.2274 | 0.1458 | 0.1826 | 0.1317 | 0.1661 |
| 104.58 | 10.58 | 0.1998 | 0.2029 | 0.1894 | 0.2406 | 0.1540 | 0.1923 | 0.1401 | 0.1754 |
| 105.15 | 10.51 | 0.2100 | 0.2122 | 0.1994 | 0.2522 | 0.1619 | 0.2009 | 0.1469 | 0.1842 |
| 105.96 | 10.39 | 0.2247 | 0.2280 | 0.2152 | 0.2688 | 0.1732 | 0.2144 | 0.1575 | 0.1980 |
| 106.46 | 10.68 | 0.2362 | 0.2381 | 0.2256 | 0.2806 | 0.1817 | 0.2241 | 0.1654 | 0.2077 |
| 107.03 | 10.56 | 0.2485 | 0.2502 | 0.2362 | 0.2934 | 0.1912 | 0.2348 | 0.1738 | 0.2185 |
| 107.72 | 10.44 | 0.2617 | 0.2630 | 0.2491 | 0.3075 | 0.2031 | 0.2472 | 0.1857 | 0.2318 |
| 108.10 | 10.25 | 0.2807 | 0.2818 | 0.2674 | 0.3285 | 0.2192 | 0.2654 | 0.2033 | 0.2485 |
| 108.85 | 10.84 | 0.2987 | 0.2998 | 0.2864 | 0.3476 | 0.2339 | 0.2807 | 0.2188 | 0.2643 |
| 109.04 | 10.59 | 0.3172 | 0.3179 | 0.3051 | 0.3674 | 0.2516 | 0.2994 | 0.2381 | 0.2827 |
| 109.67 | 10.86 | 0.3368 | 0.3375 | 0.3247 | 0.3884 | 0.2708 | 0.3196 | 0.2586 | 0.3031 |
| 109.98 | 10.60 | 0.3545 | 0.3569 | 0.3421 | 0.4075 | 0.2895 | 0.3382 | 0.2762 | 0.3205 |
| 107.60 | 10.28 | 0.3954 | 0.3979 | 0.3816 | 0.4512 | 0.3166 | 0.3630 | 0.3025 | 0.3456 |
| 108.91 | 9.48 | 0.4523 | 0.4584 | 0.4375 | 0.5104 | 0.3723 | 0.4159 | 0.3560 | 0.3983 |
| 109.73 | 9.96 | 0.4877 | 0.4972 | 0.4725 | 0.5483 | 0.4045 | 0.4461 | 0.3866 | 0.4291 |
| 65.52 | 9.77 | 0.8026 | 0.8285 | 0.8085 | 0.8836 | 0.4375 | 0.4765 | 0.4217 | 0.4600 |

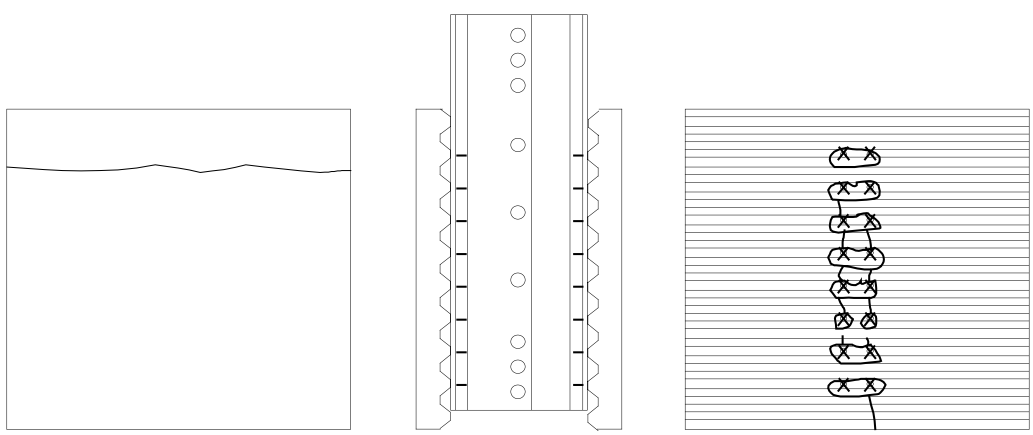
**PUSHOUT TEST SUMMARY SHEET**

Test: B16R-1 Test Date: 8-Feb-99
Test Designation: SC-8-2.5-0.250-1.0C-3.0-1R

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.5 in. | No. Per Specimen: | 32 | | |
| **Deck:** | Type: | 1.0C, 26 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 103.8 ksi | $F_u$: | 104.9 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.250 | | | | |
| | $F_y$: | 56.4 ksi | $F_u$: | 77.0 ksi | | |
| **Slab:** | Thickness: | 3.0 in. | $f'_c$: | 5530 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 24 | | |
| | | | Height Above Deck: | 0.75 in. | | |
| **Mesh:** | Type: | WWF 6x6-W2.9xW2.9 | | | | |

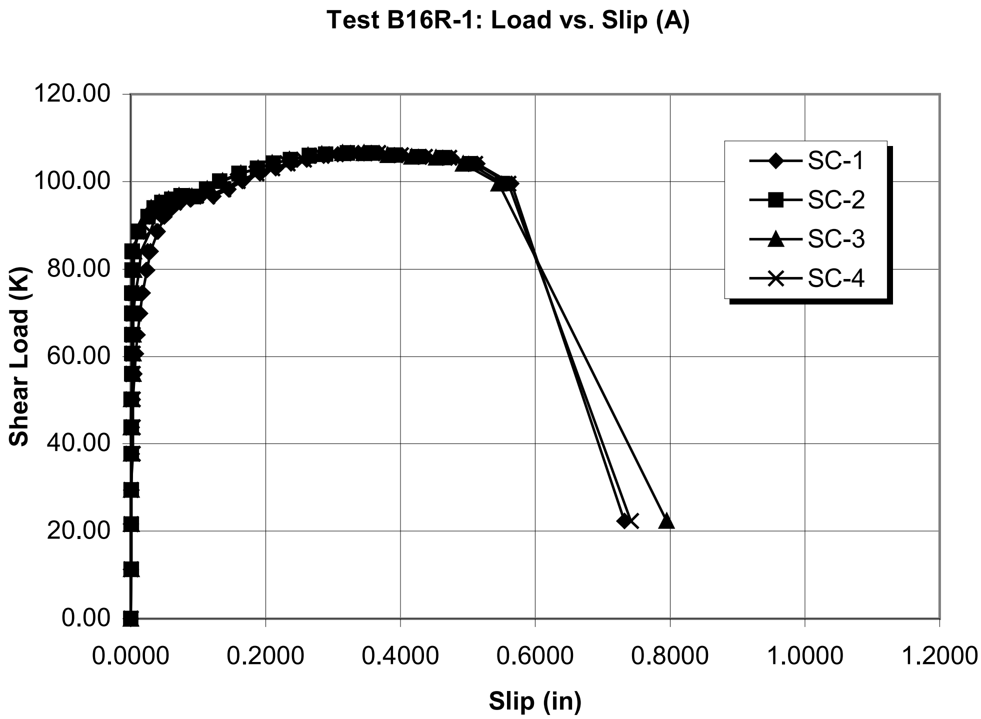
| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 106.53 kips | | | |
| **Peak Shear Load Per Screw:** | 3.33 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.3687 in. | SC5: | 0.3687 in. |
| | SC2: | 0.3552 in. | SC6: | 0.3711 in. |
| | SC3: | 0.3455 in. | SC7: | 0.3534 in. |
| | SC4: | 0.3668 in. | SC8: | 0.3638 in. |

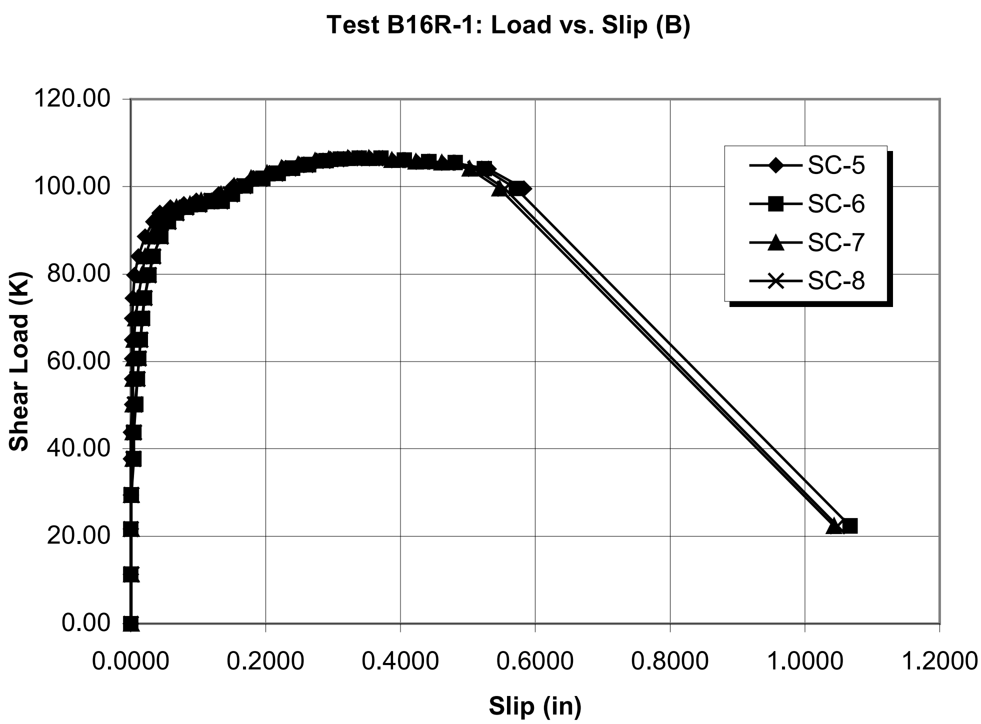
**DAMAGE**



**COMMENTS**

Failure Mode: Concrete rib failure followed by screw shear at ultimate load
Screw Rotation ≈ 10° - 20°
Deck debonded
X = Screw sheared off


Test B16R-1: Load vs. Slip (A)
Shear Load (K)
Slip (in)
SC-1
SC-2
SC-3
SC-4
0.00
20.00
40.00
60.00
80.00
100.00
120.00
0.0000
0.2000
0.4000
0.6000
0.8000
1.0000
1.2000


Test B16R-1: Load vs. Slip (B)
Shear Load (K)
Slip (in)
SC-5
SC-6
SC-7
SC-8
0.00
20.00
40.00
60.00
80.00
100.00
120.00
0.0000
0.2000
0.4000
0.6000
0.8000
1.0000
1.2000

## TEST B16R-1 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0000 |
| 11.31 | 0.92 | 0.0000 | 0.0006 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 21.61 | 1.93 | 0.0000 | 0.0006 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0000 |
| 29.40 | 2.87 | 0.0006 | 0.0006 | 0.0006 | 0.0000 | 0.0000 | 0.0006 | 0.0006 | 0.0006 |
| 37.69 | 3.71 | 0.0018 | 0.0006 | 0.0006 | 0.0031 | 0.0000 | 0.0043 | 0.0031 | 0.0037 |
| 43.72 | 4.37 | 0.0018 | 0.0006 | 0.0000 | 0.0031 | 0.0000 | 0.0043 | 0.0031 | 0.0043 |
| 50.13 | 5.06 | 0.0031 | 0.0006 | 0.0006 | 0.0031 | 0.0024 | 0.0073 | 0.0031 | 0.0061 |
| 56.03 | 5.50 | 0.0055 | 0.0018 | 0.0037 | 0.0031 | 0.0024 | 0.0098 | 0.0031 | 0.0098 |
| 60.68 | 5.99 | 0.0073 | 0.0018 | 0.0037 | 0.0031 | 0.0024 | 0.0122 | 0.0037 | 0.0122 |
| 64.95 | 6.45 | 0.0098 | 0.0018 | 0.0037 | 0.0031 | 0.0024 | 0.0140 | 0.0049 | 0.0140 |
| 69.85 | 7.16 | 0.0134 | 0.0018 | 0.0037 | 0.0037 | 0.0024 | 0.0171 | 0.0067 | 0.0165 |
| 74.50 | 7.53 | 0.0177 | 0.0018 | 0.0037 | 0.0067 | 0.0031 | 0.0208 | 0.0104 | 0.0208 |
| 79.77 | 7.99 | 0.0244 | 0.0024 | 0.0043 | 0.0128 | 0.0055 | 0.0275 | 0.0165 | 0.0262 |
| 84.05 | 8.53 | 0.0293 | 0.0024 | 0.0049 | 0.0153 | 0.0110 | 0.0336 | 0.0214 | 0.0330 |
| 88.57 | 9.08 | 0.0397 | 0.0122 | 0.0122 | 0.0287 | 0.0214 | 0.0446 | 0.0311 | 0.0446 |
| 91.96 | 9.54 | 0.0500 | 0.0256 | 0.0226 | 0.0372 | 0.0330 | 0.0562 | 0.0421 | 0.0562 |
| 93.97 | 9.71 | 0.0610 | 0.0348 | 0.0305 | 0.0507 | 0.0433 | 0.0677 | 0.0531 | 0.0677 |
| 95.23 | 9.81 | 0.0732 | 0.0458 | 0.0421 | 0.0641 | 0.0586 | 0.0830 | 0.0677 | 0.0824 |
| 95.85 | 10.09 | 0.0891 | 0.0610 | 0.0562 | 0.0781 | 0.0787 | 0.1025 | 0.0873 | 0.1013 |
| 96.73 | 10.26 | 0.1044 | 0.0745 | 0.0720 | 0.0964 | 0.0970 | 0.1202 | 0.1044 | 0.1196 |
| 96.61 | 10.22 | 0.1221 | 0.0903 | 0.0903 | 0.1135 | 0.1147 | 0.1355 | 0.1190 | 0.1337 |
| 98.24 | 10.32 | 0.1447 | 0.1123 | 0.1135 | 0.1373 | 0.1306 | 0.1508 | 0.1337 | 0.1477 |
| 100.12 | 10.40 | 0.1654 | 0.1318 | 0.1361 | 0.1587 | 0.1526 | 0.1709 | 0.1532 | 0.1678 |
| 101.88 | 10.58 | 0.1917 | 0.1605 | 0.1630 | 0.1868 | 0.1813 | 0.1959 | 0.1782 | 0.1917 |
| 103.01 | 10.59 | 0.2155 | 0.1880 | 0.1886 | 0.2100 | 0.2063 | 0.2185 | 0.2020 | 0.2148 |
| 104.14 | 10.80 | 0.2374 | 0.2112 | 0.2100 | 0.2325 | 0.2295 | 0.2399 | 0.2234 | 0.2344 |
| 105.02 | 10.87 | 0.2612 | 0.2368 | 0.2356 | 0.2563 | 0.2563 | 0.2643 | 0.2484 | 0.2594 |
| 105.90 | 10.79 | 0.2863 | 0.2649 | 0.2625 | 0.2832 | 0.2856 | 0.2899 | 0.2734 | 0.2850 |
| 106.28 | 10.73 | 0.3070 | 0.2887 | 0.2832 | 0.3040 | 0.3070 | 0.3107 | 0.2936 | 0.3058 |
| 106.53 | 10.68 | 0.3375 | 0.3217 | 0.3137 | 0.3357 | 0.3357 | 0.3387 | 0.3217 | 0.3326 |
| 106.53 | 10.63 | 0.3687 | 0.3552 | 0.3455 | 0.3668 | 0.3687 | 0.3711 | 0.3534 | 0.3638 |
| 106.03 | 10.56 | 0.4022 | 0.3900 | 0.3809 | 0.4010 | 0.4034 | 0.4059 | 0.3870 | 0.3973 |
| 105.65 | 10.02 | 0.4376 | 0.4260 | 0.4169 | 0.4364 | 0.4407 | 0.4425 | 0.4230 | 0.4333 |
| 105.40 | 9.97 | 0.4755 | 0.4626 | 0.4529 | 0.4724 | 0.4785 | 0.4816 | 0.4608 | 0.4712 |
| 104.02 | 9.77 | 0.5139 | 0.5023 | 0.4932 | 0.5109 | 0.5304 | 0.5249 | 0.5023 | 0.5109 |
| 99.50 | 10.04 | 0.5646 | 0.5518 | 0.5457 | 0.5597 | 0.5835 | 0.5719 | 0.5475 | 0.5548 |
| 22.36 | 11.47 | 0.7324 | | 0.7947 | 0.7422 | | 1.0675 | 1.0430 | 1.0485 |

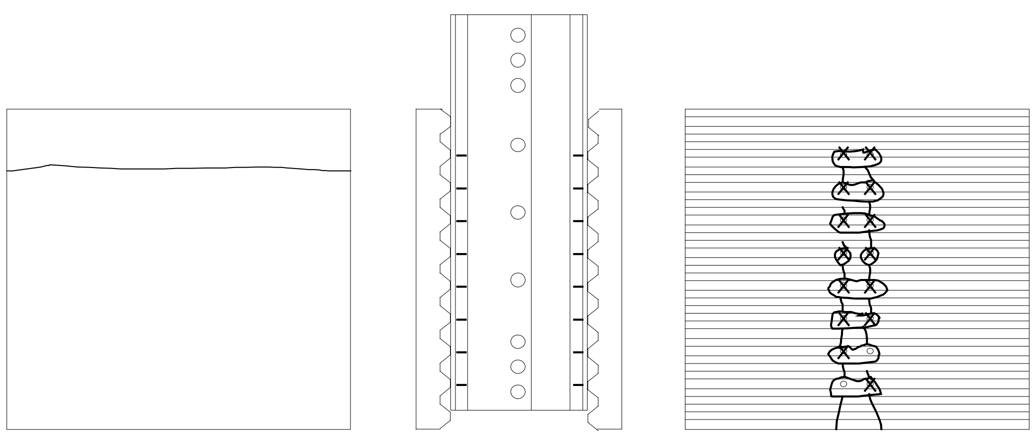
**PUSHOUT TEST SUMMARY SHEET**

Test: B16R-2 Test Date: 9-Feb-99
Test Designation: SC-8-2.5-0.250-1.0C-3.0-2R

| SPECIMEN DESCRIPTION | | | | | |
|---|---|---|---|---|---|
| **Screw:** | Height: | 2.5 in. | No. Per Specimen: | 32 | |
| **Deck:** | Type: | 1.0C, 26 ga | Width: | 36 in. | Length: 36 in. |
| | $F_y$: | 103.8 ksi | $F_u$: | 104.9 ksi | |
| **Base Member:** | Section: | 2L 2x2x0.250 | | | |
| | $F_y$: | 56.4 ksi | $F_u$: | 77.0 ksi | |
| **Slab:** | Thickness: | 3.0 in. | $f'_c$: | 5530 psi | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 24 | |
| | | | Height Above Deck: | 0.75 in. | |
| **Mesh:** | Type: | WWF 6x6-W2.9xW2.9 | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 97.49 kips | | | |
| **Peak Shear Load Per Screw:** | 3.05 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.2863 in. | SC5: | 0.3741 in. |
| | SC2: | 0.3381 in. | SC6: | 0.2875 in. |
| | SC3: | 0.3333 in. | SC7: | 0.3680 in. |
| | SC4: | 0.3180 in. | SC8: | 0.3149 in. |

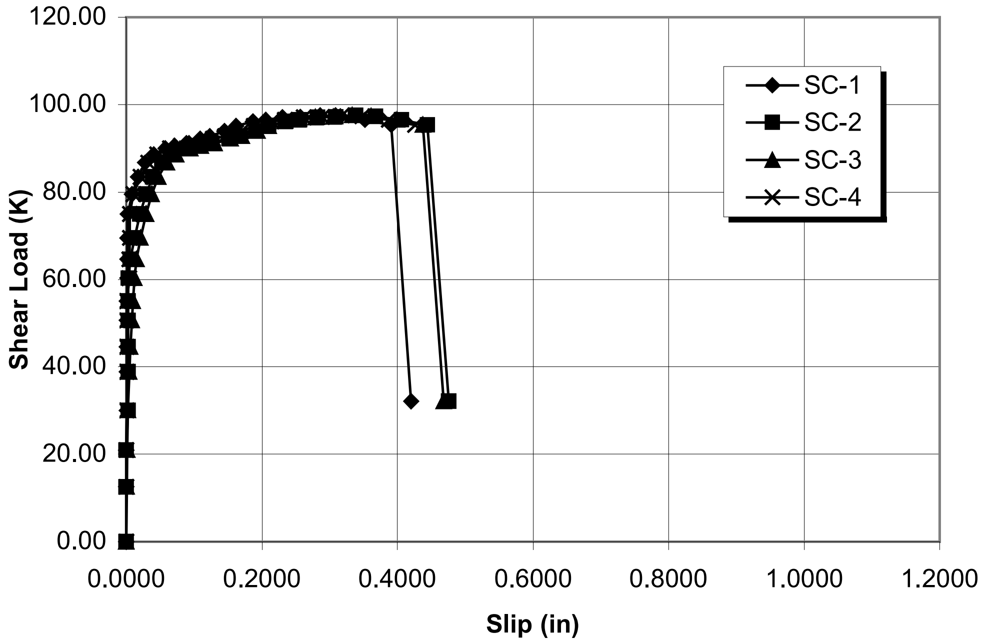
**DAMAGE**



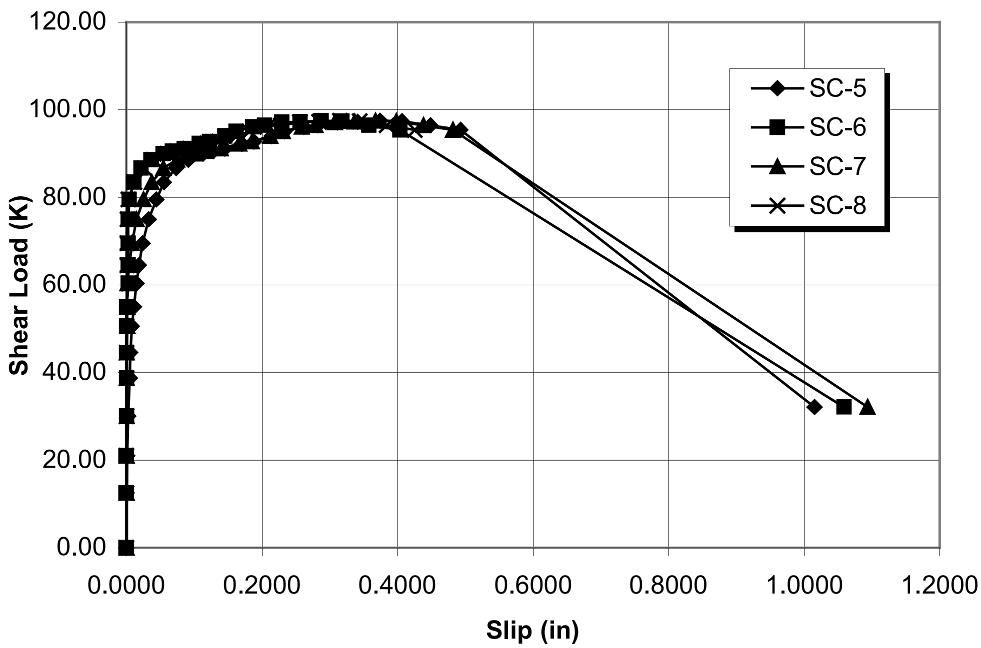
**COMMENTS**

Failure Mode: Concrete rib failure followed by screw shear at ultimate load
Screw Rotation ≈ 10° - 20°
Deck debonded
X = Screw sheared off

**Test B16R-2: Load vs. Slip (A)**




**Test B16R-2: Load vs. Slip (B)**



## TEST B16R-2 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0000 |
| 12.56 | 1.05 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0006 | 0.0000 | 0.0006 | 0.0000 |
| 20.98 | 2.01 | 0.0000 | 0.0000 | 0.0012 | 0.0000 | 0.0018 | 0.0000 | 0.0006 | 0.0000 |
| 30.03 | 2.98 | 0.0006 | 0.0031 | 0.0024 | 0.0006 | 0.0031 | 0.0006 | 0.0006 | 0.0000 |
| 38.82 | 3.72 | 0.0006 | 0.0031 | 0.0043 | 0.0006 | 0.0049 | 0.0006 | 0.0006 | 0.0000 |
| 44.60 | 4.14 | 0.0006 | 0.0031 | 0.0061 | 0.0006 | 0.0061 | 0.0006 | 0.0006 | 0.0000 |
| 50.63 | 4.90 | 0.0006 | 0.0031 | 0.0079 | 0.0006 | 0.0079 | 0.0006 | 0.0012 | 0.0000 |
| 55.03 | 5.43 | 0.0006 | 0.0031 | 0.0098 | 0.0006 | 0.0110 | 0.0006 | 0.0018 | 0.0000 |
| 60.30 | 6.01 | 0.0012 | 0.0031 | 0.0122 | 0.0043 | 0.0146 | 0.0031 | 0.0018 | 0.0037 |
| 64.57 | 6.49 | 0.0012 | 0.0061 | 0.0153 | 0.0043 | 0.0189 | 0.0031 | 0.0043 | 0.0006 |
| 69.47 | 6.96 | 0.0018 | 0.0122 | 0.0214 | 0.0049 | 0.0238 | 0.0031 | 0.0079 | 0.0006 |
| 75.00 | 7.52 | 0.0024 | 0.0201 | 0.0293 | 0.0049 | 0.0330 | 0.0031 | 0.0146 | 0.0012 |
| 79.52 | 7.90 | 0.0085 | 0.0293 | 0.0378 | 0.0104 | 0.0439 | 0.0043 | 0.0256 | 0.0031 |
| 83.42 | 8.32 | 0.0171 | 0.0391 | 0.0470 | 0.0208 | 0.0555 | 0.0116 | 0.0378 | 0.0122 |
| 86.68 | 8.78 | 0.0275 | 0.0525 | 0.0598 | 0.0323 | 0.0732 | 0.0220 | 0.0549 | 0.0262 |
| 88.57 | 9.11 | 0.0403 | 0.0684 | 0.0739 | 0.0458 | 0.0916 | 0.0366 | 0.0751 | 0.0409 |
| 89.95 | 9.47 | 0.0580 | 0.0891 | 0.0946 | 0.0647 | 0.1135 | 0.0549 | 0.0995 | 0.0598 |
| 90.58 | 9.49 | 0.0714 | 0.1062 | 0.1105 | 0.0806 | 0.1282 | 0.0684 | 0.1178 | 0.0745 |
| 91.08 | 9.59 | 0.0885 | 0.1270 | 0.1306 | 0.1019 | 0.1459 | 0.0854 | 0.1398 | 0.0940 |
| 92.21 | 9.67 | 0.1086 | 0.1514 | 0.1538 | 0.1276 | 0.1703 | 0.1080 | 0.1666 | 0.1196 |
| 92.71 | 9.75 | 0.1233 | 0.1678 | 0.1703 | 0.1453 | 0.1886 | 0.1233 | 0.1855 | 0.1367 |
| 93.97 | 9.74 | 0.1447 | 0.1917 | 0.1935 | 0.1703 | 0.2148 | 0.1459 | 0.2124 | 0.1630 |
| 95.10 | 9.84 | 0.1617 | 0.2100 | 0.2100 | 0.1886 | 0.2332 | 0.1624 | 0.2313 | 0.1813 |
| 96.11 | 9.72 | 0.1868 | 0.2356 | 0.2338 | 0.2148 | 0.2618 | 0.1868 | 0.2588 | 0.2075 |
| 96.48 | 9.72 | 0.2057 | 0.2557 | 0.2533 | 0.2344 | 0.2832 | 0.2039 | 0.2795 | 0.2283 |
| 97.11 | 9.72 | 0.2301 | 0.2820 | 0.2795 | 0.2618 | 0.3119 | 0.2295 | 0.3076 | 0.2557 |
| 97.24 | 9.79 | 0.2570 | 0.3088 | 0.3052 | 0.2893 | 0.3418 | 0.2563 | 0.3369 | 0.2844 |
| 97.49 | 9.84 | 0.2863 | 0.3381 | 0.3333 | 0.3180 | 0.3741 | 0.2875 | 0.3680 | 0.3149 |
| 97.36 | 9.86 | 0.3162 | 0.3674 | 0.3613 | 0.3479 | 0.4065 | 0.3180 | 0.3986 | 0.3448 |
| 96.48 | 9.92 | 0.3522 | 0.4059 | 0.3992 | 0.3870 | 0.4486 | 0.3583 | 0.4382 | 0.3839 |
| 95.35 | 9.88 | 0.3912 | 0.4443 | 0.4376 | 0.4260 | 0.4932 | 0.4034 | 0.4816 | 0.4254 |
| 32.16 | 10.49 | 0.4199 | 0.4755 | 0.4681 | | 1.0156 | 1.0589 | 1.0931 | |

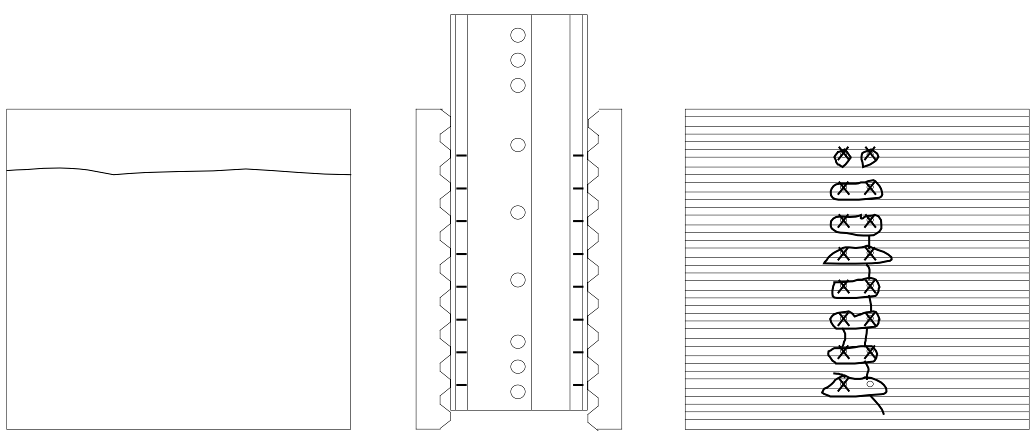
**PUSHOUT TEST SUMMARY SHEET**

Test: B16R-3 Test Date: 10-Feb-99
Test Designation: SC-8-2.5-0.250-1.0C-3.0-3R

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.5 in. | No. Per Specimen: | 32 | | |
| **Deck:** | Type: | 1.0C, 26 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 103.8 ksi | $F_u$: | 104.9 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.250 | | | | |
| | $F_y$: | 56.4 ksi | $F_u$: | 77.0 ksi | | |
| **Slab:** | Thickness: | 3.0 in. | $f'_c$: | 5530 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 24 | | |
| | | | Height Above Deck: | 0.75 in. | | |
| **Mesh:** | Type: | WWF 6x6-W2.9xW2.9 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 93.47 kips | | | |
| **Peak Shear Load Per Screw:** | 2.92 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.2979 in. | SC5: | 0.3741 in. |
| | SC2: | 0.2643 in. | SC6: | 0.3461 in. |
| | SC3: | 0.2960 in. | SC7: | 0.3577 in. |
| | SC4: | 0.3027 in. | SC8: | N.A. |

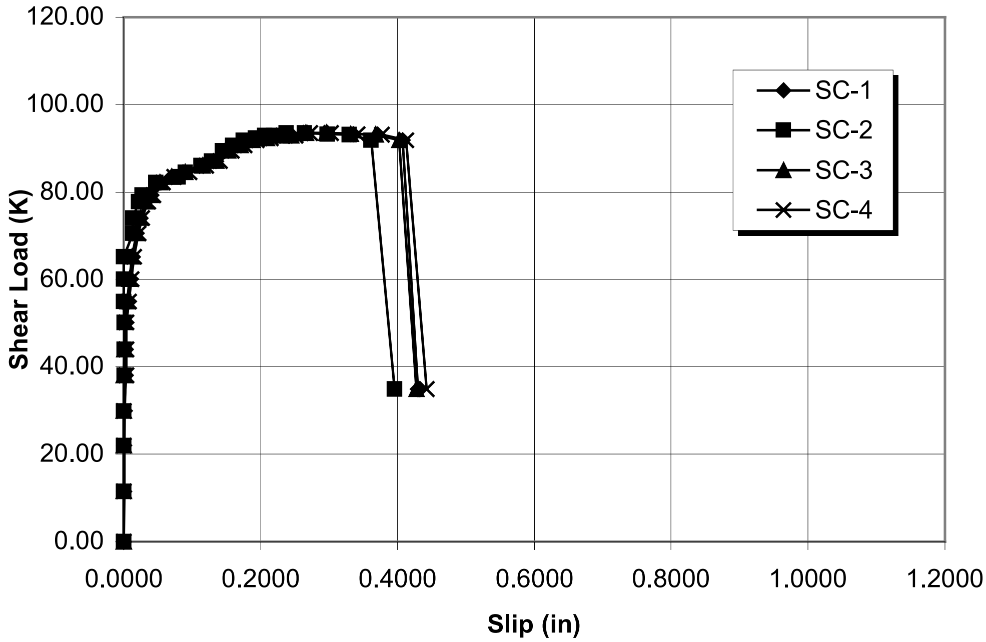
**DAMAGE**



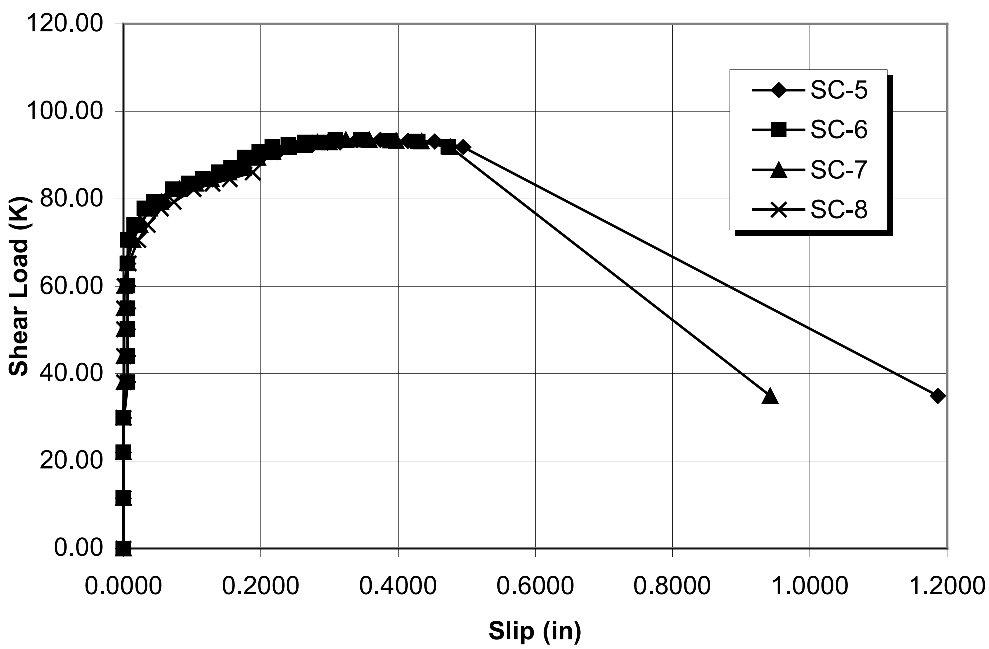
**COMMENTS**

Failure Mode: Concrete rib failure followed by screw shear at ultimate load
Screw Rotation ≈ 10° - 20°
Deck debonded
X = Screw sheared off

Test B16R-3: Load vs. Slip (A)




Test B16R-3: Load vs. Slip (B)



**TEST B16R-3 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11.56 | 1.04 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 21.98 | 1.98 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -0.0006 |
| 29.90 | 3.03 | 0.0012 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | 0.0000 |
| 38.07 | 3.99 | 0.0031 | 0.0006 | 0.0000 | 0.0037 | 0.0067 | 0.0061 | 0.0006 | 0.0006 |
| 43.97 | 4.49 | 0.0031 | 0.0006 | 0.0006 | 0.0037 | 0.0067 | 0.0061 | 0.0006 | 0.0006 |
| 50.13 | 5.02 | 0.0037 | 0.0006 | 0.0018 | 0.0037 | 0.0061 | 0.0061 | 0.0006 | 0.0006 |
| 54.90 | 5.26 | 0.0073 | 0.0000 | 0.0055 | 0.0073 | 0.0067 | 0.0061 | 0.0006 | 0.0006 |
| 60.05 | 6.06 | 0.0104 | 0.0000 | 0.0085 | 0.0110 | 0.0067 | 0.0061 | 0.0012 | 0.0012 |
| 65.20 | 6.60 | 0.0134 | 0.0000 | 0.0122 | 0.0146 | 0.0067 | 0.0061 | 0.0055 | 0.0073 |
| 70.48 | 7.08 | 0.0183 | 0.0134 | 0.0183 | 0.0214 | 0.0092 | 0.0067 | 0.0140 | 0.0214 |
| 73.99 | 7.74 | 0.0244 | 0.0134 | 0.0244 | 0.0269 | 0.0226 | 0.0159 | 0.0244 | 0.0354 |
| 77.76 | 8.13 | 0.0317 | 0.0214 | 0.0317 | 0.0360 | 0.0409 | 0.0305 | 0.0385 | 0.0549 |
| 79.27 | 8.46 | 0.0403 | 0.0269 | 0.0397 | 0.0433 | 0.0574 | 0.0446 | 0.0549 | 0.0732 |
| 82.16 | 8.98 | 0.0543 | 0.0470 | 0.0531 | 0.0574 | 0.0842 | 0.0720 | 0.0818 | 0.1025 |
| 83.42 | 9.10 | 0.0696 | 0.0793 | 0.0696 | 0.0739 | 0.1080 | 0.0946 | 0.1056 | 0.1294 |
| 84.55 | 9.26 | 0.0903 | 0.0903 | 0.0903 | 0.0958 | 0.1300 | 0.1160 | 0.1282 | 0.1550 |
| 86.06 | 9.40 | 0.1160 | 0.1129 | 0.1154 | 0.1208 | 0.1562 | 0.1392 | 0.1544 | 0.1886 |
| 87.06 | 9.42 | 0.1349 | 0.1288 | 0.1355 | 0.1404 | 0.1764 | 0.1575 | 0.1746 | |
| 89.45 | 9.45 | 0.1526 | 0.1447 | 0.1526 | 0.1581 | 0.1996 | 0.1764 | 0.1959 | |
| 90.70 | 9.40 | 0.1709 | 0.1593 | 0.1709 | 0.1764 | 0.2246 | 0.1978 | 0.2179 | |
| 91.83 | 9.68 | 0.1874 | 0.1752 | 0.1880 | 0.1941 | 0.2496 | 0.2173 | 0.2399 | |
| 92.34 | 9.56 | 0.2081 | 0.1929 | 0.2087 | 0.2148 | 0.2747 | 0.2399 | 0.2625 | |
| 92.84 | 9.70 | 0.2283 | 0.2063 | 0.2277 | 0.2332 | 0.2972 | 0.2649 | 0.2826 | |
| 92.84 | 9.82 | 0.2454 | 0.2191 | 0.2448 | 0.2509 | 0.3156 | 0.2850 | 0.3003 | |
| 93.47 | 9.78 | 0.2686 | 0.2374 | 0.2661 | 0.2722 | 0.3400 | 0.3094 | 0.3241 | |
| 93.47 | 9.71 | 0.2979 | 0.2643 | 0.2960 | 0.3027 | 0.3741 | 0.3461 | 0.3577 | |
| 93.22 | 9.74 | 0.3357 | 0.2972 | 0.3320 | 0.3412 | 0.4144 | 0.3882 | 0.3973 | |
| 93.09 | 9.49 | 0.3711 | 0.3296 | 0.3680 | 0.3772 | 0.4535 | 0.4291 | 0.4346 | |
| 91.83 | 9.86 | 0.4077 | 0.3613 | 0.4028 | 0.4126 | 0.4950 | 0.4736 | 0.4761 | |
| 34.92 | 10.64 | 0.4303 | 0.3955 | 0.4279 | 0.4425 | 1.1865 | | 0.9418 | |

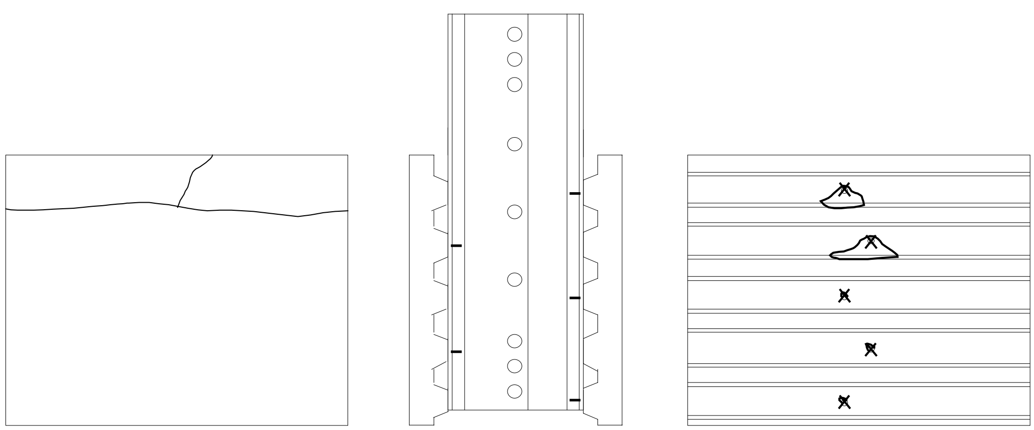
## PUSHOUT TEST SUMMARY SHEET

Test: C1R-1    Test Date: 24-May-99
Test Designation: SC-8-3.0-0.109-1.5C-3.25-1R

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 3.0 in. | No. Per Specimen: | 10 | | |
| **Deck:** | Type: | 1.5C, 22ga | Width: | 36 in. | Length: | 32 in. |
| | $F_y$: | 101.7 ksi | $F_u$: | 103.2 ksi | | |
| **Base Member:** | Section: | 2L 1.25x1.25x0.109 | | | | |
| | $F_y$: | 55.6 ksi | $F_u$: | 76.8 ksi | | |
| **Slab:** | Thickness: | 3.25 in. | $f'_c$: | 4098 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 4x4-W2.1xW2.1 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 54.02 kips | | | |
| **Peak Shear Load Per Screw:** | 5.40 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.2344 in. | SC5: | 0.3552 in. |
| | SC2: | 0.4181 in. | SC6: | 0.4718 in. |
| | SC3: | 0.3558 in. | SC7: | 0.4468 in. |
| | SC4: | 0.3998 in. | SC8: | 0.4614 in. |

### DAMAGE

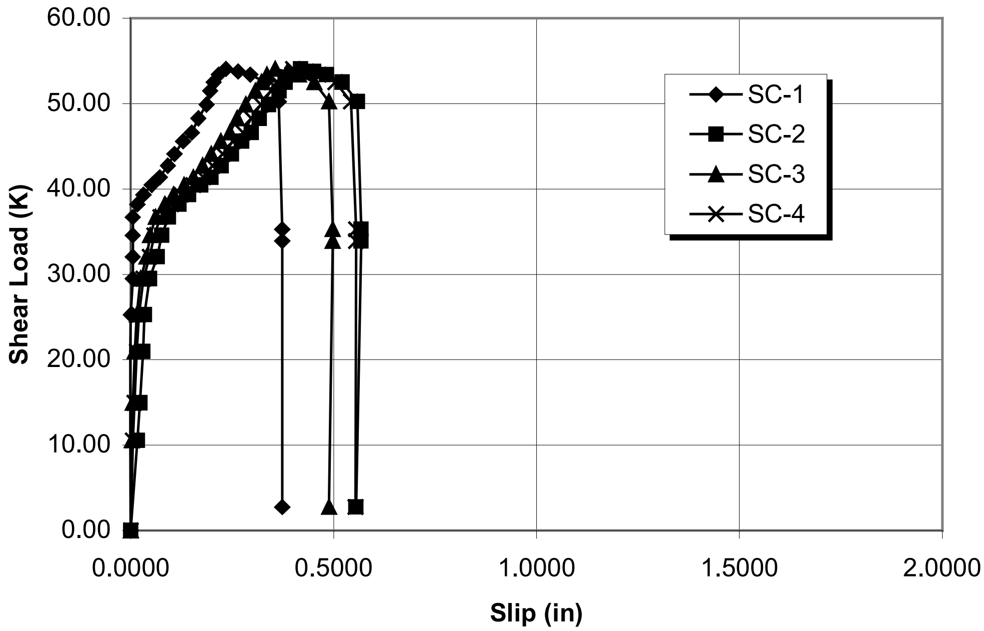


exterior, Slab A    interior, Slab B

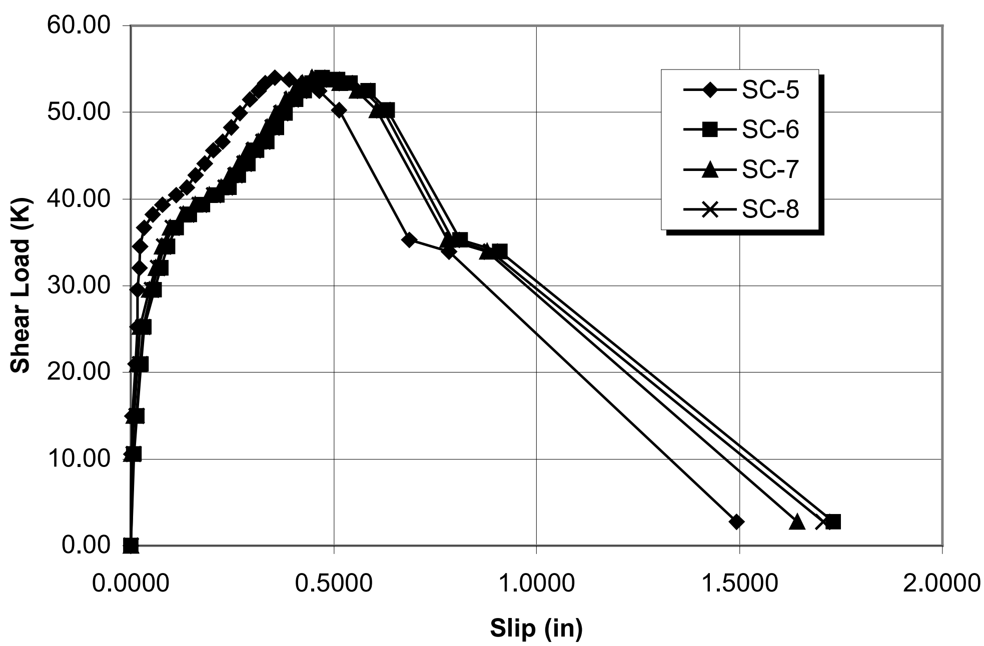
### COMMENTS

Failure Mode: Screw Shear
Screw Rotation ≈ 40° - 50°
Angles slightly deformed at screw locations due to rotation of screws
X = Screw sheared off

Test C1R-1: Load vs. Slip (A)




Test C1R-1: Load vs. Slip (B)



## Test C1R-1 Data

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10.55 | 1.04 | -0.0012 | 0.0165 | 0.0031 | 0.0049 | 0.0012 | 0.0079 | 0.0018 | 0.0061 |
| 14.95 | 1.57 | -0.0012 | 0.0226 | 0.0049 | 0.0085 | 0.0037 | 0.0153 | 0.0079 | 0.0134 |
| 20.98 | 2.08 | -0.0012 | 0.0305 | 0.0104 | 0.0153 | 0.0116 | 0.0256 | 0.0165 | 0.0226 |
| 25.25 | 2.48 | -0.0006 | 0.0342 | 0.0146 | 0.0195 | 0.0159 | 0.0330 | 0.0226 | 0.0299 |
| 29.52 | 2.81 | 0.0049 | 0.0464 | 0.0238 | 0.0317 | 0.0165 | 0.0580 | 0.0452 | 0.0519 |
| 32.04 | 3.13 | 0.0055 | 0.0647 | 0.0385 | 0.0464 | 0.0208 | 0.0745 | 0.0610 | 0.0665 |
| 34.55 | 3.45 | 0.0055 | 0.0769 | 0.0476 | 0.0580 | 0.0232 | 0.0909 | 0.0769 | 0.0818 |
| 36.68 | 3.76 | 0.0055 | 0.0922 | 0.0610 | 0.0732 | 0.0323 | 0.1117 | 0.0970 | 0.1025 |
| 38.19 | 3.78 | 0.0165 | 0.1190 | 0.0842 | 0.1001 | 0.0543 | 0.1447 | 0.1294 | 0.1379 |
| 39.32 | 4.20 | 0.0311 | 0.1434 | 0.1056 | 0.1245 | 0.0781 | 0.1764 | 0.1587 | 0.1691 |
| 40.45 | 4.44 | 0.0513 | 0.1733 | 0.1312 | 0.1538 | 0.1111 | 0.2124 | 0.1935 | 0.2051 |
| 41.33 | 4.60 | 0.0714 | 0.1984 | 0.1544 | 0.1788 | 0.1385 | 0.2417 | 0.2222 | 0.2332 |
| 42.71 | 4.61 | 0.0909 | 0.2234 | 0.1764 | 0.2020 | 0.1599 | 0.2649 | 0.2448 | 0.2570 |
| 44.10 | 4.78 | 0.1074 | 0.2478 | 0.1984 | 0.2264 | 0.1819 | 0.2881 | 0.2667 | 0.2802 |
| 45.60 | 4.99 | 0.1288 | 0.2728 | 0.2222 | 0.2515 | 0.2032 | 0.3101 | 0.2887 | 0.3027 |
| 46.61 | 5.01 | 0.1501 | 0.2972 | 0.2448 | 0.2771 | 0.2258 | 0.3351 | 0.3131 | 0.3265 |
| 48.24 | 5.17 | 0.1672 | 0.3174 | 0.2625 | 0.2972 | 0.2478 | 0.3583 | 0.3357 | 0.3491 |
| 49.87 | 5.33 | 0.1862 | 0.3400 | 0.2826 | 0.3204 | 0.2686 | 0.3802 | 0.3577 | 0.3705 |
| 51.51 | 5.48 | 0.1953 | 0.3656 | 0.3070 | 0.3455 | 0.2936 | 0.4065 | 0.3827 | 0.3961 |
| 52.51 | 5.61 | 0.2045 | 0.3809 | 0.3217 | 0.3607 | 0.3143 | 0.4272 | 0.4034 | 0.4169 |
| 53.39 | 5.70 | 0.2167 | 0.3967 | 0.3357 | 0.3778 | 0.3314 | 0.4462 | 0.4230 | 0.4364 |
| 54.02 | 5.86 | 0.2344 | 0.4181 | 0.3558 | 0.3998 | 0.3552 | 0.4718 | 0.4468 | 0.4614 |
| 53.77 | 6.00 | 0.2649 | 0.4510 | 0.3864 | 0.4327 | 0.3900 | 0.5090 | 0.4828 | 0.4980 |
| 53.39 | 6.00 | 0.2942 | 0.4822 | 0.4150 | 0.4633 | 0.4211 | 0.5408 | 0.5145 | 0.5298 |
| 52.51 | 5.99 | 0.3314 | 0.5212 | 0.4523 | 0.5035 | 0.4645 | 0.5841 | 0.5573 | 0.5743 |
| 50.25 | 6.08 | 0.3644 | 0.5591 | 0.4883 | 0.5426 | 0.5133 | 0.6329 | 0.6055 | 0.6226 |
| 35.30 | 8.00 | 0.3729 | 0.5676 | 0.4980 | 0.5548 | 0.6866 | 0.8118 | 0.7806 | 0.7928 |
| 33.92 | 3.64 | 0.3729 | 0.5676 | 0.4980 | 0.5548 | 0.7843 | 0.9094 | 0.8783 | 0.8875 |
| 2.76 | 2.49 | 0.3735 | 0.5554 | 0.4883 | 0.5536 | 1.4935 | 1.7315 | 1.6430 | 1.7059 |

## PUSHOUT TEST SUMMARY SHEET

Test: C1R-2 Test Date: 25-May-99

Test Designation: SC-8-3.0-0.109-1.5C-3.25-2R

### SPECIMEN DESCRIPTION

**Screw:** Height: 3.0 in. No. Per Specimen: 10

**Deck:** Type: 1.5C, 22ga Width: 36 in. Length: 32 in.

$F_y$: 101.7 ksi $F_u$: 103.2 ksi

**Base Member:** Section: 2L 1.25x1.25x0.109

$F_y$: 55.6 ksi $F_u$: 76.8 ksi

**Slab:** Thickness: 3.25 in. $f'_c$: 4098 psi

**Rebar:** Size: No. 4 No. Per Specimen: 8

Height Above Deck: 1.0 in.

**Mesh:** Type: WWF 4x4-W2.1xW2.1

### TEST RESULTS

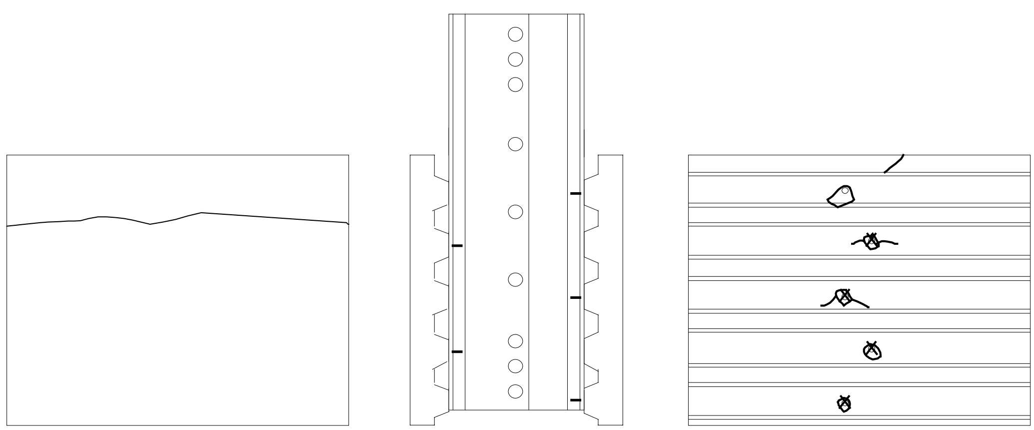
**Peak Shear Load:** 46.48 kips

**Peak Shear Load Per Screw:** 4.65 kips

**Slip at Peak Shear Load:**

| | | | |
|---|---|---|---|
| SC1: | 0.2490 in. | SC5: | 0.4041 in. |
| SC2: | 0.3455 in. | SC6: | 0.4218 in. |
| SC3: | 0.2905 in. | SC7: | 0.4529 in. |
| SC4: | 0.3192 in. | SC8: | 0.4730 in. |

### DAMAGE



exterior, Slab A interior, Slab B

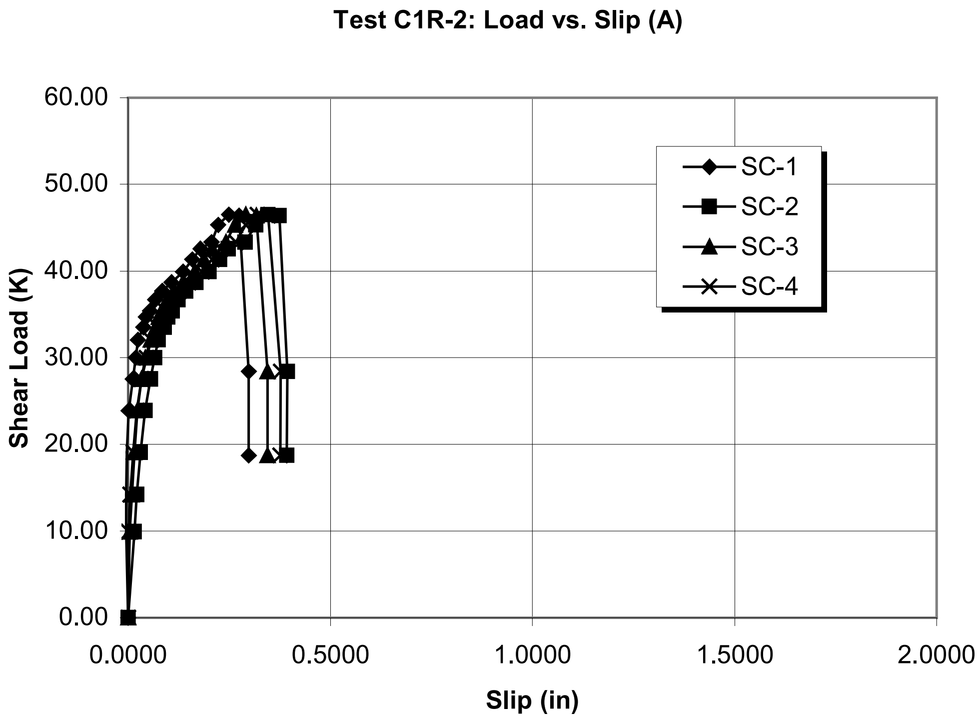
### COMMENTS

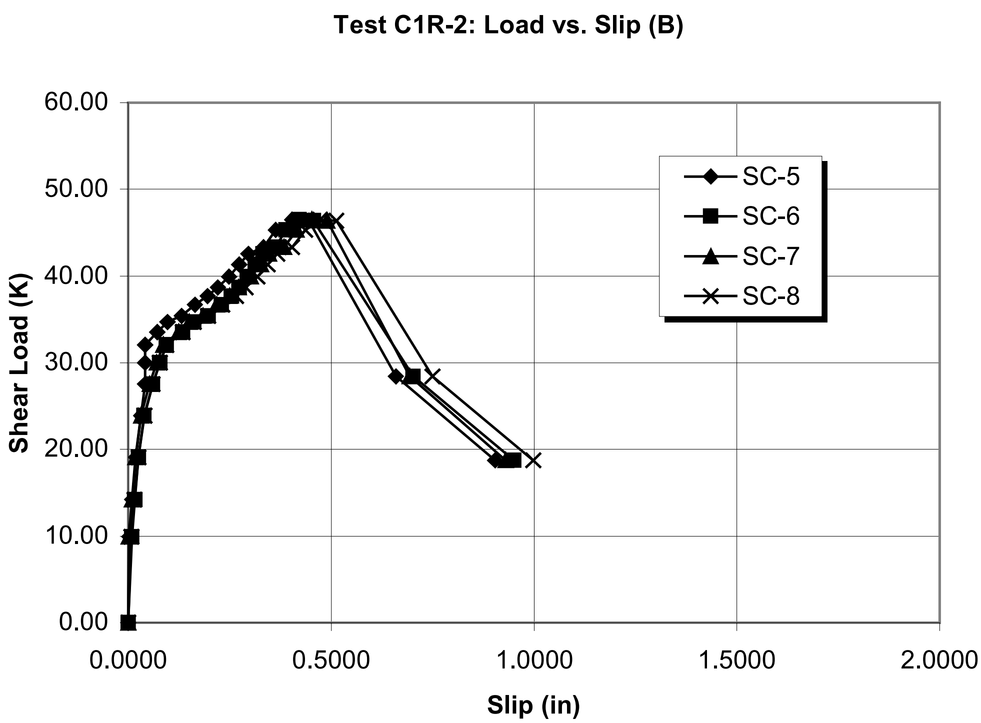
Failure Mode: Screw Shear

Screw Rotation ≈ 40° - 50°

Angles slightly deformed at screw locations due to rotation of screws

X = Screw sheared off


Test C1R-2: Load vs. Slip (A)
Shear Load (K)
Slip (in)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
0.0000
0.5000
1.0000
1.5000
2.0000
SC-1
SC-2
SC-3
SC-4


Test C1R-2: Load vs. Slip (B)
Shear Load (K)
Slip (in)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
0.0000
0.5000
1.0000
1.5000
2.0000
SC-5
SC-6
SC-7
SC-8

**Test C1R-2 Data**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 9.92 | 0.99 | -0.0049 | 0.0146 | 0.0043 | 0.0012 | 0.0031 | 0.0092 | 0.0018 | 0.0079 |
| 14.20 | 1.47 | -0.0049 | 0.0220 | 0.0092 | 0.0055 | 0.0098 | 0.0159 | 0.0085 | 0.0153 |
| 19.10 | 1.98 | -0.0037 | 0.0305 | 0.0146 | 0.0122 | 0.0183 | 0.0250 | 0.0177 | 0.0250 |
| 23.87 | 2.38 | 0.0018 | 0.0421 | 0.0232 | 0.0220 | 0.0317 | 0.0385 | 0.0317 | 0.0397 |
| 27.51 | 2.29 | 0.0110 | 0.0549 | 0.0330 | 0.0330 | 0.0409 | 0.0598 | 0.0525 | 0.0604 |
| 30.03 | 2.93 | 0.0183 | 0.0653 | 0.0433 | 0.0452 | 0.0409 | 0.0775 | 0.0702 | 0.0775 |
| 32.04 | 3.34 | 0.0244 | 0.0745 | 0.0555 | 0.0562 | 0.0415 | 0.0946 | 0.0861 | 0.0946 |
| 33.54 | 3.53 | 0.0378 | 0.0897 | 0.0677 | 0.0726 | 0.0720 | 0.1337 | 0.1239 | 0.1337 |
| 34.67 | 3.69 | 0.0446 | 0.0977 | 0.0751 | 0.0806 | 0.0970 | 0.1617 | 0.1501 | 0.1611 |
| 35.43 | 3.95 | 0.0543 | 0.1093 | 0.0848 | 0.0922 | 0.1312 | 0.1965 | 0.1849 | 0.1971 |
| 36.68 | 3.95 | 0.0671 | 0.1233 | 0.0970 | 0.1062 | 0.1642 | 0.2289 | 0.2185 | 0.2325 |
| 37.69 | 3.94 | 0.0842 | 0.1422 | 0.1129 | 0.1257 | 0.1959 | 0.2545 | 0.2496 | 0.2655 |
| 38.69 | 4.02 | 0.1068 | 0.1672 | 0.1361 | 0.1501 | 0.2209 | 0.2728 | 0.2722 | 0.2899 |
| 39.95 | 4.24 | 0.1355 | 0.1996 | 0.1648 | 0.1825 | 0.2484 | 0.2936 | 0.3027 | 0.3180 |
| 41.33 | 4.37 | 0.1587 | 0.2258 | 0.1880 | 0.2075 | 0.2728 | 0.3137 | 0.3271 | 0.3436 |
| 42.59 | 4.52 | 0.1782 | 0.2478 | 0.2075 | 0.2295 | 0.2960 | 0.3320 | 0.3479 | 0.3668 |
| 43.34 | 4.42 | 0.2057 | 0.2887 | 0.2417 | 0.2661 | 0.3333 | 0.3625 | 0.3839 | 0.4034 |
| 45.35 | 4.68 | 0.2228 | 0.3156 | 0.2637 | 0.2911 | 0.3638 | 0.3888 | 0.4150 | 0.4358 |
| 46.48 | 4.89 | 0.2490 | 0.3455 | 0.2905 | 0.3192 | 0.4041 | 0.4218 | 0.4529 | 0.4730 |
| 46.36 | 4.97 | 0.2740 | 0.3741 | 0.3174 | 0.3461 | 0.4449 | 0.4565 | 0.4907 | 0.5127 |
| 28.39 | 5.10 | 0.2979 | 0.3943 | 0.3442 | 0.3772 | 0.6598 | 0.7025 | 0.6940 | 0.7495 |
| 18.72 | 6.06 | 0.2979 | 0.3925 | 0.3442 | 0.3766 | 0.9039 | 0.9509 | 0.9308 | 0.9985 |

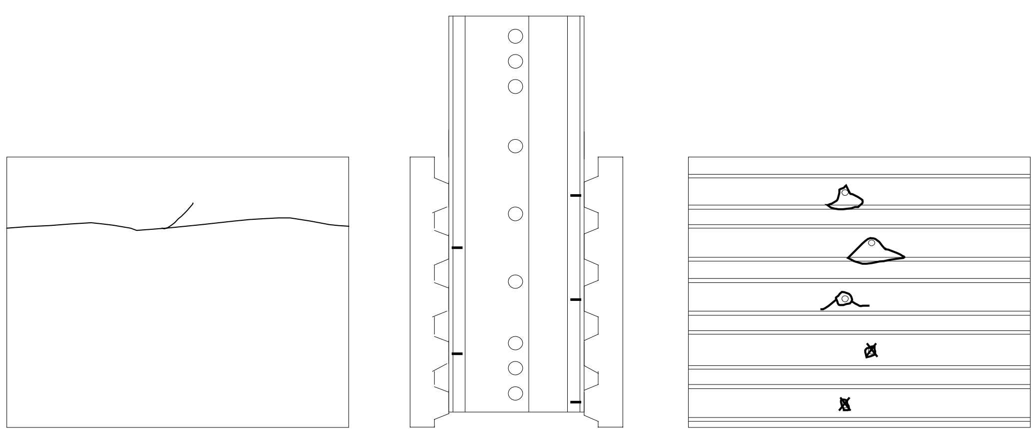
## PUSHOUT TEST SUMMARY SHEET

Test: C1R-3 Test Date: 25-May-99
Test Designation: SC-8-3.0-0.109-1.5C-3.25-3R

| SPECIMEN DESCRIPTION | | | | |
|---|---|---|---|---|
| **Screw:** | Height: 3.0 in. | No. Per Specimen: 10 | | |
| **Deck:** | Type: 1.5C, 22ga | Width: 36 in. | Length: 32 in. | |
| | $F_y$: 101.7 ksi | $F_u$: 103.2 ksi | | |
| **Base Member:** | Section: 2L 1.25x1.25x0.109 | | | |
| | $F_y$: 55.6 ksi | $F_u$: 76.8 ksi | | |
| **Slab:** | Thickness: 3.25 in. | $f'_c$: 4098 psi | | |
| **Rebar:** | Size: No. 4 | No. Per Specimen: 8 | | |
| | | Height Above Deck: 1.0 in. | | |
| **Mesh:** | Type: WWF 4x4-W2.1xW2.1 | | | |

| TEST RESULTS | | |
|---|---|---|
| **Peak Shear Load:** | 50.63 kips | |
| **Peak Shear Load Per Screw:** | 5.06 kips | |
| **Slip at Peak Shear Load:** | SC1: 0.3900 in. | SC5: 0.4565 in. |
| | SC2: 0.4260 in. | SC6: 0.5090 in. |
| | SC3: 0.4211 in. | SC7: 0.5054 in. |
| | SC4: 0.4327 in. | SC8: 0.4865 in. |

### DAMAGE

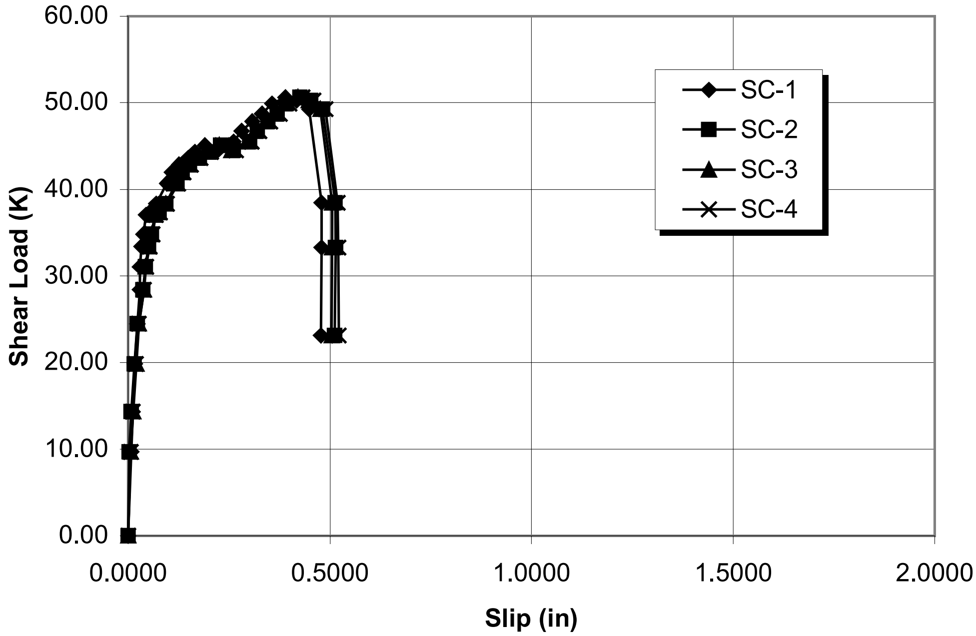


exterior, Slab A interior, Slab B

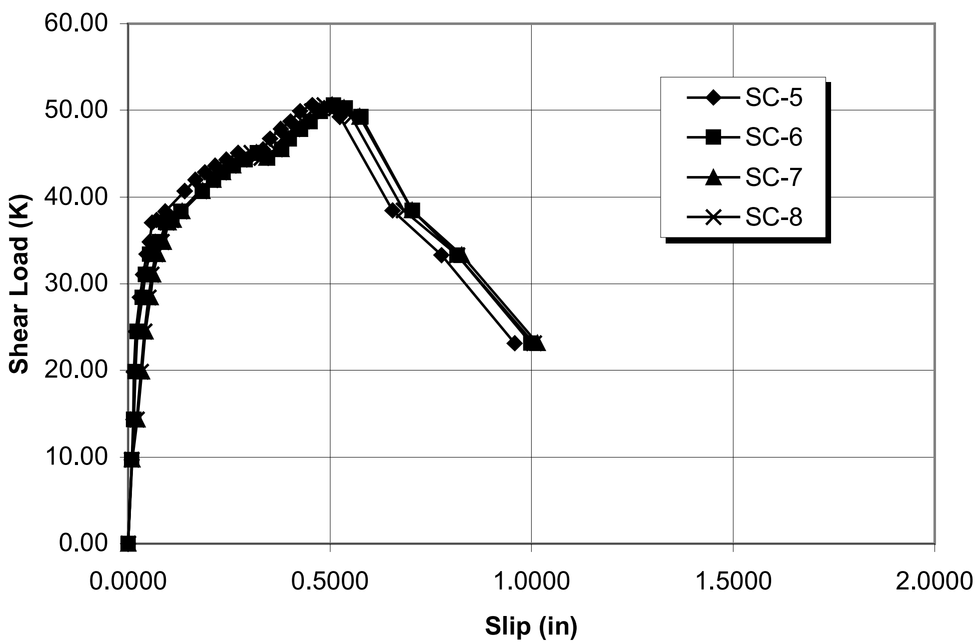
### COMMENTS

Failure Mode: Screw Shear
Screw Rotation ≈ 40° - 50°
Deck debonded
Angles slightly deformed at screw locations due to rotation of screws
X = Screw sheared off

Test C1R-3: Load vs. Slip (A)




Test C1R-3: Load vs. Slip (B)



**Test C1R-3 Data**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 9.67 | 0.96 | 0.0079 | 0.0024 | 0.0067 | 0.0061 | 0.0092 | 0.0092 | 0.0104 | 0.0085 |
| 14.32 | 1.61 | 0.0110 | 0.0073 | 0.0122 | 0.0110 | 0.0128 | 0.0140 | 0.0232 | 0.0214 |
| 19.85 | 2.05 | 0.0165 | 0.0153 | 0.0201 | 0.0189 | 0.0140 | 0.0171 | 0.0342 | 0.0311 |
| 24.50 | 2.54 | 0.0232 | 0.0226 | 0.0269 | 0.0269 | 0.0183 | 0.0232 | 0.0433 | 0.0403 |
| 28.39 | 2.85 | 0.0287 | 0.0366 | 0.0391 | 0.0391 | 0.0293 | 0.0348 | 0.0549 | 0.0507 |
| 31.03 | 3.19 | 0.0293 | 0.0433 | 0.0433 | 0.0446 | 0.0366 | 0.0427 | 0.0623 | 0.0580 |
| 33.42 | 3.44 | 0.0323 | 0.0507 | 0.0519 | 0.0531 | 0.0458 | 0.0525 | 0.0726 | 0.0684 |
| 34.80 | 3.22 | 0.0378 | 0.0580 | 0.0586 | 0.0604 | 0.0531 | 0.0787 | 0.0879 | 0.0836 |
| 37.06 | 3.68 | 0.0439 | 0.0659 | 0.0665 | 0.0677 | 0.0592 | 0.0934 | 0.1001 | 0.0952 |
| 37.31 | 4.03 | 0.0531 | 0.0769 | 0.0769 | 0.0787 | 0.0702 | 0.1080 | 0.1117 | 0.1074 |
| 38.32 | 4.24 | 0.0690 | 0.0934 | 0.0928 | 0.0958 | 0.0922 | 0.1312 | 0.1337 | 0.1282 |
| 40.70 | 4.42 | 0.0952 | 0.1215 | 0.1190 | 0.1239 | 0.1404 | 0.1843 | 0.1837 | 0.1776 |
| 41.96 | 4.47 | 0.1080 | 0.1343 | 0.1318 | 0.1373 | 0.1666 | 0.2118 | 0.2112 | 0.2045 |
| 42.84 | 4.62 | 0.1257 | 0.1526 | 0.1501 | 0.1556 | 0.1904 | 0.2362 | 0.2344 | 0.2264 |
| 43.59 | 4.75 | 0.1489 | 0.1764 | 0.1721 | 0.1794 | 0.2155 | 0.2612 | 0.2600 | 0.2509 |
| 44.35 | 4.73 | 0.1648 | 0.2020 | 0.1978 | 0.2057 | 0.2435 | 0.2905 | 0.2875 | 0.2777 |
| 45.10 | 4.73 | 0.1898 | 0.2301 | 0.2258 | 0.2332 | 0.2728 | 0.3204 | 0.3180 | 0.3058 |
| 44.47 | 4.77 | 0.2216 | 0.2612 | 0.2557 | 0.2667 | 0.2985 | 0.3461 | 0.3430 | 0.3302 |
| 45.48 | 4.69 | 0.2612 | 0.3009 | 0.2954 | 0.3070 | 0.3345 | 0.3809 | 0.3796 | 0.3650 |
| 46.73 | 4.93 | 0.2808 | 0.3204 | 0.3137 | 0.3253 | 0.3522 | 0.3992 | 0.3973 | 0.3821 |
| 47.86 | 5.08 | 0.3082 | 0.3467 | 0.3412 | 0.3522 | 0.3784 | 0.4279 | 0.4254 | 0.4089 |
| 48.74 | 5.10 | 0.3320 | 0.3699 | 0.3650 | 0.3754 | 0.4022 | 0.4517 | 0.4486 | 0.4321 |
| 49.87 | 5.17 | 0.3564 | 0.3925 | 0.3876 | 0.3992 | 0.4266 | 0.4773 | 0.4736 | 0.4553 |
| 50.63 | 5.29 | 0.3900 | 0.4260 | 0.4211 | 0.4327 | 0.4565 | 0.5090 | 0.5054 | 0.4865 |
| 50.25 | 5.38 | 0.4175 | 0.4523 | 0.4474 | 0.4596 | 0.4852 | 0.5383 | 0.5353 | 0.5145 |
| 49.25 | 5.42 | 0.4486 | 0.4822 | 0.4767 | 0.4895 | 0.5243 | 0.5774 | 0.5743 | 0.5530 |
| 38.44 | 4.61 | 0.4791 | 0.5127 | 0.5060 | 0.5194 | 0.6555 | 0.7050 | 0.7037 | 0.6836 |
| 33.29 | 4.52 | 0.4791 | 0.5139 | 0.5054 | 0.5206 | 0.7770 | 0.8160 | 0.8270 | 0.8160 |
| 23.12 | 5.55 | 0.4785 | 0.5121 | 0.5042 | 0.5219 | 0.9589 | 0.9991 | 1.0150 | 1.0064 |

**PUSHOUT TEST SUMMARY SHEET**

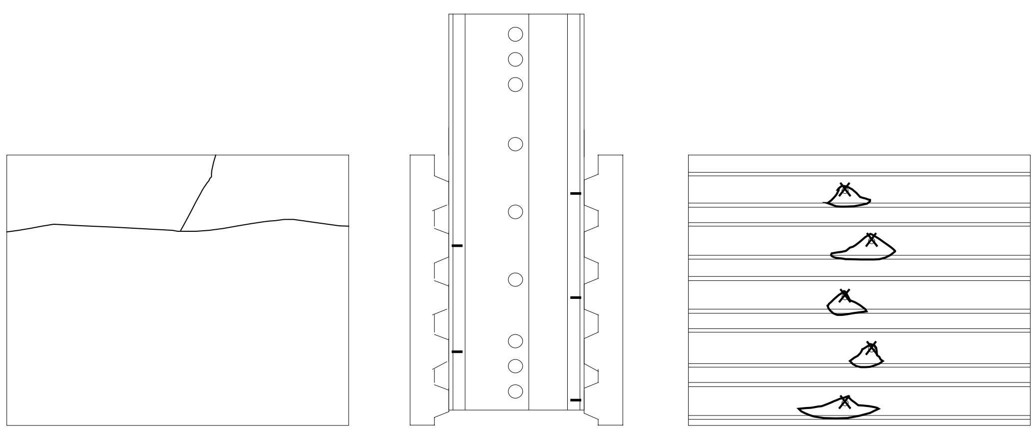
Test: C2R-1 Test Date: 26-May-99

Test Designation: SC-8-3.0-0.187-1.5C-3.25-1R

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 3.0 in. | No. Per Specimen: | 10 | | |
| **Deck:** | Type: | 1.5C, 22 ga | Width: | 36 in. | Length: | 32 in. |
| | $F_y$: | 101.7 ksi | $F_u$: | 103.2 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.187 | | | | |
| | $F_y$: | 61.9 ksi | $F_u$: | 85.6 ksi | | |
| **Slab:** | Thickness: | 3.25 in. | $f'_c$: | 4100 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 4x4-W2.1xW2.1 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 58.67 kips | | | |
| **Peak Shear Load Per Screw:** | 5.87 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.3131 in. | SC5: | 0.5060 in. |
| | SC2: | 0.4193 in. | SC6: | 0.5048 in. |
| | SC3: | 0.3528 in. | SC7: | 0.4687 in. |
| | SC4: | 0.4016 in. | SC8: | 0.5072 in. |

**DAMAGE**

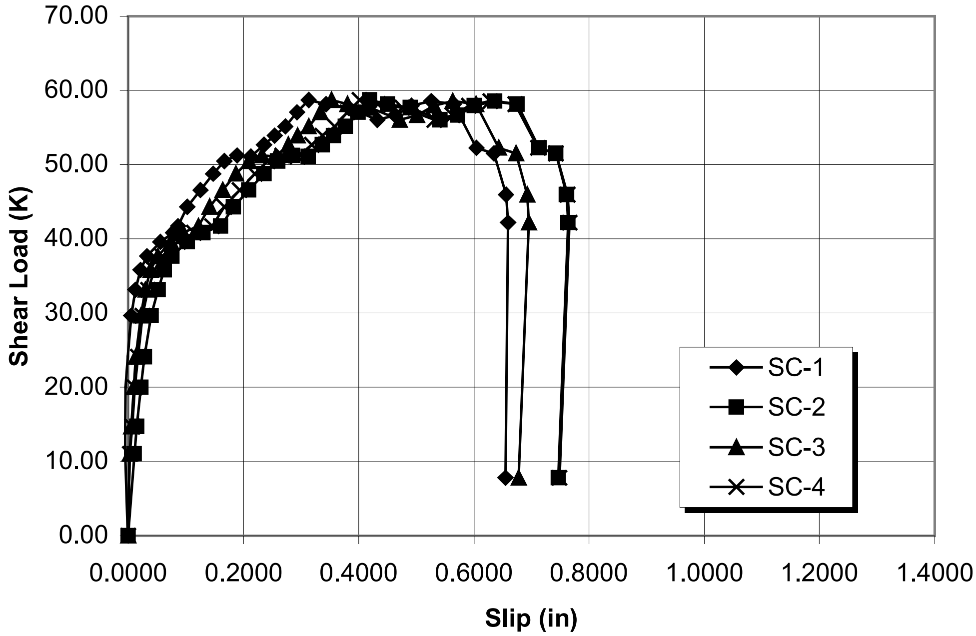


exterior, Slab A interior, Slab B

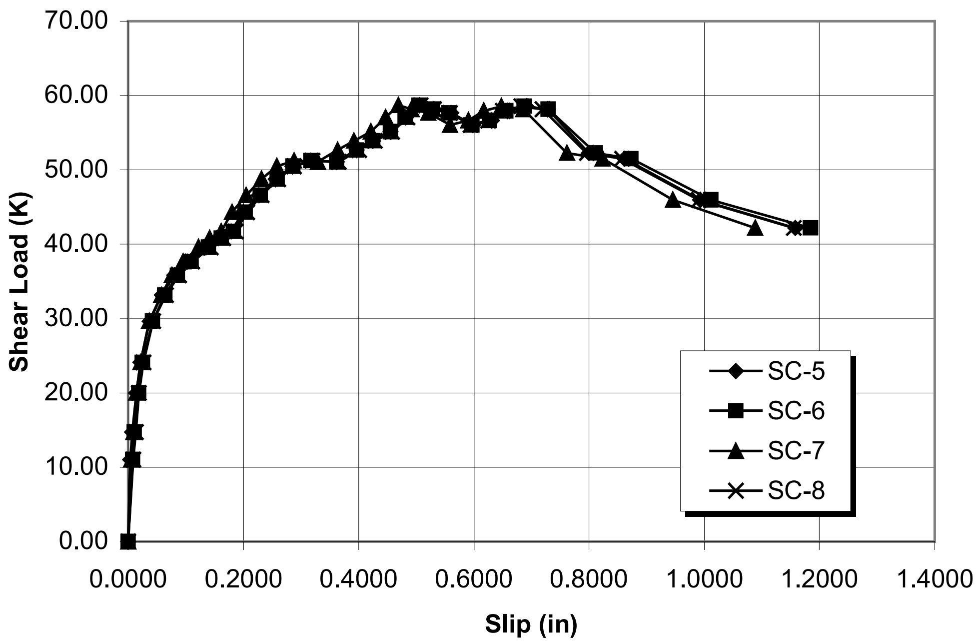
**COMMENTS**

Failure Mode: Screw Shear
Screw Rotation ≈ 40° - 50°
Deck debonded
X = Screw sheared off

**Test C2R-1: Load vs. Slip (A)**




**Test C2R-1: Load vs. Slip (B)**



**Test C2R-1 Data**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | -0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11.06 | 1.15 | -0.0055 | 0.0104 | 0.0024 | 0.0031 | 0.0037 | 0.0079 | 0.0055 | 0.0092 |
| 14.70 | 1.47 | -0.0055 | 0.0146 | 0.0055 | 0.0067 | 0.0073 | 0.0110 | 0.0085 | 0.0128 |
| 19.97 | 2.10 | -0.0043 | 0.0220 | 0.0098 | 0.0116 | 0.0140 | 0.0183 | 0.0140 | 0.0189 |
| 24.12 | 2.44 | -0.0012 | 0.0281 | 0.0128 | 0.0165 | 0.0214 | 0.0250 | 0.0208 | 0.0269 |
| 29.65 | 3.09 | 0.0049 | 0.0397 | 0.0220 | 0.0250 | 0.0372 | 0.0421 | 0.0366 | 0.0433 |
| 33.17 | 3.60 | 0.0122 | 0.0519 | 0.0299 | 0.0348 | 0.0580 | 0.0635 | 0.0574 | 0.0653 |
| 35.80 | 3.85 | 0.0214 | 0.0629 | 0.0391 | 0.0458 | 0.0806 | 0.0861 | 0.0763 | 0.0879 |
| 37.69 | 4.02 | 0.0330 | 0.0763 | 0.0513 | 0.0592 | 0.1025 | 0.1093 | 0.0952 | 0.1111 |
| 39.57 | 4.22 | 0.0555 | 0.1025 | 0.0739 | 0.0867 | 0.1337 | 0.1398 | 0.1215 | 0.1428 |
| 40.83 | 4.38 | 0.0775 | 0.1300 | 0.0952 | 0.1141 | 0.1562 | 0.1617 | 0.1416 | 0.1648 |
| 41.71 | 4.26 | 0.0867 | 0.1605 | 0.1221 | 0.1453 | 0.1782 | 0.1831 | 0.1617 | 0.1862 |
| 44.35 | 4.68 | 0.1025 | 0.1825 | 0.1416 | 0.1672 | 0.1996 | 0.2032 | 0.1801 | 0.2063 |
| 46.61 | 4.81 | 0.1251 | 0.2094 | 0.1642 | 0.1935 | 0.2264 | 0.2295 | 0.2051 | 0.2313 |
| 48.74 | 5.11 | 0.1471 | 0.2356 | 0.1874 | 0.2197 | 0.2557 | 0.2588 | 0.2313 | 0.2600 |
| 50.50 | 5.19 | 0.1672 | 0.2594 | 0.2094 | 0.2423 | 0.2850 | 0.2856 | 0.2582 | 0.2875 |
| 51.26 | 5.32 | 0.1886 | 0.2850 | 0.2325 | 0.2673 | 0.3168 | 0.3168 | 0.2875 | 0.3198 |
| 51.13 | 5.28 | 0.2130 | 0.3125 | 0.2563 | 0.2942 | 0.3619 | 0.3619 | 0.3296 | 0.3656 |
| 52.64 | 5.42 | 0.2356 | 0.3369 | 0.2783 | 0.3186 | 0.3967 | 0.3967 | 0.3638 | 0.4004 |
| 53.89 | 5.50 | 0.2539 | 0.3564 | 0.2942 | 0.3375 | 0.4248 | 0.4248 | 0.3918 | 0.4285 |
| 55.15 | 5.59 | 0.2728 | 0.3772 | 0.3131 | 0.3583 | 0.4553 | 0.4553 | 0.4211 | 0.4578 |
| 57.04 | 5.77 | 0.2930 | 0.3986 | 0.3339 | 0.3802 | 0.4822 | 0.4810 | 0.4468 | 0.4846 |
| 58.67 | 5.92 | 0.3131 | 0.4193 | 0.3528 | 0.4016 | 0.5060 | 0.5048 | 0.4687 | 0.5072 |
| 58.17 | 5.97 | 0.3430 | 0.4504 | 0.3809 | 0.4333 | 0.5304 | 0.5280 | 0.4919 | 0.5304 |
| 57.66 | 6.07 | 0.3821 | 0.4901 | 0.4205 | 0.4755 | 0.5603 | 0.5573 | 0.5212 | 0.5591 |
| 56.03 | 5.95 | 0.4327 | 0.5408 | 0.4712 | 0.5310 | 0.5988 | 0.5963 | 0.5585 | 0.5939 |
| 56.66 | 5.80 | 0.4639 | 0.5719 | 0.5011 | 0.5627 | 0.6311 | 0.6274 | 0.5902 | 0.6250 |
| 57.91 | 6.06 | 0.4919 | 0.6012 | 0.5304 | 0.5914 | 0.6586 | 0.6561 | 0.6171 | 0.6506 |
| 58.54 | 6.24 | 0.5261 | 0.6366 | 0.5634 | 0.6287 | 0.6909 | 0.6879 | 0.6482 | 0.6824 |
| 58.17 | 6.14 | 0.5646 | 0.6750 | 0.6036 | 0.6714 | 0.7281 | 0.7288 | 0.6860 | 0.7190 |
| 52.26 | 6.29 | 0.6042 | 0.7135 | 0.6439 | 0.7117 | 0.7996 | 0.8112 | 0.7617 | 0.7959 |
| 51.51 | 6.13 | 0.6348 | 0.7422 | 0.6732 | 0.7428 | 0.8618 | 0.8734 | 0.8234 | 0.8575 |
| 45.98 | 6.83 | 0.6555 | 0.7611 | 0.6927 | 0.7629 | 0.9930 | 1.0119 | 0.9454 | 0.9900 |
| 42.21 | 4.09 | 0.6592 | 0.7635 | 0.6958 | 0.7666 | 1.1578 | 1.1846 | 1.0882 | 1.1553 |
| 7.79 | 5.44 | 0.6549 | 0.7465 | 0.6781 | 0.7489 | | | | |

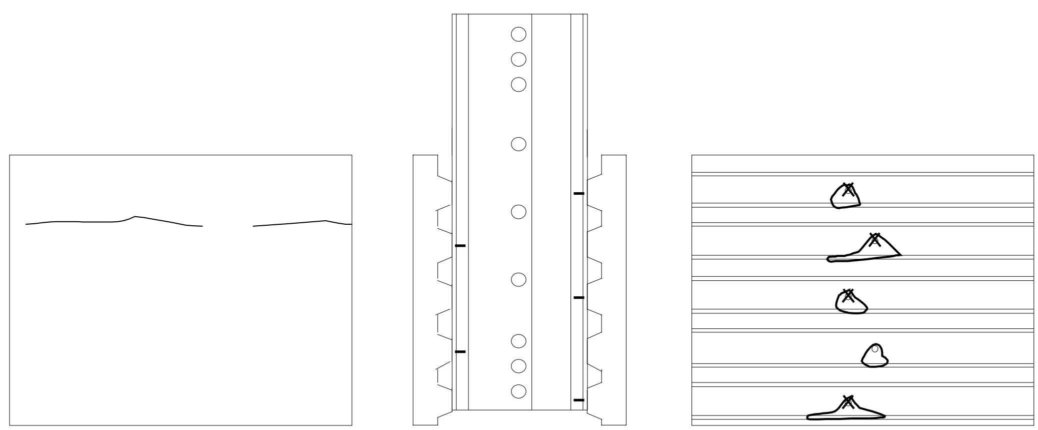
**PUSHOUT TEST SUMMARY SHEET**

Test: C2R-2 Test Date: 27-May-99
Test Designation: SC-8-3.0-0.187-1.5C-3.25-2R

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 3.0 in. | No. Per Specimen: | 10 | | |
| **Deck:** | Type: | 1.5C, 22 ga | Width: | 36 in. | Length: | 32 in. |
| | $F_y$: | 101.7 ksi | $F_u$: | 103.2 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.187 | | | | |
| | $F_y$: | 61.9 ksi | $F_u$: | 85.6 ksi | | |
| **Slab:** | Thickness: | 3.25 in. | $f'_c$: | 4100 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 4x4-W2.1xW2.1 | | | | |

| TEST RESULTS | | | | | |
|---|---|---|---|---|---|
| **Peak Shear Load:** | 56.91 kips | | | | |
| **Peak Shear Load Per Screw:** | 5.69 kips | | | | |
| **Slip at Peak Shear Load:** | | SC1: | 0.5054 in. | SC5: | 0.8783 in. |
| | | SC2: | 0.5493 in. | SC6: | 0.7770 in. |
| | | SC3: | 0.5115 in. | SC7: | 0.8844 in. |
| | | SC4: | 0.4999 in. | SC8: | 0.8984 in. |

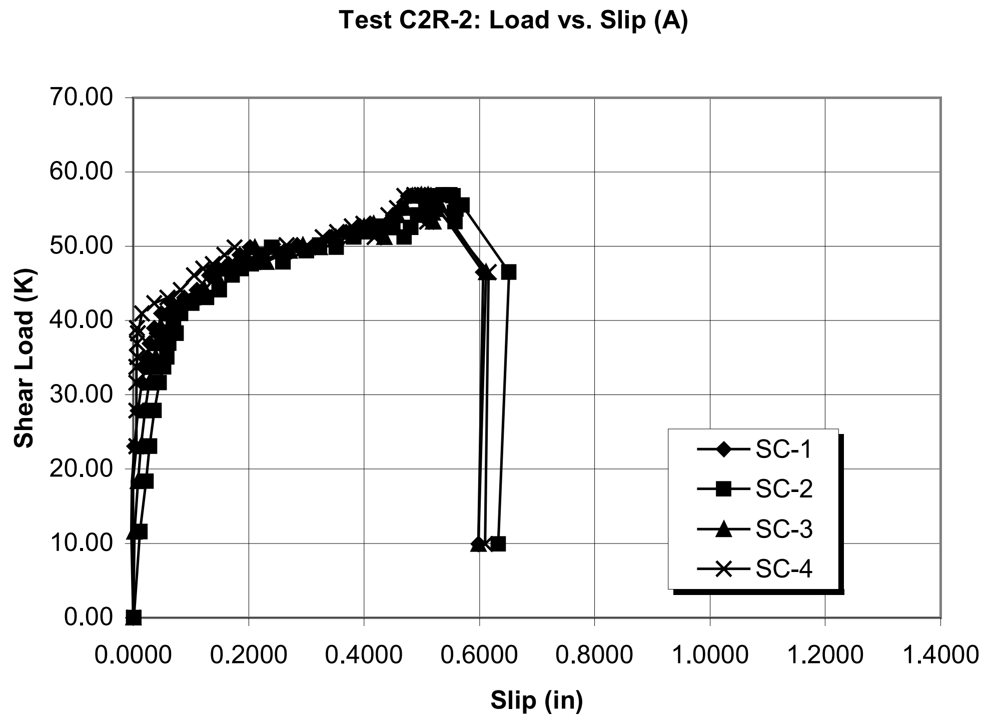
**DAMAGE**

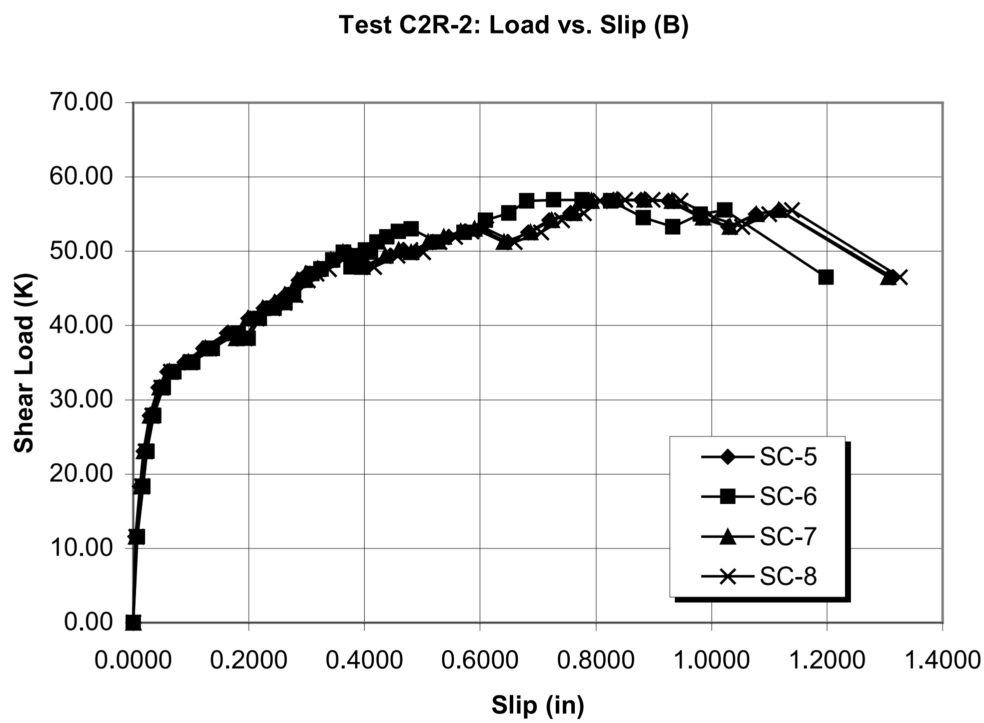


exterior, Slab A interior, Slab B

**COMMENTS**

Failure Mode: Screw Shear
Screw Rotation ≈ 40° - 50°
Deck debonded
X = Screw sheared off


Test C2R-2: Load vs. Slip (A)
Shear Load (K)
Slip (in)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.0000
0.2000
0.4000
0.6000
0.8000
1.0000
1.2000
1.4000
SC-1
SC-2
SC-3
SC-4


Test C2R-2: Load vs. Slip (B)
Shear Load (K)
Slip (in)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.0000
0.2000
0.4000
0.6000
0.8000
1.0000
1.2000
1.4000
SC-5
SC-6
SC-7
SC-8

**Test C2R-2 Data**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.01 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11.56 | 1.12 | -0.0037 | 0.0116 | 0.0018 | -0.0012 | 0.0037 | 0.0067 | 0.0043 | 0.0055 |
| 18.34 | 1.98 | -0.0024 | 0.0220 | 0.0079 | -0.0012 | 0.0116 | 0.0165 | 0.0128 | 0.0146 |
| 23.12 | 2.49 | 0.0018 | 0.0287 | 0.0128 | 0.0055 | 0.0177 | 0.0238 | 0.0189 | 0.0208 |
| 27.89 | 2.93 | 0.0079 | 0.0366 | 0.0201 | 0.0055 | 0.0281 | 0.0354 | 0.0293 | 0.0323 |
| 31.66 | 3.26 | 0.0146 | 0.0452 | 0.0275 | 0.0055 | 0.0433 | 0.0519 | 0.0458 | 0.0482 |
| 33.79 | 3.53 | 0.0201 | 0.0531 | 0.0330 | 0.0055 | 0.0586 | 0.0708 | 0.0623 | 0.0653 |
| 35.05 | 3.81 | 0.0250 | 0.0580 | 0.0385 | 0.0073 | 0.0891 | 0.1031 | 0.0952 | 0.0983 |
| 36.93 | 3.99 | 0.0287 | 0.0616 | 0.0415 | 0.0061 | 0.1202 | 0.1367 | 0.1245 | 0.1312 |
| 38.94 | 4.23 | 0.0360 | 0.0696 | 0.0482 | 0.0061 | 0.1624 | 0.1813 | 0.1636 | 0.1758 |
| 38.32 | 3.86 | 0.0409 | 0.0745 | 0.0549 | 0.0079 | 0.1788 | 0.1990 | 0.1782 | 0.1929 |
| 40.95 | 4.17 | 0.0488 | 0.0824 | 0.0623 | 0.0153 | 0.1990 | 0.2185 | 0.1978 | 0.2136 |
| 42.34 | 4.48 | 0.0665 | 0.1019 | 0.0806 | 0.0360 | 0.2252 | 0.2435 | 0.2240 | 0.2411 |
| 43.09 | 4.69 | 0.0885 | 0.1270 | 0.1031 | 0.0592 | 0.2454 | 0.2625 | 0.2441 | 0.2618 |
| 44.10 | 4.77 | 0.1105 | 0.1495 | 0.1239 | 0.0824 | 0.2637 | 0.2777 | 0.2612 | 0.2802 |
| 46.11 | 4.85 | 0.1318 | 0.1715 | 0.1440 | 0.1050 | 0.2863 | 0.2972 | 0.2832 | 0.3021 |
| 46.98 | 4.93 | 0.1465 | 0.1868 | 0.1581 | 0.1208 | 0.3009 | 0.3088 | 0.2985 | 0.3174 |
| 47.61 | 4.90 | 0.1654 | 0.2051 | 0.1770 | 0.1373 | 0.3217 | 0.3253 | 0.3186 | 0.3381 |
| 48.87 | 4.95 | 0.1849 | 0.2234 | 0.1953 | 0.1581 | 0.3461 | 0.3455 | 0.3418 | 0.3619 |
| 49.87 | 5.18 | 0.2020 | 0.2399 | 0.2106 | 0.1758 | 0.3687 | 0.3638 | 0.3625 | 0.3833 |
| 47.86 | 5.29 | 0.2209 | 0.2594 | 0.2301 | 0.1984 | 0.4028 | 0.3772 | 0.3961 | 0.4169 |
| 49.37 | 5.00 | 0.2618 | 0.3003 | 0.2710 | 0.2417 | 0.4437 | 0.3918 | 0.4358 | 0.4572 |
| 50.13 | 5.19 | 0.2844 | 0.3235 | 0.2936 | 0.2661 | 0.4669 | 0.4016 | 0.4584 | 0.4791 |
| 49.87 | 5.30 | 0.3149 | 0.3522 | 0.3229 | 0.2972 | 0.4901 | 0.4102 | 0.4810 | 0.5011 |
| 51.26 | 5.31 | 0.3436 | 0.3821 | 0.3516 | 0.3284 | 0.5176 | 0.4218 | 0.5096 | 0.5292 |
| 51.88 | 5.38 | 0.3687 | 0.4065 | 0.3748 | 0.3534 | 0.5457 | 0.4382 | 0.5371 | 0.5566 |
| 52.64 | 5.57 | 0.3925 | 0.4315 | 0.3998 | 0.3790 | 0.5750 | 0.4590 | 0.5658 | 0.5847 |
| 53.02 | 5.62 | 0.4108 | 0.4504 | 0.4169 | 0.3992 | 0.5988 | 0.4810 | 0.5896 | 0.6104 |
| 51.26 | 5.62 | 0.4291 | 0.4694 | 0.4352 | 0.4181 | 0.6470 | 0.5261 | 0.6409 | 0.6592 |
| 52.51 | 5.51 | 0.4401 | 0.4810 | 0.4462 | 0.4303 | 0.6830 | 0.5719 | 0.6866 | 0.7056 |
| 54.15 | 5.62 | 0.4504 | 0.4932 | 0.4578 | 0.4419 | 0.7190 | 0.6097 | 0.7239 | 0.7416 |
| 55.15 | 5.74 | 0.4645 | 0.5072 | 0.4712 | 0.4572 | 0.7562 | 0.6494 | 0.7623 | 0.7794 |
| 56.78 | 5.95 | 0.4767 | 0.5194 | 0.4834 | 0.4700 | 0.7855 | 0.6805 | 0.7928 | 0.8075 |
| 56.91 | 6.17 | 0.4932 | 0.5377 | 0.4999 | 0.4877 | 0.8301 | 0.7275 | 0.8368 | 0.8508 |
| 56.91 | 6.44 | 0.5054 | 0.5493 | 0.5115 | 0.4999 | 0.8783 | 0.7770 | 0.8844 | 0.8984 |
| 56.78 | 6.66 | 0.5090 | 0.5542 | 0.5164 | 0.5048 | 0.9253 | 0.8258 | 0.9320 | 0.9467 |
| 54.52 | 5.56 | 0.5121 | 0.5573 | 0.5194 | 0.5084 | 0.9808 | 0.8826 | 0.9851 | 1.0034 |
| 53.27 | 6.12 | 0.5127 | 0.5579 | 0.5200 | 0.5096 | 1.0296 | 0.9332 | 1.0321 | 1.0528 |
| 55.03 | 6.41 | 0.5151 | 0.5597 | 0.5212 | 0.5109 | 1.0766 | 0.9808 | 1.0778 | 1.0998 |
| 55.53 | 5.44 | 0.5249 | 0.5701 | 0.5316 | 0.5219 | 1.1175 | 1.0229 | 1.1163 | 1.1395 |
| 46.48 | 4.86 | 0.6067 | 0.6519 | 0.6116 | 0.6158 | 1.3128 | 1.1981 | 1.3061 | 1.3262 |
| 9.92 | 7.79 | 0.5988 | 0.6329 | 0.5988 | 0.6104 | | | | |

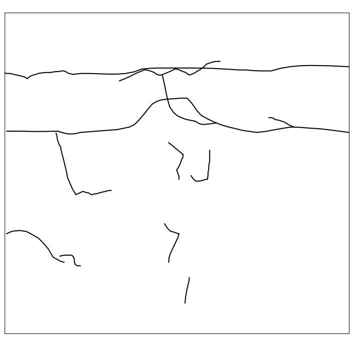
## PUSHOUT TEST SUMMARY SHEET

Test: C9-1 Test Date: 16-Jul-98
Test Designation: SC-8-3.0-0.163-1.5C-3.5-1

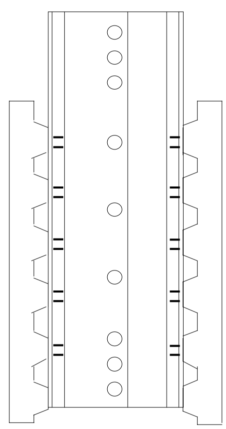
| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 3.0 in. | No. Per Specimen: | 40 | | |
| **Deck:** | Type: | 1.5C, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 101.7 ksi | $F_u$: | 103.2 ksi | | |
| **Base Member:** | Section: | 2L 2.0x2.0x0.163 | | | | |
| | $F_y$: | 57.1 ksi | $F_u$: | 77.9 ksi | | |
| **Slab:** | Thickness: | 3.5 in. | $f'_c$: | 5392 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 24 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 4x4-W2.1xW2.1 | | | | |

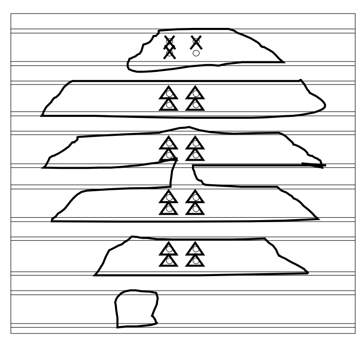
| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 136.87 kips | | | |
| **Peak Shear Load Per Screw:** | 3.42 kips | | | |
| **Slip at Peak Shear Load:** | SC1: 0.8766 in. | SC5: 0.8169 in. | | |
| | SC2: 0.2190 in. | SC6: 0.4835 in. | | |
| | SC3: 0.4814 in. | SC7: 0.1291 in. | | |
| | SC4: 0.8215 in. | SC8: 0.1203 in. | | |

### DAMAGE



exterior, Slab A

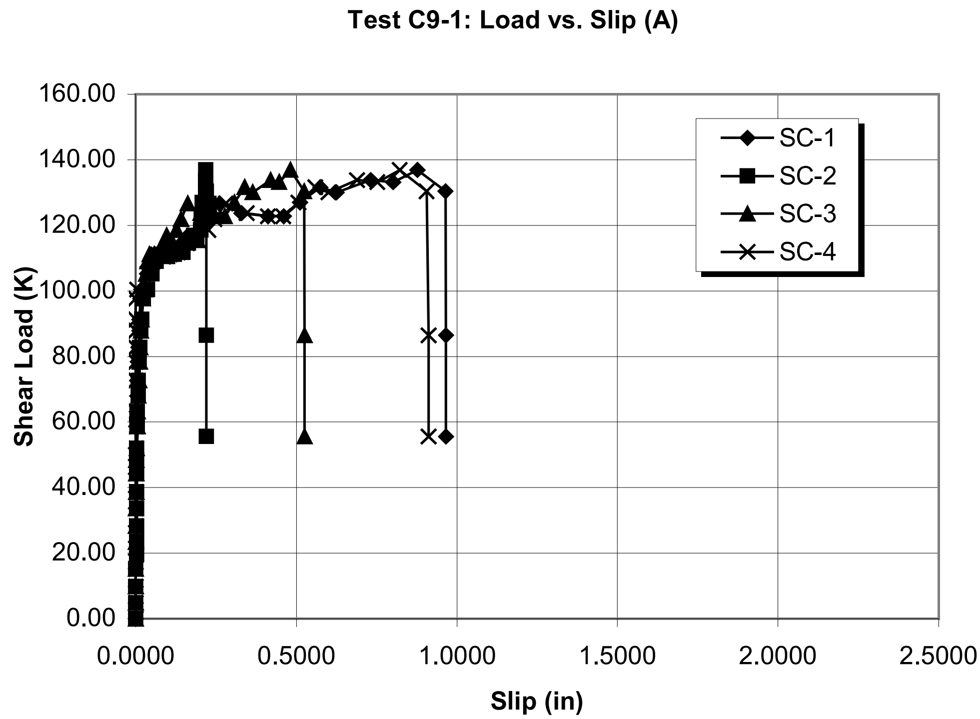


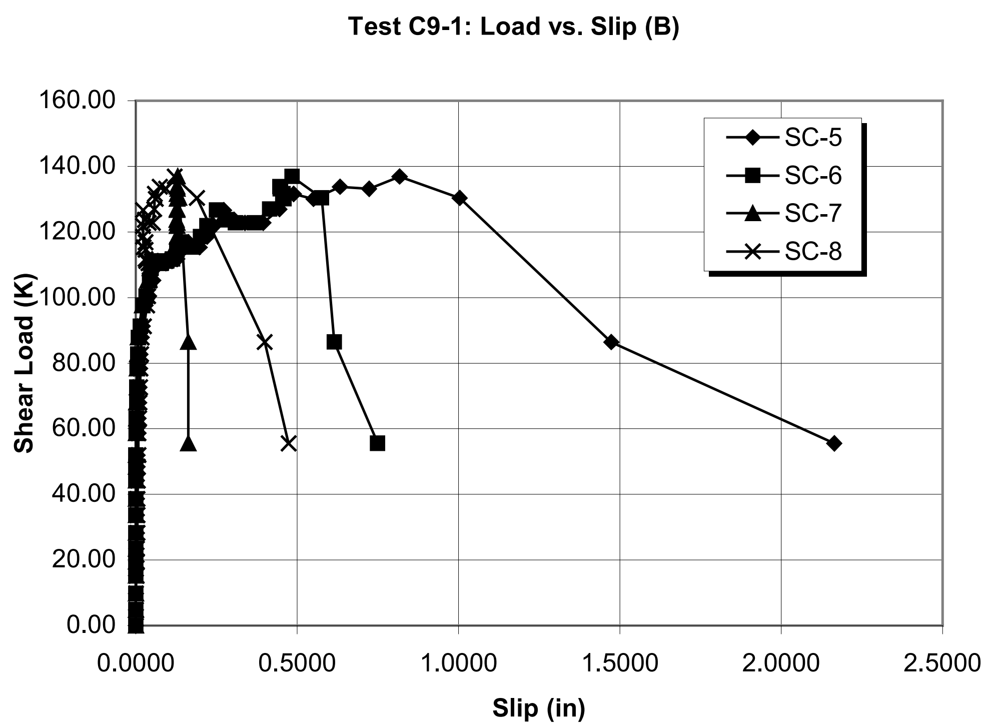


interior, Slab B

### COMMENTS

Failure Mode: Concrete cone pullout
Screw Rotation ≈ 40° - 50°
Deck debonded; Slight bulging of deck below screws
Angles slightly deformed at screw locations due to rotation of screws
X = Screw sheared off; △ = Screw pulled out of concrete


Test C9-1: Load vs. Slip (A)
Shear Load (K)
Slip (in)
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
SC-1
SC-2
SC-3
SC-4


Test C9-1: Load vs. Slip (B)
Shear Load (K)
Slip (in)
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
SC-5
SC-6
SC-7
SC-8

**TEST C9-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0005 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0002 | 0.0004 |
| 4.77 | 0.51 | 0.0000 | 0.0002 | -0.0002 | 0.0000 | 0.0002 | 0.0000 | 0.0002 | 0.0002 |
| 9.74 | 0.70 | 0.0000 | 0.0002 | 0.0002 | 0.0000 | 0.0000 | 0.0004 | -0.0002 | 0.0005 |
| 15.14 | 1.46 | -0.0002 | 0.0002 | 0.0000 | -0.0002 | 0.0004 | 0.0000 | 0.0002 | 0.0015 |
| 19.60 | 2.01 | -0.0005 | 0.0029 | -0.0013 | -0.0002 | 0.0011 | -0.0002 | 0.0004 | 0.0035 |
| 23.37 | 2.28 | -0.0005 | 0.0027 | 0.0000 | -0.0004 | 0.0011 | 0.0000 | 0.0005 | 0.0037 |
| 28.27 | 2.90 | -0.0002 | 0.0033 | 0.0005 | -0.0005 | 0.0026 | 0.0002 | 0.0005 | 0.0046 |
| 33.67 | 3.43 | 0.0000 | 0.0033 | 0.0005 | -0.0005 | 0.0024 | 0.0002 | 0.0005 | 0.0048 |
| 38.57 | 3.87 | 0.0002 | 0.0033 | 0.0009 | -0.0004 | 0.0027 | 0.0002 | 0.0005 | 0.0049 |
| 44.22 | 4.59 | 0.0007 | 0.0031 | 0.0018 | -0.0004 | 0.0035 | 0.0002 | 0.0005 | 0.0060 |
| 48.43 | 4.96 | 0.0005 | 0.0035 | 0.0022 | -0.0007 | 0.0046 | 0.0000 | 0.0004 | 0.0064 |
| 51.95 | 5.42 | 0.0007 | 0.0031 | 0.0031 | -0.0007 | 0.0053 | 0.0002 | 0.0004 | 0.0071 |
| 58.67 | 6.07 | 0.0022 | 0.0044 | 0.0057 | -0.0007 | 0.0079 | 0.0009 | 0.0007 | 0.0081 |
| 63.19 | 6.50 | 0.0035 | 0.0051 | 0.0070 | -0.0007 | 0.0084 | 0.0015 | 0.0009 | 0.0092 |
| 68.03 | 6.94 | 0.0042 | 0.0071 | 0.0081 | -0.0009 | 0.0101 | 0.0029 | 0.0016 | 0.0106 |
| 72.61 | 7.39 | 0.0049 | 0.0086 | 0.0104 | -0.0007 | 0.0106 | 0.0035 | 0.0026 | 0.0119 |
| 78.39 | 7.96 | 0.0068 | 0.0108 | 0.0121 | -0.0005 | 0.0132 | 0.0046 | 0.0038 | 0.0137 |
| 82.73 | 8.41 | 0.0079 | 0.0132 | 0.0137 | -0.0004 | 0.0147 | 0.0060 | 0.0053 | 0.0157 |
| 87.88 | 8.87 | 0.0104 | 0.0161 | 0.0157 | -0.0005 | 0.0168 | 0.0073 | 0.0064 | 0.0178 |
| 91.27 | 9.42 | 0.0110 | 0.0187 | 0.0181 | -0.0007 | 0.0212 | 0.0136 | 0.0108 | 0.0255 |
| 97.61 | 9.99 | 0.0147 | 0.0236 | 0.0222 | -0.0004 | 0.0300 | 0.0220 | 0.0194 | 0.0353 |
| 100.43 | 10.33 | 0.0167 | 0.0372 | 0.0297 | 0.0040 | 0.0405 | 0.0320 | 0.0264 | 0.0379 |
| 105.15 | 10.89 | 0.0350 | 0.0500 | 0.0311 | 0.0364 | 0.0529 | 0.0427 | 0.0366 | 0.0425 |
| 108.98 | 11.19 | 0.0461 | 0.0637 | 0.0372 | 0.0538 | 0.0590 | 0.0478 | 0.0427 | 0.0445 |
| 111.18 | 11.51 | 0.0566 | 0.0771 | 0.0429 | 0.0674 | 0.0670 | 0.0549 | 0.0511 | 0.0482 |
| 110.42 | 12.45 | 0.0742 | 0.1002 | 0.0509 | 0.0850 | 0.0932 | 0.0795 | 0.0743 | 0.0392 |
| 111.05 | 11.31 | 0.0903 | 0.1196 | 0.0584 | 0.1068 | 0.1119 | 0.0960 | 0.0901 | 0.0319 |
| 111.74 | 11.97 | 0.1172 | 0.1471 | 0.0709 | 0.1317 | 0.1280 | 0.1143 | 0.1038 | 0.0297 |
| 114.51 | 12.26 | 0.1423 | 0.1652 | 0.0857 | 0.1606 | 0.1443 | 0.1276 | 0.1154 | 0.0298 |
| 116.83 | 12.49 | 0.1624 | 0.1804 | 0.0969 | 0.1817 | 0.1617 | 0.1421 | 0.1295 | 0.0297 |
| 115.26 | 12.14 | 0.1815 | 0.1905 | 0.1101 | 0.1963 | 0.1970 | 0.1785 | 0.1297 | 0.0233 |
| 118.53 | 12.74 | 0.2071 | 0.2024 | 0.1273 | 0.2269 | 0.2201 | 0.2003 | 0.1282 | 0.0218 |
| 121.79 | 13.12 | 0.2295 | 0.2111 | 0.1416 | 0.2454 | 0.2421 | 0.2209 | 0.1276 | 0.0214 |
| 126.57 | 13.51 | 0.2611 | 0.2282 | 0.1621 | 0.2804 | 0.2723 | 0.2513 | 0.1273 | 0.0222 |
| 123.74 | 13.57 | 0.3291 | 0.2177 | 0.2011 | 0.3456 | 0.3040 | 0.2793 | 0.1267 | 0.0286 |
| 122.80 | 13.34 | 0.4111 | 0.2051 | 0.2474 | 0.4122 | 0.3381 | 0.3097 | 0.1273 | 0.0397 |
| 122.80 | 14.59 | 0.4615 | 0.2046 | 0.2767 | 0.4589 | 0.3941 | 0.3674 | 0.1273 | 0.0527 |
| 126.94 | 13.24 | 0.5118 | 0.2079 | 0.3064 | 0.5069 | 0.4445 | 0.4144 | 0.1276 | 0.0562 |
| 131.59 | 13.60 | 0.5745 | 0.2179 | 0.3392 | 0.5589 | 0.4882 | 0.4554 | 0.1280 | 0.0581 |
| 130.02 | 14.37 | 0.6248 | 0.2188 | 0.3644 | 0.6007 | 0.5499 | 0.4597 | 0.1282 | 0.0613 |
| 133.73 | 15.99 | 0.7310 | 0.2190 | 0.4197 | 0.6887 | 0.6329 | 0.4470 | 0.1280 | 0.0736 |
| 133.10 | 14.47 | 0.8010 | 0.2188 | 0.4472 | 0.7523 | 0.7228 | 0.4476 | 0.1289 | 0.0938 |
| 136.87 | 15.31 | 0.8766 | 0.2190 | 0.4814 | 0.8215 | 0.8169 | 0.4835 | 0.1291 | 0.1203 |
| 130.33 | 15.15 | 0.9640 | 0.2194 | 0.5236 | 0.9050 | 1.0024 | 0.5750 | 0.1335 | 0.1892 |
| 86.43 | 10.02 | 0.9656 | 0.2194 | 0.5254 | 0.9127 | 1.4727 | 0.6159 | 0.1628 | 0.3989 |
| 55.59 | 8.62 | 0.9664 | 0.2196 | 0.5256 | 0.9127 | 2.1642 | 0.7492 | 0.1628 | 0.4738 |

**PUSHOUT TEST SUMMARY SHEET**

Test: C9-2 | Test Date: 16-Jul-98

Test Designation: SC-8-3.0-0.163-1.5C-3.5-2

## SPECIMEN DESCRIPTION

**Screw:** Height: 3.0 in. No. Per Specimen: 40

**Deck:** Type: 1.5C, 22 ga Width: 36 in. Length: 36 in.

$F_y$: 101.7 ksi $F_u$: 103.2 ksi

**Base Member:** Section: 2L 2.0x2.0x0.163

$F_y$: 57.1 ksi $F_u$: 77.9 ksi

**Slab:** Thickness: 3.5 in. $f'_c$: 5392 psi

**Rebar:** Size: No. 4 No. Per Specimen: 24

Height Above Deck: 1.0 in.

**Mesh:** Type: WWF 4x4-W2.1xW2.1

## TEST RESULTS

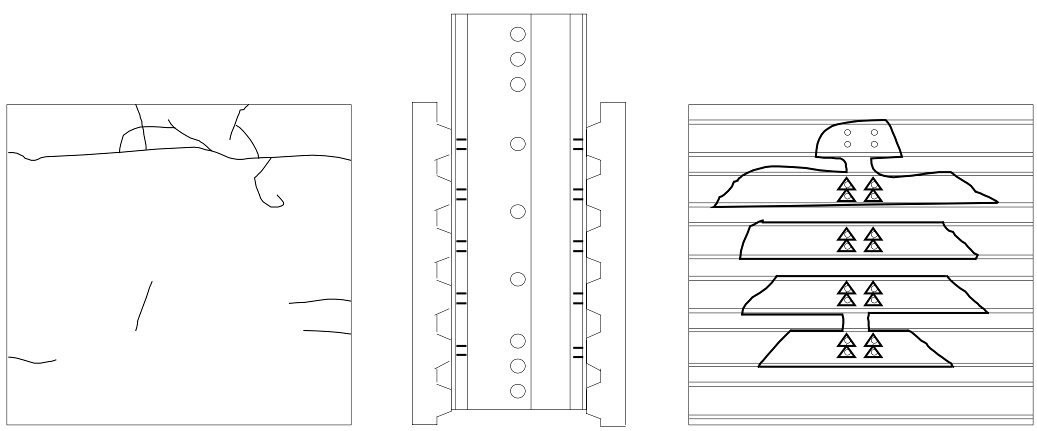
**Peak Shear Load:** 123.17 kips

**Peak Shear Load Per Screw:** 3.08 kips

**Slip at Peak Shear Load:**

| | |
|---|---|
| SC1: 0.4141 in. | SC5: 0.5173 in. |
| SC2: 0.2870 in. | SC6: 0.3126 in. |
| SC3: 0.4410 in. | SC7: 0.1677 in. |
| SC4: 0.5974 in. | SC8: 0.1699 in. |

## DAMAGE



exterior, Slab A

interior, Slab B

## COMMENTS

Failure Mode: Concrete cone pullout

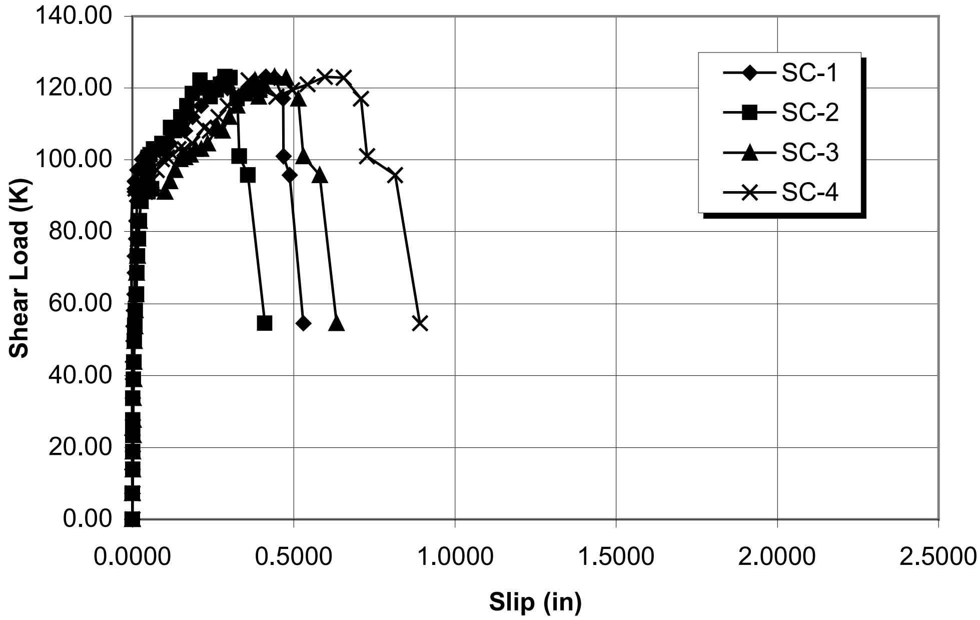
Screw Rotation ≈ 40° - 50°

Deck debonded; Slight bulging of deck below screws

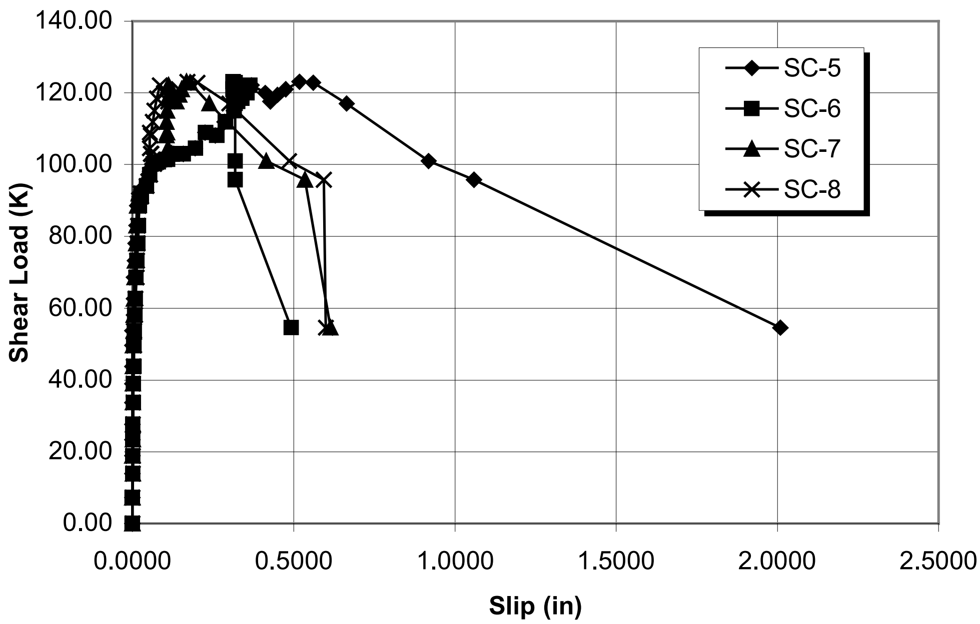
Angles slightly deformed at screw locations due to rotation of screws

△ = Screw pulled out of concrete

### Test C9-2: Load vs. Slip (A)




### Test C9-2: Load vs. Slip (B)



## TEST C9-2 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0002 | -0.0002 | 0.0000 | 0.0002 | -0.0004 | 0.0000 | 0.0002 |
| 7.22 | 0.71 | 0.0002 | 0.0000 | -0.0002 | 0.0000 | 0.0000 | 0.0002 | 0.0002 | 0.0000 |
| 13.94 | 1.45 | 0.0005 | 0.0016 | 0.0018 | -0.0013 | -0.0002 | 0.0020 | 0.0009 | 0.0011 |
| 18.91 | 1.91 | 0.0011 | 0.0016 | 0.0020 | -0.0011 | -0.0007 | 0.0022 | 0.0007 | 0.0009 |
| 23.43 | 2.45 | 0.0007 | 0.0015 | 0.0024 | -0.0013 | -0.0005 | 0.0020 | 0.0011 | 0.0011 |
| 27.70 | 2.90 | 0.0009 | 0.0016 | 0.0024 | -0.0013 | -0.0007 | 0.0022 | 0.0009 | 0.0013 |
| 33.73 | 3.44 | 0.0013 | 0.0016 | 0.0037 | -0.0015 | -0.0005 | 0.0024 | 0.0011 | 0.0022 |
| 38.94 | 4.00 | 0.0013 | 0.0031 | 0.0040 | -0.0013 | -0.0005 | 0.0035 | 0.0011 | 0.0022 |
| 43.72 | 4.63 | 0.0011 | 0.0044 | 0.0051 | -0.0011 | -0.0004 | 0.0042 | 0.0015 | 0.0037 |
| 49.62 | 5.03 | 0.0026 | 0.0059 | 0.0068 | -0.0013 | -0.0004 | 0.0053 | 0.0018 | 0.0044 |
| 53.71 | 5.58 | 0.0026 | 0.0082 | 0.0082 | -0.0013 | -0.0004 | 0.0068 | 0.0024 | 0.0055 |
| 58.17 | 5.94 | 0.0046 | 0.0097 | 0.0101 | -0.0029 | 0.0044 | 0.0081 | 0.0033 | 0.0071 |
| 62.63 | 6.40 | 0.0060 | 0.0119 | 0.0110 | -0.0031 | 0.0042 | 0.0103 | 0.0051 | 0.0090 |
| 68.53 | 6.97 | 0.0079 | 0.0136 | 0.0134 | -0.0029 | 0.0042 | 0.0117 | 0.0064 | 0.0119 |
| 73.24 | 7.52 | 0.0082 | 0.0157 | 0.0154 | -0.0027 | 0.0071 | 0.0141 | 0.0082 | 0.0136 |
| 78.08 | 7.99 | 0.0108 | 0.0190 | 0.0181 | -0.0024 | 0.0092 | 0.0167 | 0.0104 | 0.0159 |
| 82.98 | 8.40 | 0.0123 | 0.0223 | 0.0214 | -0.0024 | 0.0119 | 0.0190 | 0.0125 | 0.0181 |
| 88.51 | 8.93 | 0.0139 | 0.0267 | 0.0245 | -0.0022 | 0.0145 | 0.0225 | 0.0148 | 0.0205 |
| 91.90 | 9.09 | 0.0077 | 0.0602 | 0.0648 | 0.0101 | 0.0200 | 0.0271 | 0.0190 | 0.0245 |
| 91.14 | 9.32 | 0.0081 | 0.0493 | 0.1015 | 0.0399 | 0.0227 | 0.0291 | 0.0211 | 0.0271 |
| 94.16 | 10.14 | 0.0082 | 0.0472 | 0.1172 | 0.0579 | 0.0379 | 0.0440 | 0.0372 | 0.0436 |
| 97.24 | 10.47 | 0.0161 | 0.0476 | 0.1330 | 0.0756 | 0.0496 | 0.0542 | 0.0458 | 0.0551 |
| 100.25 | 10.73 | 0.0306 | 0.0480 | 0.1485 | 0.0914 | 0.0612 | 0.0648 | 0.0553 | 0.0683 |
| 100.75 | 10.52 | 0.0443 | 0.0487 | 0.1626 | 0.1068 | 0.0758 | 0.0800 | 0.0689 | 0.0743 |
| 101.44 | 10.67 | 0.0604 | 0.0557 | 0.1793 | 0.1243 | 0.1055 | 0.1086 | 0.0958 | 0.0630 |
| 103.01 | 11.06 | 0.0771 | 0.0667 | 0.1963 | 0.1436 | 0.1282 | 0.1304 | 0.1130 | 0.0590 |
| 102.95 | 11.68 | 0.0938 | 0.0775 | 0.2126 | 0.1612 | 0.1580 | 0.1586 | 0.1221 | 0.0568 |
| 104.52 | 10.81 | 0.1163 | 0.0916 | 0.2342 | 0.1861 | 0.1943 | 0.1954 | 0.1106 | 0.0537 |
| 108.91 | 11.66 | 0.1469 | 0.1190 | 0.2643 | 0.2220 | 0.2254 | 0.2273 | 0.1069 | 0.0531 |
| 108.16 | 11.83 | 0.1630 | 0.1313 | 0.2787 | 0.2399 | 0.2578 | 0.2615 | 0.1062 | 0.0568 |
| 111.93 | 12.69 | 0.1866 | 0.1503 | 0.3000 | 0.2661 | 0.2855 | 0.2884 | 0.1062 | 0.0630 |
| 115.13 | 11.77 | 0.2133 | 0.1685 | 0.3258 | 0.2956 | 0.3133 | 0.3150 | 0.1066 | 0.0685 |
| 118.40 | 12.45 | 0.2412 | 0.1870 | 0.3522 | 0.3256 | 0.3395 | 0.3392 | 0.1084 | 0.0753 |
| 122.11 | 12.99 | 0.2723 | 0.2091 | 0.3798 | 0.3598 | 0.3688 | 0.3642 | 0.1128 | 0.0848 |
| 119.97 | 14.24 | 0.2956 | 0.2252 | 0.3926 | 0.3864 | 0.4113 | 0.3553 | 0.1260 | 0.0980 |
| 117.58 | 13.25 | 0.3298 | 0.2410 | 0.3921 | 0.4470 | 0.4272 | 0.3271 | 0.1350 | 0.1110 |
| 119.47 | 13.42 | 0.3602 | 0.2604 | 0.3923 | 0.4948 | 0.4496 | 0.3137 | 0.1450 | 0.1253 |
| 120.97 | 12.85 | 0.3840 | 0.2725 | 0.4065 | 0.5435 | 0.4745 | 0.3124 | 0.1535 | 0.1438 |
| 123.17 | 13.61 | 0.4141 | 0.2870 | 0.4410 | 0.5974 | 0.5173 | 0.3126 | 0.1677 | 0.1699 |
| 122.86 | 13.50 | 0.4410 | 0.3027 | 0.4763 | 0.6543 | 0.5609 | 0.3194 | 0.1780 | 0.2020 |
| 117.08 | 13.37 | 0.4677 | 0.3258 | 0.5146 | 0.7087 | 0.6649 | 0.3194 | 0.2384 | 0.2992 |
| 101.00 | 14.00 | 0.4690 | 0.3322 | 0.5298 | 0.7283 | 0.9188 | 0.3192 | 0.4152 | 0.4855 |
| 95.79 | 11.57 | 0.4877 | 0.3578 | 0.5803 | 0.8140 | 1.0584 | 0.3190 | 0.5344 | 0.5930 |
| 54.52 | 14.00 | 0.5298 | 0.4100 | 0.6323 | 0.8922 | 2.0087 | 0.4926 | 0.6133 | 0.5990 |

**PUSHOUT TEST SUMMARY SHEET**

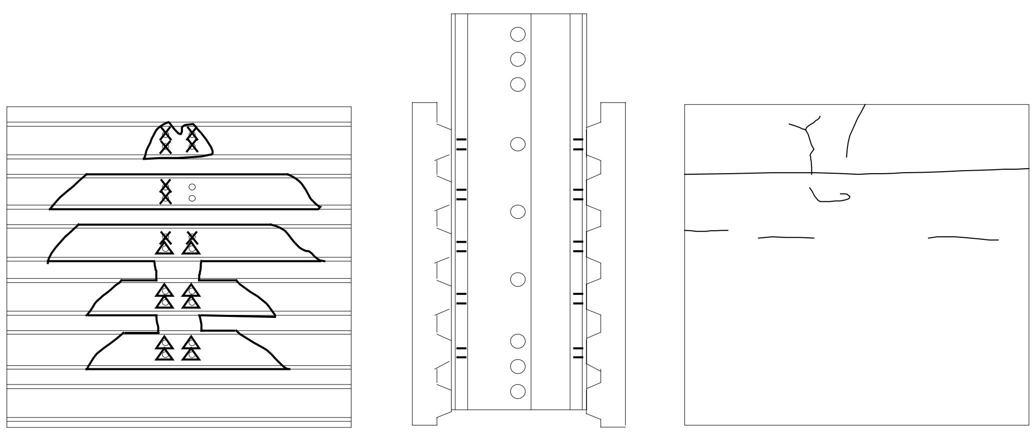
Test: C10-1 — Test Date: 21-Jul-98

Test Designation: SC-8-3.0-0.250-1.5C-3.5-1

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 3.0 in. | No. Per Specimen: | 40 | | |
| **Deck:** | Type: | 1.5C, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 101.7 ksi | $F_u$: | 103.2 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.250 | | | | |
| | $F_y$: | 54.5 ksi | $F_u$: | 77.4 ksi | | |
| **Slab:** | Thickness: | 3.5 in. | $f'_c$: | 5392 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 12 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 4x4-W2.1xW2.1 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 138.19 kips | | | |
| **Peak Shear Load Per Screw:** | 3.45 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.8840 in. | SC5: | 0.8740 in. |
| | SC2: | N.A. | SC6: | 0.6757 in. |
| | SC3: | 0.6419 in. | SC7: | 0.9028 in. |
| | SC4: | 0.7490 in. | SC8: | 0.8843 in. |

**DAMAGE**



interior, Slab A — exterior, Slab B

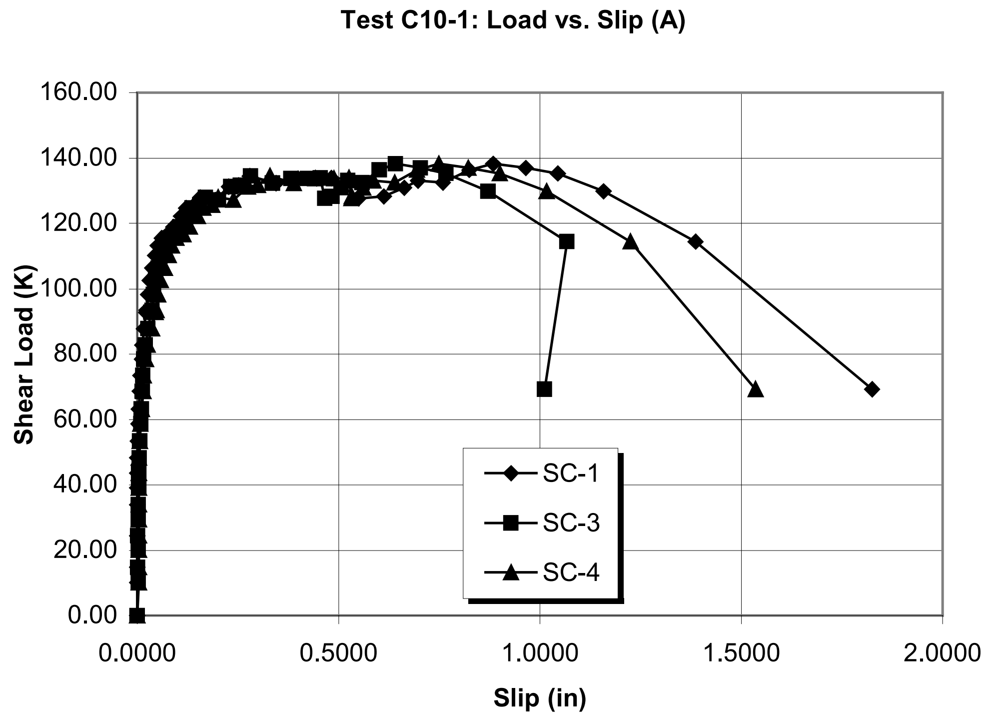
**COMMENTS**

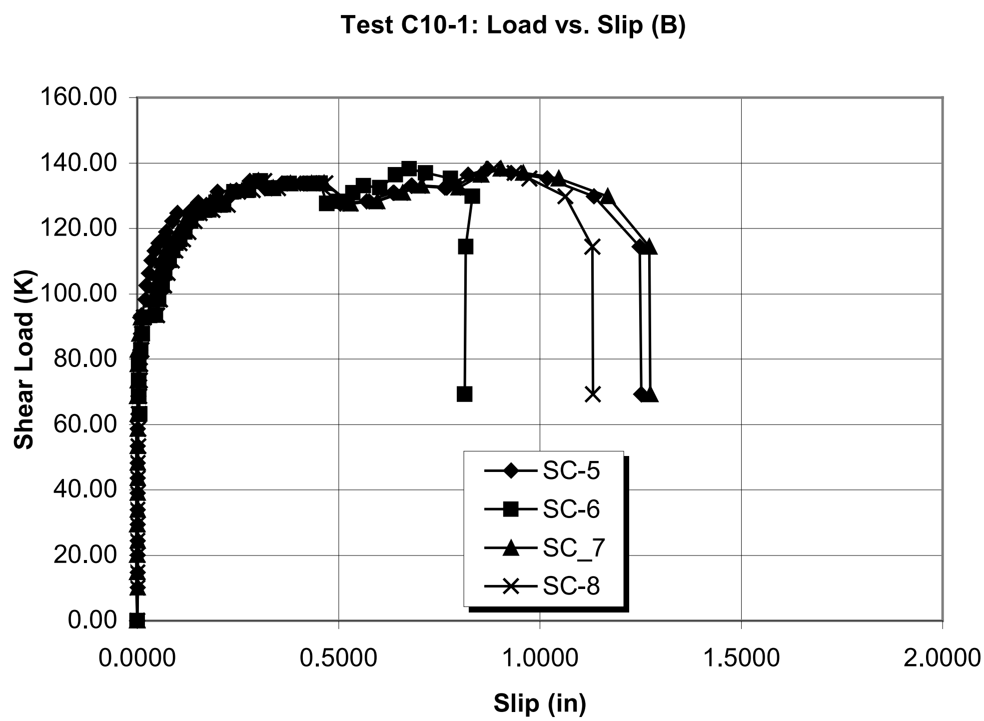
Failure Mode: Concrete cone pullout

Screw Rotation ≈ 20° - 30°

Deck debonded; Slight bulging of deck below screws

X = Screw sheared off; △ = Screw pulled out of concrete


Test C10-1: Load vs. Slip (A)
Shear Load (K)
Slip (in)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
0.0000
0.5000
1.0000
1.5000
2.0000
SC-1
SC-3
SC-4


Test C10-1: Load vs. Slip (B)
Shear Load (K)
Slip (in)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
0.0000
0.5000
1.0000
1.5000
2.0000
SC-5
SC-6
SC_7
SC-8

## TEST C10-1 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.06 | 0.00 | 0.0000 | ~~0.0000~~ | -0.0002 | 0.0000 | 0.0000 | 0.0002 | 0.0000 | 0.0002 |
| 10.05 | 0.94 | -0.0004 | ~~0.0004~~ | 0.0020 | 0.0040 | 0.0011 | -0.0024 | 0.0007 | -0.0005 |
| 14.82 | 1.52 | -0.0005 | ~~0.0005~~ | 0.0016 | 0.0038 | 0.0009 | -0.0026 | 0.0002 | -0.0005 |
| 20.04 | 2.01 | -0.0007 | ~~0.0009~~ | 0.0020 | 0.0042 | 0.0011 | -0.0029 | 0.0005 | -0.0002 |
| 24.37 | 2.44 | -0.0004 | ~~-0.0007~~ | 0.0016 | 0.0042 | 0.0009 | -0.0029 | 0.0007 | 0.0000 |
| 29.46 | 3.00 | -0.0007 | ~~-0.0009~~ | 0.0020 | 0.0040 | 0.0009 | -0.0029 | 0.0004 | 0.0002 |
| 33.86 | 3.57 | -0.0004 | ~~-0.0011~~ | 0.0020 | 0.0040 | 0.0011 | -0.0031 | 0.0009 | 0.0002 |
| 39.13 | 4.08 | -0.0005 | ~~-0.0007~~ | 0.0033 | 0.0044 | 0.0009 | -0.0027 | 0.0007 | 0.0005 |
| 43.66 | 4.49 | -0.0004 | ~~-0.0007~~ | 0.0037 | 0.0044 | 0.0011 | -0.0027 | 0.0009 | 0.0009 |
| 48.24 | 4.99 | 0.0000 | ~~-0.0009~~ | 0.0049 | 0.0044 | 0.0007 | -0.0027 | 0.0007 | 0.0013 |
| 53.33 | 5.54 | 0.0009 | ~~-0.0005~~ | 0.0066 | 0.0059 | 0.0015 | -0.0024 | 0.0009 | 0.0024 |
| 58.73 | 5.99 | 0.0020 | ~~-0.0004~~ | 0.0084 | 0.0077 | 0.0015 | -0.0024 | 0.0009 | 0.0029 |
| 63.13 | 6.54 | 0.0042 | ~~-0.0005~~ | 0.0103 | 0.0114 | 0.0020 | 0.0066 | 0.0007 | 0.0040 |
| 68.59 | 6.98 | 0.0062 | ~~0.0000~~ | 0.0121 | 0.0147 | 0.0031 | 0.0033 | 0.0005 | 0.0055 |
| 73.49 | 7.53 | 0.0079 | ~~0.0009~~ | 0.0141 | 0.0168 | 0.0048 | 0.0033 | 0.0011 | 0.0062 |
| 78.45 | 7.96 | 0.0110 | ~~0.0042~~ | 0.0167 | 0.0216 | 0.0066 | 0.0035 | 0.0011 | 0.0077 |
| 82.85 | 8.44 | 0.0132 | ~~0.0079~~ | 0.0200 | 0.0256 | 0.0081 | 0.0090 | 0.0016 | 0.0097 |
| 87.81 | 8.95 | 0.0161 | ~~0.0231~~ | 0.0271 | 0.0361 | 0.0082 | 0.0128 | 0.0046 | 0.0119 |
| 92.78 | 9.58 | 0.0212 | ~~0.0306~~ | 0.0335 | 0.0450 | 0.0079 | 0.0176 | 0.0084 | 0.0163 |
| 93.34 | 9.70 | 0.0231 | ~~0.0364~~ | 0.0368 | 0.0485 | 0.0103 | 0.0452 | 0.0286 | 0.0494 |
| 98.18 | 9.95 | 0.0260 | ~~0.0396~~ | 0.0403 | 0.0518 | 0.0205 | 0.0526 | 0.0353 | 0.0566 |
| 102.51 | 10.73 | 0.0304 | ~~0.0469~~ | 0.0460 | 0.0586 | 0.0222 | 0.0617 | 0.0436 | 0.0672 |
| 106.28 | 10.95 | 0.0361 | ~~0.0538~~ | 0.0520 | 0.0676 | 0.0286 | 0.0683 | 0.0515 | 0.0754 |
| 110.23 | 11.11 | 0.0440 | ~~0.0613~~ | 0.0608 | 0.0784 | 0.0357 | 0.0791 | 0.0604 | 0.0861 |
| 113.19 | 11.51 | 0.0507 | ~~0.0656~~ | 0.0681 | 0.0859 | 0.0432 | 0.0885 | 0.0711 | 0.0947 |
| 115.51 | 11.96 | 0.0606 | ~~0.0709~~ | 0.0789 | 0.0969 | 0.0527 | 0.0965 | 0.0811 | 0.1051 |
| 116.58 | 12.12 | 0.0747 | ~~0.0707~~ | 0.0917 | 0.1145 | 0.0613 | 0.1066 | 0.0916 | 0.1141 |
| 118.96 | 12.25 | 0.0897 | ~~0.0709~~ | 0.1058 | 0.1302 | 0.0720 | 0.1181 | 0.1024 | 0.1269 |
| 122.11 | 12.64 | 0.1090 | ~~0.0705~~ | 0.1232 | 0.1498 | 0.0874 | 0.1324 | 0.1190 | 0.1423 |
| 124.62 | 12.90 | 0.1216 | ~~0.0707~~ | 0.1362 | 0.1635 | 0.1002 | 0.1472 | 0.1317 | 0.1547 |
| 125.62 | 13.18 | 0.1417 | ~~0.0709~~ | 0.1555 | 0.1851 | 0.1333 | 0.1785 | 0.1652 | 0.1862 |
| 127.88 | 13.20 | 0.1569 | ~~0.0705~~ | 0.1696 | 0.2002 | 0.1514 | 0.1959 | 0.1824 | 0.2035 |
| 127.19 | 13.43 | 0.1939 | ~~0.0707~~ | 0.2020 | 0.2384 | 0.1720 | 0.2146 | 0.2033 | 0.2241 |
| 131.28 | 13.54 | 0.2271 | ~~0.0705~~ | 0.2329 | 0.2756 | 0.1994 | 0.2393 | 0.2306 | 0.2500 |
| 131.72 | 13.67 | 0.2514 | ~~0.0701~~ | 0.2562 | 0.2990 | 0.2463 | 0.2762 | 0.2697 | 0.2864 |
| 134.48 | 13.82 | 0.2793 | ~~0.0705~~ | 0.2815 | 0.3298 | 0.2791 | 0.3060 | 0.3011 | 0.3161 |
| 132.28 | 13.84 | 0.3446 | ~~0.2707~~ | 0.3355 | 0.3886 | 0.3164 | 0.3379 | 0.3368 | 0.3501 |
| 133.66 | 13.39 | 0.3987 | ~~0.2707~~ | 0.3809 | 0.4417 | 0.3589 | 0.3776 | 0.3794 | 0.3884 |
| 133.66 | 13.68 | 0.4459 | ~~0.2708~~ | 0.4232 | 0.4884 | 0.4126 | 0.4285 | 0.4327 | 0.4380 |
| 133.91 | 14.00 | 0.4827 | ~~0.2789~~ | 0.4542 | 0.5252 | 0.4446 | 0.4549 | 0.4631 | 0.4677 |
| 127.57 | 14.68 | 0.5492 | ~~0.3034~~ | 0.4653 | 0.5322 | 0.5040 | 0.4716 | 0.5287 | 0.5287 |
| 128.32 | 13.23 | 0.6120 | ~~0.3417~~ | 0.4831 | 0.5324 | 0.5697 | 0.4996 | 0.5953 | 0.5922 |
| 130.96 | 13.83 | 0.6635 | ~~0.3602~~ | 0.5067 | 0.5600 | 0.6353 | 0.5347 | 0.6596 | 0.6541 |
| 133.04 | 14.15 | 0.6975 | ~~0.3794~~ | 0.5230 | 0.5862 | 0.6805 | 0.5624 | 0.7052 | 0.6988 |
| 132.41 | 13.38 | 0.7587 | ~~0.4351~~ | 0.5584 | 0.6389 | 0.7644 | 0.6023 | 0.7983 | 0.7851 |
| 136.36 | 13.96 | 0.8250 | ~~0.4972~~ | 0.6014 | 0.6950 | 0.8208 | 0.6420 | 0.8534 | 0.8384 |
| 138.19 | 14.32 | 0.8840 | ~~0.5560~~ | 0.6419 | 0.7490 | 0.8704 | 0.6757 | 0.9028 | 0.8843 |
| 136.99 | 14.48 | 0.9647 | ~~0.6340~~ | 0.7027 | 0.8221 | 0.9281 | 0.7158 | 0.9589 | 0.9372 |
| 135.23 | 14.65 | 1.0436 | ~~0.7109~~ | 0.7664 | 0.9008 | 1.0178 | 0.7774 | 1.0467 | 0.9737 |
| 129.77 | 14.80 | 1.1579 | ~~0.8329~~ | 0.8708 | 1.0170 | 1.1341 | 0.8325 | 1.1678 | 1.0625 |
| 114.38 | 13.37 | 1.3866 | ~~1.0577~~ | 1.0674 | 1.2245 | 1.2471 | 0.8162 | 1.2714 | 1.1295 |
| 69.22 | 7.82 | 1.8250 | ~~1.0614~~ | 1.0114 | 1.5355 | 1.2513 | 0.8135 | 1.2742 | 1.1311 |

Note: SC-2 readings not included due to operational error

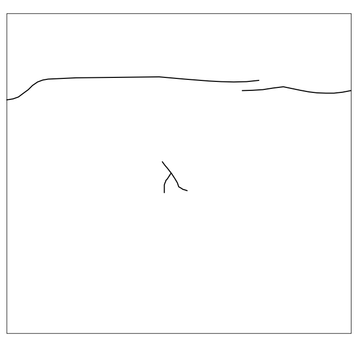
**PUSHOUT TEST SUMMARY SHEET**

Test: C10-2 Test Date: 22-Jul-98
Test Designation: SC-8-3.0-0.250-1.5C-3.5-2

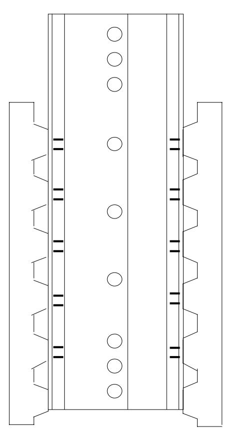
| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 3.0 in. | No. Per Specimen: | 40 | | |
| **Deck:** | Type: | 1.5C, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 101.7 ksi | $F_u$: | 103.2 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.250 | | | | |
| | $F_y$: | 54.5 ksi | $F_u$: | 77.4 ksi | | |
| **Slab:** | Thickness: | 3.5 in. | $f'_c$: | 5392 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 12 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 4x4-W2.1xW2.1 | | | | |

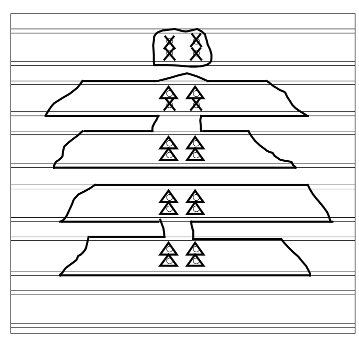
| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 149.12 kips | | | |
| **Peak Shear Load Per Screw:** | 3.73 kips | | | |
| **Slip at Peak Shear Load:** | SC1: 0.4228 in. | | SC5: 0.3663 in. | |
| | SC2: 0.4637 in. | | SC6: 0.3298 in. | |
| | SC3: 0.4366 in. | | SC7: 0.3424 in. | |
| | SC4: 0.1584 in. | | SC8: 0.2088 in. | |

**DAMAGE**



exterior, Slab A



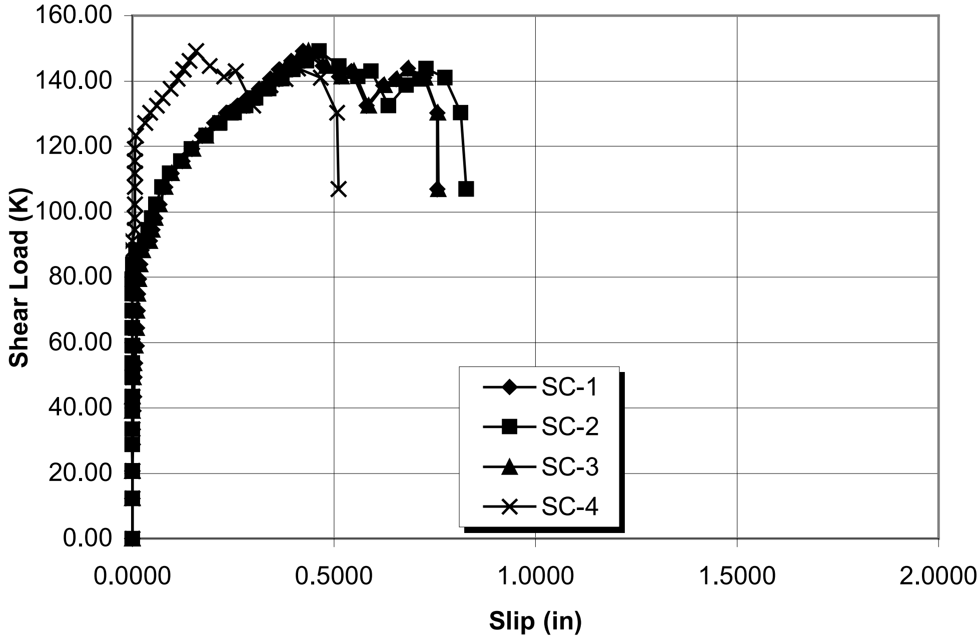


interior, Slab B

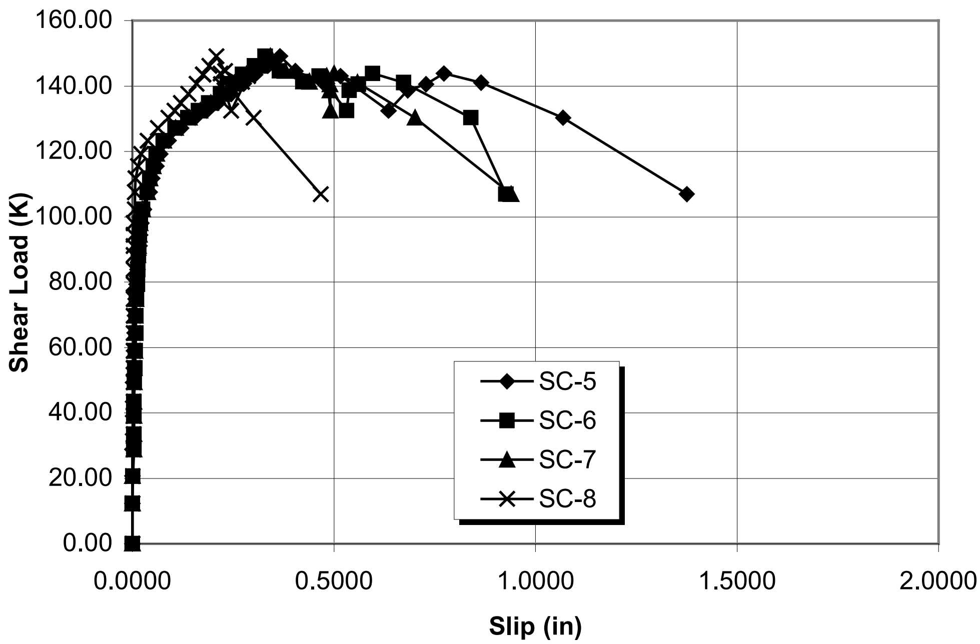
**COMMENTS**

Failure Mode: Concrete cone pullout
Screw Rotation ≈ 20° - 30°
Deck debonded; Slight bulging of deck below screws
X = Screw sheared off; △ = Screw pulled out of concrete

Test C10-2: Load vs. Slip (A)




Test C10-2: Load vs. Slip (B)



**TEST C10-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| -0.06 | 0.00 | 0.0002 | -0.0002 | 0.0000 | -0.0004 | 0.0002 | 0.0002 | -0.0002 | 0.0002 |
| 12.25 | 0.94 | 0.0002 | 0.0002 | 0.0000 | -0.0002 | -0.0002 | 0.0004 | 0.0000 | 0.0000 |
| 20.67 | 1.84 | 0.0002 | 0.0004 | 0.0000 | -0.0002 | 0.0002 | 0.0007 | -0.0002 | 0.0002 |
| 28.83 | 2.84 | 0.0009 | 0.0002 | -0.0007 | -0.0009 | 0.0004 | 0.0040 | 0.0044 | 0.0026 |
| 33.48 | 3.36 | 0.0018 | 0.0002 | -0.0007 | -0.0004 | 0.0007 | 0.0037 | 0.0042 | 0.0022 |
| 39.07 | 3.91 | 0.0026 | 0.0002 | -0.0005 | -0.0009 | 0.0007 | 0.0040 | 0.0040 | 0.0022 |
| 43.40 | 4.45 | 0.0040 | 0.0004 | 0.0002 | -0.0004 | 0.0009 | 0.0040 | 0.0042 | 0.0026 |
| 49.37 | 4.98 | 0.0055 | 0.0002 | 0.0024 | -0.0005 | 0.0016 | 0.0051 | 0.0048 | 0.0022 |
| 53.77 | 5.59 | 0.0064 | 0.0002 | 0.0040 | -0.0009 | 0.0029 | 0.0059 | 0.0051 | 0.0022 |
| 58.92 | 6.11 | 0.0097 | 0.0000 | 0.0075 | -0.0005 | 0.0035 | 0.0073 | 0.0060 | 0.0020 |
| 64.51 | 6.50 | 0.0112 | -0.0002 | 0.0095 | -0.0007 | 0.0051 | 0.0084 | 0.0066 | 0.0022 |
| 69.72 | 7.10 | 0.0130 | 0.0002 | 0.0112 | -0.0005 | 0.0064 | 0.0092 | 0.0077 | 0.0024 |
| 74.81 | 7.57 | 0.0143 | 0.0002 | 0.0137 | -0.0007 | 0.0079 | 0.0103 | 0.0088 | 0.0024 |
| 79.33 | 8.06 | 0.0168 | 0.0004 | 0.0161 | -0.0007 | 0.0103 | 0.0121 | 0.0099 | 0.0026 |
| 83.92 | 8.58 | 0.0187 | 0.0013 | 0.0189 | -0.0005 | 0.0125 | 0.0136 | 0.0119 | 0.0024 |
| 88.32 | 9.08 | 0.0233 | 0.0092 | 0.0247 | -0.0004 | 0.0147 | 0.0154 | 0.0143 | 0.0026 |
| 91.02 | 9.67 | 0.0430 | 0.0302 | 0.0427 | -0.0002 | 0.0178 | 0.0167 | 0.0157 | 0.0027 |
| 94.47 | 9.74 | 0.0493 | 0.0390 | 0.0489 | 0.0064 | 0.0190 | 0.0178 | 0.0176 | 0.0027 |
| 98.05 | 10.03 | 0.0571 | 0.0483 | 0.0564 | 0.0066 | 0.0222 | 0.0198 | 0.0192 | 0.0026 |
| 102.19 | 10.51 | 0.0668 | 0.0581 | 0.0665 | 0.0064 | 0.0286 | 0.0253 | 0.0249 | 0.0060 |
| 107.60 | 11.02 | 0.0804 | 0.0734 | 0.0804 | 0.0066 | 0.0423 | 0.0368 | 0.0385 | 0.0060 |
| 111.74 | 11.48 | 0.0967 | 0.0923 | 0.0976 | 0.0068 | 0.0494 | 0.0430 | 0.0441 | 0.0075 |
| 115.51 | 11.94 | 0.1242 | 0.1194 | 0.1262 | 0.0064 | 0.0597 | 0.0513 | 0.0518 | 0.0139 |
| 119.15 | 12.19 | 0.1474 | 0.1471 | 0.1507 | 0.0066 | 0.0698 | 0.0599 | 0.0601 | 0.0218 |
| 123.30 | 12.49 | 0.1732 | 0.1835 | 0.1818 | 0.0093 | 0.0899 | 0.0769 | 0.0780 | 0.0375 |
| 127.13 | 13.00 | 0.2033 | 0.2177 | 0.2132 | 0.0309 | 0.1214 | 0.1055 | 0.1077 | 0.0637 |
| 130.21 | 13.35 | 0.2329 | 0.2525 | 0.2430 | 0.0440 | 0.1557 | 0.1381 | 0.1414 | 0.0894 |
| 132.41 | 13.34 | 0.2606 | 0.2811 | 0.2714 | 0.0601 | 0.1842 | 0.1643 | 0.1683 | 0.1053 |
| 134.79 | 13.59 | 0.2853 | 0.3058 | 0.2969 | 0.0745 | 0.2119 | 0.1894 | 0.1941 | 0.1203 |
| 137.62 | 13.76 | 0.3146 | 0.3382 | 0.3258 | 0.0943 | 0.2448 | 0.2188 | 0.2243 | 0.1392 |
| 140.76 | 14.28 | 0.3417 | 0.3712 | 0.3542 | 0.1130 | 0.2771 | 0.2485 | 0.2547 | 0.1586 |
| 143.53 | 14.46 | 0.3639 | 0.3978 | 0.3778 | 0.1269 | 0.3045 | 0.2734 | 0.2826 | 0.1749 |
| 143.46 | 14.45 | 0.3644 | 0.3976 | 0.3780 | 0.1267 | 0.3047 | 0.2734 | 0.2827 | 0.1749 |
| 146.16 | 14.91 | 0.3939 | 0.4316 | 0.4080 | 0.1414 | 0.3359 | 0.3025 | 0.3126 | 0.1910 |
| 149.12 | 14.90 | 0.4228 | 0.4637 | 0.4366 | 0.1584 | 0.3663 | 0.3298 | 0.3424 | 0.2088 |
| 144.53 | 15.03 | 0.4717 | 0.5131 | 0.4809 | 0.1923 | 0.4045 | 0.3648 | 0.3789 | 0.2304 |
| 141.39 | 14.25 | 0.5122 | 0.5591 | 0.5192 | 0.2269 | 0.4716 | 0.4227 | 0.4391 | 0.2710 |
| 142.96 | 14.65 | 0.5433 | 0.5924 | 0.5487 | 0.2562 | 0.5164 | 0.4639 | 0.4818 | 0.2862 |
| 132.47 | 13.65 | 0.5814 | 0.6353 | 0.5853 | 0.2996 | 0.6356 | 0.5322 | 0.4910 | 0.2448 |
| 138.75 | 13.94 | 0.6219 | 0.6794 | 0.6250 | 0.3424 | 0.6831 | 0.5384 | 0.4893 | 0.2287 |
| 140.51 | 12.83 | 0.6543 | 0.7138 | 0.6569 | 0.3800 | 0.7287 | 0.5606 | 0.4901 | 0.2194 |
| 143.84 | 13.90 | 0.6825 | 0.7283 | 0.6853 | 0.4108 | 0.7730 | 0.5955 | 0.4994 | 0.2179 |
| 141.01 | 14.93 | 0.7230 | 0.7757 | 0.7256 | 0.4670 | 0.8653 | 0.6732 | 0.5582 | 0.2306 |
| 130.33 | 14.13 | 0.7558 | 0.8149 | 0.7581 | 0.5073 | 1.0681 | 0.8400 | 0.7003 | 0.3007 |
| 106.90 | 12.32 | 0.7560 | 0.8285 | 0.7589 | 0.5107 | 1.3749 | 0.9272 | 0.9398 | 0.4673 |

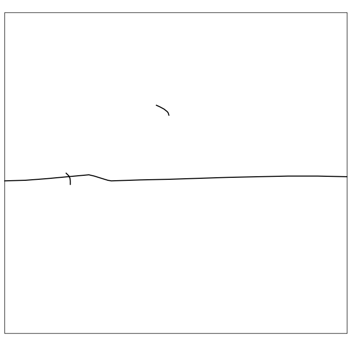
**PUSHOUT TEST SUMMARY SHEET**

Test: E1-1 Test Date: 1-Oct-98
Test Designation: SC-8-4.0-0.109-2VL-4.25-1

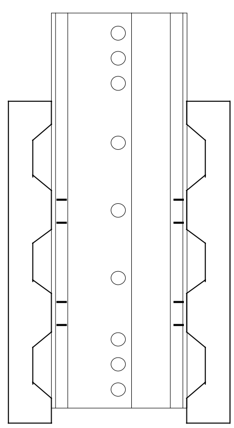
| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in. | No. Per Specimen: | 16 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 1.25x1.25x0.109 | | | | |
| | $F_y$: | 55.6 ksi | $F_u$: | 76.8 ksi | | |
| **Slab:** | Thickness: | 4.25 in. | $f'_c$: | 7441 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6xW4xW4 | | | | |

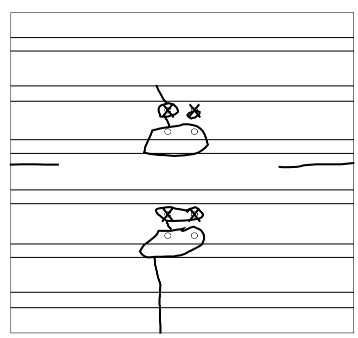
| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 56.60 kips | | | |
| **Peak Shear Load Per Screw:** | 3.54 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.3159 in. | SC5: | 0.6016 in. |
| | SC2: | 0.6151 in. | SC6: | 0.4382 in. |
| | SC3: | 0.4646 in. | SC7: | 0.5609 in. |
| | SC4: | 0.5309 in. | SC8: | 0.5571 in. |

**DAMAGE**



exterior, Slab A



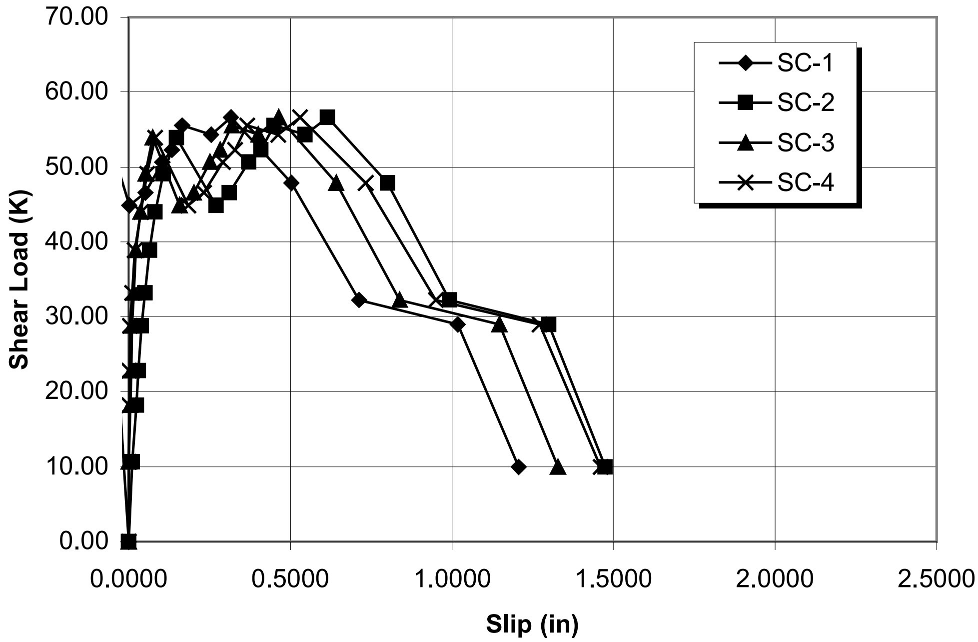


interior, Slab B

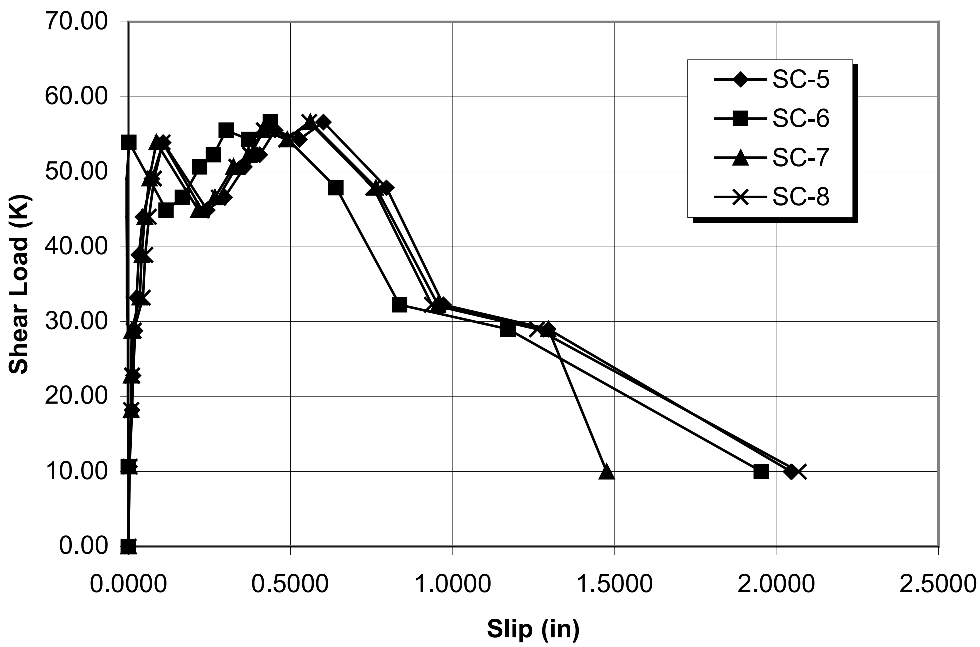
**COMMENTS**

Failure Mode: Top chord buckling with screw shear and screw pullout from angles at ultimate load
Screw Rotation ≈ 60° - 70°; Slight bulging of deck below screws
Deck debonded; Angles slightly deformed at screw locations due to rotation of screws
X = Screw sheared off

**Test E1-1: Load vs. Slip (A)**




**Test E1-1: Load vs. Slip (B)**



**TEST E1-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.01 | 0.0000 | 0.0002 | 0.0000 | -0.0002 | 0.0002 | -0.0005 | -0.0004 | 0.0000 |
| 10.68 | 0.98 | -0.0165 | 0.0110 | 0.0002 | 0.0000 | 0.0038 | -0.0004 | 0.0013 | 0.0029 |
| 18.22 | 1.90 | -0.0271 | 0.0244 | 0.0048 | 0.0020 | 0.0103 | -0.0009 | 0.0081 | 0.0084 |
| 22.80 | 2.48 | -0.0300 | 0.0300 | 0.0075 | 0.0022 | 0.0137 | -0.0011 | 0.0082 | 0.0117 |
| 28.77 | 2.94 | -0.0370 | 0.0397 | 0.0090 | 0.0037 | 0.0203 | -0.0011 | 0.0090 | 0.0159 |
| 33.23 | 3.19 | -0.0396 | 0.0505 | 0.0150 | 0.0106 | 0.0251 | -0.0040 | 0.0346 | 0.0434 |
| 38.88 | 4.07 | -0.0405 | 0.0637 | 0.0216 | 0.0192 | 0.0311 | -0.0046 | 0.0416 | 0.0515 |
| 43.97 | 4.41 | -0.0410 | 0.0822 | 0.0366 | 0.0377 | 0.0438 | -0.0057 | 0.0498 | 0.0624 |
| 49.06 | 4.92 | -0.0524 | 0.1077 | 0.0524 | 0.0564 | 0.0716 | -0.0064 | 0.0637 | 0.0787 |
| 53.89 | 5.41 | -0.0608 | 0.1472 | 0.0742 | 0.0824 | 0.1071 | 0.0013 | 0.0868 | 0.1046 |
| 44.85 | 5.65 | 0.0018 | 0.2710 | 0.1575 | 0.1833 | 0.2436 | 0.1157 | 0.2159 | 0.2267 |
| 46.61 | 5.51 | 0.0524 | 0.3122 | 0.2011 | 0.2333 | 0.2967 | 0.1657 | 0.2666 | 0.2773 |
| 50.63 | 5.75 | 0.1035 | 0.3712 | 0.2516 | 0.2917 | 0.3576 | 0.2192 | 0.3238 | 0.3335 |
| 52.26 | 5.47 | 0.1339 | 0.4089 | 0.2838 | 0.3283 | 0.4054 | 0.2617 | 0.3699 | 0.3754 |
| 55.53 | 5.77 | 0.1654 | 0.4507 | 0.3194 | 0.3674 | 0.4525 | 0.3018 | 0.4144 | 0.4172 |
| 54.33 | 5.65 | 0.2542 | 0.5463 | 0.4007 | 0.4618 | 0.5278 | 0.3701 | 0.4897 | 0.4871 |
| 56.60 | 5.90 | 0.3159 | 0.6151 | 0.4646 | 0.5309 | 0.6016 | 0.4382 | 0.5609 | 0.5571 |
| 47.86 | 6.02 | 0.5036 | 0.8008 | 0.6419 | 0.7336 | 0.7964 | 0.6402 | 0.7633 | 0.7550 |
| 32.22 | 3.77 | 0.7124 | 0.9933 | 0.8382 | 0.9503 | 0.9713 | 0.8374 | 0.9546 | 0.9367 |
| 29.02 | 4.69 | 1.0180 | 1.2998 | 1.1472 | 1.2714 | 1.2959 | 1.1707 | 1.2959 | 1.2610 |
| 9.99 | 2.55 | 1.2062 | 1.4739 | 1.3276 | 1.4593 | 2.0442 | 1.9534 | 1.4769 | 2.0689 |

**PUSHOUT TEST SUMMARY SHEET**

Test: E1-2 Test Date: 2-Oct-98
Test Designation: SC-8-4.0-0.109-2VL-4.25-2

**SPECIMEN DESCRIPTION**

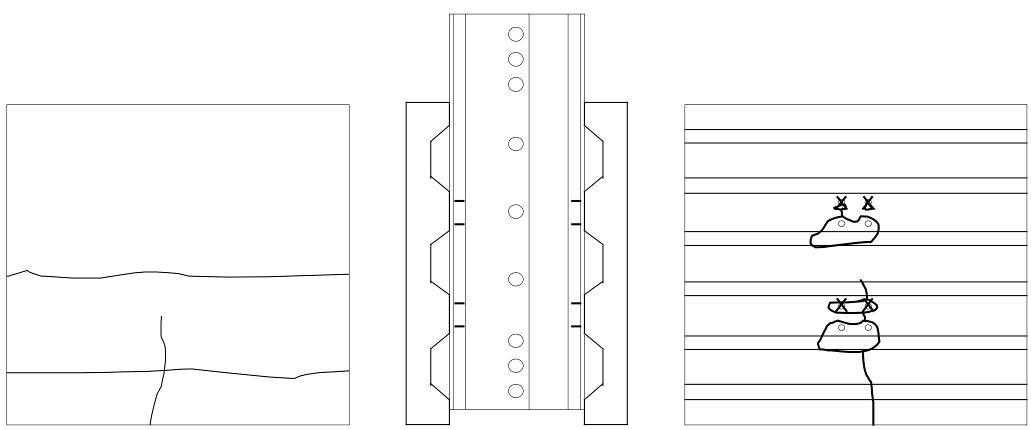
**Screw:** Height: 4.0 in. No. Per Specimen: 16
**Deck:** Type: 2VL, 22 ga Width: 36 in. Length: 36 in.
$F_y$: 51.0 ksi $F_u$: 56.7 ksi
**Base Member:** Section: 2L 1.25x1.25x0.109
$F_y$: 55.6 ksi $F_u$: 76.8 ksi
**Slab:** Thickness: 4.25 in. $f'_c$: 7441 psi
**Rebar:** Size: No. 4 No. Per Specimen: 8
Height Above Deck: 1.0 in.
**Mesh:** Type: WWF 6x6xW4xW4

**TEST RESULTS**

**Peak Shear Load:** 65.33 kips
**Peak Shear Load Per Screw:** 4.08 kips
**Slip at Peak Shear Load:**

| | |
|---|---|
| SC1: 0.2796 in. | SC5: 0.7173 in. |
| SC2: 0.6402 in. | SC6: 0.5452 in. |
| SC3: 0.4650 in. | SC7: 0.6393 in. |
| SC4: 0.5265 in. | SC8: 0.6212 in. |

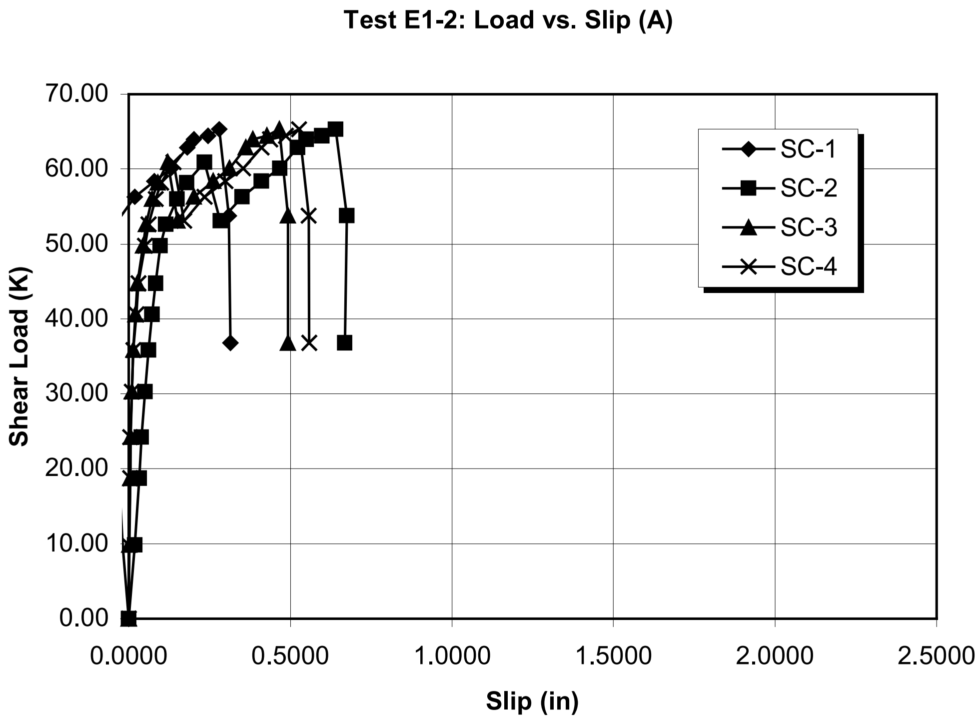
**DAMAGE**

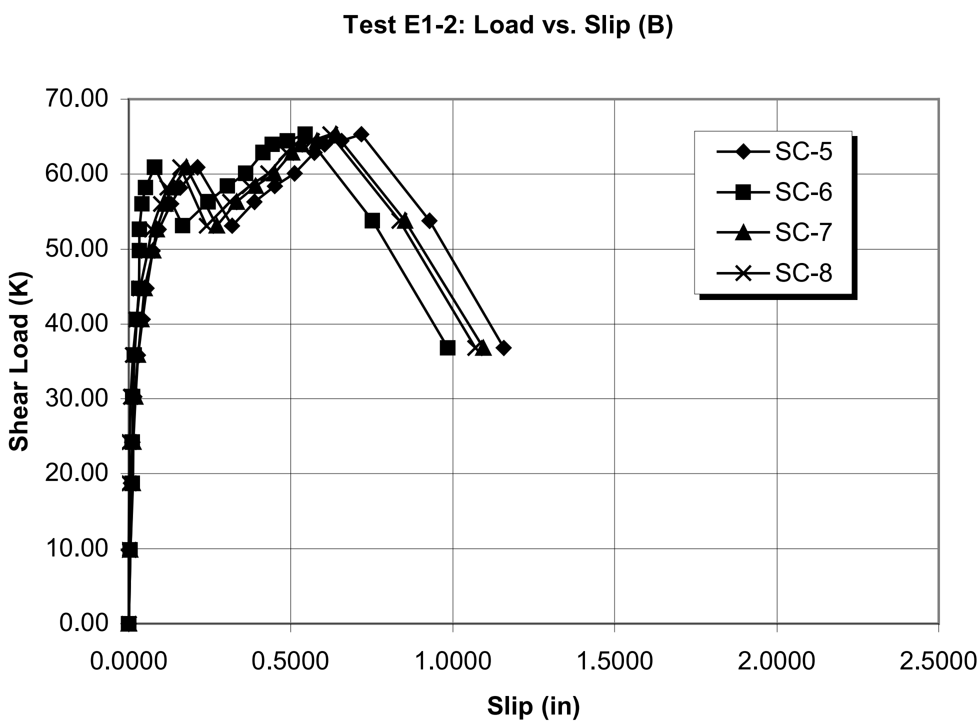


exterior, Slab A interior, Slab B

**COMMENTS**

Failure Mode: Top chord buckling with screw shear and screw pullout from angles at ultimate load
Screw Rotation ≈ 40° - 50°; Slight bulging of deck below screws
Deck debonded; Angles slightly deformed at screw locations due to rotation of screws
X = Screw sheared off


Test E1-2: Load vs. Slip (A)
Shear Load (K)
Slip (in)
SC-1
SC-2
SC-3
SC-4
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000


Test E1-2: Load vs. Slip (B)
Shear Load (K)
Slip (in)
SC-5
SC-6
SC-7
SC-8
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000

**TEST E1-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0002 | 0.0000 | 0.0000 | 0.0000 | 0.0002 | 0.0000 | 0.0000 |
| 9.86 | 0.85 | -0.0190 | 0.0181 | 0.0018 | 0.0002 | 0.0000 | 0.0042 | 0.0049 | 0.0002 |
| 18.72 | 1.83 | -0.0304 | 0.0333 | 0.0055 | 0.0055 | 0.0070 | 0.0110 | 0.0130 | 0.0009 |
| 24.25 | 2.40 | -0.0341 | 0.0397 | 0.0066 | 0.0055 | 0.0103 | 0.0112 | 0.0148 | 0.0016 |
| 30.28 | 2.94 | -0.0392 | 0.0504 | 0.0097 | 0.0088 | 0.0179 | 0.0130 | 0.0201 | 0.0059 |
| 35.87 | 3.41 | -0.0407 | 0.0612 | 0.0143 | 0.0145 | 0.0282 | 0.0174 | 0.0277 | 0.0125 |
| 40.58 | 3.95 | -0.0416 | 0.0731 | 0.0211 | 0.0233 | 0.0423 | 0.0245 | 0.0388 | 0.0240 |
| 44.72 | 4.49 | -0.0416 | 0.0831 | 0.0269 | 0.0306 | 0.0549 | 0.0309 | 0.0491 | 0.0339 |
| 49.75 | 4.95 | -0.0418 | 0.0971 | 0.0438 | 0.0496 | 0.0736 | 0.0330 | 0.0758 | 0.0604 |
| 52.64 | 5.64 | -0.0438 | 0.1154 | 0.0542 | 0.0617 | 0.0919 | 0.0333 | 0.0864 | 0.0712 |
| 56.03 | 5.84 | -0.0465 | 0.1502 | 0.0731 | 0.0828 | 0.1309 | 0.0412 | 0.1134 | 0.0987 |
| 58.17 | 6.02 | -0.0460 | 0.1791 | 0.0892 | 0.1007 | 0.1591 | 0.0511 | 0.1344 | 0.1194 |
| 60.93 | 6.25 | -0.0412 | 0.2344 | 0.1214 | 0.1386 | 0.2122 | 0.0806 | 0.1780 | 0.1591 |
| 53.08 | 6.08 | -0.0344 | 0.2827 | 0.1511 | 0.1718 | 0.3188 | 0.1657 | 0.2714 | 0.2404 |
| 56.28 | 5.79 | 0.0187 | 0.3514 | 0.2020 | 0.2339 | 0.3882 | 0.2458 | 0.3327 | 0.3131 |
| 58.42 | 6.04 | 0.0791 | 0.4102 | 0.2611 | 0.2983 | 0.4509 | 0.3042 | 0.3902 | 0.3721 |
| 60.11 | 6.01 | 0.1298 | 0.4666 | 0.3111 | 0.3544 | 0.5122 | 0.3609 | 0.4487 | 0.4296 |
| 62.88 | 6.35 | 0.1802 | 0.5225 | 0.3613 | 0.4109 | 0.5726 | 0.4150 | 0.5034 | 0.4864 |
| 63.94 | 6.09 | 0.2018 | 0.5488 | 0.3842 | 0.4369 | 0.6051 | 0.4426 | 0.5324 | 0.5153 |
| 64.45 | 6.46 | 0.2461 | 0.5981 | 0.4282 | 0.4858 | 0.6567 | 0.4895 | 0.5809 | 0.5648 |
| 65.33 | 6.52 | 0.2796 | 0.6402 | 0.4650 | 0.5265 | 0.7173 | 0.5452 | 0.6393 | 0.6212 |
| 53.77 | 7.87 | 0.3097 | 0.6743 | 0.4932 | 0.5571 | 0.9281 | 0.7519 | 0.8525 | 0.8349 |
| 36.81 | 3.81 | 0.3152 | 0.6690 | 0.4930 | 0.5585 | 1.1566 | 0.9852 | 1.0943 | 1.0694 |

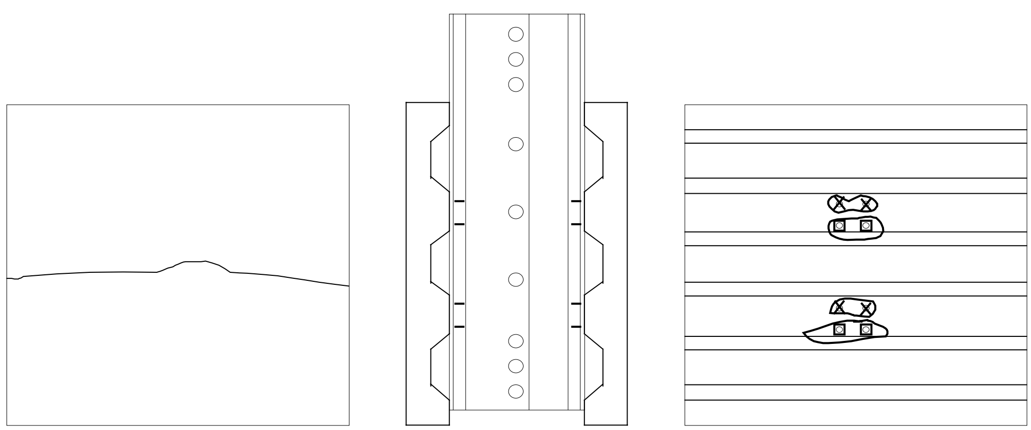
## PUSHOUT TEST SUMMARY SHEET

Test: E1R-1 Test Date: 19-Dec-98
Test Designation: SC-8-4.0-0.109-2VL-4.25-1R

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in. | No. Per Specimen: | 16 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 1.25x1.25x0.109 | | | | |
| | $F_y$: | 55.6 ksi | $F_u$: | 76.8 ksi | | |
| **Slab:** | Thickness: | 4.25 in. | $f'_c$: | 4715 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4xW4 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 63.32 kips | | | |
| **Peak Shear Load Per Screw:** | 3.96 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.5536 in. | SC5: | 0.6244 in. |
| | SC2: | 0.5573 in. | SC6: | 0.6262 in. |
| | SC3: | 0.5670 in. | SC7: | 0.6335 in. |
| | SC4: | 0.6165 in. | SC8: | 0.6262 in. |

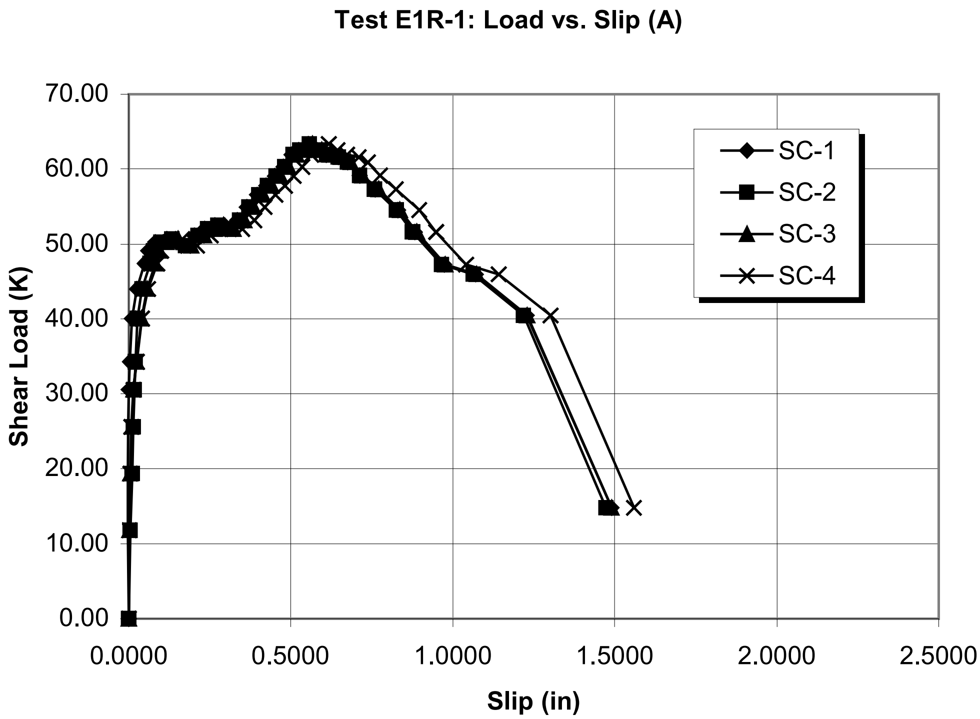
### DAMAGE

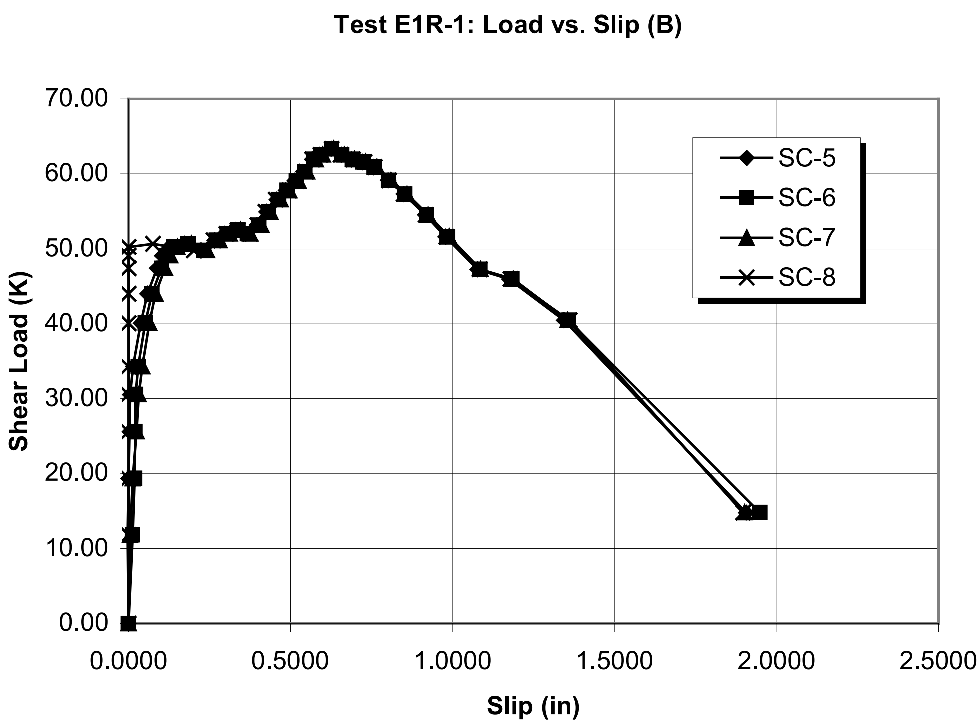


exterior, Slab A interior, Slab B

### COMMENTS

Failure Mode: Screw shear with screw pullout from angles
Screw Rotation ≈ 60° - 70°
Deck debonded; Slight bulging of deck below screws
Angles slightly deformed at screw locations due to rotation of screws
X = Screw sheared off; ☐ = Screw pulled out of angle


Test E1R-1: Load vs. Slip (A)
Shear Load (K)
Slip (in)
SC-1
SC-2
SC-3
SC-4
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000


Test E1R-1: Load vs. Slip (B)
Shear Load (K)
Slip (in)
SC-5
SC-6
SC-7
SC-8
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000

**TEST E1R-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11.81 | 1.04 | -0.0024 | 0.0055 | 0.0018 | 0.0018 | -0.0031 | 0.0122 | 0.0049 | 0.0000 |
| 19.35 | 1.93 | -0.0031 | 0.0110 | 0.0049 | 0.0049 | 0.0000 | 0.0189 | 0.0122 | 0.0000 |
| 25.63 | 2.22 | -0.0012 | 0.0134 | 0.0092 | 0.0085 | 0.0024 | 0.0208 | 0.0250 | 0.0000 |
| 30.53 | 3.08 | 0.0006 | 0.0171 | 0.0134 | 0.0134 | 0.0043 | 0.0220 | 0.0317 | 0.0000 |
| 34.30 | 3.32 | 0.0024 | 0.0208 | 0.0238 | 0.0244 | 0.0140 | 0.0305 | 0.0421 | 0.0000 |
| 40.08 | 4.22 | 0.0098 | 0.0275 | 0.0391 | 0.0409 | 0.0372 | 0.0525 | 0.0641 | 0.0000 |
| 43.97 | 4.59 | 0.0250 | 0.0415 | 0.0562 | 0.0598 | 0.0580 | 0.0720 | 0.0836 | 0.0000 |
| 47.36 | 5.13 | 0.0488 | 0.0659 | 0.0824 | 0.0885 | 0.0885 | 0.1025 | 0.1135 | 0.0000 |
| 49.12 | 5.32 | 0.0598 | 0.0769 | 0.0940 | 0.1007 | 0.1031 | 0.1160 | 0.1282 | 0.0000 |
| 50.25 | 5.35 | 0.0824 | 0.0983 | 0.1160 | 0.1251 | 0.1263 | 0.1404 | 0.1501 | 0.0000 |
| 50.63 | 5.38 | 0.1184 | 0.1337 | 0.1520 | 0.1642 | 0.1721 | 0.1831 | 0.1929 | 0.0751 |
| 49.75 | 5.35 | 0.1617 | 0.1764 | 0.1935 | 0.2106 | 0.2240 | 0.2325 | 0.2417 | 0.2014 |
| 51.13 | 5.26 | 0.2020 | 0.2142 | 0.2325 | 0.2527 | 0.2655 | 0.2722 | 0.2814 | 0.2625 |
| 52.01 | 5.38 | 0.2344 | 0.2441 | 0.2631 | 0.2844 | 0.2972 | 0.3052 | 0.3131 | 0.3021 |
| 52.51 | 5.42 | 0.2655 | 0.2747 | 0.2924 | 0.3156 | 0.3302 | 0.3369 | 0.3448 | 0.3363 |
| 52.01 | 5.50 | 0.2991 | 0.3082 | 0.3229 | 0.3503 | 0.3619 | 0.3680 | 0.3760 | 0.3748 |
| 53.14 | 5.44 | 0.3345 | 0.3418 | 0.3558 | 0.3876 | 0.3955 | 0.4016 | 0.4095 | 0.3973 |
| 54.90 | 5.61 | 0.3644 | 0.3705 | 0.3851 | 0.4187 | 0.4254 | 0.4321 | 0.4388 | 0.4224 |
| 56.53 | 5.69 | 0.3955 | 0.4022 | 0.4150 | 0.4517 | 0.4572 | 0.4633 | 0.4694 | 0.4541 |
| 57.79 | 5.76 | 0.4236 | 0.4291 | 0.4419 | 0.4816 | 0.4846 | 0.4907 | 0.4968 | 0.4956 |
| 59.05 | 5.87 | 0.4504 | 0.4547 | 0.4681 | 0.5090 | 0.5127 | 0.5182 | 0.5243 | 0.5200 |
| 60.30 | 6.18 | 0.4767 | 0.4816 | 0.4932 | 0.5359 | 0.5389 | 0.5444 | 0.5505 | 0.5487 |
| 61.93 | 6.35 | 0.5023 | 0.5066 | 0.5176 | 0.5634 | 0.5670 | 0.5713 | 0.5780 | 0.5676 |
| 62.56 | 6.41 | 0.5249 | 0.5280 | 0.5383 | 0.5859 | 0.5896 | 0.5939 | 0.6006 | 0.5914 |
| 63.32 | 6.50 | 0.5536 | 0.5573 | 0.5670 | 0.6165 | 0.6244 | 0.6262 | 0.6335 | 0.6262 |
| 62.56 | 6.49 | 0.5817 | 0.5841 | 0.5945 | 0.6439 | 0.6561 | 0.6580 | 0.6653 | 0.6543 |
| 61.93 | 6.36 | 0.6085 | 0.6110 | 0.6201 | 0.6732 | 0.6885 | 0.6909 | 0.6976 | 0.6921 |
| 61.56 | 6.43 | 0.6464 | 0.6470 | 0.6549 | 0.7092 | 0.7220 | 0.7245 | 0.7318 | 0.7288 |
| 60.93 | 6.39 | 0.6757 | 0.6757 | 0.6848 | 0.7385 | 0.7574 | 0.7587 | 0.7660 | 0.7599 |
| 59.17 | 6.36 | 0.7129 | 0.7129 | 0.7214 | 0.7764 | 0.8014 | 0.8032 | 0.8099 | 0.8038 |
| 57.29 | 6.43 | 0.7605 | 0.7587 | 0.7703 | 0.8246 | 0.8496 | 0.8521 | 0.8588 | 0.8490 |
| 54.52 | 6.58 | 0.8313 | 0.8264 | 0.8374 | 0.8966 | 0.9149 | 0.9198 | 0.9253 | 0.9174 |
| 51.63 | 6.86 | 0.8820 | 0.8765 | 0.8887 | 0.9479 | 0.9778 | 0.9833 | 0.9888 | 0.9814 |
| 51.63 | 6.86 | 0.8820 | 0.8765 | 0.8893 | 0.9479 | 0.9784 | 0.9839 | 0.9888 | 0.9814 |
| 47.24 | 5.24 | 0.9729 | 0.9662 | 0.9772 | 1.0412 | 1.0766 | 1.0845 | 1.0870 | 1.0833 |
| 45.98 | 5.54 | 1.0711 | 1.0626 | 1.0742 | 1.1413 | 1.1749 | 1.1846 | 1.1877 | 1.1798 |
| 40.45 | 5.74 | 1.2286 | 1.2182 | 1.2298 | 1.3012 | 1.3439 | 1.3580 | 1.3555 | 1.3616 |
| 14.82 | 4.96 | 1.4898 | 1.4727 | 1.4904 | 1.5588 | 1.9061 | 1.9488 | 1.9018 | 1.8975 |

## PUSHOUT TEST SUMMARY SHEET

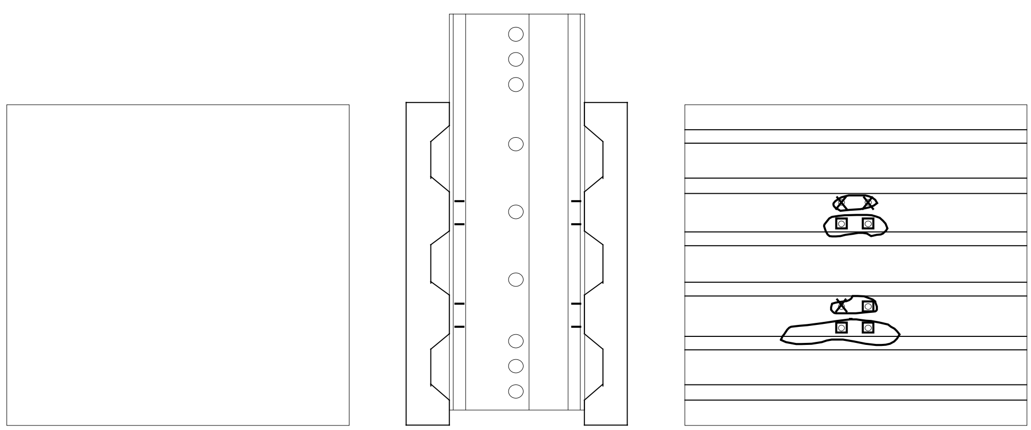
Test: E1R-2 Test Date: 19-Dec-98

Test Designation: SC-8-4.0-0.109-2VL-4.25-2R

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in. | No. Per Specimen: | 16 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 1.25x1.25x0.109 | | | | |
| | $F_y$: | 55.6 ksi | $F_u$: | 76.8 ksi | | |
| **Slab:** | Thickness: | 4.25 in. | $f'_c$: | 4715 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4xW4 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 62.44 kips | | | |
| **Peak Shear Load Per Screw:** | 3.90 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.4553 in. | SC5: | 0.5847 in. |
| | SC2: | 0.4749 in. | SC6: | 0.5986 in. |
| | SC3: | 0.4633 in. | SC7: | 0.5945 in. |
| | SC4: | 0.3247 in. | SC8: | 0.3485 in. |

### DAMAGE



exterior, Slab A

interior, Slab B

### COMMENTS

Failure Mode: Screw shear with screw pullout from angles

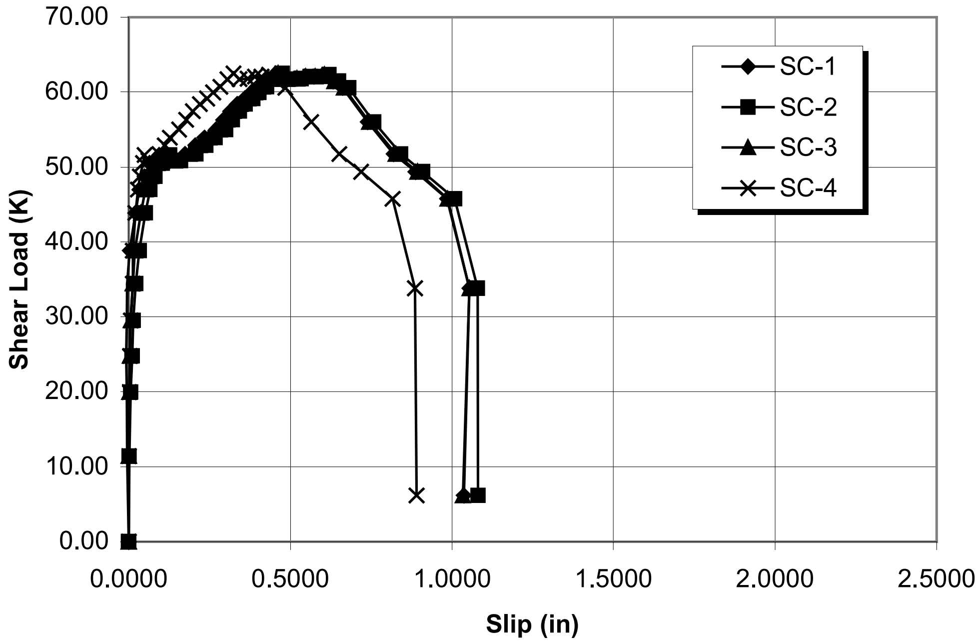
Screw Rotation ≈ 60° - 70°

Deck debonded; Slight bulging of deck below screws

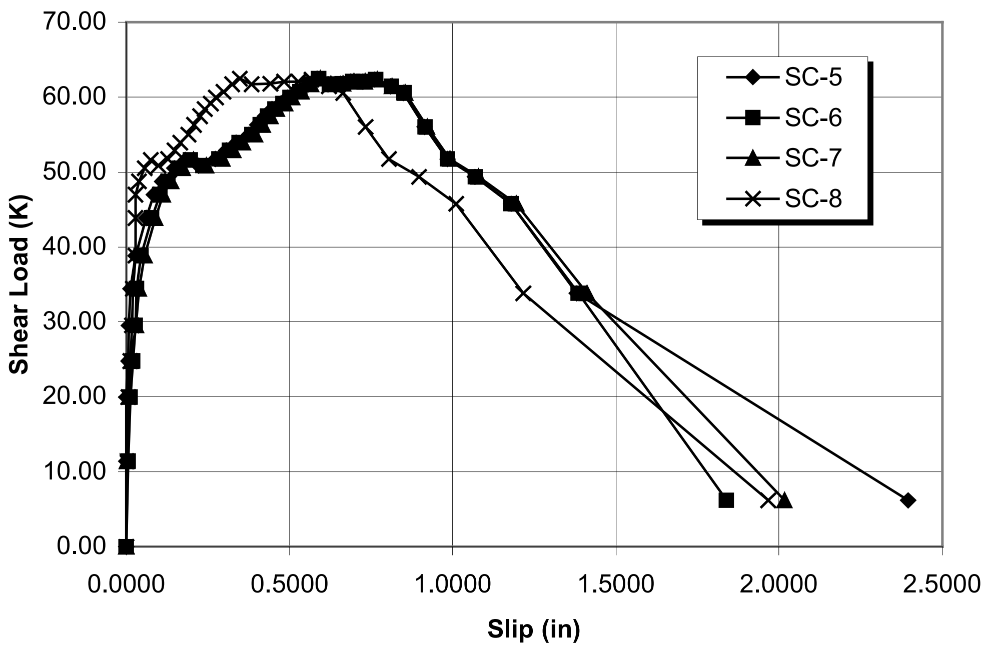
Angles slightly deformed at screw locations due to rotation of screws

X = Screw sheared off; □ = Screw pulled out of angle

Test E1R-2: Load vs. Slip (A)




Test E1R-2: Load vs. Slip (B)



**TEST E1R-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0006 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11.43 | 1.19 | -0.0049 | 0.0018 | 0.0006 | 0.0006 | 0.0000 | 0.0055 | 0.0018 | 0.0000 |
| 19.97 | 1.98 | -0.0067 | 0.0067 | 0.0018 | 0.0012 | 0.0000 | 0.0122 | 0.0079 | 0.0061 |
| 24.75 | 2.53 | -0.0073 | 0.0104 | 0.0031 | 0.0024 | 0.0067 | 0.0195 | 0.0146 | 0.0128 |
| 29.52 | 2.52 | -0.0067 | 0.0146 | 0.0061 | 0.0067 | 0.0085 | 0.0275 | 0.0299 | 0.0171 |
| 34.42 | 3.61 | -0.0043 | 0.0220 | 0.0122 | 0.0122 | 0.0122 | 0.0311 | 0.0391 | 0.0208 |
| 38.82 | 4.05 | 0.0031 | 0.0330 | 0.0195 | 0.0128 | 0.0275 | 0.0458 | 0.0555 | 0.0287 |
| 43.84 | 4.52 | 0.0201 | 0.0519 | 0.0378 | 0.0208 | 0.0604 | 0.0775 | 0.0885 | 0.0287 |
| 46.98 | 4.95 | 0.0336 | 0.0659 | 0.0513 | 0.0287 | 0.0842 | 0.1031 | 0.1129 | 0.0287 |
| 48.74 | 5.17 | 0.0494 | 0.0824 | 0.0671 | 0.0342 | 0.1086 | 0.1276 | 0.1367 | 0.0385 |
| 50.50 | 5.72 | 0.0714 | 0.1044 | 0.0885 | 0.0433 | 0.1459 | 0.1630 | 0.1727 | 0.0568 |
| 51.63 | 5.74 | 0.0946 | 0.1282 | 0.1111 | 0.0494 | 0.1807 | 0.1959 | 0.2063 | 0.0751 |
| 50.88 | 5.70 | 0.1282 | 0.1611 | 0.1434 | 0.0610 | 0.2216 | 0.2350 | 0.2448 | 0.0983 |
| 51.76 | 5.54 | 0.1746 | 0.2069 | 0.1886 | 0.0940 | 0.2728 | 0.2838 | 0.2948 | 0.1276 |
| 52.89 | 5.65 | 0.2063 | 0.2393 | 0.2191 | 0.1123 | 0.3058 | 0.3168 | 0.3271 | 0.1477 |
| 53.89 | 5.80 | 0.2350 | 0.2667 | 0.2478 | 0.1282 | 0.3375 | 0.3467 | 0.3571 | 0.1660 |
| 55.03 | 5.63 | 0.2704 | 0.3003 | 0.2820 | 0.1562 | 0.3766 | 0.3851 | 0.3943 | 0.1910 |
| 56.28 | 5.73 | 0.2924 | 0.3217 | 0.3040 | 0.1776 | 0.4010 | 0.4095 | 0.4175 | 0.2081 |
| 57.41 | 5.71 | 0.3143 | 0.3424 | 0.3247 | 0.1990 | 0.4242 | 0.4333 | 0.4407 | 0.2258 |
| 58.42 | 5.59 | 0.3351 | 0.3607 | 0.3461 | 0.2197 | 0.4468 | 0.4547 | 0.4620 | 0.2405 |
| 59.17 | 5.78 | 0.3595 | 0.3833 | 0.3693 | 0.2423 | 0.4718 | 0.4803 | 0.4865 | 0.2588 |
| 59.92 | 5.86 | 0.3796 | 0.4022 | 0.3894 | 0.2606 | 0.4950 | 0.5029 | 0.5084 | 0.2740 |
| 60.68 | 5.78 | 0.4047 | 0.4260 | 0.4138 | 0.2832 | 0.5249 | 0.5316 | 0.5365 | 0.2979 |
| 61.68 | 5.86 | 0.4315 | 0.4517 | 0.4401 | 0.3058 | 0.5560 | 0.5615 | 0.5664 | 0.3241 |
| 62.44 | 5.95 | 0.4553 | 0.4749 | 0.4633 | 0.3247 | 0.5847 | 0.5896 | 0.5945 | 0.3485 |
| 61.68 | 6.01 | 0.4797 | 0.4980 | 0.4871 | 0.3430 | 0.6183 | 0.6226 | 0.6262 | 0.3839 |
| 61.81 | 6.24 | 0.5151 | 0.5328 | 0.5200 | 0.3680 | 0.6561 | 0.6610 | 0.6641 | 0.4407 |
| 62.06 | 6.23 | 0.5432 | 0.5609 | 0.5469 | 0.3900 | 0.6885 | 0.6934 | 0.6964 | 0.4840 |
| 62.06 | 6.33 | 0.5725 | 0.5908 | 0.5768 | 0.4114 | 0.7245 | 0.7281 | 0.7312 | 0.5267 |
| 62.31 | 6.64 | 0.6006 | 0.6195 | 0.6055 | 0.4346 | 0.7617 | 0.7648 | 0.7690 | 0.5670 |
| 61.43 | 6.55 | 0.6323 | 0.6500 | 0.6360 | 0.4584 | 0.8087 | 0.8118 | 0.8148 | 0.6201 |
| 60.55 | 6.60 | 0.6616 | 0.6805 | 0.6659 | 0.4846 | 0.8490 | 0.8521 | 0.8551 | 0.6641 |
| 56.03 | 6.85 | 0.7391 | 0.7581 | 0.7440 | 0.5646 | 0.9143 | 0.9161 | 0.9222 | 0.7330 |
| 51.76 | 5.67 | 0.8197 | 0.8411 | 0.8258 | 0.6519 | 0.9839 | 0.9845 | 0.9918 | 0.8044 |
| 49.37 | 6.18 | 0.8875 | 0.9094 | 0.8929 | 0.7196 | 1.0687 | 1.0693 | 1.0797 | 0.8966 |
| 45.73 | 4.62 | 0.9851 | 1.0089 | 0.9863 | 0.8160 | 1.1791 | 1.1791 | 1.1950 | 1.0113 |
| 33.79 | 3.88 | 1.0534 | 1.0791 | 1.0534 | 0.8862 | 1.3806 | 1.3842 | 1.4111 | 1.2158 |
| 6.16 | 1.58 | 1.0369 | 1.0815 | 1.0333 | 0.8911 | 2.3962 | 1.8389 | 2.0172 | 1.9659 |

## PUSHOUT TEST SUMMARY SHEET

Test: E2-1 Test Date: 6-Oct-98

Test Designation: SC-8-4.0-0.187-2VL-4.25-1

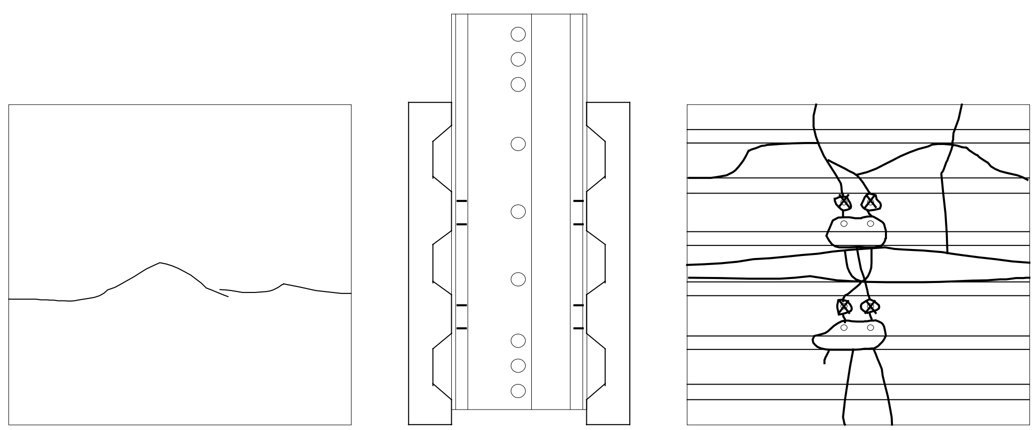
### SPECIMEN DESCRIPTION

| | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in. | No. Per Specimen: | 16 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.187 | | | | |
| | $F_y$: | 61.9 ksi | $F_u$: | 85.6 ksi | | |
| **Slab:** | Thickness: | 4.25 in. | $f'_c$: | 7162 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4xW4 | | | | |

### TEST RESULTS

| | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 96.23 kips | | | |
| **Peak Shear Load Per Screw:** | 6.01 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.5029 in. | SC5: | 0.7589 in. |
| | SC2: | 0.7569 in. | SC6: | 0.6587 in. |
| | SC3: | 0.5525 in. | SC7: | 0.7356 in. |
| | SC4: | 0.7248 in. | SC8: | 0.7063 in. |

### DAMAGE

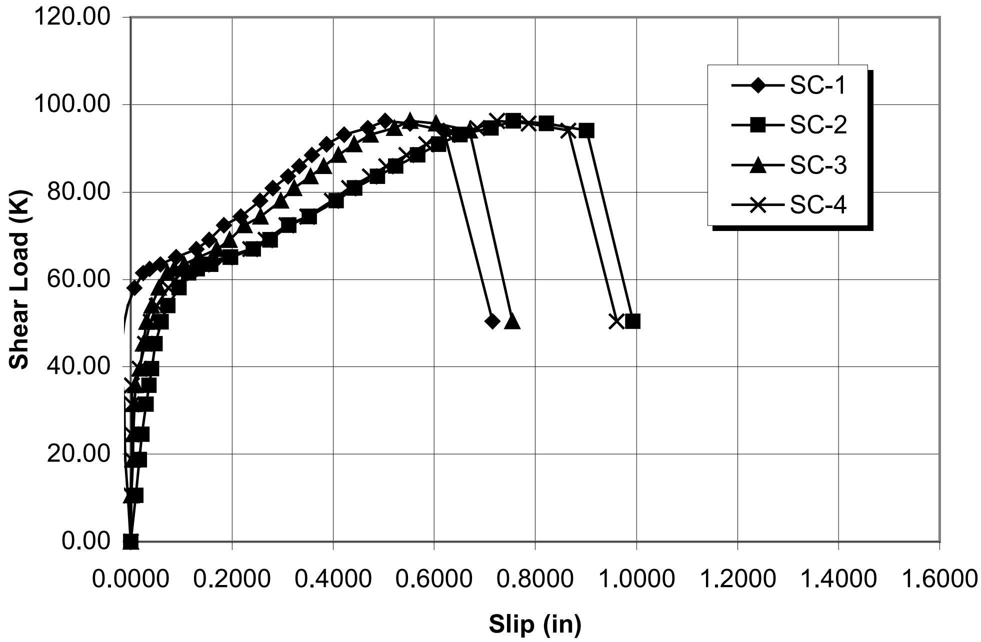


exterior, Slab A interior, Slab B

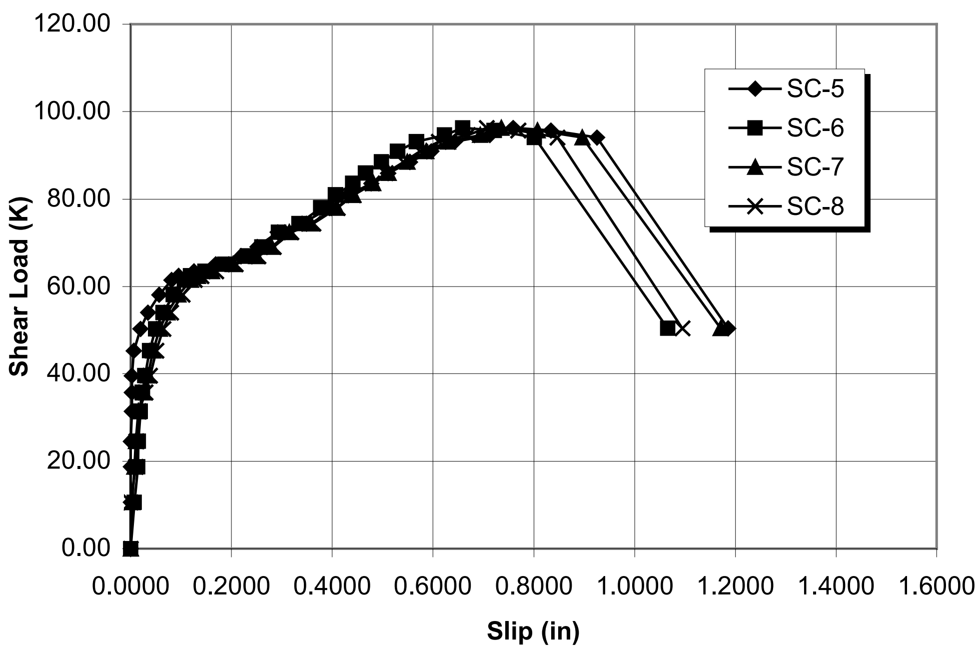
### COMMENTS

Failure Mode: Screw shear with slight top chord buckling observed
Screw Rotation ≈ 40° - 50°
Deck debonded; Slight bulging of deck below screws
Angles deformed at screw locations due to rotation of screws
X = Screw sheared off

**Test E2-1: Load vs. Slip (A)**




**Test E2-1: Load vs. Slip (B)**



**TEST E2-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10.62 | 1.07 | -0.0064 | 0.0104 | 0.0011 | 0.0000 | 0.0000 | 0.0068 | 0.0027 | 0.0004 |
| 18.72 | 1.87 | -0.0115 | 0.0172 | 0.0040 | 0.0018 | -0.0004 | 0.0139 | 0.0066 | 0.0101 |
| 24.56 | 2.40 | -0.0123 | 0.0223 | 0.0055 | 0.0016 | 0.0002 | 0.0147 | 0.0097 | 0.0108 |
| 31.47 | 2.97 | -0.0130 | 0.0300 | 0.0068 | 0.0018 | 0.0020 | 0.0187 | 0.0154 | 0.0165 |
| 35.68 | 3.40 | -0.0161 | 0.0366 | 0.0095 | 0.0020 | 0.0024 | 0.0236 | 0.0253 | 0.0295 |
| 39.57 | 3.87 | -0.0179 | 0.0408 | 0.0185 | 0.0168 | 0.0024 | 0.0280 | 0.0339 | 0.0381 |
| 45.29 | 4.47 | -0.0181 | 0.0487 | 0.0242 | 0.0280 | 0.0062 | 0.0374 | 0.0443 | 0.0500 |
| 50.31 | 4.87 | -0.0130 | 0.0602 | 0.0317 | 0.0396 | 0.0187 | 0.0498 | 0.0577 | 0.0643 |
| 54.02 | 5.39 | -0.0060 | 0.0738 | 0.0408 | 0.0515 | 0.0344 | 0.0643 | 0.0727 | 0.0802 |
| 58.10 | 5.93 | 0.0075 | 0.0952 | 0.0555 | 0.0747 | 0.0566 | 0.0850 | 0.0947 | 0.1026 |
| 61.43 | 6.40 | 0.0242 | 0.1150 | 0.0729 | 0.1000 | 0.0809 | 0.1066 | 0.1188 | 0.1271 |
| 62.44 | 6.58 | 0.0370 | 0.1322 | 0.0855 | 0.1176 | 0.0947 | 0.1192 | 0.1328 | 0.1406 |
| 63.44 | 6.60 | 0.0581 | 0.1584 | 0.1053 | 0.1410 | 0.1254 | 0.1476 | 0.1617 | 0.1692 |
| 65.01 | 6.68 | 0.0899 | 0.1974 | 0.1344 | 0.1875 | 0.1688 | 0.1864 | 0.2027 | 0.2080 |
| 66.90 | 6.80 | 0.1295 | 0.2430 | 0.1699 | 0.2368 | 0.2190 | 0.2318 | 0.2491 | 0.2534 |
| 68.97 | 7.03 | 0.1555 | 0.2754 | 0.1956 | 0.2670 | 0.2516 | 0.2608 | 0.2796 | 0.2838 |
| 72.42 | 7.33 | 0.1846 | 0.3128 | 0.2247 | 0.3084 | 0.2917 | 0.2936 | 0.3148 | 0.3188 |
| 74.37 | 7.67 | 0.2172 | 0.3533 | 0.2569 | 0.3492 | 0.3403 | 0.3337 | 0.3573 | 0.3624 |
| 77.95 | 7.92 | 0.2560 | 0.4062 | 0.2967 | 0.3972 | 0.3952 | 0.3780 | 0.4084 | 0.4106 |
| 80.84 | 8.26 | 0.2806 | 0.4424 | 0.3229 | 0.4316 | 0.4322 | 0.4071 | 0.4419 | 0.4424 |
| 83.61 | 8.63 | 0.3106 | 0.4879 | 0.3556 | 0.4727 | 0.4776 | 0.4408 | 0.4816 | 0.4791 |
| 85.93 | 8.73 | 0.3331 | 0.5247 | 0.3811 | 0.5051 | 0.5106 | 0.4659 | 0.5115 | 0.5054 |
| 88.44 | 8.87 | 0.3582 | 0.5673 | 0.4109 | 0.5457 | 0.5541 | 0.4976 | 0.5496 | 0.5406 |
| 90.89 | 9.15 | 0.3875 | 0.6091 | 0.4417 | 0.5842 | 0.5968 | 0.5303 | 0.5867 | 0.5741 |
| 93.15 | 9.34 | 0.4214 | 0.6512 | 0.4743 | 0.6265 | 0.6433 | 0.5677 | 0.6303 | 0.6115 |
| 94.60 | 9.63 | 0.4688 | 0.7129 | 0.5214 | 0.6856 | 0.7124 | 0.6226 | 0.6935 | 0.6691 |
| 96.23 | 9.91 | 0.5029 | 0.7569 | 0.5525 | 0.7248 | 0.7589 | 0.6587 | 0.7356 | 0.7063 |
| 95.73 | 10.05 | 0.5525 | 0.8226 | 0.6040 | 0.7869 | 0.8341 | 0.7217 | 0.8076 | 0.7691 |
| 94.10 | 10.37 | 0.6186 | 0.9015 | 0.6706 | 0.8655 | 0.9253 | 0.8019 | 0.8964 | 0.8473 |
| 50.44 | 10.72 | 0.7158 | 0.9935 | 0.7549 | 0.9607 | 1.1861 | 1.0659 | 1.1711 | 1.0949 |

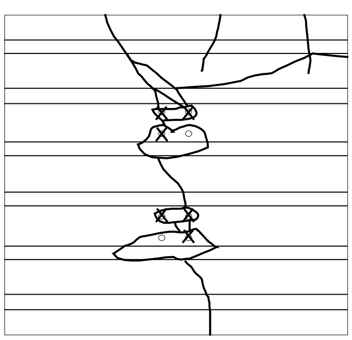
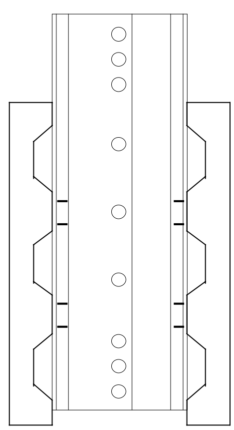
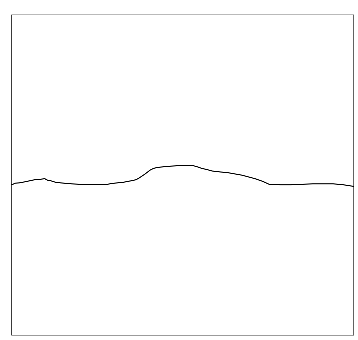
## PUSHOUT TEST SUMMARY SHEET

Test: E2-2  
Test Date: 15-Oct-98  
Test Designation: SC-8-4.0-0.187-2VL-4.25-2

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in. | No. Per Specimen: | 16 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.187 | | | | |
| | $F_y$: | 61.9 ksi | $F_u$: | 85.6 ksi | | |
| **Slab:** | Thickness: | 4.25 in. | $f'_c$: | 7162 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4xW4 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 98.81 kips | | | |
| **Peak Shear Load Per Screw:** | 6.18 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.7732 in. | SC5: | 0.6862 in. |
| | SC2: | 0.8369 in. | SC6: | 0.6713 in. |
| | SC3: | 0.7671 in. | SC7: | 0.7005 in. |
| | SC4: | 0.8722 in. | SC8: | 0.7360 in. |

### DAMAGE

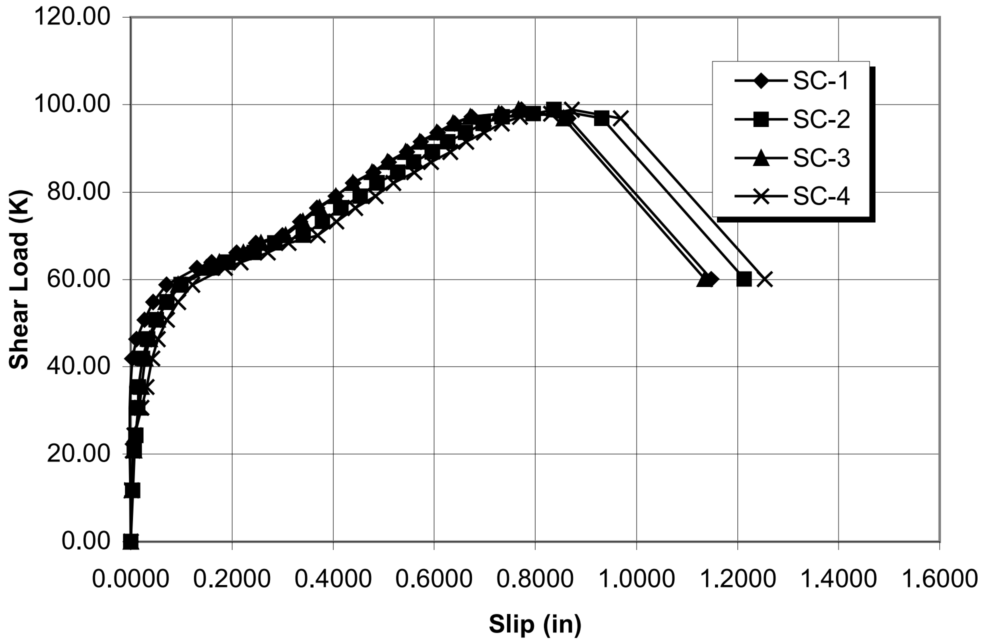
interior, Slab A

exterior, Slab B

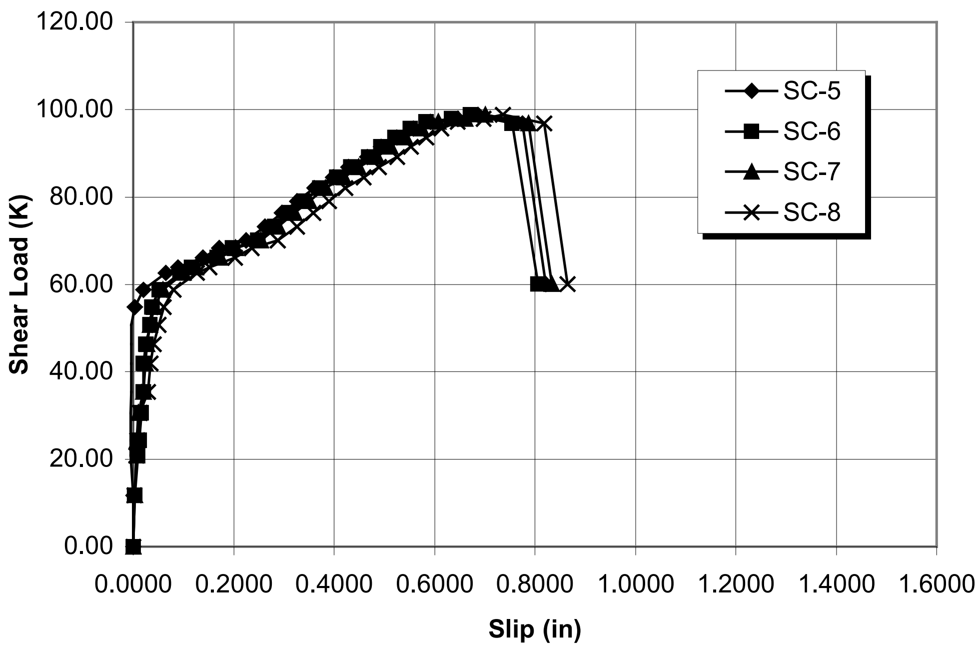
### COMMENTS

Failure Mode: Screw shear  
Screw Rotation ≈ 40° - 50°  
Deck debonded; Slight bulging of deck below screws  
Angles deformed at screw locations due to rotation of screws  
X = Screw sheared off

**Test E2-2: Load vs. Slip (A)**




**Test E2-2: Load vs. Slip (B)**



**TEST E2-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | -0.0002 | 0.0000 | -0.0004 | -0.0004 | 0.0000 | 0.0000 | 0.0004 | -0.0002 |
| 11.75 | 1.03 | -0.0009 | 0.0037 | 0.0016 | 0.0005 | 0.0000 | 0.0035 | 0.0026 | 0.0016 |
| 20.85 | 2.04 | -0.0022 | 0.0073 | 0.0060 | 0.0044 | -0.0055 | 0.0093 | 0.0073 | 0.0060 |
| 24.31 | 2.42 | -0.0022 | 0.0097 | 0.0077 | 0.0071 | -0.0055 | 0.0123 | 0.0075 | 0.0079 |
| 30.59 | 2.97 | -0.0018 | 0.0141 | 0.0172 | 0.0214 | -0.0053 | 0.0163 | 0.0104 | 0.0134 |
| 35.43 | 3.52 | -0.0015 | 0.0152 | 0.0207 | 0.0311 | -0.0040 | 0.0200 | 0.0201 | 0.0293 |
| 41.90 | 4.07 | 0.0027 | 0.0229 | 0.0282 | 0.0419 | -0.0040 | 0.0205 | 0.0238 | 0.0346 |
| 46.36 | 4.54 | 0.0110 | 0.0335 | 0.0372 | 0.0533 | -0.0038 | 0.0253 | 0.0277 | 0.0407 |
| 50.69 | 5.00 | 0.0267 | 0.0507 | 0.0535 | 0.0718 | -0.0037 | 0.0330 | 0.0337 | 0.0507 |
| 54.84 | 5.44 | 0.0445 | 0.0712 | 0.0696 | 0.0932 | 0.0029 | 0.0372 | 0.0418 | 0.0608 |
| 58.73 | 6.02 | 0.0709 | 0.0996 | 0.0938 | 0.1221 | 0.0198 | 0.0518 | 0.0582 | 0.0802 |
| 62.56 | 6.42 | 0.1313 | 0.1621 | 0.1492 | 0.1866 | 0.0646 | 0.0928 | 0.1002 | 0.1267 |
| 63.94 | 6.50 | 0.1597 | 0.1919 | 0.1753 | 0.2172 | 0.0886 | 0.1161 | 0.1243 | 0.1516 |
| 66.08 | 6.70 | 0.2095 | 0.2443 | 0.2229 | 0.2708 | 0.1384 | 0.1666 | 0.1727 | 0.2024 |
| 68.28 | 6.94 | 0.2476 | 0.2849 | 0.2577 | 0.3124 | 0.1714 | 0.1972 | 0.2035 | 0.2364 |
| 70.04 | 7.25 | 0.3000 | 0.3412 | 0.3056 | 0.3692 | 0.2249 | 0.2481 | 0.2544 | 0.2873 |
| 73.24 | 7.36 | 0.3349 | 0.3789 | 0.3397 | 0.4067 | 0.2622 | 0.2820 | 0.2888 | 0.3256 |
| 76.32 | 7.71 | 0.3686 | 0.4153 | 0.3728 | 0.4439 | 0.2956 | 0.3131 | 0.3210 | 0.3587 |
| 79.08 | 8.04 | 0.4053 | 0.4538 | 0.4060 | 0.4836 | 0.3262 | 0.3399 | 0.3507 | 0.3895 |
| 82.04 | 8.28 | 0.4399 | 0.4875 | 0.4390 | 0.5195 | 0.3600 | 0.3712 | 0.3833 | 0.4225 |
| 84.55 | 8.55 | 0.4800 | 0.5280 | 0.4769 | 0.5609 | 0.3976 | 0.4051 | 0.4192 | 0.4589 |
| 86.87 | 8.61 | 0.5102 | 0.5593 | 0.5074 | 0.5933 | 0.4280 | 0.4336 | 0.4483 | 0.4890 |
| 89.13 | 8.85 | 0.5461 | 0.5966 | 0.5430 | 0.6318 | 0.4659 | 0.4688 | 0.4853 | 0.5259 |
| 91.46 | 9.37 | 0.5737 | 0.6270 | 0.5719 | 0.6633 | 0.4932 | 0.4933 | 0.5120 | 0.5532 |
| 93.53 | 9.53 | 0.6063 | 0.6624 | 0.6045 | 0.6979 | 0.5250 | 0.5219 | 0.5417 | 0.5831 |
| 95.67 | 9.64 | 0.6398 | 0.6977 | 0.6371 | 0.7332 | 0.5576 | 0.5518 | 0.5737 | 0.6137 |
| 97.17 | 9.82 | 0.6741 | 0.7343 | 0.6715 | 0.7693 | 0.5917 | 0.5831 | 0.6074 | 0.6461 |
| 97.86 | 9.97 | 0.7332 | 0.7962 | 0.7279 | 0.8310 | 0.6461 | 0.6340 | 0.6615 | 0.6975 |
| 98.81 | 10.14 | 0.7732 | 0.8369 | 0.7671 | 0.8722 | 0.6862 | 0.6713 | 0.7005 | 0.7360 |
| 96.86 | 10.34 | 0.8655 | 0.9316 | 0.8569 | 0.9695 | 0.7752 | 0.7549 | 0.7871 | 0.8182 |
| 60.11 | 7.11 | 1.1485 | 1.2134 | 1.1348 | 1.2542 | 0.8213 | 0.8059 | 0.8332 | 0.8645 |

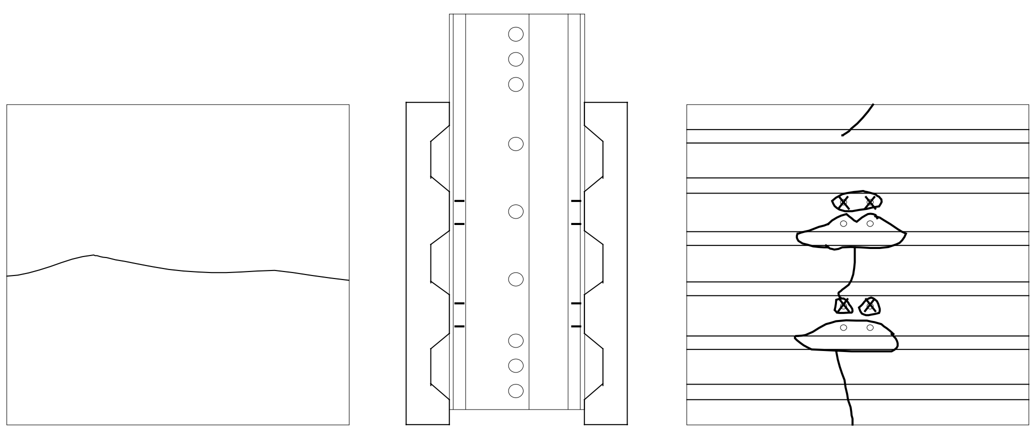
## PUSHOUT TEST SUMMARY SHEET

Test: E2R-1 Test Date: 23-Dec-98
Test Designation: SC-8-4.0-0.187-2VL-4.25-1R

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in. | No. Per Specimen: | 16 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.187 | | | | |
| | $F_y$: | 61.9 ksi | $F_u$: | 85.6 ksi | | |
| **Slab:** | Thickness: | 4.25 in. | $f'_c$: | 4953 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4xW4 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 93.09 kips | | | |
| **Peak Shear Load Per Screw:** | 5.82 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.9009 in. | SC5: | 1.0003 in. |
| | SC2: | 0.6140 in. | SC6: | 0.9735 in. |
| | SC3: | 0.9314 in. | SC7: | 1.0351 in. |
| | SC4: | 0.9949 in. | SC8: | 0.8173 in. |

### DAMAGE

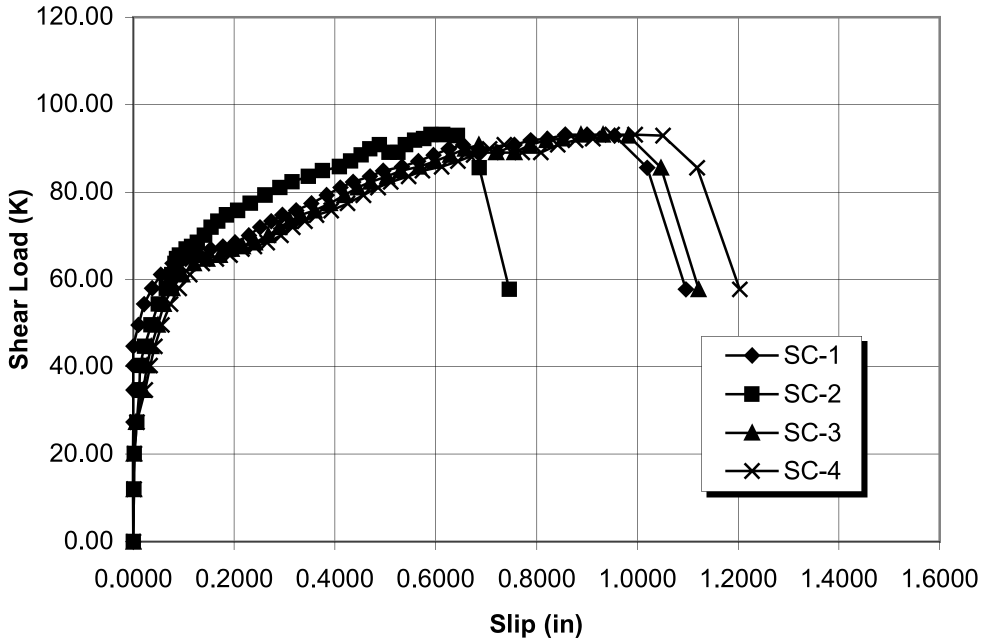


exterior, Slab A interior, Slab B

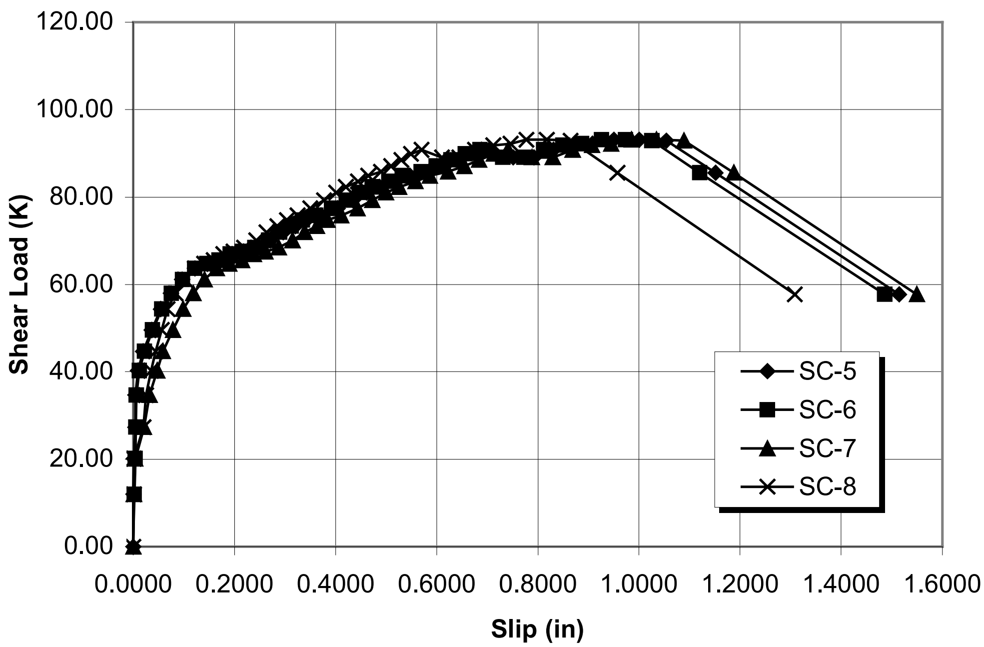
### COMMENTS

Failure Mode: Screw shear
Screw Rotation ≈ 30° - 40°
Deck debonded; Slight bulging of deck below screws
Angles slightly deformed at screw locations due to rotation of screws
X = Screw sheared off

Test E2R-1: Load vs. Slip (A)




Test E2R-1: Load vs. Slip (B)



**TEST E2R-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -0.0006 | 0.0000 | 0.0000 |
| 11.93 | 0.94 | -0.0006 | 0.0012 | 0.0006 | 0.0006 | 0.0000 | 0.0024 | 0.0006 | 0.0006 |
| 20.10 | 2.05 | -0.0006 | 0.0024 | 0.0012 | 0.0024 | 0.0006 | 0.0037 | 0.0037 | 0.0012 |
| 27.39 | 3.02 | 0.0000 | 0.0067 | 0.0049 | 0.0067 | 0.0037 | 0.0055 | 0.0214 | 0.0201 |
| 34.67 | 3.38 | 0.0000 | 0.0122 | 0.0195 | 0.0232 | 0.0043 | 0.0061 | 0.0323 | 0.0250 |
| 40.33 | 4.90 | 0.0000 | 0.0134 | 0.0275 | 0.0330 | 0.0092 | 0.0122 | 0.0470 | 0.0354 |
| 44.72 | 4.68 | 0.0000 | 0.0226 | 0.0354 | 0.0427 | 0.0195 | 0.0226 | 0.0586 | 0.0439 |
| 49.62 | 5.18 | 0.0098 | 0.0354 | 0.0482 | 0.0568 | 0.0360 | 0.0378 | 0.0781 | 0.0568 |
| 54.40 | 5.49 | 0.0214 | 0.0494 | 0.0610 | 0.0732 | 0.0543 | 0.0562 | 0.0983 | 0.0671 |
| 57.91 | 5.96 | 0.0372 | 0.0653 | 0.0781 | 0.0909 | 0.0745 | 0.0751 | 0.1184 | 0.0830 |
| 61.06 | 6.34 | 0.0549 | 0.0763 | 0.0964 | 0.1117 | 0.0964 | 0.0977 | 0.1410 | 0.1019 |
| 63.69 | 6.67 | 0.0781 | 0.0824 | 0.1202 | 0.1367 | 0.1221 | 0.1215 | 0.1654 | 0.1215 |
| 64.70 | 6.88 | 0.1044 | 0.0854 | 0.1465 | 0.1648 | 0.1471 | 0.1459 | 0.1898 | 0.1398 |
| 65.58 | 6.99 | 0.1312 | 0.0922 | 0.1721 | 0.1923 | 0.1721 | 0.1697 | 0.2155 | 0.1593 |
| 66.96 | 6.99 | 0.1532 | 0.1050 | 0.1947 | 0.2155 | 0.1947 | 0.1917 | 0.2380 | 0.1782 |
| 67.46 | 7.10 | 0.1776 | 0.1166 | 0.2173 | 0.2405 | 0.2179 | 0.2148 | 0.2618 | 0.1978 |
| 68.47 | 7.16 | 0.2014 | 0.1276 | 0.2411 | 0.2655 | 0.2429 | 0.2399 | 0.2875 | 0.2197 |
| 70.10 | 7.32 | 0.2289 | 0.1416 | 0.2673 | 0.2930 | 0.2710 | 0.2673 | 0.3149 | 0.2429 |
| 71.98 | 7.59 | 0.2515 | 0.1544 | 0.2893 | 0.3162 | 0.2966 | 0.2899 | 0.3394 | 0.2637 |
| 73.37 | 7.65 | 0.2734 | 0.1678 | 0.3107 | 0.3406 | 0.3210 | 0.3131 | 0.3625 | 0.2850 |
| 74.75 | 7.84 | 0.2954 | 0.1843 | 0.3320 | 0.3632 | 0.3430 | 0.3345 | 0.3845 | 0.3033 |
| 75.75 | 8.02 | 0.3229 | 0.2069 | 0.3589 | 0.3931 | 0.3711 | 0.3607 | 0.4114 | 0.3247 |
| 77.39 | 8.16 | 0.3534 | 0.2325 | 0.3894 | 0.4254 | 0.4041 | 0.3918 | 0.4431 | 0.3503 |
| 79.27 | 8.29 | 0.3833 | 0.2618 | 0.4187 | 0.4559 | 0.4340 | 0.4211 | 0.4730 | 0.3772 |
| 81.03 | 8.34 | 0.4108 | 0.2905 | 0.4456 | 0.4858 | 0.4614 | 0.4480 | 0.4999 | 0.4016 |
| 82.29 | 8.50 | 0.4364 | 0.3149 | 0.4706 | 0.5109 | 0.4865 | 0.4724 | 0.5255 | 0.4205 |
| 83.54 | 8.57 | 0.4694 | 0.3473 | 0.5035 | 0.5457 | 0.5194 | 0.5054 | 0.5585 | 0.4449 |
| 84.80 | 8.64 | 0.4956 | 0.3754 | 0.5304 | 0.5731 | 0.5469 | 0.5316 | 0.5859 | 0.4651 |
| 85.80 | 8.80 | 0.5334 | 0.4089 | 0.5676 | 0.6122 | 0.5841 | 0.5688 | 0.6226 | 0.4895 |
| 87.06 | 9.02 | 0.5652 | 0.4315 | 0.5981 | 0.6445 | 0.6158 | 0.5994 | 0.6543 | 0.5096 |
| 88.44 | 9.26 | 0.5957 | 0.4523 | 0.6293 | 0.6757 | 0.6458 | 0.6287 | 0.6842 | 0.5298 |
| 89.82 | 9.25 | 0.6256 | 0.4694 | 0.6580 | 0.7068 | 0.6750 | 0.6567 | 0.7135 | 0.5487 |
| 90.83 | 9.27 | 0.6543 | 0.4883 | 0.6854 | 0.7355 | 0.7037 | 0.6854 | 0.7416 | 0.5701 |
| 89.07 | 9.45 | 0.6885 | 0.5078 | 0.7202 | 0.7715 | 0.7507 | 0.7312 | 0.7886 | 0.6104 |
| 89.07 | 9.59 | 0.7233 | 0.5249 | 0.7556 | 0.8081 | 0.7922 | 0.7727 | 0.8301 | 0.6445 |
| 90.83 | 9.64 | 0.7556 | 0.5402 | 0.7861 | 0.8417 | 0.8307 | 0.8118 | 0.8685 | 0.6763 |
| 91.83 | 9.37 | 0.7880 | 0.5579 | 0.8197 | 0.8771 | 0.8698 | 0.8502 | 0.9070 | 0.7117 |
| 92.21 | 9.45 | 0.8215 | 0.5762 | 0.8521 | 0.9113 | 0.9082 | 0.8868 | 0.9448 | 0.7458 |
| 93.09 | 9.50 | 0.8569 | 0.5908 | 0.8881 | 0.9503 | 0.9503 | 0.9259 | 0.9851 | 0.7776 |
| 93.09 | 9.51 | 0.9009 | 0.6140 | 0.9314 | 0.9949 | 1.0003 | 0.9735 | 1.0351 | 0.8173 |
| 92.84 | 9.62 | 0.9552 | 0.6427 | 0.9821 | 1.0504 | 1.0540 | 1.0253 | 1.0888 | 0.8649 |
| 85.55 | 8.91 | 1.0192 | 0.6860 | 1.0467 | 1.1187 | 1.1511 | 1.1199 | 1.1877 | 0.9576 |
| 57.79 | 5.16 | 1.0961 | 0.7465 | 1.1218 | 1.2036 | 1.5142 | 1.4862 | 1.5502 | 1.3079 |

## PUSHOUT TEST SUMMARY SHEET

Test: E2R-2 Test Date: 23-Dec-98
Test Designation: SC-8-4.0-0.187-2VL-4.25-2R

### SPECIMEN DESCRIPTION

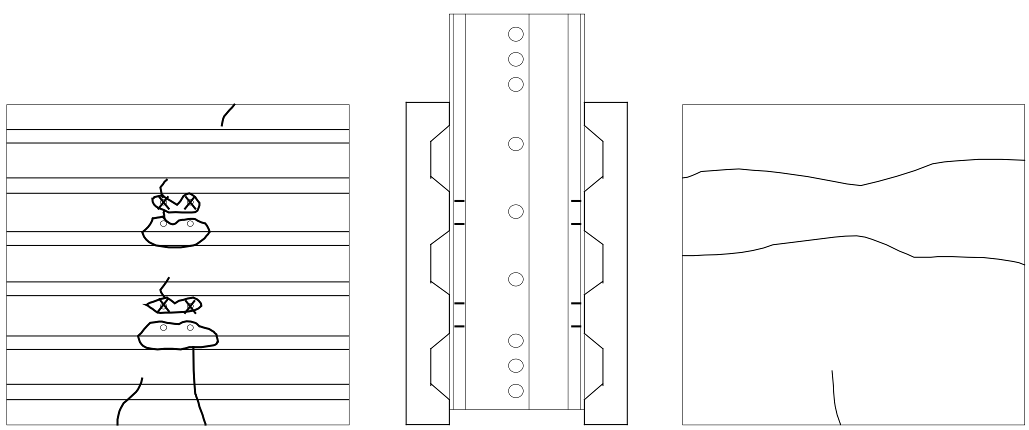
| | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in. | No. Per Specimen: | 16 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.187 | | | | |
| | $F_y$: | 61.9 ksi | $F_u$: | 85.6 ksi | | |
| **Slab:** | Thickness: | 4.25 in. | $f'_c$: | 4953 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4xW4 | | | | |

### TEST RESULTS

**Peak Shear Load:** 89.70 kips
**Peak Shear Load Per Screw:** 5.60 kips
**Slip at Peak Shear Load:**

| | | | |
|---|---|---|---|
| SC1: | 0.7031 in. | SC5: | 0.6879 in. |
| SC2: | 0.7373 in. | SC6: | 0.6622 in. |
| SC3: | 0.7318 in. | SC7: | 0.7349 in. |
| SC4: | 0.7819 in. | SC8: | 0.6946 in. |

### DAMAGE

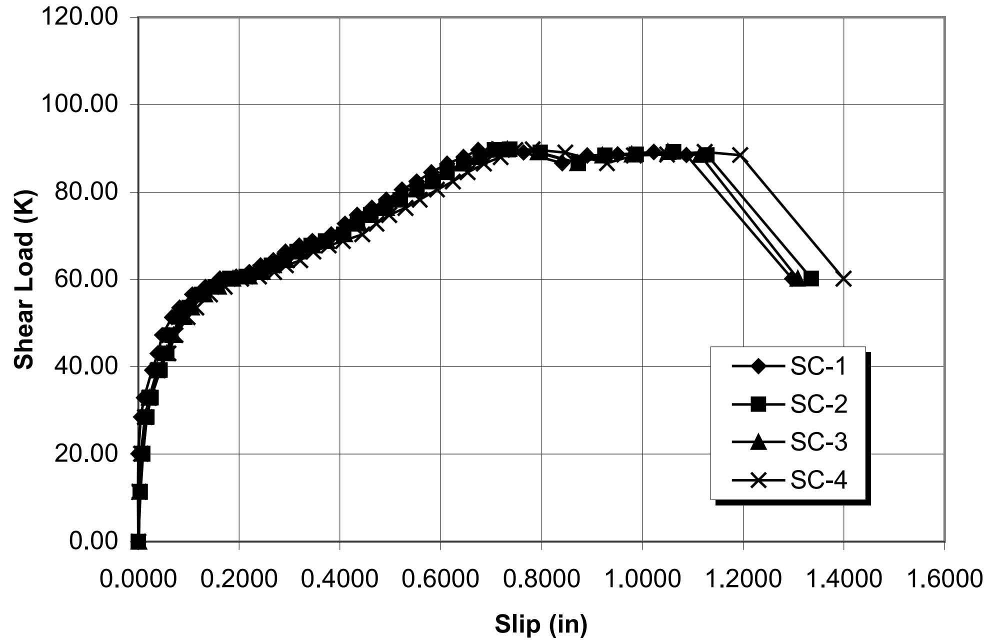


interior, Slab A exterior, Slab B

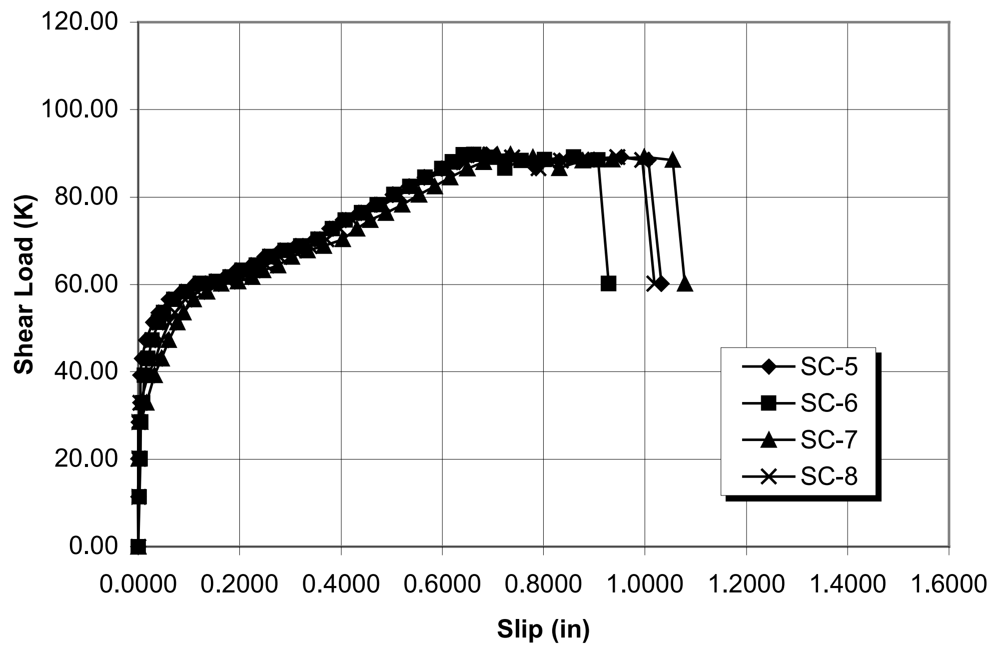
### COMMENTS

Failure Mode: Screw shear
Screw Rotation ≈ 30° - 40°
Deck debonded; Slight bulging of deck below screws
Angles slightly deformed at screw locations due to rotation of screws
X = Screw sheared off

**Test E2R-2: Load vs. Slip (A)**




**Test E2R-2: Load vs. Slip (B)**



## TEST E2R-2 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11.43 | 1.00 | -0.0006 | 0.0043 | 0.0018 | 0.0006 | 0.0000 | 0.0018 | -0.0006 | 0.0000 |
| 20.10 | 1.86 | 0.0000 | 0.0092 | 0.0067 | 0.0055 | 0.0000 | 0.0037 | 0.0006 | 0.0000 |
| 28.52 | 3.13 | 0.0055 | 0.0171 | 0.0140 | 0.0128 | 0.0012 | 0.0049 | 0.0037 | 0.0000 |
| 32.91 | 2.81 | 0.0110 | 0.0250 | 0.0208 | 0.0208 | 0.0043 | 0.0085 | 0.0165 | 0.0043 |
| 39.20 | 3.11 | 0.0275 | 0.0433 | 0.0378 | 0.0385 | 0.0043 | 0.0122 | 0.0317 | 0.0195 |
| 43.09 | 3.98 | 0.0385 | 0.0562 | 0.0562 | 0.0598 | 0.0073 | 0.0195 | 0.0458 | 0.0342 |
| 47.24 | 4.95 | 0.0476 | 0.0647 | 0.0696 | 0.0739 | 0.0153 | 0.0275 | 0.0598 | 0.0464 |
| 51.38 | 5.29 | 0.0665 | 0.0848 | 0.0909 | 0.0977 | 0.0293 | 0.0397 | 0.0769 | 0.0616 |
| 53.52 | 5.48 | 0.0818 | 0.1013 | 0.1062 | 0.1147 | 0.0397 | 0.0500 | 0.0891 | 0.0726 |
| 56.53 | 5.78 | 0.1068 | 0.1263 | 0.1318 | 0.1422 | 0.0598 | 0.0702 | 0.1093 | 0.0928 |
| 58.29 | 6.15 | 0.1337 | 0.1532 | 0.1593 | 0.1721 | 0.0848 | 0.0952 | 0.1355 | 0.1178 |
| 60.18 | 6.35 | 0.1611 | 0.1819 | 0.1880 | 0.2039 | 0.1129 | 0.1221 | 0.1636 | 0.1459 |
| 60.68 | 6.51 | 0.1935 | 0.2142 | 0.2197 | 0.2393 | 0.1440 | 0.1544 | 0.1965 | 0.1776 |
| 61.68 | 6.48 | 0.2203 | 0.2423 | 0.2466 | 0.2692 | 0.1715 | 0.1819 | 0.2246 | 0.2051 |
| 63.19 | 6.55 | 0.2423 | 0.2643 | 0.2686 | 0.2924 | 0.1929 | 0.2045 | 0.2460 | 0.2264 |
| 64.32 | 6.61 | 0.2679 | 0.2899 | 0.2936 | 0.3210 | 0.2228 | 0.2332 | 0.2759 | 0.2533 |
| 66.33 | 6.86 | 0.2917 | 0.3149 | 0.3186 | 0.3473 | 0.2490 | 0.2600 | 0.3027 | 0.2789 |
| 67.71 | 6.99 | 0.3192 | 0.3436 | 0.3467 | 0.3772 | 0.2802 | 0.2905 | 0.3339 | 0.3082 |
| 68.84 | 7.09 | 0.3455 | 0.3711 | 0.3741 | 0.4059 | 0.3113 | 0.3217 | 0.3668 | 0.3381 |
| 70.35 | 7.20 | 0.3827 | 0.4077 | 0.4102 | 0.4443 | 0.3479 | 0.3558 | 0.4034 | 0.3711 |
| 72.74 | 7.29 | 0.4095 | 0.4352 | 0.4382 | 0.4724 | 0.3772 | 0.3839 | 0.4321 | 0.3979 |
| 74.75 | 7.66 | 0.4346 | 0.4614 | 0.4626 | 0.4980 | 0.4034 | 0.4089 | 0.4578 | 0.4224 |
| 76.38 | 7.82 | 0.4633 | 0.4919 | 0.4926 | 0.5298 | 0.4352 | 0.4407 | 0.4889 | 0.4529 |
| 78.27 | 8.11 | 0.4913 | 0.5194 | 0.5200 | 0.5585 | 0.4669 | 0.4718 | 0.5206 | 0.4834 |
| 80.53 | 8.23 | 0.5231 | 0.5530 | 0.5524 | 0.5927 | 0.5017 | 0.5054 | 0.5536 | 0.5164 |
| 82.41 | 8.35 | 0.5524 | 0.5841 | 0.5804 | 0.6238 | 0.5341 | 0.5359 | 0.5847 | 0.5481 |
| 84.55 | 8.68 | 0.5811 | 0.6128 | 0.6085 | 0.6531 | 0.5652 | 0.5664 | 0.6152 | 0.5768 |
| 86.43 | 8.97 | 0.6128 | 0.6458 | 0.6415 | 0.6854 | 0.6000 | 0.5994 | 0.6494 | 0.6116 |
| 87.94 | 9.02 | 0.6451 | 0.6781 | 0.6720 | 0.7184 | 0.6329 | 0.6207 | 0.6812 | 0.6427 |
| 89.57 | 9.32 | 0.6738 | 0.7068 | 0.7013 | 0.7483 | 0.6610 | 0.6415 | 0.7086 | 0.6708 |
| 89.70 | 9.54 | 0.7031 | 0.7373 | 0.7318 | 0.7819 | 0.6879 | 0.6622 | 0.7349 | 0.6946 |
| 89.07 | 9.37 | 0.7642 | 0.7971 | 0.7928 | 0.8466 | 0.7318 | 0.6970 | 0.7788 | 0.7373 |
| 86.56 | 9.28 | 0.8411 | 0.8734 | 0.8710 | 0.9302 | 0.7849 | 0.7239 | 0.8313 | 0.7898 |
| 88.32 | 9.42 | 0.8899 | 0.9253 | 0.9204 | 0.9833 | 0.8313 | 0.7556 | 0.8777 | 0.8337 |
| 88.57 | 9.06 | 0.9509 | 0.9888 | 0.9796 | 1.0485 | 0.8887 | 0.8020 | 0.9351 | 0.8862 |
| 89.20 | 9.06 | 1.0223 | 1.0620 | 1.0510 | 1.1236 | 0.9534 | 0.8588 | 0.9991 | 0.9454 |
| 88.44 | 9.72 | 1.0876 | 1.1285 | 1.1145 | 1.1938 | 1.0070 | 0.9076 | 1.0546 | 0.9943 |
| 60.18 | 9.01 | 1.2969 | 1.3360 | 1.3079 | 1.3989 | 1.0333 | 0.9290 | 1.0791 | 1.0186 |

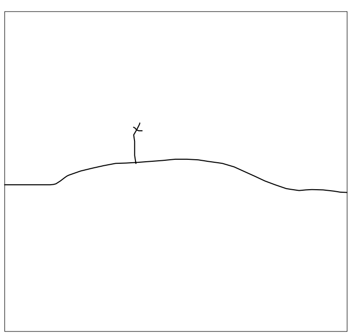
**PUSHOUT TEST SUMMARY SHEET**

Test: E3-1 Test Date: 8-Jul-98
Test Designation: SC-8-4.0-0.250-2VL-4.25-1

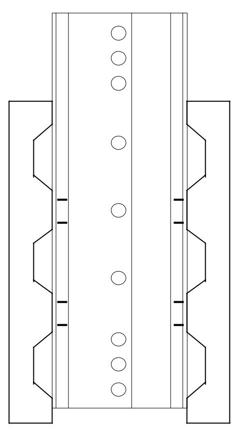
| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in. | No. Per Specimen: | 16 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.250 | | | | |
| | $F_y$: | 54.5 ksi | $F_u$: | 77.4 ksi | | |
| **Slab:** | Thickness: | 4.25 in. | $f'_c$: | 7212 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4xW4 | | | | |

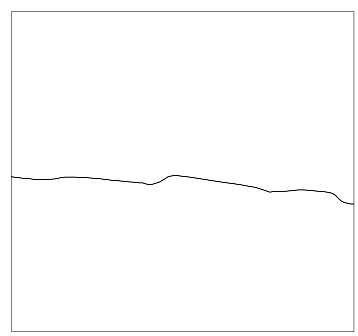
| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 66.39 kips | | | |
| **Peak Shear Load Per Screw:** | 4.15 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | N.A. | SC5: | 0.1659 in. |
| | SC2: | 0.1472 in. | SC6: | 0.2093 in. |
| | SC3: | 0.2780 in. | SC7: | 0.1884 in. |
| | SC4: | 0.3690 in. | SC8: | 0.2344 in. |

**DAMAGE**



exterior, Slab A



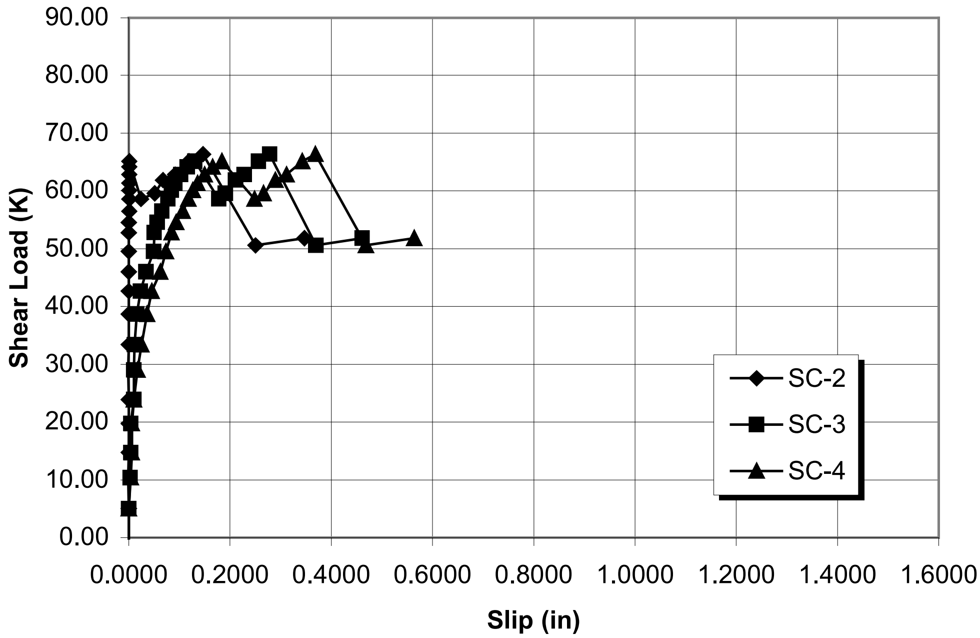


exterior, Slab B

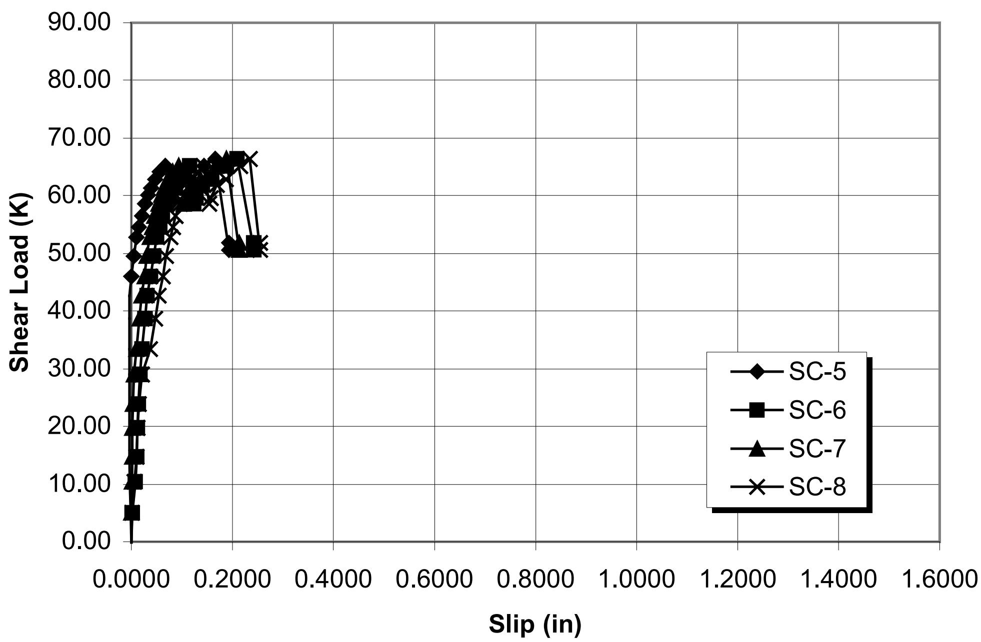
**COMMENTS**

Failure Mode: Screw shear
Screw Rotation $\approx$ 20° - 30°
Deck debonded; Slight bulging of deck below screws
Interior damage not available

**Test E3-1: Load vs. Slip (A)**




**Test E3-1: Load vs. Slip (B)**



**TEST E3-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| -0.06 | 0.00 | 0.0000 | 0.0000 | -0.0002 | 0.0002 | -0.0002 | -0.0004 | -0.0004 | -0.0002 |
| 5.03 | 0.64 | 0.0000 | -0.0004 | 0.0000 | -0.0002 | -0.0007 | 0.0020 | -0.0002 | 0.0011 |
| 10.36 | 0.87 | -0.0004 | -0.0005 | 0.0027 | 0.0042 | -0.0033 | 0.0084 | 0.0013 | 0.0060 |
| 14.70 | 1.38 | -0.0004 | -0.0002 | 0.0037 | 0.0057 | -0.0042 | 0.0115 | 0.0016 | 0.0099 |
| 19.72 | 2.09 | -0.0005 | -0.0002 | 0.0042 | 0.0060 | -0.0040 | 0.0119 | 0.0018 | 0.0119 |
| 23.87 | 2.47 | -0.0005 | -0.0002 | 0.0101 | 0.0101 | -0.0038 | 0.0145 | 0.0026 | 0.0148 |
| 28.96 | 2.83 | -0.0007 | -0.0005 | 0.0104 | 0.0172 | -0.0038 | 0.0174 | 0.0051 | 0.0209 |
| 33.42 | 3.36 | -0.0007 | -0.0002 | 0.0112 | 0.0255 | -0.0042 | 0.0207 | 0.0103 | 0.0368 |
| 38.69 | 4.01 | -0.0009 | -0.0004 | 0.0161 | 0.0366 | -0.0042 | 0.0273 | 0.0157 | 0.0469 |
| 42.65 | 4.83 | -0.0007 | -0.0002 | 0.0229 | 0.0450 | -0.0040 | 0.0309 | 0.0203 | 0.0542 |
| 46.04 | 4.72 | -0.0013 | 0.0000 | 0.0337 | 0.0628 | 0.0000 | 0.0379 | 0.0258 | 0.0623 |
| 49.56 | 5.03 | -0.0007 | 0.0000 | 0.0491 | 0.0738 | 0.0048 | 0.0445 | 0.0304 | 0.0687 |
| 52.76 | 5.41 | -0.0011 | -0.0002 | 0.0498 | 0.0842 | 0.0104 | 0.0507 | 0.0364 | 0.0773 |
| 54.59 | 5.65 | -0.0011 | 0.0000 | 0.0568 | 0.0938 | 0.0154 | 0.0562 | 0.0408 | 0.0826 |
| 56.47 | 5.90 | -0.0007 | 0.0007 | 0.0654 | 0.1062 | 0.0209 | 0.0615 | 0.0456 | 0.0881 |
| 58.61 | 6.04 | -0.0009 | 0.0005 | 0.0771 | 0.1178 | 0.0275 | 0.0700 | 0.0533 | 0.0971 |
| 60.11 | 6.18 | -0.0007 | 0.0005 | 0.0844 | 0.1269 | 0.0335 | 0.0764 | 0.0590 | 0.1046 |
| 61.37 | 6.32 | -0.0011 | 0.0005 | 0.0917 | 0.1361 | 0.0388 | 0.0833 | 0.0646 | 0.1110 |
| 62.88 | 6.54 | -0.0009 | 0.0007 | 0.1026 | 0.1498 | 0.0472 | 0.0927 | 0.0729 | 0.1203 |
| 64.20 | 6.67 | -0.0011 | 0.0007 | 0.1152 | 0.1655 | 0.0560 | 0.1033 | 0.0815 | 0.1308 |
| 65.14 | 7.03 | -0.0011 | 0.0009 | 0.1302 | 0.1835 | 0.0674 | 0.1154 | 0.0932 | 0.1432 |
| 58.61 | 7.01 | -0.0013 | 0.0236 | 0.1776 | 0.2483 | 0.0765 | 0.1243 | 0.1033 | 0.1538 |
| 59.61 | 6.11 | -0.0009 | 0.0513 | 0.1914 | 0.2666 | 0.0811 | 0.1280 | 0.1069 | 0.1571 |
| 61.87 | 6.57 | -0.0013 | 0.0674 | 0.2106 | 0.2897 | 0.0939 | 0.1410 | 0.1192 | 0.1690 |
| 62.81 | 6.84 | -0.0011 | 0.0916 | 0.2282 | 0.3117 | 0.1139 | 0.1590 | 0.1372 | 0.1875 |
| 65.14 | 7.00 | -0.0013 | 0.1190 | 0.2560 | 0.3432 | 0.1445 | 0.1884 | 0.1668 | 0.2157 |
| 66.39 | 6.85 | -0.0015 | 0.1472 | 0.2780 | 0.3690 | 0.1659 | 0.2093 | 0.1884 | 0.2344 |
| 50.57 | 5.11 | -0.0015 | 0.2502 | 0.3699 | 0.4688 | 0.1928 | 0.2425 | 0.2139 | 0.2544 |
| 51.82 | 5.73 | -0.0018 | 0.3468 | 0.4609 | 0.5642 | 0.1930 | 0.2425 | 0.2139 | 0.2549 |

Note: SC-1 readings not included due to operational error

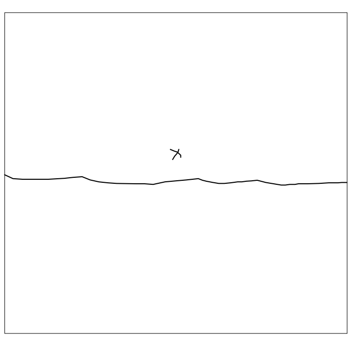
**PUSHOUT TEST SUMMARY SHEET**

Test: E3-2 Test Date: 9-Jul-98
Test Designation: SC-8-4.0-0.250-2VL-4.25-2

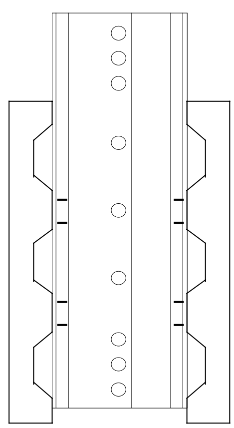
| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in. | No. Per Specimen: | 16 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.250 | | | | |
| | $F_y$: | 54.5 ksi | $F_u$: | 77.4 ksi | | |
| **Slab:** | Thickness: | 4.25 in. | $f'_c$: | 7212 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4xW4 | | | | |

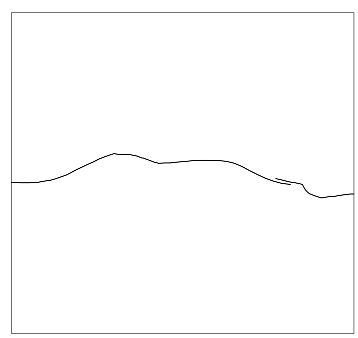
| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 77.64 kips | | | |
| **Peak Shear Load Per Screw:** | 4.85 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | N.A. | SC5: | 0.2100 in. |
| | SC2: | 0.2846 in. | SC6: | 0.2260 in. |
| | SC3: | 0.2549 in. | SC7: | 0.2240 in. |
| | SC4: | 0.3038 in. | SC8: | 0.2481 in. |

**DAMAGE**



exterior, Slab A

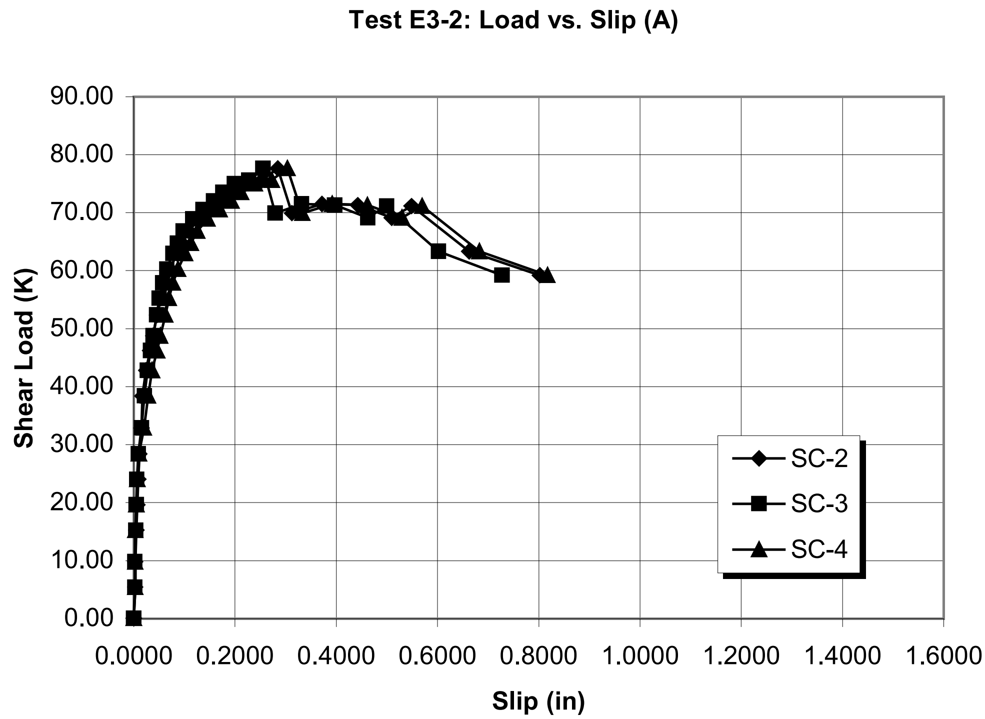


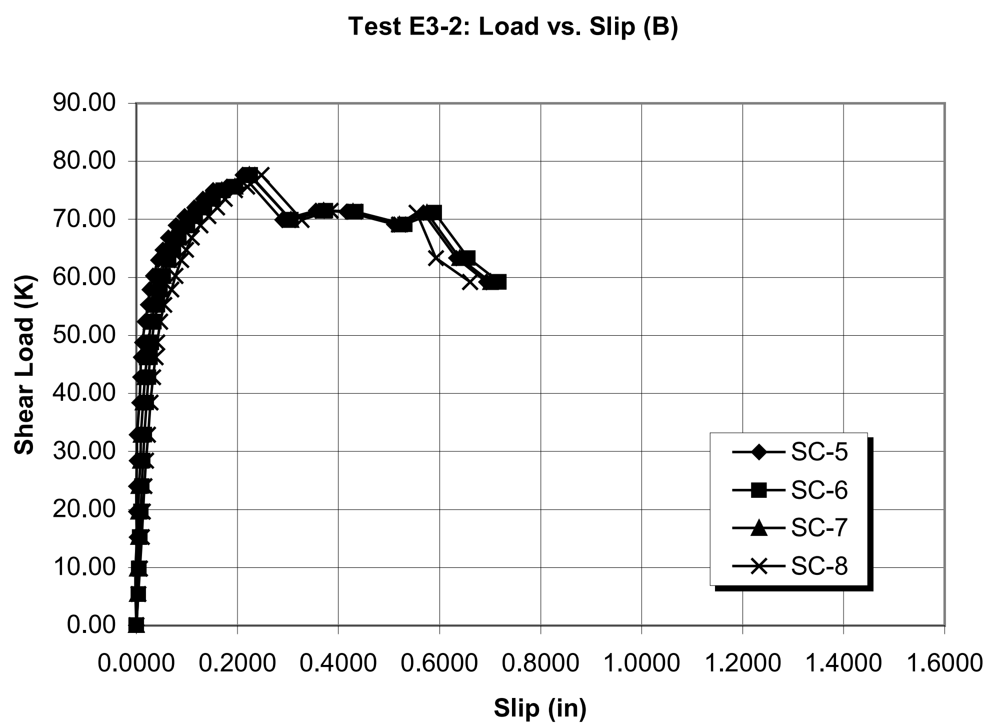


exterior, Slab B

**COMMENTS**

Failure Mode: Screw shear
Screw Rotation ≈ 20° - 30°
Deck debonded; Slight bulging of deck below screws
Interior damage not available


Test E3-2: Load vs. Slip (A)
Shear Load (K)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.0000
0.2000
0.4000
0.6000
0.8000
1.0000
1.2000
1.4000
1.6000
Slip (in)
SC-2
SC-3
SC-4


Test E3-2: Load vs. Slip (B)
Shear Load (K)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.0000
0.2000
0.4000
0.6000
0.8000
1.0000
1.2000
1.4000
1.6000
Slip (in)
SC-5
SC-6
SC-7
SC-8

## TEST E3-2 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.13 | 0.00 | 0.0000 | -0.0002 | -0.0002 | 0.0002 | 0.0000 | -0.0002 | -0.0002 | 0.0002 |
| 5.40 | 0.52 | -0.0004 | 0.0026 | 0.0018 | 0.0031 | -0.0024 | 0.0037 | 0.0018 | 0.0044 |
| 9.86 | 0.94 | -0.0005 | 0.0029 | 0.0024 | 0.0033 | -0.0024 | 0.0046 | 0.0018 | 0.0066 |
| 15.26 | 1.39 | -0.0004 | 0.0051 | 0.0038 | 0.0033 | 0.0005 | 0.0071 | 0.0037 | 0.0108 |
| 19.66 | 1.86 | -0.0004 | 0.0073 | 0.0048 | 0.0048 | 0.0004 | 0.0086 | 0.0038 | 0.0126 |
| 24.06 | 2.41 | -0.0005 | 0.0093 | 0.0064 | 0.0075 | 0.0004 | 0.0114 | 0.0048 | 0.0159 |
| 28.45 | 2.80 | -0.0007 | 0.0110 | 0.0086 | 0.0103 | 0.0011 | 0.0132 | 0.0081 | 0.0190 |
| 32.91 | 3.22 | -0.0007 | 0.0147 | 0.0150 | 0.0201 | 0.0011 | 0.0157 | 0.0095 | 0.0231 |
| 38.44 | 3.87 | -0.0005 | 0.0170 | 0.0209 | 0.0286 | 0.0062 | 0.0203 | 0.0132 | 0.0282 |
| 42.78 | 4.34 | -0.0009 | 0.0238 | 0.0273 | 0.0364 | 0.0084 | 0.0238 | 0.0170 | 0.0335 |
| 46.23 | 4.74 | -0.0009 | 0.0322 | 0.0333 | 0.0467 | 0.0093 | 0.0273 | 0.0209 | 0.0383 |
| 48.81 | 5.09 | -0.0009 | 0.0377 | 0.0385 | 0.0524 | 0.0117 | 0.0300 | 0.0242 | 0.0416 |
| 52.39 | 5.43 | -0.0009 | 0.0460 | 0.0449 | 0.0626 | 0.0167 | 0.0357 | 0.0293 | 0.0476 |
| 55.28 | 5.60 | -0.0011 | 0.0537 | 0.0505 | 0.0692 | 0.0234 | 0.0421 | 0.0370 | 0.0559 |
| 57.85 | 5.91 | -0.0013 | 0.0602 | 0.0570 | 0.0775 | 0.0264 | 0.0471 | 0.0452 | 0.0692 |
| 60.30 | 6.22 | -0.0011 | 0.0709 | 0.0656 | 0.0872 | 0.0330 | 0.0535 | 0.0531 | 0.0771 |
| 62.94 | 6.55 | -0.0011 | 0.0850 | 0.0773 | 0.1011 | 0.0430 | 0.0641 | 0.0641 | 0.0890 |
| 64.76 | 6.72 | -0.0013 | 0.0954 | 0.0866 | 0.1130 | 0.0527 | 0.0734 | 0.0727 | 0.0985 |
| 66.83 | 7.03 | -0.0011 | 0.1086 | 0.0974 | 0.1256 | 0.0630 | 0.0848 | 0.0837 | 0.1099 |
| 68.97 | 7.25 | -0.0015 | 0.1297 | 0.1163 | 0.1460 | 0.0789 | 0.1015 | 0.0993 | 0.1273 |
| 70.54 | 7.50 | -0.0016 | 0.1516 | 0.1362 | 0.1694 | 0.0952 | 0.1167 | 0.1146 | 0.1427 |
| 72.05 | 7.74 | -0.0016 | 0.1758 | 0.1577 | 0.1927 | 0.1145 | 0.1348 | 0.1331 | 0.1597 |
| 73.49 | 7.67 | -0.0015 | 0.1952 | 0.1760 | 0.2122 | 0.1317 | 0.1522 | 0.1500 | 0.1756 |
| 75.00 | 7.86 | -0.0016 | 0.2207 | 0.1992 | 0.2393 | 0.1520 | 0.1720 | 0.1694 | 0.1954 |
| 75.63 | 7.84 | -0.0018 | 0.2529 | 0.2269 | 0.2719 | 0.1789 | 0.1967 | 0.1952 | 0.2192 |
| 77.64 | 8.08 | -0.0024 | 0.2846 | 0.2549 | 0.3038 | 0.2100 | 0.2260 | 0.2240 | 0.2481 |
| 69.91 | 7.92 | -0.0020 | 0.3122 | 0.2796 | 0.3322 | 0.2886 | 0.3060 | 0.3062 | 0.3271 |
| 71.48 | 7.44 | -0.0026 | 0.3721 | 0.3315 | 0.3915 | 0.3553 | 0.3743 | 0.3705 | 0.3846 |
| 71.36 | 7.44 | -0.0024 | 0.4426 | 0.3970 | 0.4609 | 0.4159 | 0.4353 | 0.4291 | 0.4320 |
| 69.10 | 6.79 | -0.0024 | 0.5100 | 0.4624 | 0.5292 | 0.5106 | 0.5316 | 0.5204 | 0.5199 |
| 71.11 | 7.12 | -0.0026 | 0.5488 | 0.4992 | 0.5703 | 0.5677 | 0.5904 | 0.5754 | 0.5545 |
| 63.32 | 6.91 | -0.0026 | 0.6627 | 0.6023 | 0.6822 | 0.6329 | 0.6565 | 0.6393 | 0.5932 |
| 59.17 | 6.12 | -0.0027 | 0.8016 | 0.7276 | 0.8175 | 0.6926 | 0.7180 | 0.7006 | 0.6604 |

Note: SC-1 readings not included due to operational error

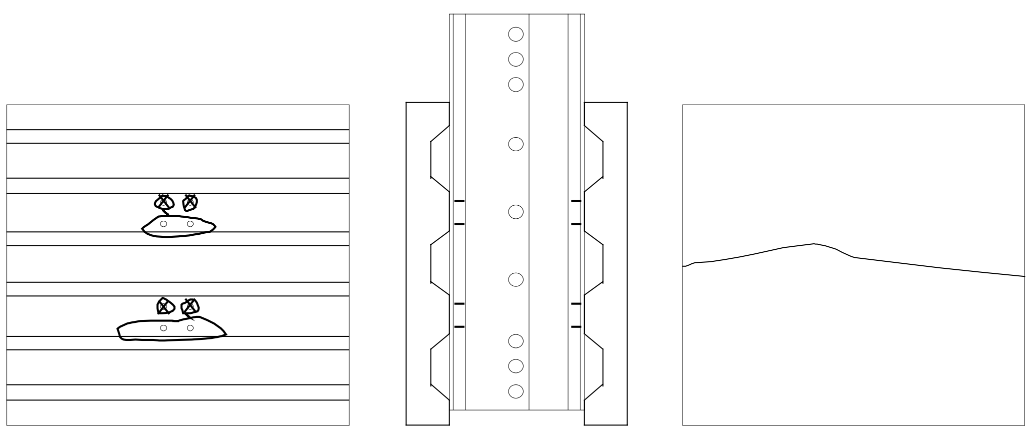
**PUSHOUT TEST SUMMARY SHEET**

Test: E3R-1 Test Date: 21-Dec-98
Test Designation: SC-8-4.0-0.250-2VL-4.25-1R

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in. | No. Per Specimen: | 16 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.250 | | | | |
| | $F_y$: | 54.5 ksi | $F_u$: | 77.4 ksi | | |
| **Slab:** | Thickness: | 4.25 in. | $f'_c$: | 4953 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4xW4 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 66.71 kips | | | |
| **Peak Shear Load Per Screw:** | 4.17 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.5066 in. | SC5: | 0.5408 in. |
| | SC2: | 0.5463 in. | SC6: | 0.3857 in. |
| | SC3: | 0.5231 in. | SC7: | 0.5481 in. |
| | SC4: | 0.5640 in. | SC8: | 0.5615 in. |

**DAMAGE**

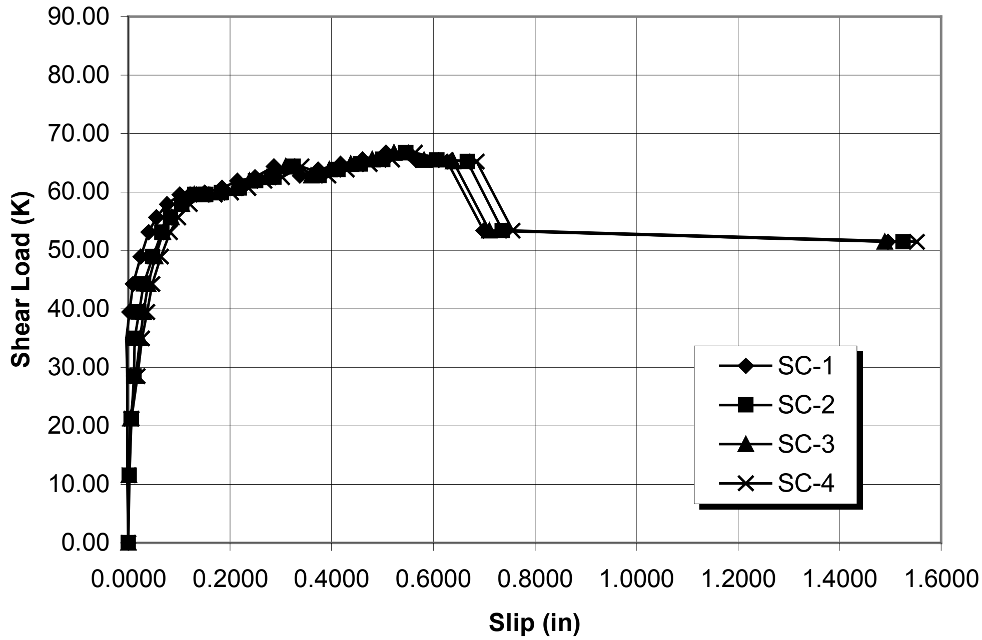


interior, Slab A exterior, Slab B

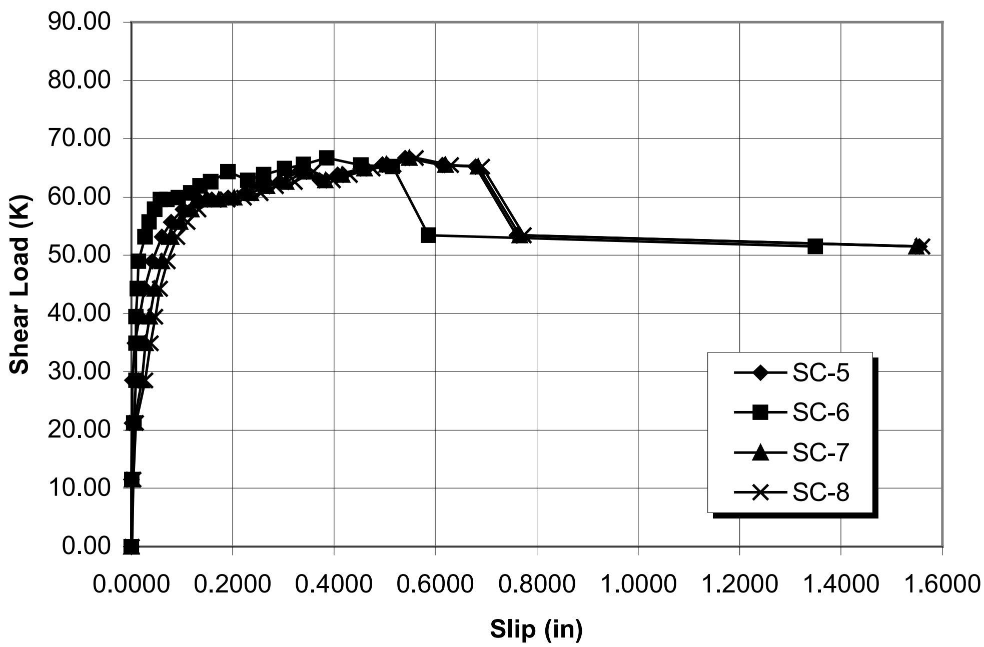
**COMMENTS**

Failure Mode: Screw shear
Screw Rotation ≈ 10° - 20°
Deck debonded; Slight bulging of deck below screws
X = Screw sheared off

**Test E3R-1: Load vs. Slip (A)**




**Test E3R-1: Load vs. Slip (B)**



**TEST E3R-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0006 |
| 11.56 | 1.09 | -0.0018 | 0.0018 | 0.0012 | 0.0000 | 0.0000 | 0.0012 | 0.0012 | 0.0037 |
| 21.23 | 2.08 | -0.0018 | 0.0061 | 0.0043 | 0.0061 | 0.0012 | 0.0049 | 0.0055 | 0.0092 |
| 28.52 | 2.70 | -0.0018 | 0.0110 | 0.0146 | 0.0183 | 0.0018 | 0.0085 | 0.0208 | 0.0275 |
| 34.92 | 3.62 | -0.0037 | 0.0122 | 0.0226 | 0.0269 | 0.0073 | 0.0085 | 0.0281 | 0.0378 |
| 39.45 | 4.29 | 0.0018 | 0.0208 | 0.0299 | 0.0366 | 0.0165 | 0.0092 | 0.0366 | 0.0470 |
| 44.22 | 4.52 | 0.0092 | 0.0305 | 0.0391 | 0.0470 | 0.0262 | 0.0116 | 0.0458 | 0.0562 |
| 48.99 | 5.22 | 0.0238 | 0.0476 | 0.0531 | 0.0641 | 0.0409 | 0.0140 | 0.0604 | 0.0714 |
| 53.14 | 5.48 | 0.0397 | 0.0659 | 0.0684 | 0.0818 | 0.0598 | 0.0269 | 0.0787 | 0.0903 |
| 55.65 | 5.91 | 0.0549 | 0.0836 | 0.0854 | 0.0983 | 0.0787 | 0.0354 | 0.0964 | 0.1105 |
| 57.91 | 5.99 | 0.0757 | 0.1056 | 0.1056 | 0.1215 | 0.1019 | 0.0464 | 0.1190 | 0.1324 |
| 59.55 | 6.17 | 0.1007 | 0.1312 | 0.1288 | 0.1477 | 0.1318 | 0.0574 | 0.1471 | 0.1624 |
| 59.55 | 6.41 | 0.1208 | 0.1526 | 0.1489 | 0.1703 | 0.1587 | 0.0702 | 0.1727 | 0.1898 |
| 59.92 | 6.38 | 0.1508 | 0.1837 | 0.1782 | 0.2020 | 0.1904 | 0.0928 | 0.2032 | 0.2222 |
| 60.68 | 6.26 | 0.1843 | 0.2185 | 0.2106 | 0.2368 | 0.2240 | 0.1172 | 0.2356 | 0.2551 |
| 61.93 | 6.38 | 0.2142 | 0.2502 | 0.2386 | 0.2673 | 0.2545 | 0.1355 | 0.2673 | 0.2856 |
| 62.56 | 6.40 | 0.2490 | 0.2863 | 0.2728 | 0.3021 | 0.2924 | 0.1569 | 0.3058 | 0.3223 |
| 64.32 | 6.47 | 0.2869 | 0.3247 | 0.3101 | 0.3406 | 0.3302 | 0.1910 | 0.3424 | 0.3583 |
| 62.81 | 6.64 | 0.3375 | 0.3760 | 0.3601 | 0.3937 | 0.3717 | 0.2301 | 0.3827 | 0.3979 |
| 63.82 | 6.74 | 0.3741 | 0.4126 | 0.3961 | 0.4303 | 0.4065 | 0.2612 | 0.4156 | 0.4309 |
| 64.82 | 6.63 | 0.4181 | 0.4565 | 0.4382 | 0.4749 | 0.4517 | 0.3027 | 0.4602 | 0.4761 |
| 65.58 | 6.60 | 0.4608 | 0.5011 | 0.4803 | 0.5194 | 0.4950 | 0.3394 | 0.5029 | 0.5176 |
| 66.71 | 6.50 | 0.5066 | 0.5463 | 0.5231 | 0.5640 | 0.5408 | 0.3857 | 0.5481 | 0.5615 |
| 65.45 | 6.38 | 0.5664 | 0.6073 | 0.5823 | 0.6244 | 0.6134 | 0.4529 | 0.6195 | 0.6305 |
| 65.20 | 6.62 | 0.6268 | 0.6677 | 0.6396 | 0.6848 | 0.6793 | 0.5157 | 0.6836 | 0.6921 |
| 53.39 | 5.62 | 0.6989 | 0.7367 | 0.7104 | 0.7568 | 0.7605 | 0.5865 | 0.7666 | 0.7739 |
| 51.51 | 4.84 | 1.4953 | 1.5246 | 1.4892 | 1.5515 | 1.5551 | 1.3500 | 1.5490 | 1.5606 |

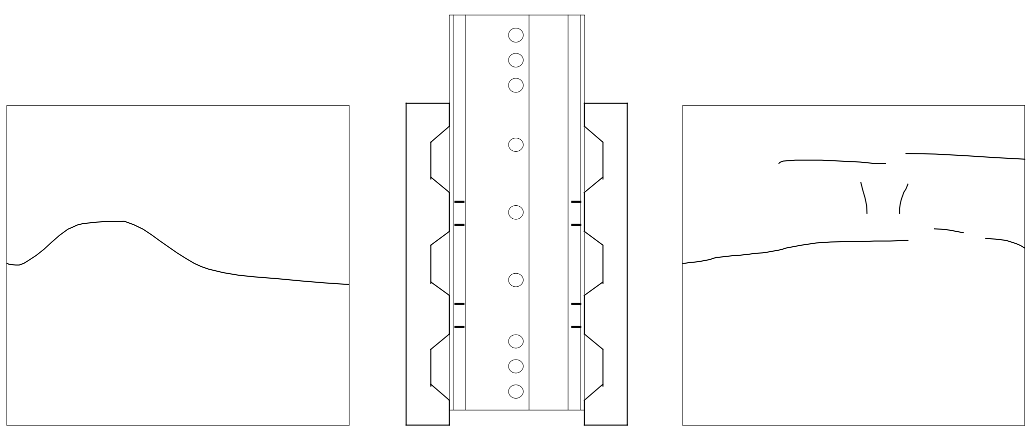
**PUSHOUT TEST SUMMARY SHEET**

Test: E3R-2 Test Date: 22-Dec-98
Test Designation: SC-8-4.0-0.250-2VL-4.25-2R

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in. | No. Per Specimen: | 16 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.250 | | | | |
| | $F_y$: | 54.5 ksi | $F_u$: | 77.4 ksi | | |
| **Slab:** | Thickness: | 4.25 in. | $f'_c$: | 4953 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4xW4 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 83.67 kips | | | |
| **Peak Shear Load Per Screw:** | 5.23 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.7794 in. | SC5: | 0.8716 in. |
| | SC2: | 0.8136 in. | SC6: | 0.8679 in. |
| | SC3: | 0.7782 in. | SC7: | 0.8630 in. |
| | SC4: | 0.8350 in. | SC8: | 0.7397 in. |

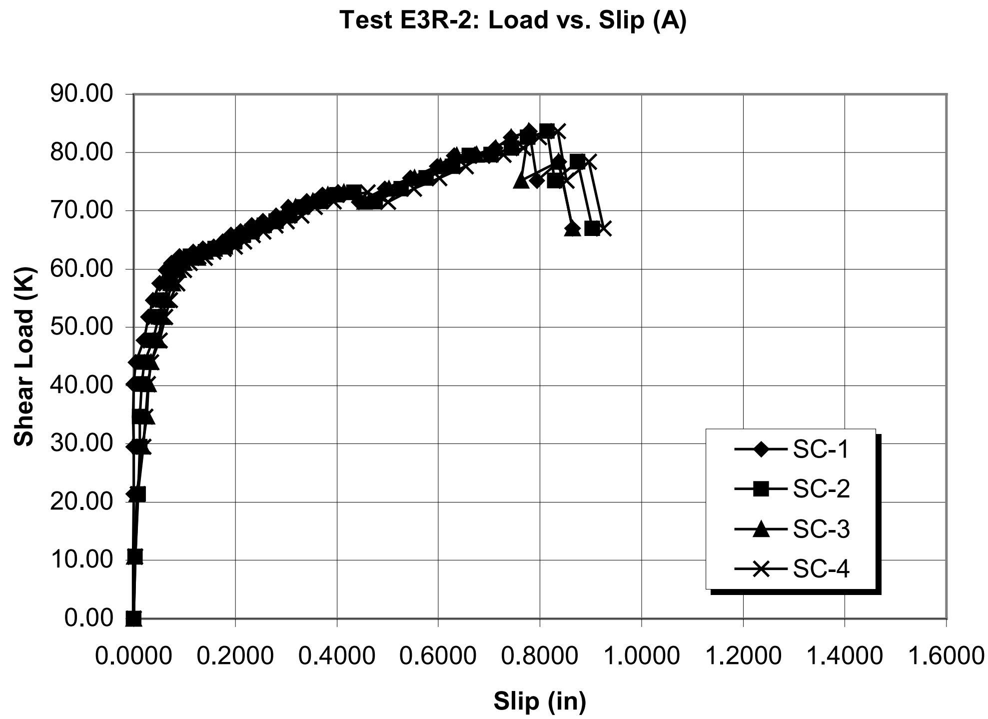
**DAMAGE**

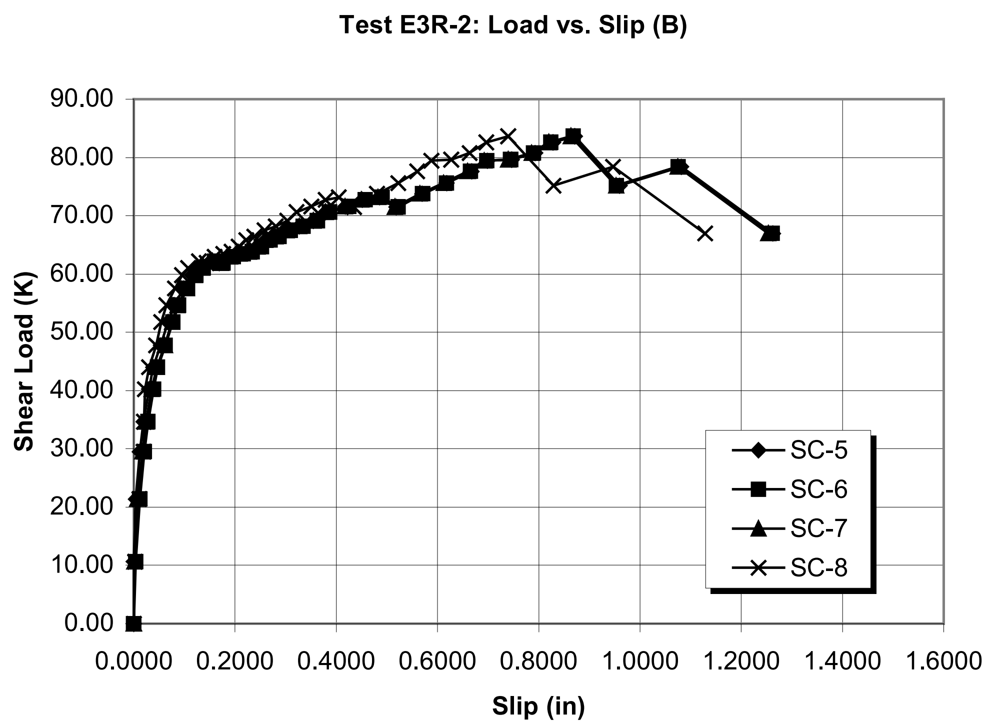


exterior, Slab A exterior, Slab B

**COMMENTS**

Failure Mode: Screw shear
Screw Rotation ≈ 10° - 20°
Deck debonded; Slight bulging of deck below screws
Interior damage not available


Test E3R-2: Load vs. Slip (A)
Shear Load (K)
Slip (in)
SC-1
SC-2
SC-3
SC-4


Test E3R-2: Load vs. Slip (B)
Shear Load (K)
Slip (in)
SC-5
SC-6
SC-7
SC-8

**TEST E3R-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | -0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10.68 | 0.90 | -0.0006 | 0.0031 | 0.0006 | 0.0031 | 0.0000 | 0.0043 | 0.0006 | 0.0024 |
| 21.36 | 2.03 | 0.0000 | 0.0085 | 0.0061 | 0.0079 | 0.0037 | 0.0116 | 0.0073 | 0.0110 |
| 29.52 | 2.89 | 0.0000 | 0.0116 | 0.0171 | 0.0189 | 0.0122 | 0.0214 | 0.0171 | 0.0195 |
| 34.67 | 3.54 | -0.0006 | 0.0122 | 0.0256 | 0.0232 | 0.0189 | 0.0281 | 0.0244 | 0.0201 |
| 40.20 | 4.09 | 0.0000 | 0.0165 | 0.0293 | 0.0281 | 0.0299 | 0.0391 | 0.0348 | 0.0226 |
| 43.97 | 4.52 | 0.0043 | 0.0214 | 0.0336 | 0.0336 | 0.0378 | 0.0470 | 0.0452 | 0.0299 |
| 47.74 | 4.97 | 0.0195 | 0.0385 | 0.0476 | 0.0513 | 0.0537 | 0.0623 | 0.0616 | 0.0439 |
| 51.76 | 5.36 | 0.0293 | 0.0488 | 0.0562 | 0.0623 | 0.0671 | 0.0769 | 0.0751 | 0.0543 |
| 54.65 | 5.74 | 0.0378 | 0.0574 | 0.0647 | 0.0708 | 0.0793 | 0.0885 | 0.0861 | 0.0641 |
| 57.54 | 5.94 | 0.0513 | 0.0720 | 0.0775 | 0.0861 | 0.0983 | 0.1068 | 0.1050 | 0.0818 |
| 59.80 | 5.86 | 0.0629 | 0.0836 | 0.0885 | 0.0989 | 0.1154 | 0.1227 | 0.1202 | 0.0952 |
| 61.06 | 6.02 | 0.0745 | 0.0958 | 0.0995 | 0.1105 | 0.1300 | 0.1379 | 0.1349 | 0.1080 |
| 62.19 | 5.94 | 0.0897 | 0.1117 | 0.1141 | 0.1276 | 0.1520 | 0.1599 | 0.1562 | 0.1282 |
| 61.93 | 5.70 | 0.1019 | 0.1245 | 0.1263 | 0.1398 | 0.1691 | 0.1770 | 0.1721 | 0.1434 |
| 62.94 | 6.02 | 0.1172 | 0.1410 | 0.1416 | 0.1569 | 0.1892 | 0.1965 | 0.1904 | 0.1593 |
| 63.44 | 6.16 | 0.1361 | 0.1599 | 0.1593 | 0.1770 | 0.2075 | 0.2161 | 0.2087 | 0.1770 |
| 63.82 | 6.32 | 0.1575 | 0.1807 | 0.1788 | 0.1990 | 0.2264 | 0.2344 | 0.2271 | 0.1929 |
| 64.70 | 6.19 | 0.1752 | 0.1990 | 0.1965 | 0.2173 | 0.2435 | 0.2521 | 0.2441 | 0.2069 |
| 65.83 | 6.36 | 0.1917 | 0.2161 | 0.2130 | 0.2344 | 0.2600 | 0.2692 | 0.2594 | 0.2222 |
| 66.46 | 6.37 | 0.2106 | 0.2338 | 0.2307 | 0.2551 | 0.2783 | 0.2875 | 0.2789 | 0.2380 |
| 67.46 | 6.41 | 0.2319 | 0.2570 | 0.2502 | 0.2789 | 0.3009 | 0.3094 | 0.3015 | 0.2588 |
| 68.22 | 6.46 | 0.2545 | 0.2802 | 0.2710 | 0.3015 | 0.3265 | 0.3351 | 0.3265 | 0.2802 |
| 69.10 | 6.28 | 0.2808 | 0.3076 | 0.2960 | 0.3308 | 0.3546 | 0.3625 | 0.3546 | 0.3033 |
| 70.60 | 6.71 | 0.3040 | 0.3320 | 0.3186 | 0.3564 | 0.3790 | 0.3870 | 0.3790 | 0.3217 |
| 71.61 | 7.04 | 0.3400 | 0.3687 | 0.3528 | 0.3937 | 0.4181 | 0.4254 | 0.4169 | 0.3503 |
| 72.74 | 7.36 | 0.3711 | 0.4010 | 0.3821 | 0.4260 | 0.4517 | 0.4578 | 0.4492 | 0.3790 |
| 73.12 | 7.54 | 0.4028 | 0.4333 | 0.4138 | 0.4602 | 0.4852 | 0.4901 | 0.4822 | 0.4053 |
| 71.48 | 7.28 | 0.4431 | 0.4755 | 0.4541 | 0.5011 | 0.5188 | 0.5225 | 0.5157 | 0.4352 |
| 73.74 | 7.59 | 0.4950 | 0.5267 | 0.5023 | 0.5518 | 0.5695 | 0.5713 | 0.5652 | 0.4803 |
| 75.63 | 7.39 | 0.5450 | 0.5762 | 0.5524 | 0.6018 | 0.6177 | 0.6177 | 0.6116 | 0.5231 |
| 77.64 | 7.51 | 0.5975 | 0.6281 | 0.6036 | 0.6543 | 0.6671 | 0.6653 | 0.6598 | 0.5603 |
| 79.40 | 7.54 | 0.6305 | 0.6610 | 0.6354 | 0.6866 | 0.6989 | 0.6970 | 0.6927 | 0.5878 |
| 79.65 | 7.96 | 0.6720 | 0.7037 | 0.6750 | 0.7281 | 0.7471 | 0.7446 | 0.7397 | 0.6274 |
| 80.78 | 8.18 | 0.7123 | 0.7440 | 0.7129 | 0.7672 | 0.7935 | 0.7904 | 0.7855 | 0.6635 |
| 82.54 | 8.26 | 0.7434 | 0.7758 | 0.7428 | 0.7977 | 0.8282 | 0.8246 | 0.8203 | 0.6964 |
| 83.67 | 8.43 | 0.7794 | 0.8136 | 0.7782 | 0.8350 | 0.8716 | 0.8679 | 0.8630 | 0.7397 |
| 75.13 | 7.95 | 0.7941 | 0.8295 | 0.7629 | 0.8521 | 0.9595 | 0.9540 | 0.9528 | 0.8295 |
| 78.39 | 7.74 | 0.8374 | 0.8740 | 0.8362 | 0.8960 | 1.0815 | 1.0754 | 1.0742 | 0.9467 |
| 66.96 | 7.74 | 0.8636 | 0.9027 | 0.8643 | 0.9253 | 1.2622 | 1.2615 | 1.2536 | 1.1291 |

**PUSHOUT TEST SUMMARY SHEET**

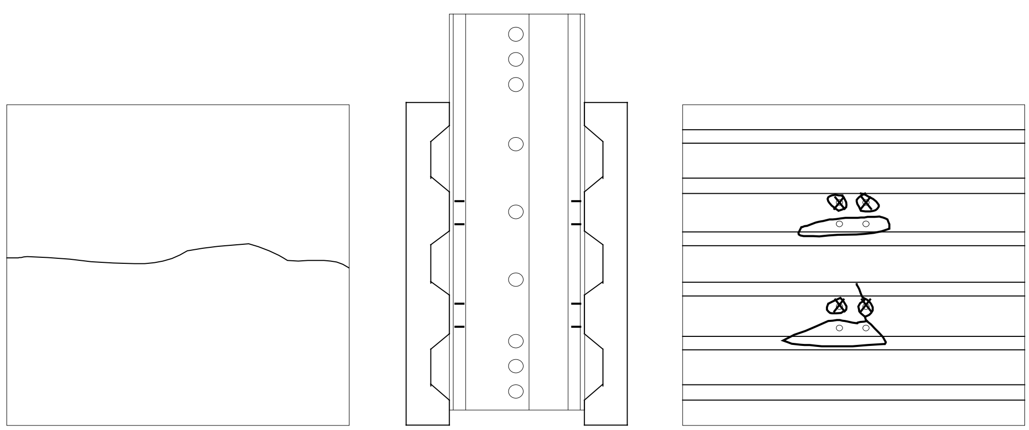
Test: E3R-3 | Test Date: 22-Dec-98

Test Designation: SC-8-4.0-0.250-2VL-4.25-3R

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in. | No. Per Specimen: | 16 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.250 | | | | |
| | $F_y$: | 54.5 ksi | $F_u$: | 77.4 ksi | | |
| **Slab:** | Thickness: | 4.25 in. | $f'_c$: | 4953 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4xW4 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 81.03 kips | | | |
| **Peak Shear Load Per Screw:** | 5.06 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.5170 in. | SC5: | 0.6750 in. |
| | SC2: | 0.5255 in. | SC6: | 0.2283 in. |
| | SC3: | 0.5530 in. | SC7: | 0.7043 in. |
| | SC4: | 0.6439 in. | SC8: | 0.5347 in. |

**DAMAGE**

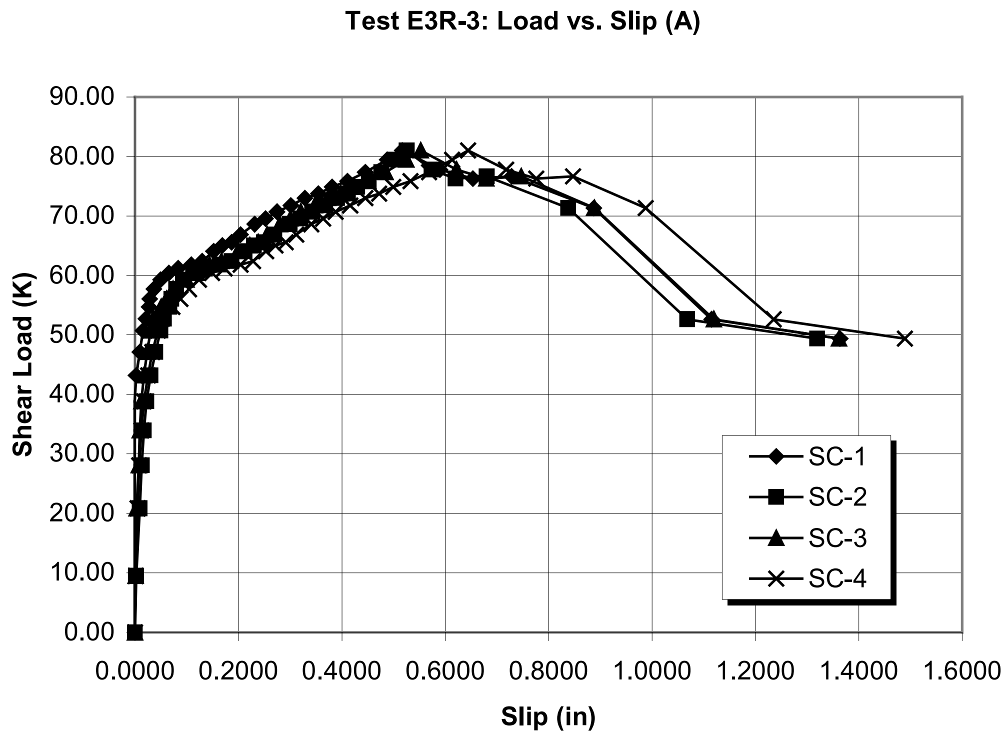


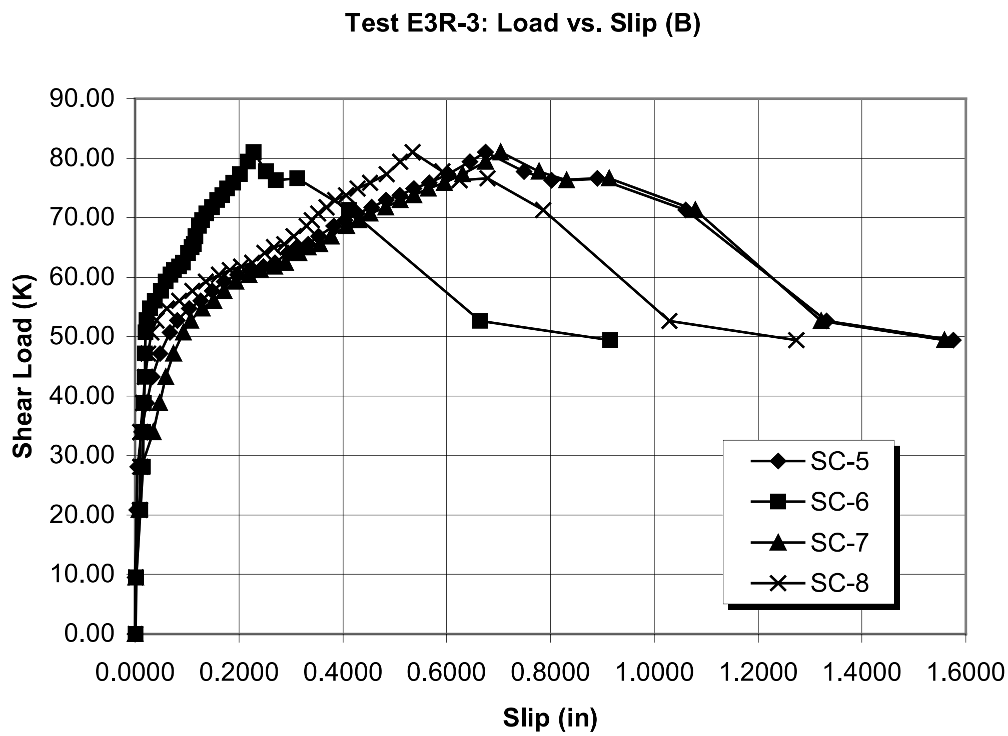
exterior, Slab A

interior, Slab B

**COMMENTS**

Failure Mode: Screw shear
Screw Rotation ≈ 20° - 30°
Deck debonded; Slight bulging of deck below screws
X = Screw sheared off


Test E3R-3: Load vs. Slip (A)
Shear Load (K)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.0000
0.2000
0.4000
0.6000
0.8000
1.0000
1.2000
1.4000
1.6000
Slip (in)
SC-1
SC-2
SC-3
SC-4


Test E3R-3: Load vs. Slip (B)
Shear Load (K)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.0000
0.2000
0.4000
0.6000
0.8000
1.0000
1.2000
1.4000
1.6000
Slip (in)
SC-5
SC-6
SC-7
SC-8

**TEST E3R-3 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | -0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 |
| 9.55 | 1.02 | -0.0006 | 0.0024 | 0.0006 | 0.0006 | 0.0000 | 0.0018 | 0.0012 | 0.0012 |
| 20.85 | 1.96 | -0.0006 | 0.0085 | 0.0031 | 0.0049 | 0.0031 | 0.0104 | 0.0073 | 0.0085 |
| 28.14 | 2.64 | -0.0006 | 0.0128 | 0.0067 | 0.0079 | 0.0055 | 0.0153 | 0.0122 | 0.0104 |
| 33.92 | 3.38 | -0.0006 | 0.0171 | 0.0085 | 0.0122 | 0.0116 | 0.0165 | 0.0348 | 0.0104 |
| 38.82 | 3.98 | -0.0006 | 0.0226 | 0.0122 | 0.0171 | 0.0220 | 0.0171 | 0.0470 | 0.0146 |
| 43.22 | 4.51 | 0.0024 | 0.0305 | 0.0171 | 0.0250 | 0.0330 | 0.0189 | 0.0586 | 0.0189 |
| 47.11 | 4.91 | 0.0085 | 0.0397 | 0.0232 | 0.0336 | 0.0482 | 0.0189 | 0.0739 | 0.0250 |
| 50.75 | 5.33 | 0.0146 | 0.0488 | 0.0305 | 0.0439 | 0.0671 | 0.0201 | 0.0928 | 0.0311 |
| 52.76 | 5.50 | 0.0208 | 0.0562 | 0.0354 | 0.0519 | 0.0812 | 0.0220 | 0.1074 | 0.0409 |
| 54.77 | 5.48 | 0.0275 | 0.0659 | 0.0500 | 0.0720 | 0.1044 | 0.0287 | 0.1294 | 0.0610 |
| 56.03 | 5.74 | 0.0281 | 0.0708 | 0.0616 | 0.0879 | 0.1263 | 0.0378 | 0.1508 | 0.0854 |
| 57.66 | 6.02 | 0.0360 | 0.0793 | 0.0739 | 0.1050 | 0.1483 | 0.0500 | 0.1715 | 0.1105 |
| 59.30 | 6.19 | 0.0488 | 0.0922 | 0.0995 | 0.1239 | 0.1709 | 0.0592 | 0.1947 | 0.1361 |
| 60.43 | 6.51 | 0.0653 | 0.1129 | 0.1196 | 0.1483 | 0.1971 | 0.0677 | 0.2191 | 0.1611 |
| 61.18 | 6.53 | 0.0836 | 0.1349 | 0.1337 | 0.1733 | 0.2209 | 0.0751 | 0.2411 | 0.1819 |
| 61.81 | 6.56 | 0.1086 | 0.1636 | 0.1434 | 0.2045 | 0.2478 | 0.0848 | 0.2679 | 0.2045 |
| 62.44 | 6.42 | 0.1294 | 0.1868 | 0.1665 | 0.2283 | 0.2692 | 0.0922 | 0.2893 | 0.2252 |
| 64.07 | 6.69 | 0.1520 | 0.2118 | 0.1987 | 0.2533 | 0.2942 | 0.1025 | 0.3156 | 0.2490 |
| 65.08 | 6.53 | 0.1691 | 0.2301 | 0.2222 | 0.2716 | 0.3113 | 0.1093 | 0.3339 | 0.2673 |
| 65.58 | 6.72 | 0.1868 | 0.2490 | 0.2386 | 0.2911 | 0.3333 | 0.1135 | 0.3558 | 0.2869 |
| 66.83 | 6.96 | 0.2045 | 0.2692 | 0.2551 | 0.3113 | 0.3534 | 0.1166 | 0.3772 | 0.3052 |
| 68.59 | 7.20 | 0.2313 | 0.2997 | 0.2802 | 0.3412 | 0.3827 | 0.1227 | 0.4077 | 0.3302 |
| 69.60 | 7.26 | 0.2527 | 0.3204 | 0.3003 | 0.3638 | 0.4041 | 0.1294 | 0.4303 | 0.3406 |
| 70.73 | 7.41 | 0.2740 | 0.3430 | 0.3210 | 0.3876 | 0.4272 | 0.1373 | 0.4529 | 0.3528 |
| 71.73 | 7.37 | 0.3015 | 0.3680 | 0.3473 | 0.4163 | 0.4553 | 0.1483 | 0.4822 | 0.3687 |
| 72.99 | 7.70 | 0.3290 | 0.3912 | 0.3729 | 0.4456 | 0.4834 | 0.1581 | 0.5103 | 0.3857 |
| 73.74 | 7.41 | 0.3552 | 0.4120 | 0.3979 | 0.4724 | 0.5096 | 0.1678 | 0.5371 | 0.4065 |
| 74.87 | 7.68 | 0.3809 | 0.4303 | 0.4230 | 0.4999 | 0.5371 | 0.1776 | 0.5652 | 0.4285 |
| 75.88 | 8.08 | 0.4108 | 0.4523 | 0.4517 | 0.5322 | 0.5670 | 0.1892 | 0.5957 | 0.4529 |
| 77.39 | 8.22 | 0.4456 | 0.4761 | 0.4846 | 0.5688 | 0.6024 | 0.2026 | 0.6311 | 0.4846 |
| 79.40 | 8.04 | 0.4877 | 0.5048 | 0.5249 | 0.6128 | 0.6445 | 0.2173 | 0.6744 | 0.5103 |
| 81.03 | 8.17 | 0.5170 | 0.5255 | 0.5530 | 0.6439 | 0.6750 | 0.2283 | 0.7043 | 0.5347 |
| 77.76 | 8.30 | 0.5896 | 0.5737 | 0.6219 | 0.7178 | 0.7489 | 0.2527 | 0.7782 | 0.5914 |
| 76.26 | 8.33 | 0.6537 | 0.6201 | 0.6793 | 0.7764 | 0.8020 | 0.2716 | 0.8307 | 0.6244 |
| 76.63 | 7.96 | 0.7288 | 0.6805 | 0.7471 | 0.8472 | 0.8899 | 0.3125 | 0.9131 | 0.6787 |
| 71.36 | 7.57 | 0.8875 | 0.8386 | 0.8881 | 0.9882 | 1.0607 | 0.4126 | 1.0797 | 0.7855 |
| 52.64 | 4.96 | 1.1151 | 1.0687 | 1.1199 | 1.2353 | 1.3317 | 0.6653 | 1.3214 | 1.0296 |
| 49.37 | 5.01 | 1.3641 | 1.3201 | 1.3623 | 1.4898 | 1.5759 | 0.9149 | 1.5588 | 1.2731 |

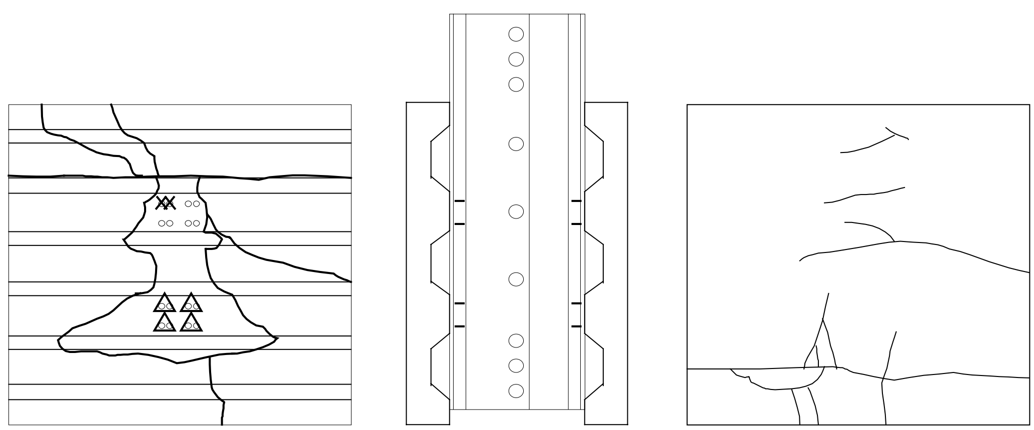
**PUSHOUT TEST SUMMARY SHEET**

Test: E4-1 Test Date: 18-Oct-98
Test Designation: SC-8-4.0-0.163-2VL-4.25-1

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in. | No. Per Specimen: | 32 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.163 | | | | |
| | $F_y$: | 57.1 ksi | $F_u$: | 77.9 ksi | | |
| **Slab:** | Thickness: | 4.25 in. | $f'_c$: | 5033 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4xW4 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 137.18 kips | | | |
| **Peak Shear Load Per Screw:** | 4.29 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.8655 in. | SC5: | 0.9021 in. |
| | SC2: | 0.8788 in. | SC6: | 0.3842 in. |
| | SC3: | 0.7312 in. | SC7: | 0.8878 in. |
| | SC4: | 0.7695 in. | SC8: | 0.7144 in. |

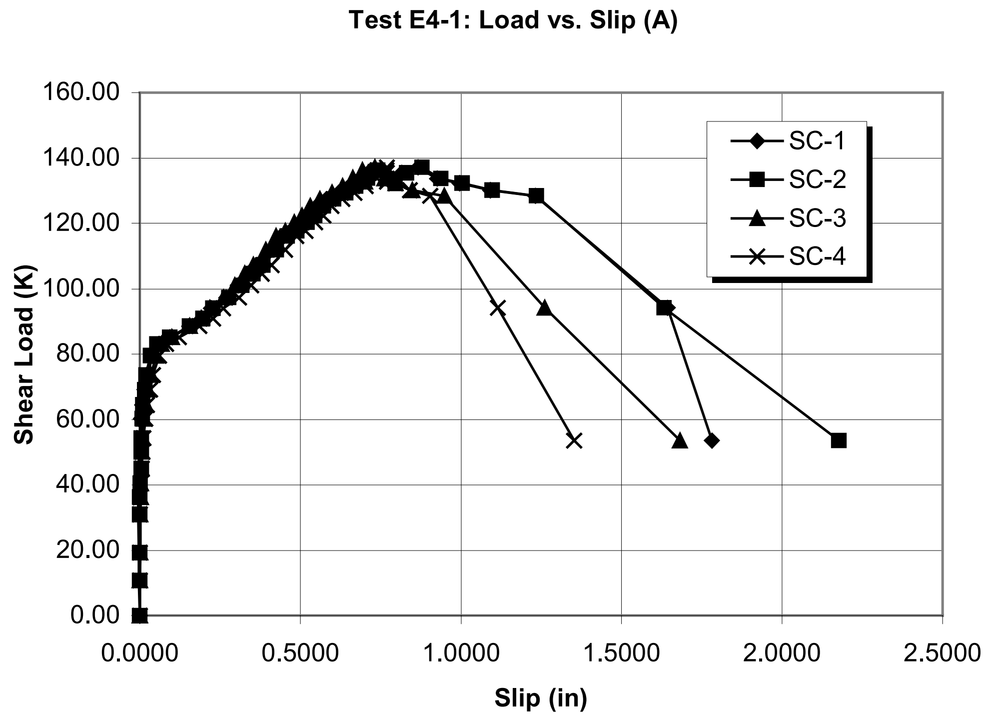
**DAMAGE**

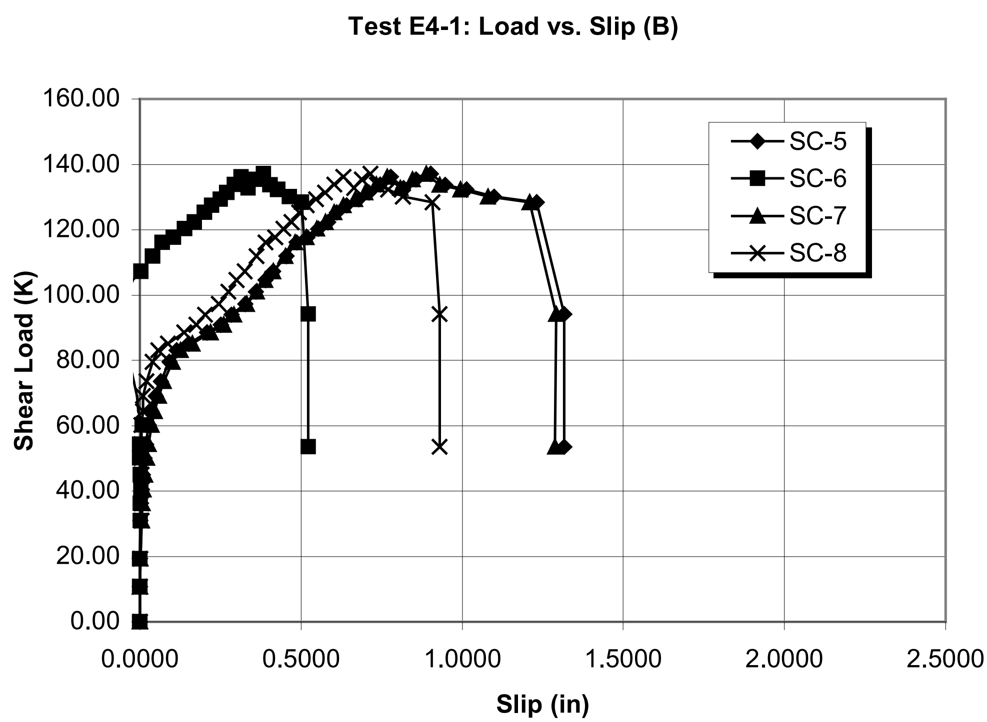


interior, Slab A exterior, Slab B

**COMMENTS**

Failure Mode: Concrete cone pullout
Screw Rotation ≈ 40° - 50°
Deck debonded; Slight bulging of deck below screws
Angles slightly deformed at screw locations due to rotation of screws
X = Screw sheared off; △= Screw pulled out of concrete


Test E4-1: Load vs. Slip (A)
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Shear Load (K)
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
Slip (in)
SC-1
SC-2
SC-3
SC-4


Test E4-1: Load vs. Slip (B)
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Shear Load (K)
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
Slip (in)
SC-5
SC-6
SC-7
SC-8

## TEST E4-1 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0002 | 0.0000 | 0.0002 | 0.0000 | -0.0002 | 0.0002 | 0.0000 |
| 10.80 | 0.92 | -0.0024 | -0.0002 | 0.0002 | -0.0002 | -0.0002 | 0.0000 | 0.0004 | 0.0000 |
| 19.35 | 1.93 | -0.0027 | 0.0000 | 0.0009 | 0.0000 | 0.0004 | 0.0002 | 0.0020 | 0.0009 |
| 30.90 | 3.13 | -0.0046 | 0.0004 | 0.0022 | 0.0002 | 0.0020 | 0.0013 | 0.0059 | 0.0053 |
| 36.31 | 3.51 | -0.0049 | 0.0005 | 0.0035 | 0.0013 | 0.0035 | 0.0018 | 0.0084 | 0.0051 |
| 40.45 | 4.00 | -0.0048 | 0.0009 | 0.0038 | 0.0026 | 0.0059 | 0.0024 | 0.0117 | 0.0051 |
| 44.97 | 4.64 | -0.0033 | 0.0044 | 0.0051 | 0.0064 | 0.0103 | 0.0013 | 0.0165 | 0.0053 |
| 50.06 | 5.21 | -0.0033 | 0.0048 | 0.0070 | 0.0084 | 0.0141 | 0.0005 | 0.0220 | 0.0055 |
| 54.40 | 5.51 | -0.0016 | 0.0053 | 0.0092 | 0.0110 | 0.0183 | -0.0002 | 0.0262 | 0.0053 |
| 60.18 | 5.95 | 0.0024 | 0.0075 | 0.0134 | 0.0170 | 0.0271 | 0.0081 | 0.0357 | 0.0051 |
| 64.38 | 6.47 | 0.0071 | 0.0095 | 0.0183 | 0.0223 | 0.0348 | -0.0044 | 0.0450 | 0.0090 |
| 69.10 | 7.09 | 0.0148 | 0.0159 | 0.0258 | 0.0322 | 0.0491 | -0.0090 | 0.0588 | 0.0097 |
| 73.56 | 7.45 | 0.0233 | 0.0196 | 0.0341 | 0.0410 | 0.0650 | -0.0189 | 0.0745 | 0.0205 |
| 79.52 | 7.95 | 0.0401 | 0.0330 | 0.0502 | 0.0599 | 0.0914 | -0.0309 | 0.1015 | 0.0392 |
| 83.04 | 8.40 | 0.0584 | 0.0533 | 0.0681 | 0.0822 | 0.1139 | -0.0335 | 0.1256 | 0.0564 |
| 85.18 | 8.94 | 0.0939 | 0.0936 | 0.0996 | 0.1212 | 0.1522 | -0.0412 | 0.1624 | 0.0863 |
| 88.57 | 9.42 | 0.1535 | 0.1555 | 0.1549 | 0.1857 | 0.2088 | -0.0410 | 0.2188 | 0.1375 |
| 90.95 | 9.46 | 0.1928 | 0.1967 | 0.1923 | 0.2278 | 0.2514 | -0.0407 | 0.2599 | 0.1756 |
| 93.97 | 9.53 | 0.2220 | 0.2285 | 0.2187 | 0.2595 | 0.2846 | -0.0394 | 0.2917 | 0.2022 |
| 97.24 | 9.67 | 0.2692 | 0.2776 | 0.2619 | 0.3086 | 0.3274 | -0.0359 | 0.3315 | 0.2454 |
| 101.00 | 9.98 | 0.3062 | 0.3186 | 0.2963 | 0.3474 | 0.3606 | -0.0359 | 0.3622 | 0.2751 |
| 104.52 | 10.43 | 0.3366 | 0.3525 | 0.3260 | 0.3802 | 0.3891 | -0.0225 | 0.3882 | 0.3005 |
| 107.28 | 10.82 | 0.3648 | 0.3833 | 0.3531 | 0.4093 | 0.4142 | 0.0031 | 0.4142 | 0.3251 |
| 111.87 | 11.19 | 0.4073 | 0.4261 | 0.3930 | 0.4532 | 0.4545 | 0.0397 | 0.4520 | 0.3617 |
| 116.14 | 11.68 | 0.4397 | 0.4597 | 0.4250 | 0.4873 | 0.4862 | 0.0698 | 0.4818 | 0.3902 |
| 117.71 | 12.07 | 0.4692 | 0.4893 | 0.4525 | 0.5161 | 0.5192 | 0.1047 | 0.5153 | 0.4194 |
| 120.35 | 12.22 | 0.4998 | 0.5214 | 0.4816 | 0.5470 | 0.5545 | 0.1384 | 0.5487 | 0.4455 |
| 122.36 | 12.51 | 0.5239 | 0.5446 | 0.5051 | 0.5708 | 0.5836 | 0.1685 | 0.5754 | 0.4703 |
| 125.31 | 12.65 | 0.5503 | 0.5715 | 0.5307 | 0.5974 | 0.6111 | 0.2005 | 0.6023 | 0.4933 |
| 127.51 | 12.69 | 0.5805 | 0.6032 | 0.5602 | 0.6298 | 0.6408 | 0.2221 | 0.6312 | 0.5179 |
| 129.39 | 13.20 | 0.6195 | 0.6417 | 0.5992 | 0.6688 | 0.6783 | 0.2494 | 0.6679 | 0.5457 |
| 131.40 | 13.44 | 0.6525 | 0.6734 | 0.6314 | 0.7028 | 0.7109 | 0.2697 | 0.6999 | 0.5739 |
| 133.79 | 13.41 | 0.6869 | 0.7087 | 0.6638 | 0.7380 | 0.7457 | 0.2937 | 0.7345 | 0.6027 |
| 136.24 | 13.77 | 0.7182 | 0.7404 | 0.6933 | 0.7686 | 0.7785 | 0.3146 | 0.7668 | 0.6311 |
| 132.72 | 14.53 | 0.7783 | 0.7953 | 0.7017 | 0.7695 | 0.8169 | 0.3364 | 0.8078 | 0.6646 |
| 135.48 | 14.81 | 0.8157 | 0.8305 | 0.7102 | 0.7695 | 0.8565 | 0.3606 | 0.8453 | 0.6884 |
| 137.18 | 14.91 | 0.8655 | 0.8788 | 0.7312 | 0.7695 | 0.9021 | 0.3842 | 0.8878 | 0.7144 |
| 133.66 | 13.79 | 0.9259 | 0.9367 | 0.7614 | 0.7695 | 0.9462 | 0.4036 | 0.9299 | 0.7362 |
| 132.22 | 13.49 | 0.9960 | 1.0040 | 0.7957 | 0.7970 | 1.0126 | 0.4283 | 0.9940 | 0.7699 |
| 130.15 | 13.47 | 1.0901 | 1.0969 | 0.8481 | 0.8402 | 1.0989 | 0.4633 | 1.0800 | 0.8160 |
| 128.39 | 12.85 | 1.2320 | 1.2355 | 0.9479 | 0.9045 | 1.2304 | 0.5016 | 1.2082 | 0.9078 |
| 94.16 | 13.06 | 1.6433 | 1.6316 | 1.2608 | 1.1146 | 1.3161 | 0.5223 | 1.2912 | 0.9303 |
| 53.58 | 15.22 | 1.7812 | 2.1772 | 1.6812 | 1.3523 | 1.3161 | 0.5223 | 1.2881 | 0.9301 |

## PUSHOUT TEST SUMMARY SHEET

Test: E4-2 Test Date: 19-Oct-98
Test Designation: SC-8-4.0-0.163-2VL-4.25-2

### SPECIMEN DESCRIPTION

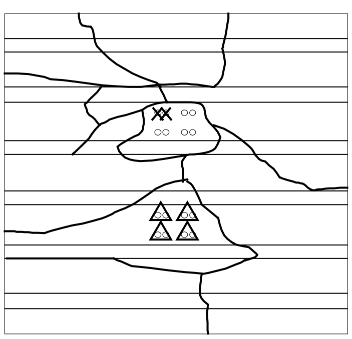
**Screw:** Height: 4.0 in. No. Per Specimen: 32
**Deck:** Type: 2VL, 22 ga Width: 36 in. Length: 36 in.
$F_y$: 51.0 ksi $F_u$: 56.7 ksi
**Base Member:** Section: 2L 2x2x0.163
$F_y$: 57.1 ksi $F_u$: 77.9 ksi
**Slab:** Thickness: 4.25 in. $f'_c$: 5033 psi
**Rebar:** Size: No. 4 No. Per Specimen: 8
Height Above Deck: 1.0 in.
**Mesh:** Type: WWF 6x6-W4xW4

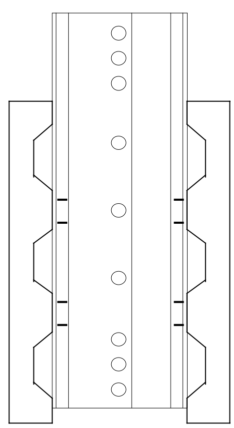
### TEST RESULTS

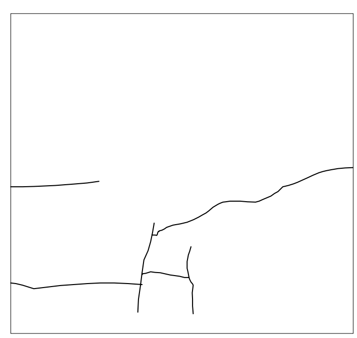
**Peak Shear Load:** 121.60 kips
**Peak Shear Load Per Screw:** 3.80 kips
**Slip at Peak Shear Load:**

| | | | |
|---|---|---|---|
| SC1: | 0.5930 in. | SC5: | 0.6900 in. |
| SC2: | 0.6935 in. | SC6: | 0.5809 in. |
| SC3: | 0.6322 in. | SC7: | 0.5329 in. |
| SC4: | 0.7208 in. | SC8: | 0.3873 in. |

### DAMAGE





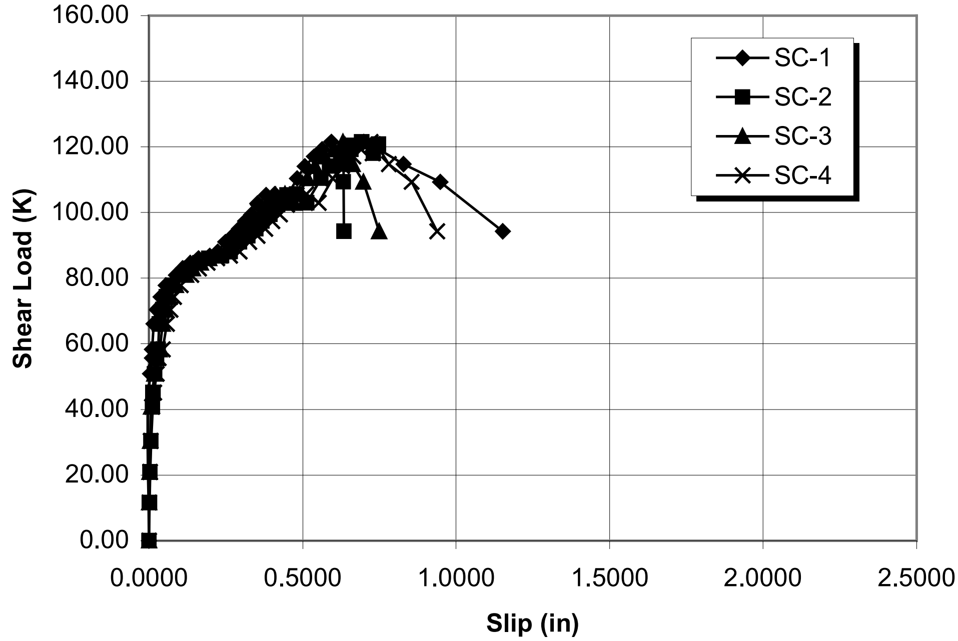


interior, Slab A exterior, Slab B

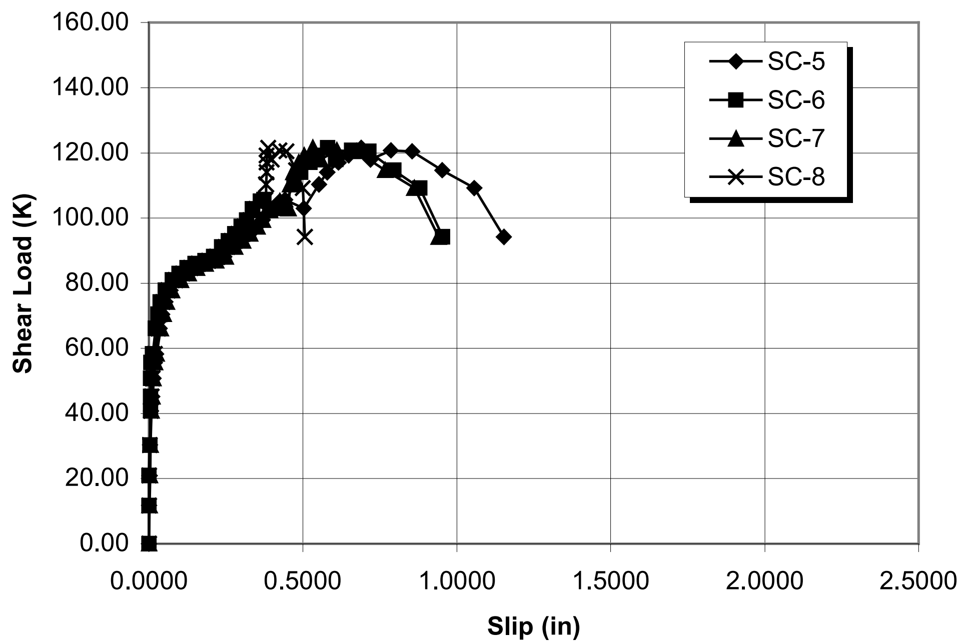
### COMMENTS

Failure Mode: Concrete cone pullout
Screw Rotation ≈ 40° - 50°
Deck debonded; Slight bulging of deck below screws
Angles slightly deformed at screw locations due to rotation of screws
X = Screw sheared off; △ = Screw pulled out of concrete

Test E4-2: Load vs. Slip (A)




Test E4-2: Load vs. Slip (B)



## TEST E4-2 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | -0.0002 | -0.0002 | 0.0000 | 0.0002 | -0.0002 | -0.0002 | 0.0000 |
| 11.68 | 1.03 | -0.0024 | 0.0020 | 0.0004 | 0.0004 | 0.0004 | 0.0002 | 0.0013 | 0.0002 |
| 20.92 | 1.91 | -0.0040 | 0.0040 | 0.0015 | 0.0033 | 0.0015 | 0.0000 | 0.0029 | 0.0007 |
| 30.34 | 2.81 | -0.0048 | 0.0070 | 0.0037 | 0.0057 | 0.0035 | 0.0040 | 0.0049 | 0.0024 |
| 40.83 | 4.09 | -0.0046 | 0.0110 | 0.0066 | 0.0095 | 0.0071 | 0.0042 | 0.0088 | 0.0062 |
| 45.16 | 4.55 | -0.0011 | 0.0132 | 0.0114 | 0.0168 | 0.0097 | 0.0046 | 0.0114 | 0.0081 |
| 50.82 | 5.04 | 0.0038 | 0.0189 | 0.0172 | 0.0242 | 0.0141 | 0.0048 | 0.0154 | 0.0115 |
| 55.59 | 5.49 | 0.0093 | 0.0247 | 0.0238 | 0.0319 | 0.0178 | 0.0073 | 0.0200 | 0.0147 |
| 58.35 | 6.00 | 0.0106 | 0.0297 | 0.0346 | 0.0443 | 0.0225 | 0.0115 | 0.0251 | 0.0187 |
| 66.08 | 6.56 | 0.0152 | 0.0339 | 0.0452 | 0.0582 | 0.0346 | 0.0218 | 0.0381 | 0.0291 |
| 70.41 | 7.01 | 0.0255 | 0.0441 | 0.0555 | 0.0689 | 0.0429 | 0.0297 | 0.0474 | 0.0359 |
| 74.25 | 7.49 | 0.0377 | 0.0560 | 0.0663 | 0.0815 | 0.0527 | 0.0372 | 0.0577 | 0.0441 |
| 77.76 | 7.97 | 0.0553 | 0.0767 | 0.0872 | 0.1020 | 0.0694 | 0.0524 | 0.0751 | 0.0606 |
| 80.90 | 8.38 | 0.0883 | 0.1132 | 0.1205 | 0.1383 | 0.0961 | 0.0767 | 0.1037 | 0.0868 |
| 82.91 | 8.54 | 0.1095 | 0.1379 | 0.1430 | 0.1624 | 0.1203 | 0.0983 | 0.1282 | 0.1093 |
| 84.61 | 8.78 | 0.1342 | 0.1654 | 0.1692 | 0.1910 | 0.1487 | 0.1240 | 0.1558 | 0.1351 |
| 85.99 | 8.96 | 0.1608 | 0.1956 | 0.1961 | 0.2218 | 0.1775 | 0.1498 | 0.1837 | 0.1608 |
| 86.81 | 8.97 | 0.1974 | 0.2364 | 0.2307 | 0.2643 | 0.2137 | 0.1822 | 0.2188 | 0.1927 |
| 88.07 | 8.89 | 0.2236 | 0.2652 | 0.2567 | 0.2945 | 0.2448 | 0.2095 | 0.2492 | 0.2207 |
| 91.08 | 8.97 | 0.2494 | 0.2950 | 0.2826 | 0.3260 | 0.2754 | 0.2366 | 0.2795 | 0.2476 |
| 92.90 | 8.95 | 0.2723 | 0.3214 | 0.3058 | 0.3529 | 0.3016 | 0.2584 | 0.3051 | 0.2681 |
| 95.10 | 9.15 | 0.2939 | 0.3474 | 0.3265 | 0.3783 | 0.3274 | 0.2802 | 0.3293 | 0.2901 |
| 97.36 | 9.74 | 0.3130 | 0.3683 | 0.3446 | 0.4007 | 0.3492 | 0.2987 | 0.3516 | 0.3086 |
| 99.31 | 10.01 | 0.3333 | 0.3939 | 0.3655 | 0.4260 | 0.3686 | 0.3172 | 0.3705 | 0.3274 |
| 102.82 | 10.37 | 0.3536 | 0.4177 | 0.3853 | 0.4487 | 0.3919 | 0.3364 | 0.3923 | 0.3465 |
| 102.32 | 10.34 | 0.3547 | 0.4186 | 0.3857 | 0.4499 | 0.3930 | 0.3371 | 0.3932 | 0.3479 |
| 105.21 | 10.77 | 0.3805 | 0.4485 | 0.4131 | 0.4800 | 0.4256 | 0.3620 | 0.4243 | 0.3745 |
| 105.65 | 10.82 | 0.4098 | 0.4813 | 0.4421 | 0.5128 | 0.4412 | 0.3736 | 0.4412 | 0.3776 |
| 102.95 | 11.89 | 0.4379 | 0.5146 | 0.4730 | 0.5518 | 0.5025 | 0.4302 | 0.4536 | 0.3807 |
| 110.36 | 11.99 | 0.4820 | 0.5604 | 0.5151 | 0.5988 | 0.5516 | 0.4710 | 0.4582 | 0.3809 |
| 114.07 | 12.00 | 0.5076 | 0.5882 | 0.5404 | 0.6281 | 0.5787 | 0.4928 | 0.4683 | 0.3813 |
| 117.02 | 12.05 | 0.5377 | 0.6248 | 0.5721 | 0.6640 | 0.6144 | 0.5225 | 0.4862 | 0.3813 |
| 119.22 | 12.13 | 0.5642 | 0.6583 | 0.6018 | 0.6913 | 0.6485 | 0.5470 | 0.5040 | 0.3813 |
| 121.60 | 12.34 | 0.5930 | 0.6935 | 0.6322 | 0.7208 | 0.6900 | 0.5809 | 0.5329 | 0.3873 |
| 117.96 | 12.40 | 0.6309 | 0.7312 | 0.6311 | 0.7270 | 0.7201 | 0.6063 | 0.5574 | 0.3987 |
| 120.85 | 13.14 | 0.6756 | 0.7477 | 0.6307 | 0.7296 | 0.7853 | 0.6583 | 0.6107 | 0.4228 |
| 120.41 | 13.52 | 0.7267 | 0.6549 | 0.6382 | 0.7426 | 0.8554 | 0.7147 | 0.6746 | 0.4465 |
| 114.69 | 12.53 | 0.8288 | 0.6340 | 0.6637 | 0.7807 | 0.9521 | 0.7953 | 0.7677 | 0.4774 |
| 109.23 | 12.09 | 0.9475 | 0.6340 | 0.6986 | 0.8559 | 1.0559 | 0.8788 | 0.8618 | 0.4994 |
| 94.28 | 12.02 | 1.1515 | 0.6356 | 0.7490 | 0.9378 | 1.1524 | 0.9535 | 0.9400 | 0.5060 |

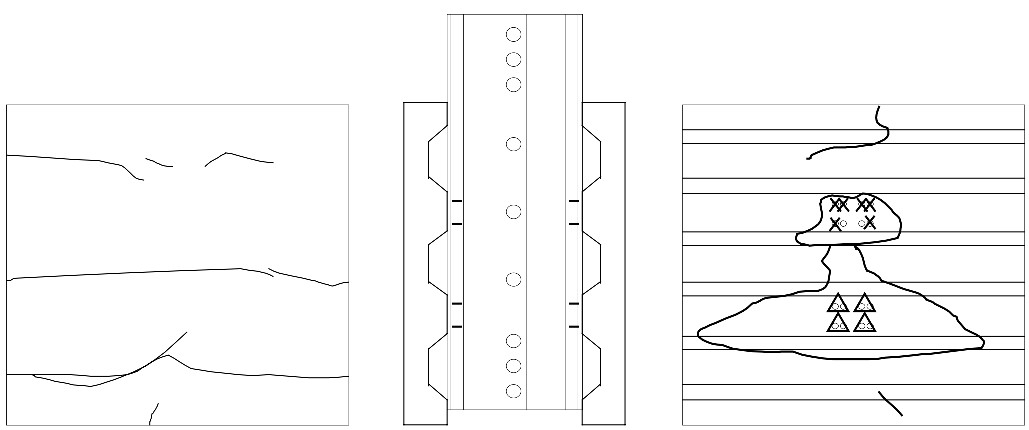
**PUSHOUT TEST SUMMARY SHEET**

Test: E5-1 Test Date: 21-Oct-98
Test Designation: SC-8-4.0-0.250-2VL-4.25-1

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in | No. Per Specimen: | 32 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.250 | | | | |
| | $F_y$: | 54.5 ksi | $F_u$: | 77.4 ksi | | |
| **Slab:** | Thickness: | 4.25 in. | $f'_c$: | 4838 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4xW4 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 112.12 kips | | | |
| **Peak Shear Load Per Screw:** | 3.50 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.3877 in. | SC5: | 0.4043 in. |
| | SC2: | 0.4302 in. | SC6: | N.A. |
| | SC3: | 0.4282 in. | SC7: | 0.4426 in. |
| | SC4: | 0.4199 in. | SC8: | 0.4415 in. |

**DAMAGE**



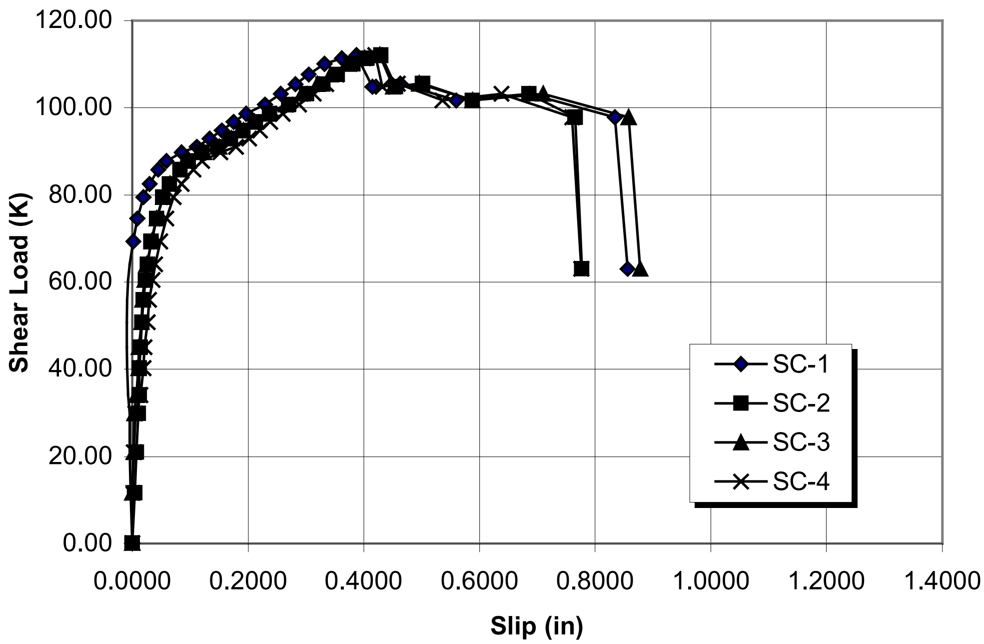
exterior, Slab A

interior, Slab B

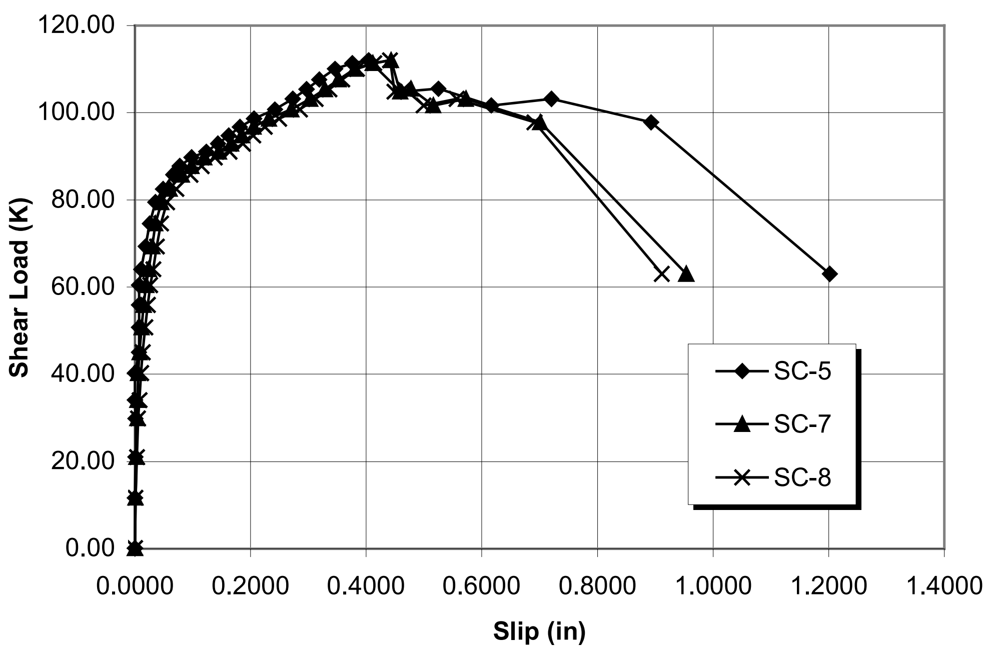
**COMMENTS**

Failure Mode: Concrete cone pullout
Screw Rotation ≈ 20° - 30°
Deck debonded; Slight bulging of deck below screws
Angles slightly deformed at screw locations due to rotation of screws
X = Screw sheared off; △ = Screw pulled out of concrete

**Test E5-1: Load vs. Slip (A)**




**Test E5-1: Load vs. Slip (B)**



**TEST E5-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.06 | 0.01 | -0.0004 | 0.0002 | -0.0004 | 0.0002 | -0.0002 | ~~-0.0002~~ | 0.0000 | -0.0004 |
| 11.68 | 1.12 | -0.0022 | 0.0046 | -0.0004 | 0.0002 | -0.0004 | ~~0.0002~~ | 0.0009 | 0.0007 |
| 20.98 | 2.08 | -0.0042 | 0.0070 | 0.0026 | 0.0024 | 0.0009 | ~~0.0024~~ | 0.0027 | 0.0031 |
| 29.90 | 2.94 | -0.0044 | 0.0104 | 0.0031 | 0.0055 | 0.0005 | ~~0.0055~~ | 0.0042 | 0.0053 |
| 34.11 | 3.08 | -0.0066 | 0.0123 | 0.0068 | 0.0139 | 0.0002 | ~~0.0064~~ | 0.0042 | 0.0077 |
| 40.33 | 4.01 | -0.0086 | 0.0126 | 0.0104 | 0.0194 | 0.0004 | ~~0.0084~~ | 0.0055 | 0.0104 |
| 45.04 | 4.52 | -0.0093 | 0.0141 | 0.0115 | 0.0214 | 0.0068 | ~~0.0106~~ | 0.0079 | 0.0128 |
| 50.82 | 5.38 | -0.0095 | 0.0163 | 0.0154 | 0.0260 | 0.0068 | ~~0.0147~~ | 0.0114 | 0.0178 |
| 55.90 | 5.83 | -0.0090 | 0.0192 | 0.0174 | 0.0293 | 0.0070 | ~~0.0167~~ | 0.0147 | 0.0218 |
| 60.49 | 6.11 | -0.0073 | 0.0227 | 0.0212 | 0.0355 | 0.0073 | ~~0.0212~~ | 0.0192 | 0.0264 |
| 64.07 | 6.50 | -0.0048 | 0.0260 | 0.0245 | 0.0397 | 0.0106 | ~~0.0260~~ | 0.0234 | 0.0313 |
| 69.28 | 7.04 | 0.0016 | 0.0324 | 0.0330 | 0.0487 | 0.0185 | ~~0.0319~~ | 0.0297 | 0.0383 |
| 74.62 | 7.50 | 0.0090 | 0.0421 | 0.0419 | 0.0590 | 0.0255 | ~~0.0368~~ | 0.0353 | 0.0452 |
| 79.52 | 8.14 | 0.0192 | 0.0524 | 0.0538 | 0.0716 | 0.0348 | ~~0.0397~~ | 0.0454 | 0.0559 |
| 82.54 | 8.59 | 0.0297 | 0.0639 | 0.0646 | 0.0850 | 0.0483 | ~~0.0447~~ | 0.0597 | 0.0716 |
| 85.74 | 8.85 | 0.0450 | 0.0822 | 0.0837 | 0.1053 | 0.0659 | ~~0.0505~~ | 0.0809 | 0.0961 |
| 87.75 | 9.09 | 0.0588 | 0.0963 | 0.0980 | 0.1203 | 0.0773 | ~~0.0516~~ | 0.0974 | 0.1152 |
| 89.76 | 9.50 | 0.0852 | 0.1205 | 0.1243 | 0.1524 | 0.0980 | ~~0.0515~~ | 0.1198 | 0.1384 |
| 91.08 | 9.55 | 0.1119 | 0.1476 | 0.1502 | 0.1795 | 0.1232 | ~~0.0529~~ | 0.1449 | 0.1641 |
| 92.90 | 9.76 | 0.1335 | 0.1698 | 0.1716 | 0.2020 | 0.1436 | ~~0.0570~~ | 0.1663 | 0.1864 |
| 94.79 | 9.96 | 0.1547 | 0.1919 | 0.1921 | 0.2209 | 0.1623 | ~~0.0599~~ | 0.1853 | 0.2046 |
| 96.80 | 10.09 | 0.1745 | 0.2124 | 0.2111 | 0.2379 | 0.1811 | ~~0.0634~~ | 0.2049 | 0.2243 |
| 98.68 | 10.30 | 0.1972 | 0.2375 | 0.2342 | 0.2599 | 0.2060 | ~~0.0678~~ | 0.2317 | 0.2494 |
| 100.75 | 10.33 | 0.2291 | 0.2708 | 0.2650 | 0.2884 | 0.2419 | ~~0.0694~~ | 0.2707 | 0.2853 |
| 103.20 | 10.60 | 0.2566 | 0.3018 | 0.2939 | 0.3141 | 0.2727 | ~~0.0696~~ | 0.3025 | 0.3130 |
| 105.46 | 10.96 | 0.2824 | 0.3298 | 0.3197 | 0.3349 | 0.2967 | ~~0.0692~~ | 0.3283 | 0.3366 |
| 107.60 | 11.30 | 0.3045 | 0.3538 | 0.3432 | 0.3536 | 0.3190 | ~~0.0694~~ | 0.3520 | 0.3580 |
| 110.05 | 11.42 | 0.3326 | 0.3815 | 0.3712 | 0.3758 | 0.3463 | ~~0.0694~~ | 0.3805 | 0.3840 |
| 111.36 | 10.94 | 0.3620 | 0.4056 | 0.4016 | 0.3990 | 0.3760 | ~~0.0696~~ | 0.4113 | 0.4141 |
| 112.12 | 10.81 | 0.3877 | 0.4302 | 0.4282 | 0.4199 | 0.4043 | ~~0.0696~~ | 0.4426 | 0.4415 |
| 104.83 | 11.32 | 0.4148 | 0.4549 | 0.4505 | 0.4327 | 0.4597 | ~~0.0817~~ | 0.4591 | 0.4494 |
| 105.52 | 10.83 | 0.4635 | 0.5014 | 0.4957 | 0.4589 | 0.5245 | ~~0.0980~~ | 0.4772 | 0.4659 |
| 101.63 | 10.18 | 0.5598 | 0.5878 | 0.5884 | 0.5364 | 0.6168 | ~~0.1146~~ | 0.5162 | 0.4988 |
| 103.20 | 9.86 | 0.6865 | 0.6858 | 0.7098 | 0.6382 | 0.7201 | ~~0.1243~~ | 0.5721 | 0.5562 |
| 97.86 | 8.25 | 0.8343 | 0.7655 | 0.8574 | 0.7598 | 0.8929 | ~~0.1546~~ | 0.7012 | 0.6911 |
| 63.00 | 9.50 | 0.8561 | 0.7768 | 0.8775 | 0.7757 | 1.2022 | ~~0.3901~~ | 0.9535 | 0.9112 |

Note: SC-6 readings not included due to operational error

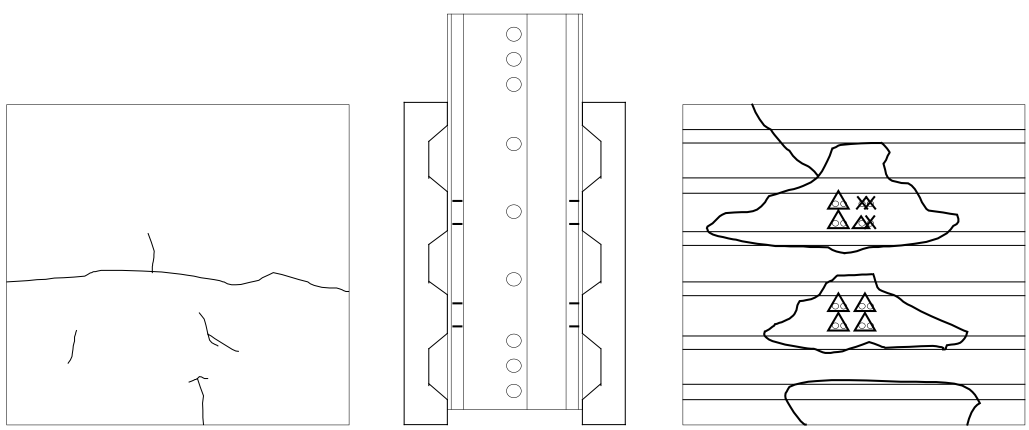
## PUSHOUT TEST SUMMARY SHEET

Test: E5-2 Test Date: 28-Oct-98
Test Designation: SC-8-4.0-0.250-2VL-4.25-2

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in | No. Per Specimen: | 32 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.250 | | | | |
| | $F_y$: | 54.5 ksi | $F_u$: | 77.4 ksi | | |
| **Slab:** | Thickness: | 4.25 in. | $f'_c$: | 4838 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4xW4 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 108.16 kips | | | |
| **Peak Shear Load Per Screw:** | 3.38 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.3686 in. | SC5: | 0.5137 in. |
| | SC2: | 0.1569 in. | SC6: | 0.2262 in. |
| | SC3: | 0.3835 in. | SC7: | 0.3221 in. |
| | SC4: | 0.4651 in. | SC8: | 0.3489 in. |

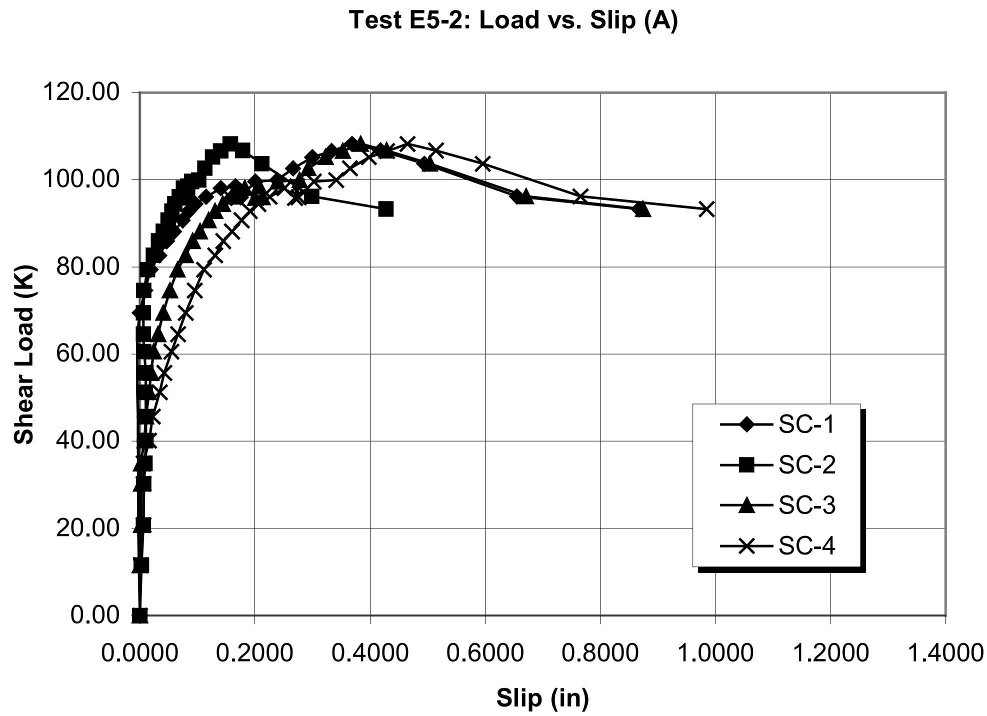
### DAMAGE

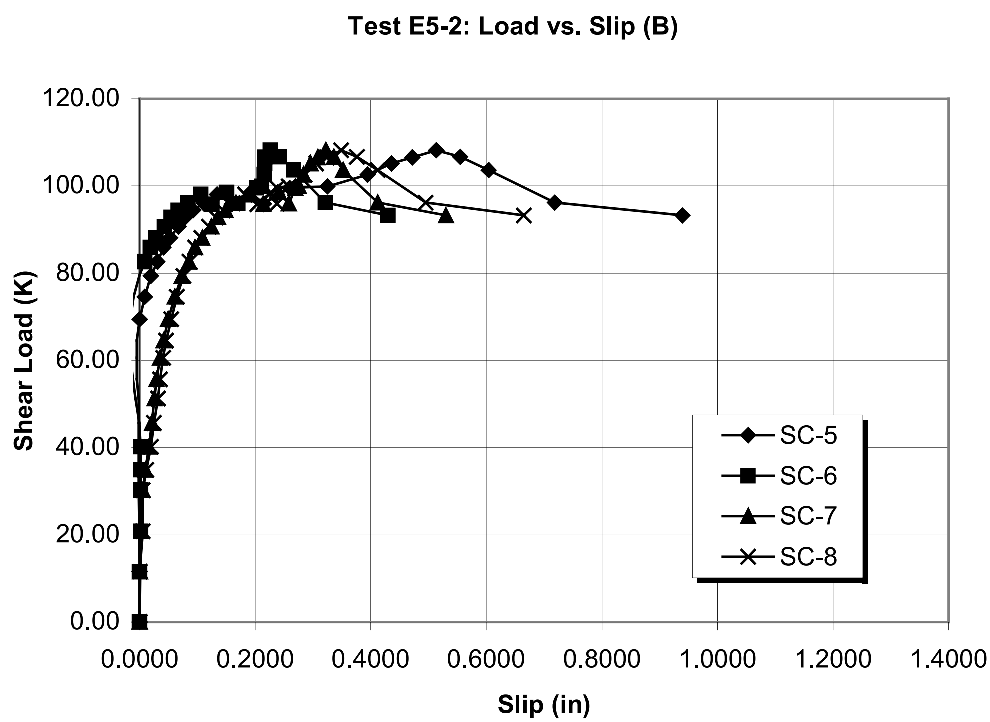


exterior, Slab A interior, Slab B

### COMMENTS

Failure Mode: Concrete cone pullout
Screw Rotation $\approx 20^\circ - 30^\circ$
Deck debonded; Slight bulging of deck below screws
Angles slightly deformed at screw locations due to rotation of screws
X = Screw sheared off; △ = Screw pulled out of concrete


Test E5-2: Load vs. Slip (A)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Shear Load (K)
0.0000
0.2000
0.4000
0.6000
0.8000
1.0000
1.2000
1.4000
Slip (in)
SC-1
SC-2
SC-3
SC-4


Test E5-2: Load vs. Slip (B)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Shear Load (K)
0.0000
0.2000
0.4000
0.6000
0.8000
1.0000
1.2000
1.4000
Slip (in)
SC-5
SC-6
SC-7
SC-8

**TEST E5-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0002 | 0.0002 | 0.0002 | -0.0002 | 0.0002 | 0.0000 | 0.0000 | -0.0002 |
| 11.56 | 1.01 | -0.0015 | 0.0029 | 0.0000 | -0.0002 | 0.0000 | 0.0004 | 0.0013 | 0.0000 |
| 20.73 | 1.75 | -0.0029 | 0.0060 | 0.0018 | 0.0064 | -0.0013 | 0.0016 | 0.0038 | 0.0055 |
| 30.21 | 3.06 | -0.0029 | 0.0071 | 0.0016 | 0.0066 | -0.0016 | 0.0022 | 0.0057 | 0.0055 |
| 34.86 | 3.05 | -0.0029 | 0.0084 | 0.0016 | 0.0066 | -0.0015 | 0.0018 | 0.0095 | 0.0117 |
| 40.14 | 4.08 | -0.0031 | 0.0104 | 0.0077 | 0.0159 | -0.0016 | 0.0016 | 0.0159 | 0.0192 |
| 45.60 | 4.36 | -0.0037 | 0.0104 | 0.0110 | 0.0218 | -0.0018 | -0.0011 | 0.0209 | 0.0249 |
| 51.19 | 5.14 | -0.0040 | 0.0101 | 0.0156 | 0.0342 | -0.0020 | -0.0073 | 0.0255 | 0.0315 |
| 55.65 | 5.53 | -0.0040 | 0.0103 | 0.0192 | 0.0425 | -0.0051 | -0.0117 | 0.0295 | 0.0353 |
| 60.55 | 6.06 | -0.0042 | 0.0073 | 0.0242 | 0.0549 | -0.0053 | -0.0157 | 0.0352 | 0.0403 |
| 64.51 | 6.43 | -0.0040 | 0.0062 | 0.0315 | 0.0667 | -0.0053 | -0.0172 | 0.0412 | 0.0460 |
| 69.41 | 7.07 | 0.0000 | 0.0066 | 0.0407 | 0.0798 | -0.0004 | -0.0159 | 0.0496 | 0.0544 |
| 74.56 | 7.60 | 0.0084 | 0.0070 | 0.0518 | 0.0950 | 0.0088 | -0.0108 | 0.0608 | 0.0641 |
| 79.33 | 8.07 | 0.0181 | 0.0128 | 0.0654 | 0.1117 | 0.0196 | -0.0011 | 0.0729 | 0.0756 |
| 82.66 | 8.54 | 0.0337 | 0.0234 | 0.0793 | 0.1304 | 0.0304 | 0.0090 | 0.0850 | 0.0864 |
| 85.87 | 8.79 | 0.0465 | 0.0326 | 0.0917 | 0.1449 | 0.0410 | 0.0185 | 0.0960 | 0.0958 |
| 88.19 | 9.00 | 0.0593 | 0.0407 | 0.1042 | 0.1597 | 0.0531 | 0.0284 | 0.1080 | 0.1066 |
| 90.70 | 9.37 | 0.0745 | 0.0496 | 0.1190 | 0.1769 | 0.0672 | 0.0436 | 0.1238 | 0.1199 |
| 92.78 | 9.60 | 0.0848 | 0.0555 | 0.1306 | 0.1910 | 0.0787 | 0.0546 | 0.1359 | 0.1317 |
| 94.41 | 9.71 | 0.0963 | 0.0613 | 0.1439 | 0.2060 | 0.0925 | 0.0672 | 0.1491 | 0.1445 |
| 96.11 | 9.92 | 0.1146 | 0.0687 | 0.1602 | 0.2254 | 0.1106 | 0.0835 | 0.1668 | 0.1610 |
| 98.05 | 10.10 | 0.1401 | 0.0764 | 0.1820 | 0.2513 | 0.1337 | 0.1057 | 0.1903 | 0.1824 |
| 95.79 | 10.12 | 0.1595 | 0.0826 | 0.2007 | 0.2699 | 0.1593 | 0.1254 | 0.2139 | 0.2031 |
| 98.56 | 10.36 | 0.1663 | 0.0828 | 0.2071 | 0.2732 | 0.1919 | 0.1507 | 0.2410 | 0.2273 |
| 95.98 | 10.80 | 0.1749 | 0.0830 | 0.2130 | 0.2760 | 0.2152 | 0.1698 | 0.2582 | 0.2373 |
| 99.56 | 10.51 | 0.2011 | 0.0901 | 0.2399 | 0.3020 | 0.2600 | 0.2024 | 0.2696 | 0.2379 |
| 99.94 | 11.04 | 0.2384 | 0.1029 | 0.2774 | 0.3415 | 0.3245 | 0.2111 | 0.2758 | 0.2582 |
| 102.63 | 11.55 | 0.2661 | 0.1128 | 0.2928 | 0.3653 | 0.3943 | 0.2161 | 0.2833 | 0.2855 |
| 105.15 | 11.68 | 0.3000 | 0.1267 | 0.3223 | 0.3979 | 0.4360 | 0.2166 | 0.2961 | 0.3056 |
| 106.59 | 11.17 | 0.3335 | 0.1408 | 0.3523 | 0.4298 | 0.4717 | 0.2168 | 0.3086 | 0.3241 |
| 108.16 | 11.33 | 0.3686 | 0.1569 | 0.3835 | 0.4651 | 0.5137 | 0.2262 | 0.3221 | 0.3489 |
| 106.72 | 11.33 | 0.4179 | 0.1785 | 0.4285 | 0.5146 | 0.5543 | 0.2425 | 0.3362 | 0.3760 |
| 103.70 | 11.40 | 0.4939 | 0.2119 | 0.5038 | 0.5957 | 0.6040 | 0.2670 | 0.3520 | 0.4119 |
| 96.17 | 10.90 | 0.6547 | 0.2987 | 0.6710 | 0.7658 | 0.7182 | 0.3214 | 0.4124 | 0.4944 |
| 93.28 | 11.40 | 0.8667 | 0.4280 | 0.8741 | 0.9847 | 0.9394 | 0.4300 | 0.5302 | 0.6649 |

## PUSHOUT TEST SUMMARY SHEET

Test: E6-1 Test Date: 29-Oct-98
Test Designation: SC-8-4.0-0.163-2VL-4.5-1

### SPECIMEN DESCRIPTION

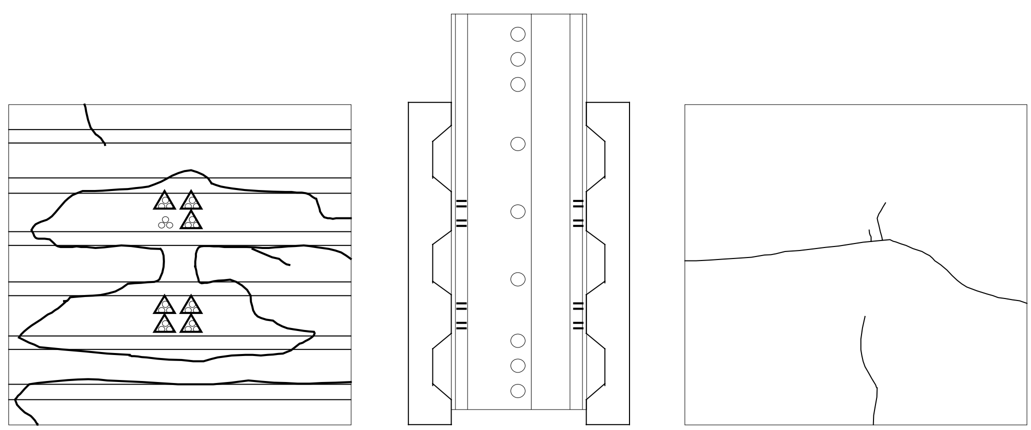
**Screw:** Height: 4.0 in. No. Per Specimen: 48
**Deck:** Type: 2VL, 22 ga Width: 36 in. Length: 36 in.
$F_y$: 51.0 ksi $F_u$: 56.7 ksi
**Base Member:** Section: 2L 2x2x0.163
$F_y$: 57.1 ksi $F_u$: 77.9 ksi
**Slab:** Thickness: 4.5 in. $f'_c$: 4894 psi
**Rebar:** Size: No. 4 No. Per Specimen: 16
Height Above Deck: 1.0 in.
**Mesh:** Type: WWF 6x6-W4xW4

### TEST RESULTS

**Peak Shear Load:** 133.04 kips
**Peak Shear Load Per Screw:** 2.77 kips
**Slip at Peak Shear Load:**

| | |
|---|---|
| SC1: 0.8658 in. | SC5: 0.7173 in. |
| SC2: 0.3316 in. | SC6: 0.5847 in. |
| SC3: 0.3489 in. | SC7: 0.4855 in. |
| SC4: 0.4767 in. | SC8: 0.1791 in. |

### DAMAGE

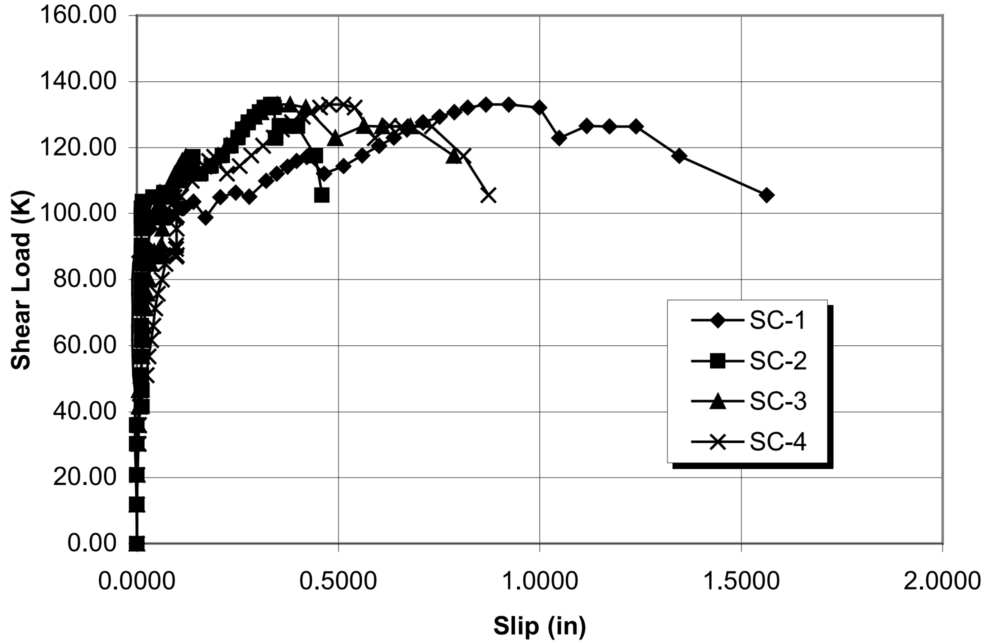


interior, Slab A exterior, Slab B

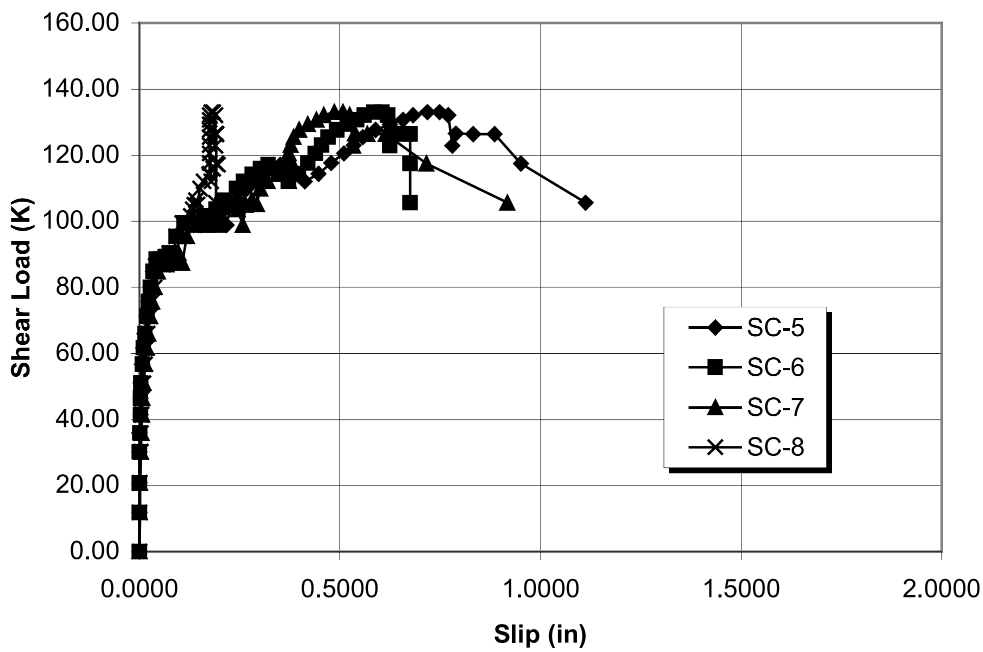
### COMMENTS

Failure Mode: Concrete cone pullout
Screw Rotation ≈ 40° - 50°
Deck debonded; Slight bulging of deck below screws
Angles significantly deformed at screw locations due to rotation of screws
△ = Screw pulled out of concrete

Test E6-1: Load vs. Slip (A)




Test E6-1: Load vs. Slip (B)



## TEST E6-1 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11.81 | 0.88 | -0.0013 | 0.0002 | 0.0000 | 0.0000 | 0.0000 | 0.0002 | 0.0007 | -0.0004 |
| 20.85 | 2.03 | -0.0026 | 0.0000 | 0.0015 | 0.0013 | 0.0002 | 0.0002 | 0.0018 | 0.0015 |
| 30.21 | 3.00 | -0.0053 | 0.0000 | 0.0029 | 0.0038 | 0.0002 | 0.0004 | 0.0044 | 0.0033 |
| 35.93 | 3.61 | -0.0055 | 0.0004 | 0.0035 | 0.0053 | 0.0000 | 0.0007 | 0.0049 | 0.0044 |
| 41.52 | 4.23 | -0.0055 | 0.0121 | 0.0046 | 0.0077 | 0.0029 | 0.0024 | 0.0066 | 0.0049 |
| 46.36 | 4.70 | -0.0055 | 0.0121 | 0.0057 | 0.0099 | 0.0027 | 0.0027 | 0.0081 | 0.0075 |
| 51.01 | 5.20 | -0.0086 | 0.0117 | 0.0106 | 0.0236 | 0.0031 | 0.0044 | 0.0106 | 0.0104 |
| 56.66 | 5.66 | -0.0103 | 0.0117 | 0.0130 | 0.0293 | 0.0062 | 0.0077 | 0.0141 | 0.0134 |
| 61.62 | 6.21 | -0.0108 | 0.0121 | 0.0159 | 0.0355 | 0.0090 | 0.0104 | 0.0176 | 0.0179 |
| 65.95 | 6.65 | -0.0108 | 0.0119 | 0.0179 | 0.0403 | 0.0125 | 0.0136 | 0.0220 | 0.0209 |
| 71.23 | 7.19 | -0.0106 | 0.0119 | 0.0212 | 0.0458 | 0.0174 | 0.0185 | 0.0266 | 0.0262 |
| 75.63 | 7.83 | -0.0108 | 0.0119 | 0.0251 | 0.0513 | 0.0227 | 0.0234 | 0.0319 | 0.0313 |
| 80.03 | 8.14 | -0.0108 | 0.0119 | 0.0297 | 0.0615 | 0.0282 | 0.0280 | 0.0385 | 0.0385 |
| 84.80 | 8.66 | -0.0084 | 0.0119 | 0.0346 | 0.0709 | 0.0348 | 0.0339 | 0.0460 | 0.0447 |
| 88.51 | 9.11 | -0.0044 | 0.0117 | 0.0425 | 0.0828 | 0.0412 | 0.0425 | 0.0549 | 0.0522 |
| 87.00 | 9.62 | 0.0066 | 0.0119 | 0.0540 | 0.0974 | 0.0522 | 0.0505 | 0.0676 | 0.0590 |
| 89.32 | 9.52 | 0.0148 | 0.0121 | 0.0559 | 0.0974 | 0.0720 | 0.0648 | 0.0879 | 0.0667 |
| 90.33 | 9.44 | 0.0209 | 0.0117 | 0.0601 | 0.0976 | 0.0817 | 0.0754 | 0.0980 | 0.0751 |
| 87.44 | 9.49 | 0.0266 | 0.0114 | 0.0615 | 0.0985 | 0.0894 | 0.0811 | 0.1071 | 0.0828 |
| 95.48 | 9.53 | 0.0331 | 0.0117 | 0.0626 | 0.0983 | 0.0996 | 0.0912 | 0.1183 | 0.0910 |
| 99.50 | 9.68 | 0.0419 | 0.0119 | 0.0676 | 0.0985 | 0.1210 | 0.1117 | 0.1416 | 0.1069 |
| 98.74 | 11.36 | 0.0819 | 0.0115 | 0.0597 | 0.0963 | 0.1452 | 0.1346 | 0.1698 | 0.1198 |
| 101.57 | 10.48 | 0.1156 | 0.0114 | 0.0579 | 0.0941 | 0.1736 | 0.1619 | 0.2058 | 0.1278 |
| 103.64 | 11.05 | 0.1405 | 0.0141 | 0.0571 | 0.0939 | 0.2058 | 0.1919 | 0.2445 | 0.1337 |
| 98.87 | 11.31 | 0.1705 | 0.0255 | 0.0460 | 0.0927 | 0.2170 | 0.1992 | 0.2575 | 0.1368 |
| 104.96 | 11.81 | 0.2077 | 0.0405 | 0.0476 | 0.0932 | 0.2284 | 0.2049 | 0.2648 | 0.1372 |
| 106.34 | 11.11 | 0.2445 | 0.0665 | 0.0571 | 0.0938 | 0.2458 | 0.2126 | 0.2807 | 0.1408 |
| 105.15 | 11.13 | 0.2796 | 0.0885 | 0.0701 | 0.1101 | 0.2555 | 0.2300 | 0.2928 | 0.1447 |
| 109.98 | 11.32 | 0.3207 | 0.1102 | 0.0853 | 0.1370 | 0.2679 | 0.2421 | 0.3003 | 0.1509 |
| 112.06 | 11.33 | 0.3472 | 0.1236 | 0.0952 | 0.1540 | 0.2873 | 0.2600 | 0.3190 | 0.1604 |
| 114.19 | 11.31 | 0.3743 | 0.1348 | 0.1049 | 0.1677 | 0.3102 | 0.2811 | 0.3421 | 0.1734 |
| 115.95 | 11.98 | 0.3970 | 0.1381 | 0.1124 | 0.1796 | 0.3304 | 0.3012 | 0.3615 | 0.1844 |
| 117.08 | 11.92 | 0.4219 | 0.1383 | 0.1216 | 0.1919 | 0.3516 | 0.3210 | 0.3824 | 0.1956 |
| 111.99 | 12.13 | 0.4648 | 0.1588 | 0.1465 | 0.2238 | 0.4119 | 0.3719 | 0.3728 | 0.1789 |
| 114.44 | 12.04 | 0.5126 | 0.1850 | 0.1754 | 0.2556 | 0.4465 | 0.3974 | 0.3705 | 0.1756 |
| 117.58 | 12.08 | 0.5596 | 0.2119 | 0.2020 | 0.2840 | 0.4787 | 0.4197 | 0.3699 | 0.1747 |
| 120.47 | 12.41 | 0.6012 | 0.2337 | 0.2240 | 0.3130 | 0.5096 | 0.4386 | 0.3719 | 0.1745 |
| 123.05 | 12.69 | 0.6378 | 0.2511 | 0.2432 | 0.3403 | 0.5338 | 0.4545 | 0.3771 | 0.1747 |
| 125.43 | 12.98 | 0.6706 | 0.2632 | 0.2571 | 0.3602 | 0.5567 | 0.4710 | 0.3840 | 0.1745 |
| 127.57 | 13.00 | 0.7093 | 0.2765 | 0.2730 | 0.3849 | 0.5884 | 0.4926 | 0.3987 | 0.1747 |
| 129.39 | 12.97 | 0.7514 | 0.2915 | 0.2915 | 0.4120 | 0.6245 | 0.5186 | 0.4195 | 0.1749 |
| 130.65 | 13.16 | 0.7884 | 0.3047 | 0.3075 | 0.4314 | 0.6565 | 0.5417 | 0.4413 | 0.1751 |
| 132.03 | 13.54 | 0.8213 | 0.3168 | 0.3238 | 0.4551 | 0.6827 | 0.5607 | 0.4591 | 0.1751 |
| 133.04 | 13.81 | 0.8658 | 0.3316 | 0.3489 | 0.4767 | 0.7173 | 0.5847 | 0.4855 | 0.1791 |
| 132.97 | 13.64 | 0.9235 | 0.3390 | 0.3798 | 0.5124 | 0.7479 | 0.6047 | 0.5071 | 0.1842 |
| 132.03 | 13.49 | 0.9991 | 0.3404 | 0.4190 | 0.5406 | 0.7702 | 0.6190 | 0.5239 | 0.1884 |
| 122.80 | 13.77 | 1.0478 | 0.3450 | 0.4930 | 0.5908 | 0.7801 | 0.6245 | 0.5322 | 0.1894 |
| 126.50 | 13.07 | 1.1165 | 0.3540 | 0.5635 | 0.6257 | 0.7891 | 0.6301 | 0.5380 | 0.1905 |
| 126.38 | 13.03 | 1.1734 | 0.3721 | 0.6087 | 0.6563 | 0.8321 | 0.6530 | 0.5686 | 0.1912 |
| 126.38 | 13.35 | 1.2386 | 0.3990 | 0.6787 | 0.7320 | 0.8849 | 0.6745 | 0.6135 | 0.1917 |
| 117.46 | 13.77 | 1.3465 | 0.4430 | 0.7867 | 0.8102 | 0.9510 | 0.6750 | 0.7153 | 0.1917 |
| 105.59 | 14.86 | 1.5637 | 0.4595 | | 0.8721 | 1.1123 | 0.6750 | 0.9171 | 0.1908 |

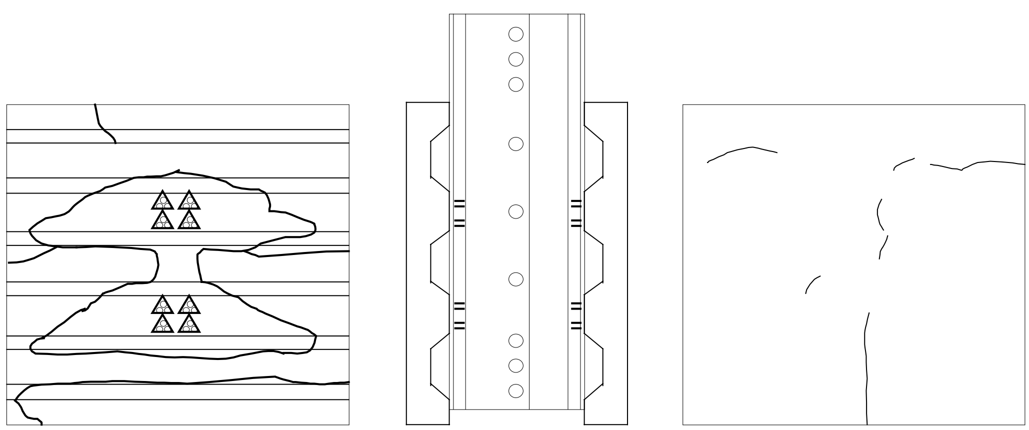
**PUSHOUT TEST SUMMARY SHEET**

Test: E6-2 Test Date: 3-Nov-98
Test Designation: SC-8-4.0-0.163-2VL-4.5-2

| SPECIMEN DESCRIPTION | | | |
|---|---|---|---|
| **Screw:** | Height: 4.0 in. | No. Per Specimen: 48 | |
| **Deck:** | Type: 2VL, 22 ga | Width: 36 in. | Length: 36 in. |
| | $F_y$: 51.0 ksi | $F_u$: 56.7 ksi | |
| **Base Member:** | Section: 2L 2x2x0.163 | | |
| | $F_y$: 57.1 ksi | $F_u$: 77.9 ksi | |
| **Slab:** | Thickness: 4.5 in. | $f'_c$: 4894 psi | |
| **Rebar:** | Size: No. 4 | No. Per Specimen: 16 | |
| | | Height Above Deck: 1.0 in. | |
| **Mesh:** | Type: WWF 6x6-W4xW4 | | |

| TEST RESULTS | | |
|---|---|---|
| **Peak Shear Load:** | 135.48 kips | |
| **Peak Shear Load Per Screw:** | 2.82 kips | |
| **Slip at Peak Shear Load:** | SC1: 0.6232 in. | SC5: 0.7598 in. |
| | SC2: 0.4445 in. | SC6: 0.2811 in. |
| | SC3: 0.4168 in. | SC7: 0.5774 in. |
| | SC4: 0.3474 in. | SC8: 0.4023 in. |

**DAMAGE**

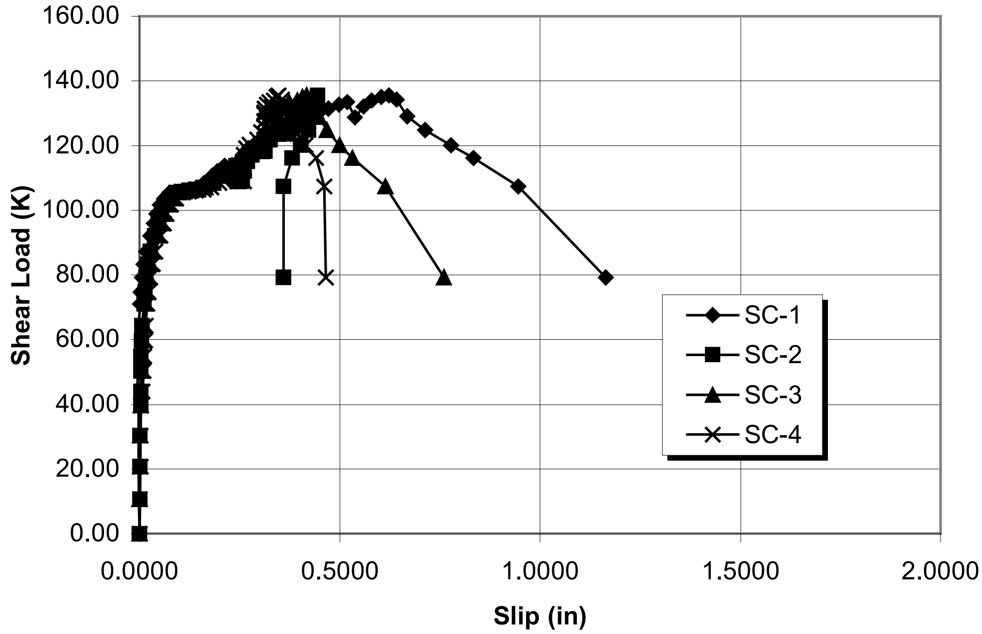


interior, Slab A exterior, Slab B

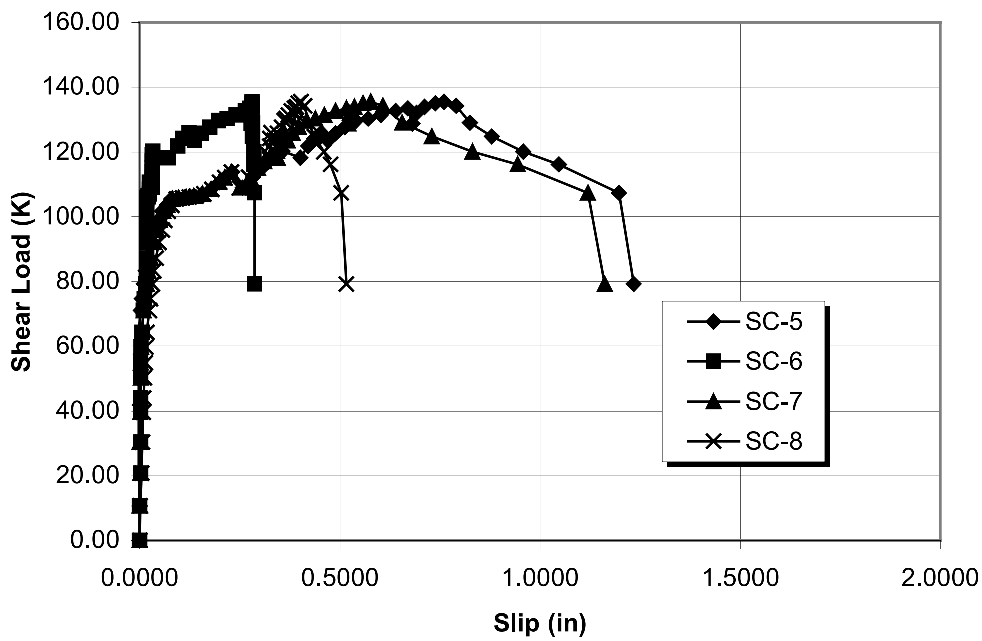
**COMMENTS**

Failure Mode: Concrete cone pullout
Screw Rotation ≈ 40° - 50°
Deck debonded; Slight bulging of deck below screws
Angles significantly deformed at screw locations due to rotation of screws
△ = Screw pulled out of concrete

### Test E6-2: Load vs. Slip (A)




### Test E6-2: Load vs. Slip (B)



**TEST E6-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0002 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -0.0002 | 0.0000 | 0.0000 |
| 10.62 | 1.31 | -0.0009 | 0.0011 | -0.0002 | 0.0000 | 0.0002 | 0.0002 | -0.0002 | 0.0009 |
| 20.79 | 2.09 | -0.0027 | 0.0015 | 0.0013 | 0.0022 | -0.0022 | 0.0024 | 0.0009 | 0.0051 |
| 30.34 | 3.15 | -0.0029 | 0.0018 | 0.0009 | 0.0022 | -0.0024 | 0.0024 | 0.0004 | 0.0066 |
| 39.64 | 3.93 | -0.0026 | 0.0033 | 0.0031 | 0.0042 | -0.0020 | 0.0024 | 0.0013 | 0.0088 |
| 44.03 | 4.52 | -0.0048 | 0.0035 | 0.0046 | 0.0082 | -0.0022 | 0.0026 | 0.0018 | 0.0097 |
| 50.31 | 5.03 | -0.0048 | 0.0033 | 0.0066 | 0.0103 | -0.0024 | 0.0022 | 0.0020 | 0.0115 |
| 54.84 | 5.32 | -0.0042 | 0.0038 | 0.0073 | 0.0117 | -0.0022 | 0.0026 | 0.0026 | 0.0137 |
| 59.67 | 6.31 | -0.0042 | 0.0046 | 0.0092 | 0.0136 | -0.0024 | 0.0040 | 0.0040 | 0.0152 |
| 64.32 | 6.71 | -0.0024 | 0.0064 | 0.0110 | 0.0154 | -0.0020 | 0.0062 | 0.0051 | 0.0183 |
| 70.98 | 7.22 | 0.0009 | 0.0112 | 0.0156 | 0.0194 | 0.0020 | 0.0093 | 0.0099 | 0.0242 |
| 74.69 | 7.64 | 0.0031 | 0.0145 | 0.0179 | 0.0223 | 0.0051 | 0.0114 | 0.0117 | 0.0267 |
| 79.15 | 8.08 | 0.0066 | 0.0168 | 0.0233 | 0.0264 | 0.0099 | 0.0148 | 0.0172 | 0.0313 |
| 83.35 | 8.52 | 0.0106 | 0.0203 | 0.0275 | 0.0328 | 0.0156 | 0.0179 | 0.0222 | 0.0361 |
| 87.25 | 8.67 | 0.0163 | 0.0262 | 0.0339 | 0.0396 | 0.0205 | 0.0181 | 0.0275 | 0.0408 |
| 92.15 | 9.17 | 0.0267 | 0.0379 | 0.0467 | 0.0522 | 0.0298 | 0.0181 | 0.0363 | 0.0483 |
| 95.92 | 9.80 | 0.0352 | 0.0465 | 0.0555 | 0.0604 | 0.0385 | 0.0179 | 0.0438 | 0.0557 |
| 98.81 | 9.99 | 0.0416 | 0.0542 | 0.0628 | 0.0678 | 0.0454 | 0.0178 | 0.0505 | 0.0623 |
| 101.69 | 10.34 | 0.0505 | 0.0652 | 0.0734 | 0.0789 | 0.0562 | 0.0178 | 0.0602 | 0.0711 |
| 103.51 | 10.76 | 0.0606 | 0.0762 | 0.0839 | 0.0919 | 0.0670 | 0.0178 | 0.0703 | 0.0804 |
| 105.52 | 10.99 | 0.0747 | 0.0921 | 0.0987 | 0.1086 | 0.0793 | 0.0178 | 0.0822 | 0.0921 |
| 105.84 | 11.06 | 0.0881 | 0.1062 | 0.1121 | 0.1236 | 0.0965 | 0.0183 | 0.0983 | 0.1064 |
| 106.03 | 11.16 | 0.1064 | 0.1251 | 0.1286 | 0.1414 | 0.1137 | 0.0220 | 0.1157 | 0.1236 |
| 106.46 | 11.13 | 0.1234 | 0.1434 | 0.1463 | 0.1599 | 0.1344 | 0.0220 | 0.1351 | 0.1414 |
| 107.09 | 11.06 | 0.1427 | 0.1646 | 0.1648 | 0.1793 | 0.1564 | 0.0242 | 0.1562 | 0.1599 |
| 108.41 | 11.05 | 0.1617 | 0.1855 | 0.1835 | 0.1991 | 0.1780 | 0.0240 | 0.1776 | 0.1807 |
| 110.67 | 11.24 | 0.1818 | 0.2075 | 0.2035 | 0.2201 | 0.1992 | 0.0245 | 0.1980 | 0.1991 |
| 112.12 | 11.34 | 0.1947 | 0.2220 | 0.2166 | 0.2320 | 0.2133 | 0.0320 | 0.2121 | 0.2124 |
| 113.75 | 11.56 | 0.2122 | 0.2408 | 0.2315 | 0.2474 | 0.2318 | 0.0322 | 0.2289 | 0.2284 |
| 108.98 | 11.70 | 0.2284 | 0.2566 | 0.2452 | 0.2602 | 0.2564 | 0.0322 | 0.2507 | 0.2487 |
| 112.24 | 11.61 | 0.2350 | 0.2613 | 0.2463 | 0.2600 | 0.2838 | 0.0320 | 0.2756 | 0.2719 |
| 115.07 | 11.70 | 0.2452 | 0.2699 | 0.2547 | 0.2600 | 0.3053 | 0.0320 | 0.2952 | 0.2906 |
| 117.02 | 11.72 | 0.2578 | 0.2813 | 0.2674 | 0.2604 | 0.3210 | 0.0320 | 0.3113 | 0.3055 |
| 119.09 | 12.08 | 0.2716 | 0.2932 | 0.2795 | 0.2659 | 0.3393 | 0.0320 | 0.3280 | 0.3210 |
| 120.28 | 12.32 | 0.2853 | 0.3042 | 0.2914 | 0.2745 | 0.3575 | 0.0326 | 0.3426 | 0.3329 |
| 118.21 | 12.91 | 0.2965 | 0.3135 | 0.3044 | 0.2831 | 0.4018 | 0.0716 | 0.3439 | 0.3251 |
| 121.79 | 13.12 | 0.3111 | 0.3260 | 0.3183 | 0.2936 | 0.4201 | 0.0949 | 0.3472 | 0.3252 |
| 124.24 | 13.25 | 0.3287 | 0.3388 | 0.3346 | 0.3040 | 0.4360 | 0.1084 | 0.3523 | 0.3258 |
| 125.94 | 13.38 | 0.3421 | 0.3503 | 0.3437 | 0.3110 | 0.4534 | 0.1231 | 0.3609 | 0.3280 |
| 123.55 | 14.24 | 0.3776 | 0.3697 | 0.3437 | 0.3115 | 0.4701 | 0.1372 | 0.3703 | 0.3351 |
| 125.75 | 13.33 | 0.3970 | 0.3820 | 0.3410 | 0.3113 | 0.4888 | 0.1544 | 0.3820 | 0.3441 |
| 127.63 | 13.54 | 0.4124 | 0.3913 | 0.3410 | 0.3115 | 0.5122 | 0.1749 | 0.3979 | 0.3547 |
| 129.64 | 13.73 | 0.4293 | 0.4001 | 0.3412 | 0.3113 | 0.5406 | 0.1970 | 0.4173 | 0.3615 |
| 130.33 | 13.82 | 0.4487 | 0.4095 | 0.3419 | 0.3115 | 0.5704 | 0.2185 | 0.4379 | 0.3661 |
| 131.34 | 13.86 | 0.4710 | 0.4184 | 0.3459 | 0.3120 | 0.6029 | 0.2414 | 0.4607 | 0.3707 |
| 132.66 | 13.87 | 0.4976 | 0.4296 | 0.3611 | 0.3179 | 0.6391 | 0.2644 | 0.4895 | 0.3782 |
| 133.47 | 13.92 | 0.5184 | 0.4375 | 0.3730 | 0.3240 | 0.6699 | 0.2743 | 0.5153 | 0.3868 |
| 128.70 | 14.15 | 0.5380 | 0.4413 | 0.3771 | 0.3269 | 0.6809 | 0.2780 | 0.5206 | 0.3879 |
| 132.09 | 13.25 | 0.5587 | 0.4430 | 0.3848 | 0.3298 | 0.6919 | 0.2811 | 0.5247 | 0.3879 |
| 133.98 | 13.53 | 0.5794 | 0.4441 | 0.3943 | 0.3349 | 0.7111 | 0.2811 | 0.5356 | 0.3912 |
| 134.98 | 13.68 | 0.6040 | 0.4445 | 0.4062 | 0.3417 | 0.7382 | 0.2809 | 0.5580 | 0.3961 |
| 135.48 | 13.79 | 0.6232 | 0.4445 | 0.4168 | 0.3474 | 0.7598 | 0.2811 | 0.5774 | 0.4023 |
| 134.29 | 14.11 | 0.6422 | 0.4435 | 0.4325 | 0.3562 | 0.7904 | 0.2811 | 0.6074 | 0.4111 |
| 129.02 | 14.39 | 0.6690 | 0.4344 | 0.4470 | 0.3675 | 0.8243 | 0.2815 | 0.6550 | 0.4217 |
| 124.81 | 14.26 | 0.7133 | 0.4214 | 0.4677 | 0.3853 | 0.8792 | 0.2822 | 0.7294 | 0.4360 |
| 120.10 | 13.97 | 0.7772 | 0.4029 | 0.4994 | 0.4137 | 0.9579 | 0.2862 | 0.8314 | 0.4597 |
| 116.08 | 12.87 | 0.8340 | 0.3809 | 0.5314 | 0.4415 | 1.0465 | 0.2864 | 0.9442 | 0.4763 |
| 107.34 | 13.32 | 0.9457 | 0.3593 | 0.6131 | 0.4607 | 1.1965 | 0.2875 | 1.1189 | 0.5036 |
| 79.27 | 14.67 | 1.1639 | 0.3595 | 0.7592 | 0.4651 | 1.2344 | 0.2877 | 1.1612 | 0.5159 |

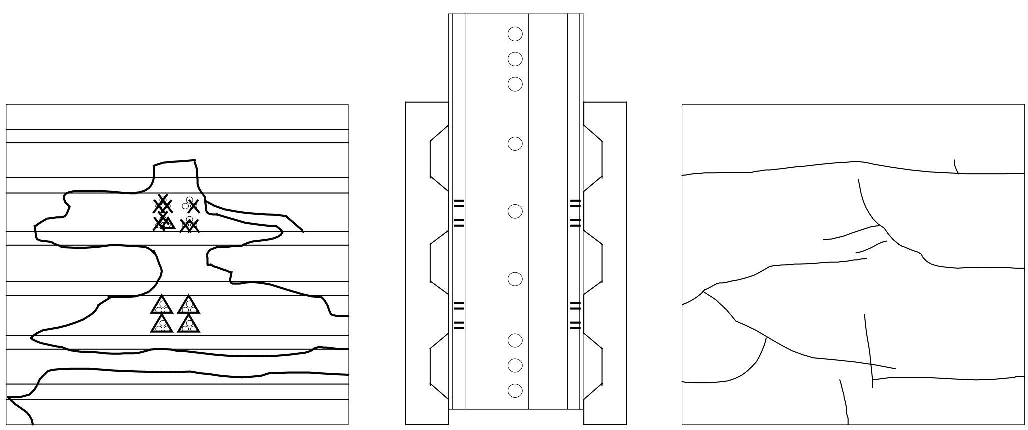
**PUSHOUT TEST SUMMARY SHEET**

Test: E7-1 Test Date: 13-Nov-98
Test Designation: SC-8-4.0-0.250-2VL-4.5-1

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 4.0 in. | No. Per Specimen: | 48 | | |
| **Deck:** | Type: | 2VL, 22 ga | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | 51.0 ksi | $F_u$: | 56.7 ksi | | |
| **Base Member:** | Section: | 2L 2x2x0.250 | | | | |
| | $F_y$: | 54.5 ksi | $F_u$: | 77.4 ksi | | |
| **Slab:** | Thickness: | 4.5 in. | $f'_c$: | 3830 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 16 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4xW4 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 125.81 kips | | | |
| **Peak Shear Load Per Screw:** | 2.62 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.4972 in. | SC5: | 0.7342 in. |
| | SC2: | 0.1090 in. | SC6: | 0.3038 in. |
| | SC3: | 0.2434 in. | SC7: | 0.4659 in. |
| | SC4: | 0.0722 in. | SC8: | 0.0348 in. |

**DAMAGE**

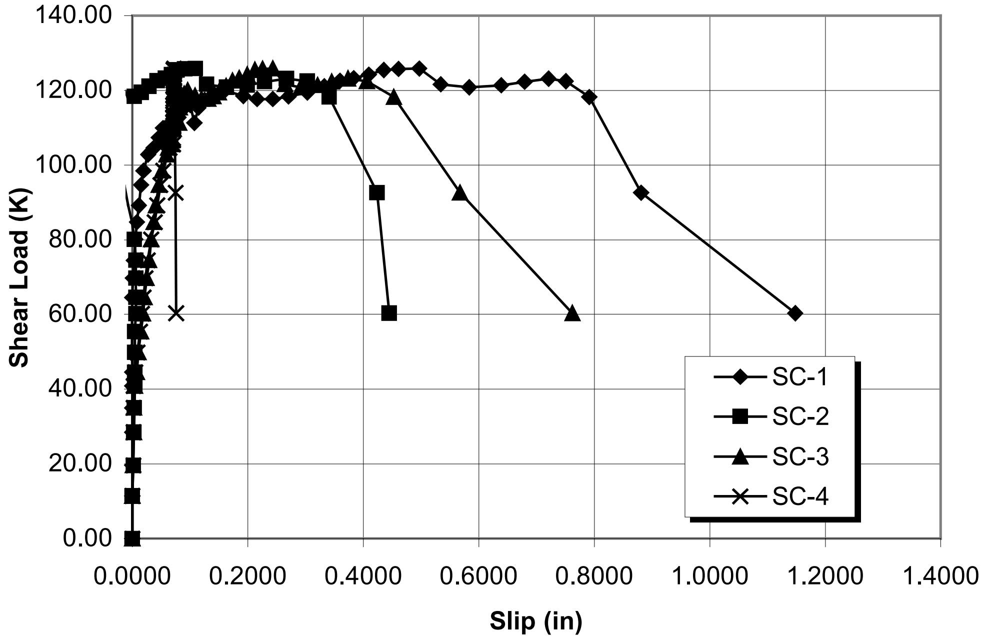


interior, Slab A exterior, Slab B

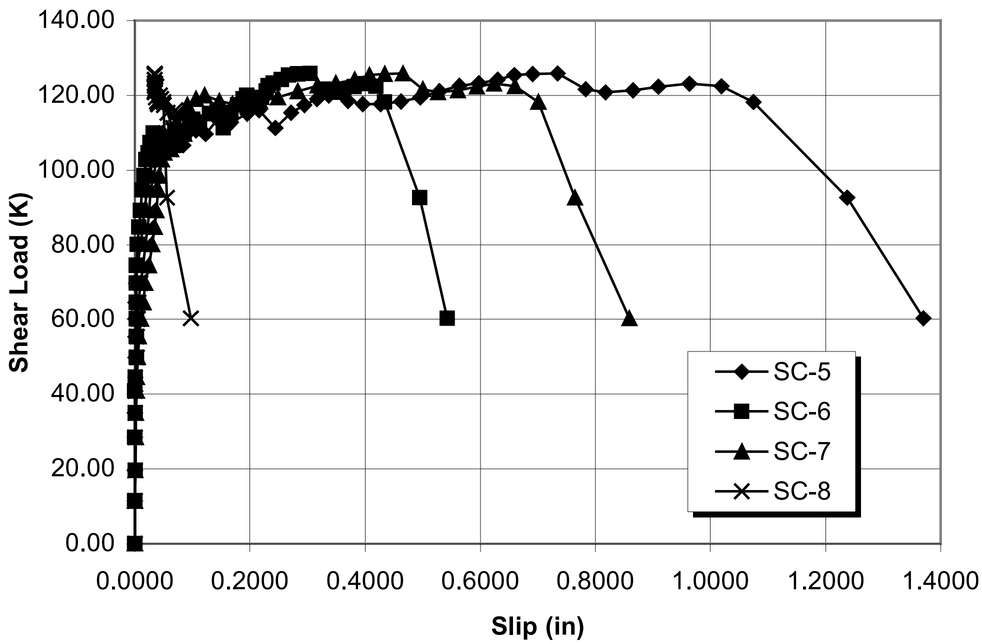
**COMMENTS**

Failure Mode: Concrete cone pullout followed by screw shear at ultimate load
Screw Rotation ≈ 20° - 30°
Deck debonded; Slight bulging of deck below screws
Angles slightly deformed at screw locations due to rotation of screws
X = Screw sheared off; △ = Screw pulled out of concrete

## Test E7-1: Load vs. Slip (A)




## Test E7-1: Load vs. Slip (B)



**TEST E7-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | -0.0002 | 0.0000 | 0.0000 | -0.0002 | 0.0000 | 0.0000 |
| 11.43 | 1.14 | 0.0004 | 0.0002 | 0.0000 | 0.0002 | 0.0002 | 0.0004 | 0.0004 | 0.0000 |
| 19.60 | 1.97 | -0.0002 | 0.0015 | 0.0009 | 0.0020 | -0.0002 | 0.0005 | 0.0009 | 0.0000 |
| 28.52 | 3.04 | -0.0002 | 0.0026 | 0.0024 | 0.0020 | -0.0002 | 0.0004 | 0.0015 | 0.0002 |
| 35.05 | 3.56 | 0.0000 | 0.0033 | 0.0029 | 0.0022 | 0.0000 | 0.0005 | 0.0020 | 0.0000 |
| 40.89 | 4.07 | 0.0000 | 0.0042 | 0.0046 | 0.0022 | 0.0013 | 0.0004 | 0.0035 | 0.0004 |
| 44.54 | 4.39 | -0.0002 | 0.0046 | 0.0082 | 0.0055 | 0.0013 | 0.0007 | 0.0038 | 0.0004 |
| 49.81 | 5.08 | -0.0009 | 0.0042 | 0.0110 | 0.0090 | 0.0011 | 0.0024 | 0.0051 | 0.0035 |
| 55.46 | 5.49 | -0.0007 | 0.0048 | 0.0148 | 0.0132 | 0.0011 | 0.0024 | 0.0075 | 0.0038 |
| 60.18 | 6.04 | -0.0007 | 0.0064 | 0.0185 | 0.0165 | 0.0013 | 0.0024 | 0.0104 | 0.0049 |
| 64.51 | 6.50 | -0.0002 | 0.0059 | 0.0212 | 0.0194 | 0.0013 | 0.0026 | 0.0148 | 0.0066 |
| 69.72 | 7.00 | 0.0007 | 0.0062 | 0.0249 | 0.0229 | 0.0015 | 0.0026 | 0.0174 | 0.0095 |
| 74.56 | 7.55 | 0.0027 | 0.0064 | 0.0291 | 0.0267 | 0.0044 | 0.0029 | 0.0245 | 0.0145 |
| 80.03 | 8.15 | 0.0053 | 0.0037 | 0.0330 | 0.0330 | 0.0093 | 0.0046 | 0.0302 | 0.0185 |
| 84.74 | 8.53 | 0.0082 | -0.0013 | 0.0374 | 0.0388 | 0.0132 | 0.0071 | 0.0348 | 0.0218 |
| 89.26 | 9.08 | 0.0114 | -0.0073 | 0.0407 | 0.0430 | 0.0170 | 0.0097 | 0.0375 | 0.0244 |
| 94.66 | 9.45 | 0.0152 | -0.0139 | 0.0458 | 0.0483 | 0.0214 | 0.0123 | 0.0403 | 0.0278 |
| 98.49 | 9.96 | 0.0196 | -0.0185 | 0.0513 | 0.0540 | 0.0256 | 0.0156 | 0.0429 | 0.0324 |
| 102.76 | 10.57 | 0.0269 | -0.0231 | 0.0593 | 0.0610 | 0.0317 | 0.0198 | 0.0467 | 0.0375 |
| 104.64 | 11.07 | 0.0366 | -0.0278 | 0.0621 | 0.0641 | 0.0366 | 0.0227 | 0.0509 | 0.0423 |
| 107.28 | 11.20 | 0.0454 | -0.0282 | 0.0652 | 0.0657 | 0.0423 | 0.0269 | 0.0553 | 0.0489 |
| 109.86 | 11.30 | 0.0529 | -0.0284 | 0.0676 | 0.0676 | 0.0478 | 0.0319 | 0.0601 | 0.0542 |
| 105.52 | 11.42 | 0.0566 | -0.0288 | 0.0685 | 0.0701 | 0.0562 | 0.0392 | 0.0632 | 0.0615 |
| 107.22 | 11.92 | 0.0579 | -0.0289 | 0.0685 | 0.0703 | 0.0690 | 0.0502 | 0.0650 | 0.0661 |
| 106.65 | 12.18 | 0.0621 | -0.0300 | 0.0694 | 0.0705 | 0.0837 | 0.0604 | 0.0703 | 0.0665 |
| 110.61 | 11.57 | 0.0657 | -0.0300 | 0.0705 | 0.0703 | 0.1057 | 0.0747 | 0.0780 | 0.0670 |
| 109.61 | 11.76 | 0.0696 | -0.0302 | 0.0711 | 0.0703 | 0.1229 | 0.0855 | 0.0857 | 0.0694 |
| 113.56 | 12.15 | 0.0760 | -0.0302 | 0.0736 | 0.0703 | 0.1436 | 0.1009 | 0.0927 | 0.0718 |
| 112.81 | 12.44 | 0.0804 | -0.0304 | 0.0749 | 0.0705 | 0.1668 | 0.1126 | 0.1004 | 0.0716 |
| 115.01 | 12.58 | 0.0885 | -0.0289 | 0.0758 | 0.0703 | 0.1958 | 0.1300 | 0.0949 | 0.0714 |
| 116.08 | 12.15 | 0.1005 | -0.0264 | 0.0795 | 0.0707 | 0.2159 | 0.1436 | 0.0879 | 0.0711 |
| 111.24 | 11.35 | 0.1077 | -0.0247 | 0.0811 | 0.0718 | 0.2439 | 0.1536 | 0.0861 | 0.0661 |
| 115.38 | 11.35 | 0.1145 | -0.0249 | 0.0819 | 0.0720 | 0.2714 | 0.1672 | 0.0864 | 0.0566 |
| 117.46 | 11.38 | 0.1254 | -0.0240 | 0.0850 | 0.0722 | 0.2943 | 0.1784 | 0.0908 | 0.0502 |
| 118.96 | 12.06 | 0.1408 | -0.0187 | 0.0901 | 0.0722 | 0.3163 | 0.1883 | 0.1057 | 0.0456 |
| 119.97 | 12.38 | 0.1604 | -0.0132 | 0.0963 | 0.0720 | 0.3364 | 0.1943 | 0.1207 | 0.0432 |
| 118.46 | 12.35 | 0.1921 | -0.0090 | 0.1080 | 0.0720 | 0.3705 | 0.2018 | 0.1465 | 0.0401 |
| 117.65 | 12.29 | 0.2163 | -0.0082 | 0.1196 | 0.0716 | 0.3963 | 0.2057 | 0.1696 | 0.0403 |
| 117.71 | 12.22 | 0.2436 | -0.0031 | 0.1309 | 0.0716 | 0.4267 | 0.2106 | 0.1925 | 0.0394 |
| 118.34 | 12.32 | 0.2707 | 0.0037 | 0.1401 | 0.0720 | 0.4620 | 0.2150 | 0.2174 | 0.0377 |
| 119.40 | 12.26 | 0.3029 | 0.0157 | 0.1500 | 0.0718 | 0.4961 | 0.2205 | 0.2480 | 0.0361 |
| 121.10 | 12.79 | 0.3320 | 0.0291 | 0.1617 | 0.0718 | 0.5294 | 0.2284 | 0.2831 | 0.0344 |
| 122.61 | 12.72 | 0.3591 | 0.0434 | 0.1732 | 0.0718 | 0.5639 | 0.2318 | 0.3172 | 0.0346 |
| 123.24 | 12.66 | 0.3837 | 0.0571 | 0.1853 | 0.0720 | 0.5977 | 0.2403 | 0.3494 | 0.0346 |
| 124.18 | 12.90 | 0.4095 | 0.0678 | 0.1991 | 0.0720 | 0.6301 | 0.2544 | 0.3822 | 0.0344 |
| 125.37 | 12.95 | 0.4353 | 0.0778 | 0.2121 | 0.0718 | 0.6594 | 0.2674 | 0.4078 | 0.0348 |
| 125.69 | 12.96 | 0.4611 | 0.0906 | 0.2254 | 0.0722 | 0.6915 | 0.2829 | 0.4344 | 0.0348 |
| 125.81 | 13.06 | 0.4972 | 0.1090 | 0.2434 | 0.0722 | 0.7342 | 0.3038 | 0.4659 | 0.0348 |
| 121.67 | 13.12 | 0.5344 | 0.1289 | 0.2646 | 0.0723 | 0.7827 | 0.3285 | 0.5007 | 0.0350 |
| 120.79 | 13.40 | 0.5836 | 0.1626 | 0.2915 | 0.0723 | 0.8177 | 0.3432 | 0.5269 | 0.0348 |
| 121.29 | 12.42 | 0.6387 | 0.1991 | 0.3203 | 0.0722 | 0.8653 | 0.3631 | 0.5613 | 0.0350 |
| 122.29 | 12.69 | 0.6794 | 0.2293 | 0.3456 | 0.0722 | 0.9094 | 0.3807 | 0.5935 | 0.0350 |
| 123.17 | 12.99 | 0.7206 | 0.2670 | 0.3732 | 0.0722 | 0.9633 | 0.3996 | 0.6237 | 0.0350 |
| 122.48 | 13.32 | 0.7510 | 0.3033 | 0.4060 | 0.0720 | 1.0192 | 0.4188 | 0.6598 | 0.0372 |
| 118.15 | 12.43 | 0.7911 | 0.3414 | 0.4525 | 0.0720 | 1.0751 | 0.4338 | 0.7010 | 0.0496 |
| 92.65 | 13.98 | 0.8808 | 0.4234 | 0.5673 | 0.0751 | 1.2377 | 0.4952 | 0.7646 | 0.0560 |
| 60.30 | 10.29 | 1.1478 | 0.4450 | 0.7622 | 0.0754 | 1.3701 | 0.5428 | 0.8589 | 0.0976 |

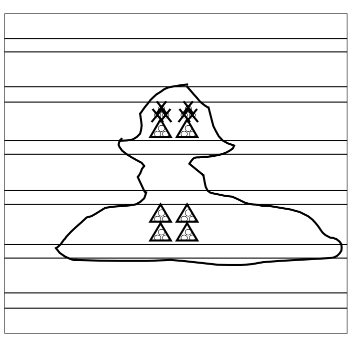
**PUSHOUT TEST SUMMARY SHEET**

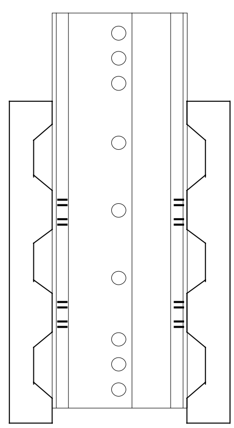
Test: E7-2 Test Date: 15-Nov-98
Test Designation: SC-8-4.0-0.250-2VL-4.5-2

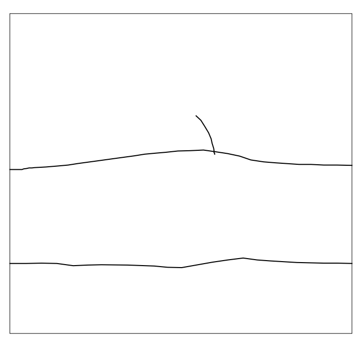
| SPECIMEN DESCRIPTION | | | | |
|---|---|---|---|---|
| **Screw:** | Height: 4.0 in. | No. Per Specimen: 48 | | |
| **Deck:** | Type: 2VL, 22 ga | Width: 36 in. | Length: 36 in. | |
| | $F_y$: 51.0 ksi | $F_u$: 56.7 ksi | | |
| **Base Member:** | Section: 2L 2x2x0.250 | | | |
| | $F_y$: 54.5 ksi | $F_u$: 77.4 ksi | | |
| **Slab:** | Thickness: 4.5 in. | $f'_c$: 3830 psi | | |
| **Rebar:** | Size: No. 4 | No. Per Specimen: 16 | | |
| | | Height Above Deck: 1.0 in. | | |
| **Mesh:** | Type: WWF 6x6-W4xW4 | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 132.91 kips | | | |
| **Peak Shear Load Per Screw:** | 2.77 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.6395 in. | SC5: | 0.1628 in. |
| | SC2: | N.A. | SC6: | 0.1234 in. |
| | SC3: | 0.4725 in. | SC7: | 0.2047 in. |
| | SC4: | 0.2069 in. | SC8: | 0.1661 in. |

**DAMAGE**

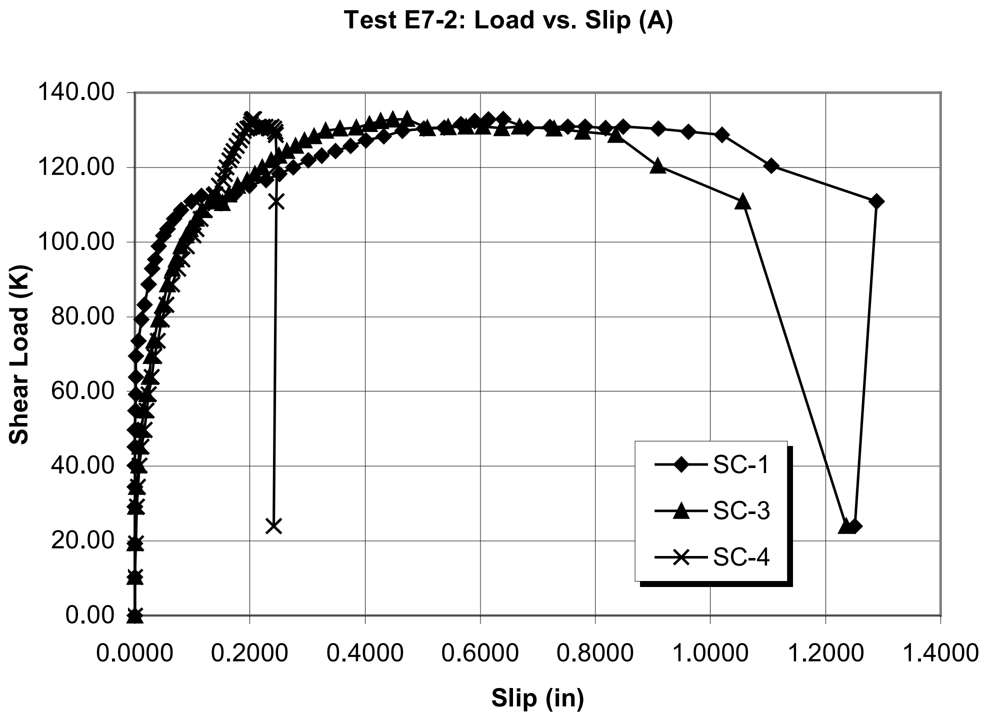

interior, Slab A

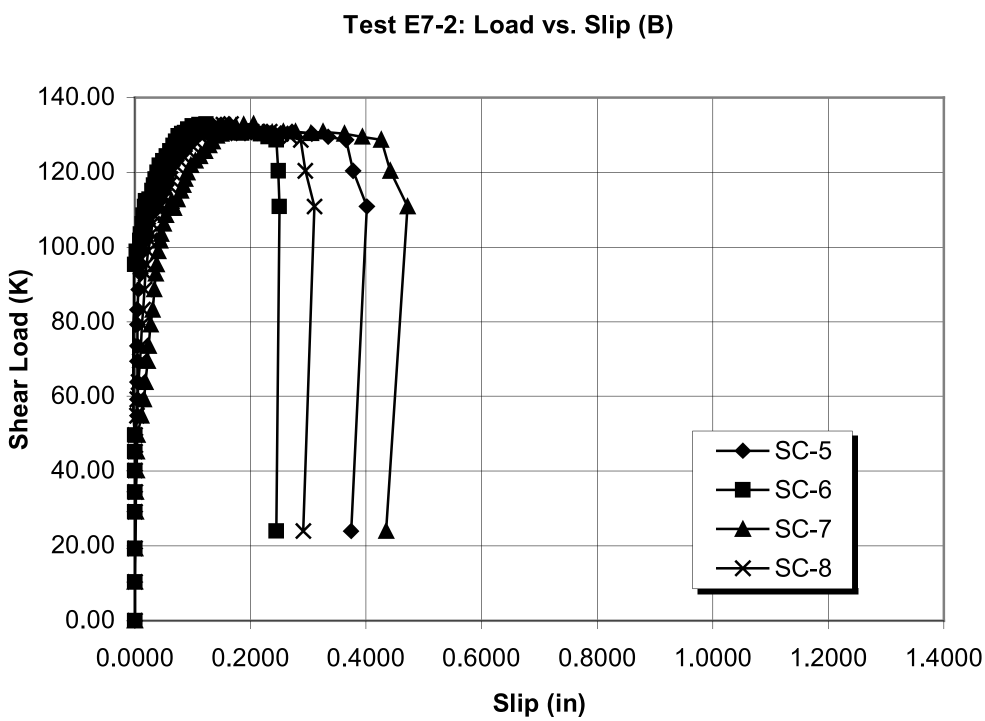



exterior, Slab B

**COMMENTS**

Failure Mode: Concrete cone pullout followed by screw shear at ultimate load
Screw Rotation ≈ 20° - 30°
Deck debonded; Slight bulging of deck below screws
Angles slightly deformed at screw locations due to rotation of screws
X = Screw sheared off; △ = Screw pulled out of concrete


Test E7-2: Load vs. Slip (A)
Shear Load (K)
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0000
0.2000
0.4000
0.6000
0.8000
1.0000
1.2000
1.4000
Slip (in)
SC-1
SC-3
SC-4


Test E7-2: Load vs. Slip (B)
Shear Load (K)
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0000
0.2000
0.4000
0.6000
0.8000
1.0000
1.2000
1.4000
Slip (in)
SC-5
SC-6
SC-7
SC-8

**TEST E7-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0002 | -0.0004 | 0.0000 | -0.0002 | 0.0000 | 0.0002 | 0.0002 |
| 10.30 | 1.09 | -0.0002 | 0.0007 | -0.0002 | 0.0002 | -0.0004 | 0.0000 | -0.0002 | 0.0000 |
| 19.35 | 1.99 | 0.0000 | 0.0018 | 0.0002 | 0.0015 | -0.0004 | 0.0000 | 0.0007 | 0.0002 |
| 29.21 | 2.74 | 0.0000 | 0.0042 | 0.0013 | 0.0038 | 0.0000 | 0.0000 | 0.0016 | 0.0002 |
| 34.42 | 3.58 | -0.0004 | 0.0046 | 0.0029 | 0.0049 | 0.0000 | 0.0000 | 0.0022 | 0.0005 |
| 40.14 | 3.95 | 0.0000 | 0.0057 | 0.0059 | 0.0082 | 0.0000 | 0.0004 | 0.0031 | 0.0002 |
| 45.16 | 4.50 | -0.0002 | 0.0059 | 0.0079 | 0.0114 | 0.0005 | 0.0000 | 0.0035 | 0.0004 |
| 49.69 | 5.04 | 0.0002 | 0.0070 | 0.0114 | 0.0167 | 0.0013 | 0.0004 | 0.0048 | 0.0002 |
| 54.90 | 5.54 | 0.0013 | 0.0088 | 0.0154 | 0.0200 | 0.0044 | -0.0024 | 0.0115 | 0.0031 |
| 59.23 | 6.01 | 0.0015 | 0.0084 | 0.0201 | 0.0240 | 0.0042 | -0.0026 | 0.0159 | 0.0044 |
| 63.82 | 6.49 | 0.0015 | 0.0055 | 0.0244 | 0.0288 | 0.0042 | -0.0024 | 0.0183 | 0.0066 |
| 69.47 | 7.07 | 0.0020 | 0.0037 | 0.0286 | 0.0333 | 0.0044 | -0.0024 | 0.0218 | 0.0086 |
| 73.49 | 7.81 | 0.0062 | 0.0022 | 0.0330 | 0.0397 | 0.0044 | -0.0026 | 0.0238 | 0.0104 |
| 79.21 | 8.00 | 0.0115 | -0.0002 | 0.0408 | 0.0471 | 0.0042 | -0.0024 | 0.0269 | 0.0119 |
| 83.23 | 8.52 | 0.0168 | -0.0016 | 0.0485 | 0.0548 | 0.0042 | -0.0022 | 0.0306 | 0.0143 |
| 88.69 | 9.02 | 0.0236 | -0.0020 | 0.0570 | 0.0648 | 0.0066 | -0.0020 | 0.0339 | 0.0167 |
| 92.84 | 9.48 | 0.0302 | -0.0020 | 0.0656 | 0.0749 | 0.0093 | -0.0020 | 0.0364 | 0.0187 |
| 95.35 | 9.61 | 0.0352 | -0.0024 | 0.0716 | 0.0820 | 0.0110 | 0.0002 | 0.0379 | 0.0203 |
| 98.81 | 10.23 | 0.0412 | -0.0005 | 0.0798 | 0.0905 | 0.0136 | 0.0024 | 0.0405 | 0.0227 |
| 101.69 | 10.59 | 0.0494 | 0.0020 | 0.0894 | 0.1013 | 0.0172 | 0.0084 | 0.0440 | 0.0260 |
| 103.45 | 10.61 | 0.0566 | 0.0042 | 0.0967 | 0.1069 | 0.0196 | 0.0101 | 0.0461 | 0.0284 |
| 106.21 | 10.82 | 0.0683 | 0.0077 | 0.1071 | 0.1139 | 0.0227 | 0.0121 | 0.0500 | 0.0300 |
| 108.54 | 10.97 | 0.0800 | 0.0097 | 0.1168 | 0.1209 | 0.0266 | 0.0137 | 0.0538 | 0.0324 |
| 110.92 | 11.31 | 0.0980 | 0.0126 | 0.1308 | 0.1313 | 0.0300 | 0.0163 | 0.0588 | 0.0355 |
| 112.37 | 11.59 | 0.1154 | 0.0150 | 0.1425 | 0.1373 | 0.0348 | 0.0189 | 0.0632 | 0.0388 |
| 110.48 | 12.25 | 0.1474 | 0.0161 | 0.1518 | 0.1395 | 0.0390 | 0.0201 | 0.0678 | 0.0427 |
| 112.81 | 11.56 | 0.1732 | 0.0159 | 0.1639 | 0.1399 | 0.0445 | 0.0251 | 0.0738 | 0.0489 |
| 115.13 | 11.75 | 0.1991 | 0.0148 | 0.1784 | 0.1461 | 0.0505 | 0.0298 | 0.0802 | 0.0546 |
| 116.64 | 11.91 | 0.2276 | 0.0136 | 0.1952 | 0.1529 | 0.0542 | 0.0326 | 0.0841 | 0.0582 |
| 118.15 | 11.99 | 0.2507 | 0.0104 | 0.2084 | 0.1564 | 0.0571 | 0.0355 | 0.0875 | 0.0617 |
| 120.03 | 12.10 | 0.2747 | 0.0088 | 0.2212 | 0.1595 | 0.0606 | 0.0388 | 0.0908 | 0.0654 |
| 121.85 | 12.14 | 0.3011 | 0.0066 | 0.2370 | 0.1644 | 0.0648 | 0.0423 | 0.0971 | 0.0701 |
| 123.05 | 12.16 | 0.3247 | 0.0049 | 0.2502 | 0.1679 | 0.0720 | 0.0483 | 0.1049 | 0.0771 |
| 124.37 | 12.29 | 0.3483 | 0.0044 | 0.2641 | 0.1716 | 0.0776 | 0.0544 | 0.1128 | 0.0839 |
| 125.69 | 12.32 | 0.3745 | 0.0040 | 0.2789 | 0.1771 | 0.0866 | 0.0608 | 0.1216 | 0.0921 |
| 127.19 | 12.54 | 0.4014 | 0.0035 | 0.2943 | 0.1824 | 0.0928 | 0.0659 | 0.1284 | 0.0989 |
| 128.26 | 12.85 | 0.4324 | 0.0031 | 0.3113 | 0.1862 | 0.0993 | 0.0705 | 0.1344 | 0.1047 |
| 129.83 | 12.89 | 0.4650 | 0.0033 | 0.3311 | 0.1894 | 0.1047 | 0.0751 | 0.1419 | 0.1117 |
| 130.33 | 12.96 | 0.5016 | 0.0033 | 0.3564 | 0.1958 | 0.1126 | 0.0811 | 0.1500 | 0.1187 |
| 130.59 | 13.04 | 0.5373 | 0.0035 | 0.3846 | 0.1996 | 0.1196 | 0.0864 | 0.1575 | 0.1254 |
| 131.59 | 13.08 | 0.5666 | 0.0033 | 0.4071 | 0.2013 | 0.1254 | 0.0916 | 0.1646 | 0.1313 |
| 132.41 | 13.09 | 0.5906 | 0.0031 | 0.4272 | 0.2020 | 0.1355 | 0.0998 | 0.1743 | 0.1405 |
| 132.78 | 13.05 | 0.6140 | 0.0026 | 0.4483 | 0.2042 | 0.1487 | 0.1106 | 0.1884 | 0.1531 |
| 132.91 | 13.00 | 0.6395 | 0.0004 | 0.4725 | 0.2069 | 0.1628 | 0.1234 | 0.2047 | 0.1661 |
| 130.52 | 13.19 | 0.6825 | -0.0013 | 0.5080 | 0.2119 | 0.1760 | 0.1357 | 0.2198 | 0.1784 |
| 130.71 | 13.23 | 0.7210 | -0.0020 | 0.5446 | 0.2165 | 0.1912 | 0.1483 | 0.2375 | 0.1905 |
| 130.84 | 13.23 | 0.7519 | -0.0026 | 0.5752 | 0.2218 | 0.2088 | 0.1582 | 0.2567 | 0.2024 |
| 130.84 | 13.21 | 0.7825 | -0.0027 | 0.6043 | 0.2274 | 0.2285 | 0.1705 | 0.2780 | 0.2121 |
| 130.52 | 13.23 | 0.8178 | -0.0031 | 0.6377 | 0.2328 | 0.2527 | 0.1846 | 0.3045 | 0.2227 |
| 130.90 | 13.30 | 0.8481 | -0.0035 | 0.6686 | 0.2377 | 0.2725 | 0.1972 | 0.3258 | 0.2333 |
| 130.33 | 13.43 | 0.9098 | -0.0029 | 0.7279 | 0.2423 | 0.3060 | 0.2172 | 0.3628 | 0.2527 |
| 129.58 | 13.54 | 0.9618 | -0.0013 | 0.7781 | 0.2443 | 0.3342 | 0.2306 | 0.3932 | 0.2688 |
| 128.64 | 12.90 | 1.0196 | -0.0007 | 0.8356 | 0.2448 | 0.3652 | 0.2447 | 0.4265 | 0.2868 |
| 120.41 | 12.21 | 1.1060 | 0.0005 | 0.9089 | 0.2463 | 0.3776 | 0.2480 | 0.4424 | 0.2952 |
| 110.86 | 13.34 | 1.2884 | -0.0106 | 1.0566 | 0.2458 | 0.4014 | 0.2498 | 0.4719 | 0.3110 |
| 23.93 | 0.28 | 1.2509 | 0.0236 | 1.2353 | 0.2412 | 0.3741 | 0.2445 | 0.4353 | 0.2914 |

Note: SC-2 readings not included due to operational error

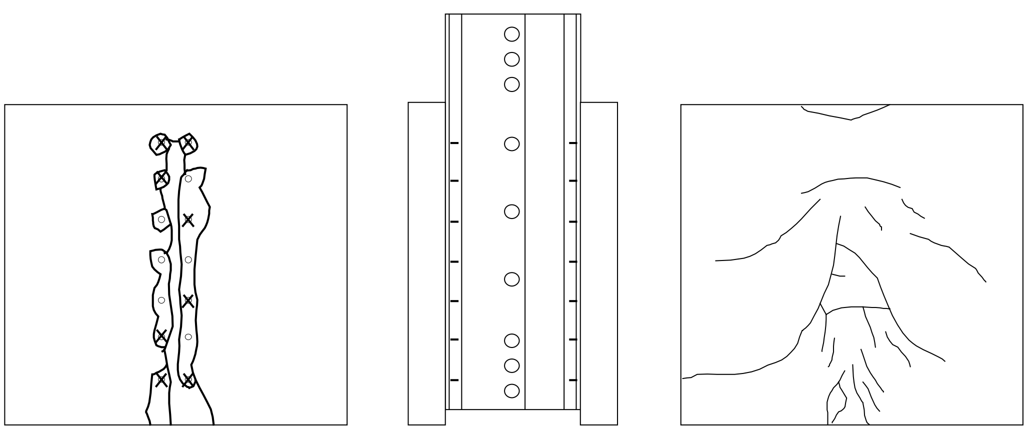
**PUSHOUT TEST SUMMARY SHEET**

Test: F1-1 Test Date: 25-Nov-98
Test Designation: SC-8-2.0-0.163-S-2.5-1

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.0 in. | No. Per Specimen: | 28 | | |
| **Deck:** | Type: | none | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | N.A. | $F_u$: | N.A. | | |
| **Base Member:** | Section: | 2L 2x2x0.163 | | | | |
| | $F_y$: | 57.1 ksi | $F_u$: | 77.9 ksi | | |
| **Slab:** | Thickness: | 2.5 in. | $f'_c$: | 3793 psi | | |
| **Rebar:** | Size: | No.4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W2.9xW2.9 | | | | |

| TEST RESULTS | | | | | |
|---|---|---|---|---|---|
| **Peak Shear Load:** | 190.20 kips | | | | |
| **Peak Shear Load Per Screw:** | 6.79 kips | | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.6781 in. | SC5: | 0.6677 in. | |
| | SC2: | 0.6909 in. | SC6: | 0.6305 in. | |
| | SC3: | 0.6738 in. | SC7: | 0.6494 in. | |
| | SC4: | 0.7397 in. | SC8: | 0.6097 in. | |

**DAMAGE**

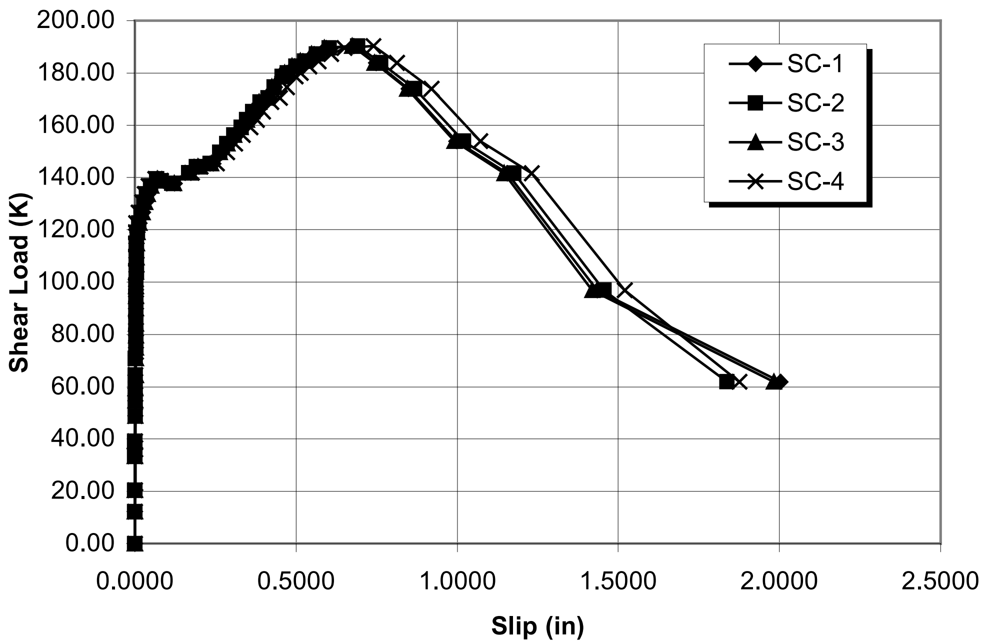


interior, Slab A exterior, Slab B

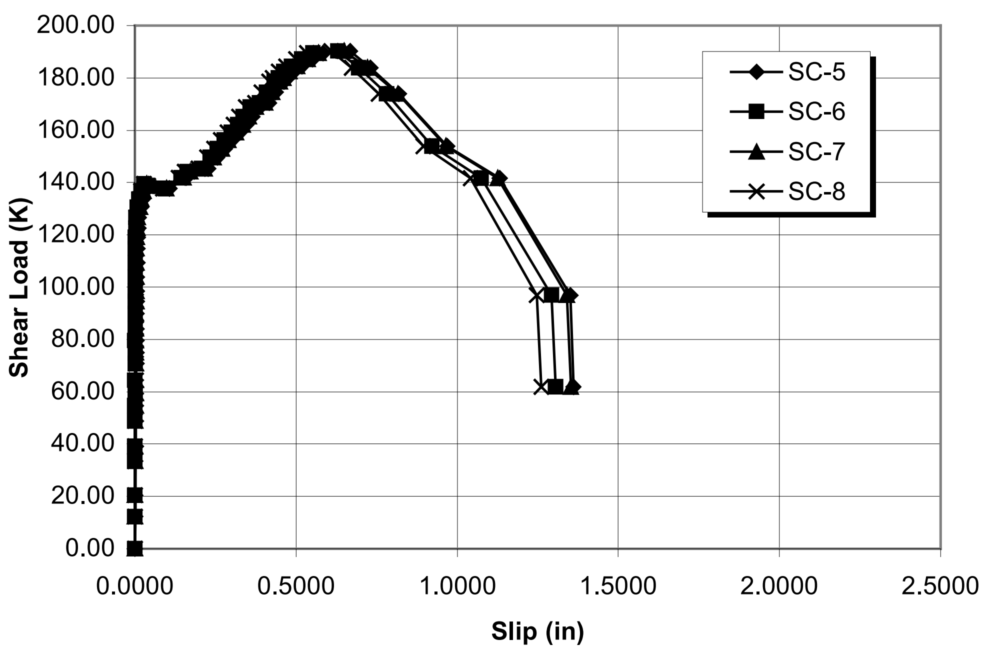
**COMMENTS**

Failure Mode: Screw Shear
Screw Rotation ≈ 40° - 50°
X = Screw sheared off

**Test F1-1: Load vs. Slip (A)**




**Test F1-1: Load vs. Slip (B)**



**TEST F1-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 12.19 | 1.02 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0012 | 0.0000 | 0.0006 | 0.0000 |
| 20.48 | 1.77 | 0.0012 | 0.0006 | 0.0000 | 0.0000 | 0.0018 | 0.0000 | 0.0006 | 0.0000 |
| 33.54 | 2.92 | 0.0012 | 0.0006 | 0.0006 | 0.0000 | 0.0018 | 0.0000 | 0.0012 | 0.0000 |
| 39.07 | 4.07 | 0.0012 | 0.0006 | 0.0006 | 0.0000 | 0.0024 | 0.0000 | 0.0018 | 0.0000 |
| 48.87 | 5.01 | 0.0012 | 0.0012 | 0.0012 | 0.0000 | 0.0031 | 0.0000 | 0.0018 | 0.0000 |
| 54.65 | 5.36 | 0.0018 | 0.0012 | 0.0018 | 0.0000 | 0.0031 | 0.0000 | 0.0024 | 0.0000 |
| 59.42 | 5.98 | 0.0018 | 0.0018 | 0.0018 | 0.0018 | 0.0037 | 0.0012 | 0.0024 | 0.0031 |
| 64.32 | 6.47 | 0.0018 | 0.0018 | 0.0024 | 0.0018 | 0.0037 | 0.0006 | 0.0031 | 0.0031 |
| 70.73 | 7.01 | 0.0024 | 0.0018 | 0.0024 | 0.0018 | 0.0043 | 0.0012 | 0.0031 | 0.0037 |
| 75.00 | 7.47 | 0.0024 | 0.0024 | 0.0024 | 0.0018 | 0.0043 | 0.0012 | 0.0031 | 0.0031 |
| 79.65 | 8.03 | 0.0024 | 0.0024 | 0.0024 | 0.0018 | 0.0043 | 0.0006 | 0.0031 | 0.0031 |
| 84.05 | 8.58 | 0.0024 | 0.0024 | 0.0031 | 0.0018 | 0.0049 | 0.0012 | 0.0037 | 0.0037 |
| 89.82 | 9.00 | 0.0031 | 0.0024 | 0.0031 | 0.0018 | 0.0055 | 0.0012 | 0.0037 | 0.0031 |
| 94.60 | 9.45 | 0.0037 | 0.0031 | 0.0037 | 0.0024 | 0.0067 | 0.0018 | 0.0043 | 0.0037 |
| 98.37 | 9.97 | 0.0037 | 0.0037 | 0.0037 | 0.0018 | 0.0067 | 0.0012 | 0.0043 | 0.0037 |
| 103.89 | 10.57 | 0.0043 | 0.0043 | 0.0037 | 0.0018 | 0.0067 | 0.0012 | 0.0043 | 0.0037 |
| 109.29 | 11.00 | 0.0049 | 0.0049 | 0.0049 | 0.0018 | 0.0073 | 0.0012 | 0.0049 | 0.0037 |
| 114.82 | 11.61 | 0.0049 | 0.0055 | 0.0061 | 0.0018 | 0.0079 | 0.0012 | 0.0055 | 0.0037 |
| 119.09 | 12.10 | 0.0085 | 0.0085 | 0.0085 | 0.0018 | 0.0092 | 0.0018 | 0.0061 | 0.0049 |
| 122.61 | 12.59 | 0.0140 | 0.0128 | 0.0134 | 0.0024 | 0.0104 | 0.0024 | 0.0073 | 0.0049 |
| 126.75 | 13.14 | 0.0250 | 0.0195 | 0.0232 | 0.0116 | 0.0122 | 0.0037 | 0.0092 | 0.0055 |
| 130.52 | 13.34 | 0.0330 | 0.0281 | 0.0311 | 0.0214 | 0.0195 | 0.0085 | 0.0153 | 0.0104 |
| 133.66 | 13.73 | 0.0403 | 0.0360 | 0.0391 | 0.0293 | 0.0250 | 0.0128 | 0.0201 | 0.0140 |
| 136.80 | 14.32 | 0.0531 | 0.0488 | 0.0507 | 0.0427 | 0.0317 | 0.0189 | 0.0269 | 0.0195 |
| 139.57 | 14.88 | 0.0720 | 0.0677 | 0.0702 | 0.0629 | 0.0421 | 0.0287 | 0.0360 | 0.0281 |
| 138.81 | 15.21 | 0.0879 | 0.0818 | 0.0854 | 0.0800 | 0.0562 | 0.0409 | 0.0494 | 0.0403 |
| 137.68 | 14.81 | 0.1233 | 0.1160 | 0.1208 | 0.1196 | 0.1068 | 0.0909 | 0.0977 | 0.0861 |
| 141.83 | 15.80 | 0.1733 | 0.1672 | 0.1697 | 0.1764 | 0.1593 | 0.1434 | 0.1508 | 0.1361 |
| 144.22 | 16.06 | 0.1996 | 0.1917 | 0.1953 | 0.2039 | 0.1825 | 0.1630 | 0.1715 | 0.1550 |
| 145.35 | 14.69 | 0.2435 | 0.2344 | 0.2368 | 0.2545 | 0.2271 | 0.2063 | 0.2167 | 0.1965 |
| 149.62 | 15.57 | 0.2698 | 0.2631 | 0.2643 | 0.2856 | 0.2557 | 0.2338 | 0.2454 | 0.2234 |
| 152.88 | 15.81 | 0.2936 | 0.2863 | 0.2875 | 0.3113 | 0.2795 | 0.2563 | 0.2698 | 0.2460 |
| 156.15 | 15.97 | 0.3143 | 0.3076 | 0.3070 | 0.3351 | 0.3015 | 0.2777 | 0.2911 | 0.2667 |
| 159.17 | 16.10 | 0.3363 | 0.3296 | 0.3290 | 0.3589 | 0.3247 | 0.2997 | 0.3137 | 0.2869 |
| 162.06 | 16.21 | 0.3552 | 0.3479 | 0.3467 | 0.3790 | 0.3461 | 0.3186 | 0.3345 | 0.3064 |
| 165.20 | 16.84 | 0.3717 | 0.3656 | 0.3632 | 0.3979 | 0.3644 | 0.3363 | 0.3528 | 0.3235 |
| 168.96 | 17.48 | 0.3949 | 0.3888 | 0.3857 | 0.4224 | 0.3882 | 0.3583 | 0.3754 | 0.3448 |
| 170.47 | 17.78 | 0.4156 | 0.4138 | 0.4071 | 0.4504 | 0.4163 | 0.3870 | 0.4047 | 0.3729 |
| 174.49 | 17.82 | 0.4333 | 0.4327 | 0.4242 | 0.4712 | 0.4376 | 0.4083 | 0.4254 | 0.3931 |
| 178.51 | 18.40 | 0.4578 | 0.4578 | 0.4480 | 0.4980 | 0.4626 | 0.4327 | 0.4498 | 0.4169 |
| 179.89 | 18.37 | 0.4724 | 0.4742 | 0.4645 | 0.5151 | 0.4742 | 0.4443 | 0.4614 | 0.4285 |
| 182.53 | 18.84 | 0.4962 | 0.4999 | 0.4877 | 0.5420 | 0.4938 | 0.4626 | 0.4803 | 0.4474 |
| 184.42 | 19.03 | 0.5212 | 0.5267 | 0.5127 | 0.5701 | 0.5170 | 0.4858 | 0.5042 | 0.4694 |
| 187.18 | 19.57 | 0.5560 | 0.5640 | 0.5475 | 0.6097 | 0.5505 | 0.5182 | 0.5359 | 0.5011 |
| 189.44 | 19.99 | 0.5939 | 0.6036 | 0.5865 | 0.6500 | 0.5847 | 0.5518 | 0.5701 | 0.5328 |
| 190.20 | 20.59 | 0.6781 | 0.6909 | 0.6738 | 0.7397 | 0.6677 | 0.6305 | 0.6494 | 0.6097 |
| 183.91 | 21.25 | 0.7483 | 0.7629 | 0.7428 | 0.8136 | 0.7312 | 0.6940 | 0.7208 | 0.6720 |
| 173.86 | 22.08 | 0.8496 | 0.8679 | 0.8441 | 0.9198 | 0.8191 | 0.7812 | 0.8167 | 0.7556 |
| 153.89 | 16.83 | 0.9979 | 1.0192 | 0.9918 | 1.0723 | 0.9698 | 0.9222 | 0.9637 | 0.8942 |
| 141.70 | 18.69 | 1.1547 | 1.1761 | 1.1462 | 1.2316 | 1.1309 | 1.0742 | 1.1248 | 1.0424 |
| 96.86 | 11.31 | 1.4349 | 1.4544 | 1.4184 | 1.5197 | 1.3513 | 1.2921 | 1.3403 | 1.2469 |
| 61.81 | 8.22 | 2.0025 | 1.8377 | 1.9824 | 1.8749 | 1.3610 | 1.3049 | 1.3525 | 1.2609 |

## PUSHOUT TEST SUMMARY SHEET

Test: F1-2 | Test Date: 25-Nov-98

Test Designation: SC-8-2.0-0.163-S-2.5-2

### SPECIMEN DESCRIPTION

**Screw:** Height: 2.0 in. | No. Per Specimen: 28

**Deck:** Type: none | Width: 36 in. | Length: 36 in.

$F_y$: N.A. | $F_u$: N.A.

**Base Member:** Section: 2L 2x2x0.163

$F_y$: 57.1 ksi | $F_u$: 77.9 ksi

**Slab:** Thickness: 2.5 in. | $f'_c$: 3793 psi

**Rebar:** Size: No.4 | No. Per Specimen: 8

Height Above Deck: 1.0 in.

**Mesh:** Type: WWF 6x6-W2.9xW2.9

### TEST RESULTS

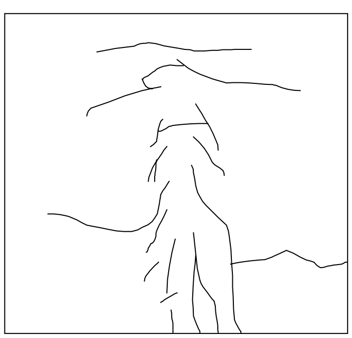
**Peak Shear Load:** 181.90 kips

**Peak Shear Load Per Screw:** 6.50 kips

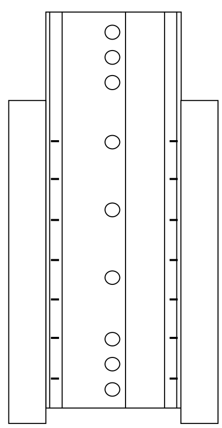
**Slip at Peak Shear Load:**

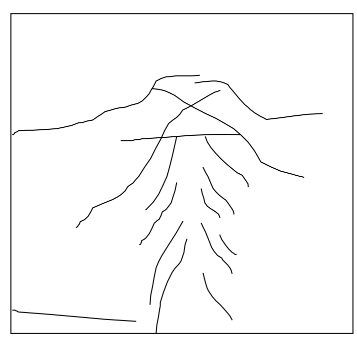
| | | | |
|---|---|---|---|
| SC1: | 0.5396 in. | SC5: | 0.5310 in. |
| SC2: | 0.5542 in. | SC6: | 0.4901 in. |
| SC3: | 0.5573 in. | SC7: | 0.5212 in. |
| SC4: | 0.5615 in. | SC8: | 0.5048 in. |

### DAMAGE



exterior, Slab A





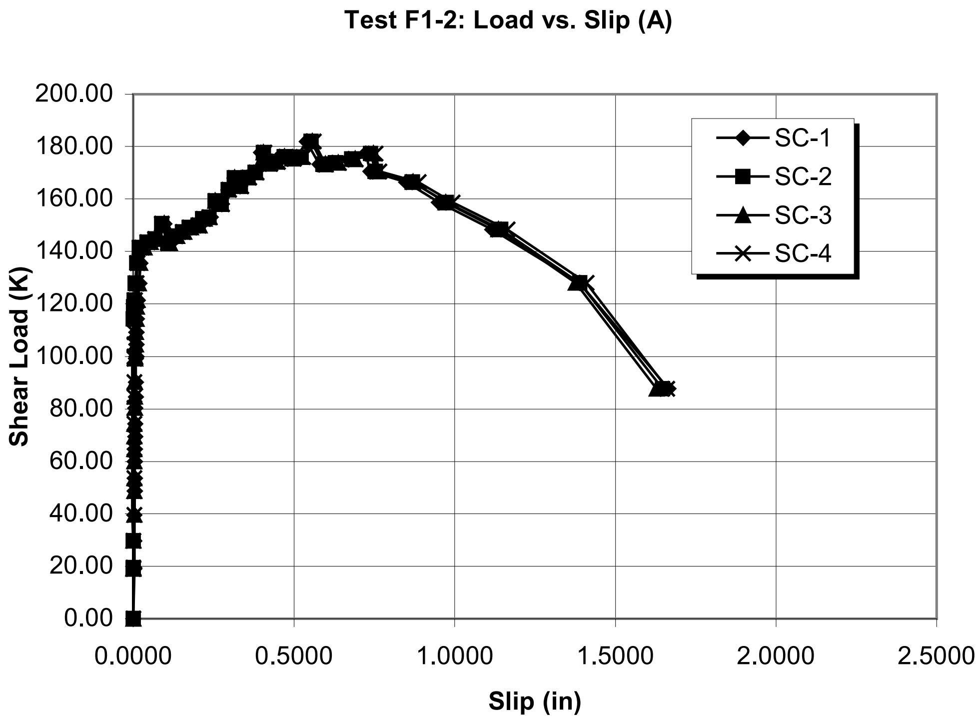
exterior, Slab B

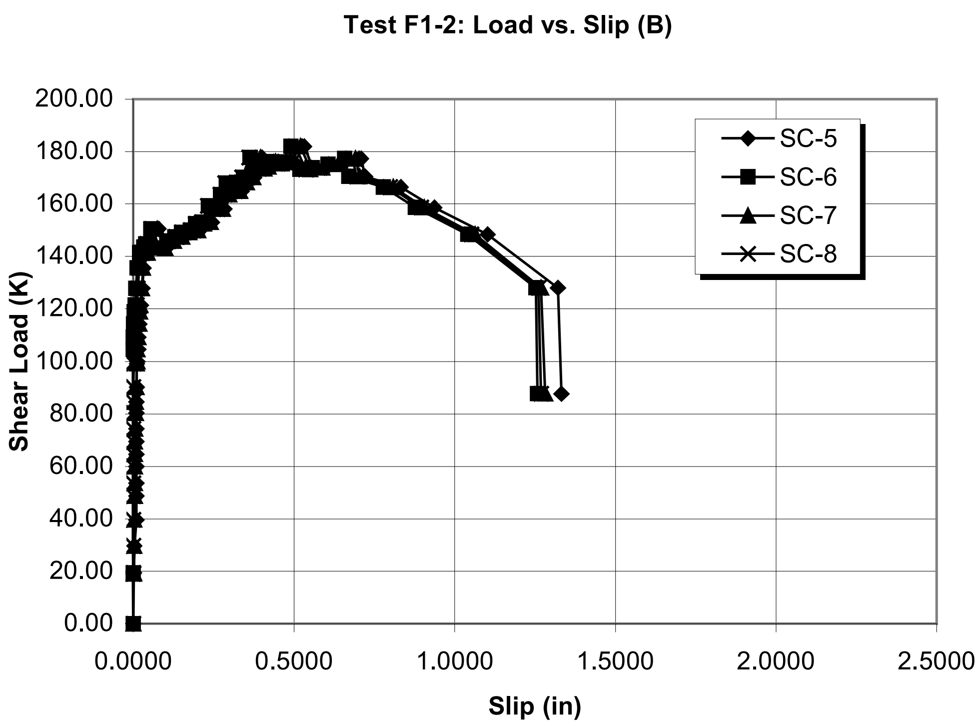
### COMMENTS

Failure Mode: screw shear

Screw Rotation ≈ 40° - 50°

Interior damage not available


Test F1-2: Load vs. Slip (A)
Shear Load (K)
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
Slip (in)
SC-1
SC-2
SC-3
SC-4


Test F1-2: Load vs. Slip (B)
Shear Load (K)
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
Slip (in)
SC-5
SC-6
SC-7
SC-8

TEST F1-2 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 18.97 | 1.04 | 0.0031 | -0.0006 | 0.0006 | 0.0000 | 0.0006 | -0.0012 | 0.0018 | 0.0000 |
| 19.47 | 2.03 | 0.0031 | -0.0006 | 0.0006 | 0.0000 | 0.0012 | -0.0006 | 0.0018 | 0.0000 |
| 29.65 | 3.07 | 0.0037 | -0.0006 | 0.0006 | 0.0000 | 0.0024 | -0.0012 | 0.0024 | 0.0000 |
| 39.57 | 4.00 | 0.0037 | -0.0031 | 0.0037 | 0.0031 | 0.0092 | -0.0018 | 0.0037 | -0.0006 |
| 48.74 | 5.08 | 0.0043 | -0.0031 | 0.0037 | 0.0031 | 0.0092 | -0.0018 | 0.0043 | -0.0006 |
| 53.52 | 5.53 | 0.0049 | -0.0031 | 0.0037 | 0.0031 | 0.0092 | -0.0018 | 0.0043 | -0.0006 |
| 59.92 | 6.14 | 0.0055 | -0.0031 | 0.0037 | 0.0031 | 0.0092 | -0.0018 | 0.0049 | -0.0006 |
| 64.57 | 6.46 | 0.0055 | -0.0031 | 0.0037 | 0.0031 | 0.0092 | -0.0018 | 0.0055 | -0.0006 |
| 69.47 | 7.15 | 0.0061 | -0.0031 | 0.0037 | 0.0031 | 0.0092 | -0.0018 | 0.0055 | 0.0000 |
| 74.37 | 7.59 | 0.0061 | -0.0031 | 0.0037 | 0.0031 | 0.0092 | -0.0018 | 0.0061 | 0.0000 |
| 80.28 | 8.10 | 0.0067 | -0.0031 | 0.0043 | 0.0031 | 0.0098 | -0.0018 | 0.0073 | 0.0006 |
| 84.67 | 8.67 | 0.0073 | -0.0031 | 0.0049 | 0.0031 | 0.0098 | -0.0018 | 0.0079 | 0.0006 |
| 90.20 | 9.12 | 0.0079 | -0.0031 | 0.0055 | 0.0031 | 0.0104 | -0.0012 | 0.0092 | 0.0006 |
| 99.12 | 9.62 | 0.0085 | -0.0031 | 0.0061 | 0.0031 | 0.0116 | -0.0012 | 0.0110 | 0.0012 |
| 99.87 | 10.21 | 0.0092 | -0.0031 | 0.0067 | 0.0031 | 0.0128 | -0.0012 | 0.0122 | 0.0024 |
| 104.52 | 10.59 | 0.0098 | -0.0012 | 0.0073 | 0.0031 | 0.0153 | -0.0006 | 0.0134 | 0.0037 |
| 109.17 | 11.05 | 0.0098 | -0.0012 | 0.0079 | 0.0031 | 0.0165 | 0.0000 | 0.0159 | 0.0055 |
| 114.19 | 11.70 | 0.0110 | -0.0006 | 0.0092 | 0.0031 | 0.0195 | 0.0018 | 0.0183 | 0.0073 |
| 118.96 | 12.11 | 0.0128 | 0.0012 | 0.0110 | 0.0037 | 0.0220 | 0.0037 | 0.0208 | 0.0098 |
| 121.48 | 12.56 | 0.0146 | 0.0024 | 0.0128 | 0.0055 | 0.0244 | 0.0067 | 0.0226 | 0.0110 |
| 127.76 | 13.14 | 0.0189 | 0.0067 | 0.0171 | 0.0098 | 0.0287 | 0.0085 | 0.0262 | 0.0140 |
| 135.67 | 13.73 | 0.0214 | 0.0110 | 0.0201 | 0.0128 | 0.0323 | 0.0128 | 0.0299 | 0.0177 |
| 141.33 | 14.28 | 0.0281 | 0.0189 | 0.0269 | 0.0208 | 0.0403 | 0.0201 | 0.0378 | 0.0244 |
| 141.33 | 14.81 | 0.0366 | 0.0269 | 0.0354 | 0.0275 | 0.0476 | 0.0262 | 0.0446 | 0.0299 |
| 143.59 | 15.31 | 0.0537 | 0.0433 | 0.0531 | 0.0446 | 0.0549 | 0.0330 | 0.0519 | 0.0366 |
| 144.72 | 15.88 | 0.0757 | 0.0684 | 0.0751 | 0.0684 | 0.0610 | 0.0391 | 0.0580 | 0.0433 |
| 150.62 | 16.33 | 0.0964 | 0.0885 | 0.0958 | 0.0891 | 0.0787 | 0.0555 | 0.0751 | 0.0586 |
| 143.21 | 15.67 | 0.1160 | 0.1074 | 0.1141 | 0.1080 | 0.1031 | 0.0781 | 0.0995 | 0.0824 |
| 145.97 | 16.30 | 0.1385 | 0.1300 | 0.1355 | 0.1306 | 0.1312 | 0.1050 | 0.1270 | 0.1080 |
| 147.48 | 16.72 | 0.1611 | 0.1538 | 0.1587 | 0.1550 | 0.1581 | 0.1300 | 0.1526 | 0.1331 |
| 149.24 | 17.00 | 0.1813 | 0.1746 | 0.1794 | 0.1752 | 0.1782 | 0.1495 | 0.1733 | 0.1526 |
| 150.00 | 15.50 | 0.2075 | 0.2026 | 0.2063 | 0.2039 | 0.2075 | 0.1782 | 0.2026 | 0.1794 |
| 152.38 | 15.78 | 0.2228 | 0.2173 | 0.2209 | 0.2185 | 0.2246 | 0.1947 | 0.2203 | 0.1947 |
| 153.01 | 16.07 | 0.2399 | 0.2362 | 0.2380 | 0.2374 | 0.2448 | 0.2155 | 0.2405 | 0.2142 |
| 159.17 | 16.32 | 0.2563 | 0.2545 | 0.2545 | 0.2557 | 0.2643 | 0.2344 | 0.2594 | 0.2332 |
| 158.16 | 16.51 | 0.2747 | 0.2734 | 0.2734 | 0.2747 | 0.2826 | 0.2527 | 0.2789 | 0.2502 |
| 163.44 | 16.72 | 0.2960 | 0.2960 | 0.2954 | 0.2972 | 0.3052 | 0.2722 | 0.2997 | 0.2704 |
| 167.96 | 16.85 | 0.3143 | 0.3156 | 0.3143 | 0.3174 | 0.3217 | 0.2893 | 0.3168 | 0.2869 |
| 164.94 | 16.92 | 0.3320 | 0.3333 | 0.3333 | 0.3351 | 0.3369 | 0.3046 | 0.3326 | 0.3015 |
| 168.09 | 17.48 | 0.3546 | 0.3577 | 0.3571 | 0.3601 | 0.3583 | 0.3247 | 0.3534 | 0.3217 |
| 170.22 | 17.59 | 0.3748 | 0.3796 | 0.3809 | 0.3833 | 0.3772 | 0.3430 | 0.3729 | 0.3394 |
| 177.63 | 17.90 | 0.3973 | 0.4047 | 0.4047 | 0.4077 | 0.3998 | 0.3632 | 0.3949 | 0.3601 |
| 173.49 | 17.93 | 0.4126 | 0.4218 | 0.4218 | 0.4260 | 0.4120 | 0.3772 | 0.4077 | 0.3735 |
| 174.12 | 18.20 | 0.4321 | 0.4437 | 0.4431 | 0.4486 | 0.4260 | 0.3925 | 0.4211 | 0.3882 |
| 176.13 | 18.36 | 0.4559 | 0.4694 | 0.4700 | 0.4749 | 0.4504 | 0.4144 | 0.4437 | 0.4169 |
| 175.37 | 18.44 | 0.4803 | 0.4938 | 0.4950 | 0.4999 | 0.4700 | 0.4333 | 0.4626 | 0.4413 |
| 176.00 | 18.49 | 0.5078 | 0.5219 | 0.5243 | 0.5292 | 0.4993 | 0.4608 | 0.4901 | 0.4724 |
| 181.90 | 18.57 | 0.5396 | 0.5542 | 0.5573 | 0.5615 | 0.5310 | 0.4901 | 0.5212 | 0.5048 |
| 173.24 | 18.66 | 0.5786 | 0.5908 | 0.5975 | 0.5981 | 0.5609 | 0.5188 | 0.5499 | 0.5359 |
| 173.74 | 18.80 | 0.6195 | 0.6299 | 0.6384 | 0.6396 | 0.6018 | 0.5566 | 0.5884 | 0.5750 |
| 175.12 | 19.02 | 0.6689 | 0.6805 | 0.6903 | 0.6915 | 0.6525 | 0.6061 | 0.6372 | 0.6281 |
| 177.38 | 19.42 | 0.7239 | 0.7391 | 0.7471 | 0.7526 | 0.7086 | 0.6586 | 0.6909 | 0.6824 |
| 170.60 | 19.31 | 0.7373 | 0.7526 | 0.7599 | 0.7660 | 0.7214 | 0.6714 | 0.7037 | 0.6946 |
| 166.45 | 17.69 | 0.8496 | 0.8685 | 0.8710 | 0.8881 | 0.8319 | 0.7782 | 0.8081 | 0.7983 |
| 158.66 | 18.87 | 0.9515 | 0.9753 | 0.9717 | 0.9937 | 0.9375 | 0.8789 | 0.9052 | 0.8954 |
| 148.36 | 15.67 | 1.1169 | 1.1444 | 1.1364 | 1.1639 | 1.1035 | 1.0406 | 1.0626 | 1.0522 |
| 128.01 | 18.44 | 1.3891 | 1.3897 | 1.3769 | 1.4105 | 1.3208 | 1.2530 | 1.2695 | 1.2615 |
| 87.69 | 19.25 | 1.6638 | 1.6479 | 1.6278 | 1.6619 | 1.3330 | 1.2585 | 1.2823 | 1.2695 |

**PUSHOUT TEST SUMMARY SHEET**

Test: F2-1 — Test Date: 7-Dec-98

Test Designation: SC-8-2.0-0.250-S-2.5-1

**SPECIMEN DESCRIPTION**

**Screw:** Height: 2.0 in. — No. Per Specimen: 28

**Deck:** Type: none — Width: 36 in. — Length: 36 in.

$F_y$: N.A. — $F_u$: N.A.

**Base Member:** Section: 2L 2x2x0.250

$F_y$: 54.5 ksi — $F_u$: 77.4 ksi

**Slab:** Thickness: 2.5 in. — $f'_c$: 3681 psi

**Rebar:** Size: No. 4 — No. Per Specimen: 8

Height Above Deck: 1.0 in.

**Mesh:** Type: WWF 6x6-W2.9xW2.9

**TEST RESULTS**

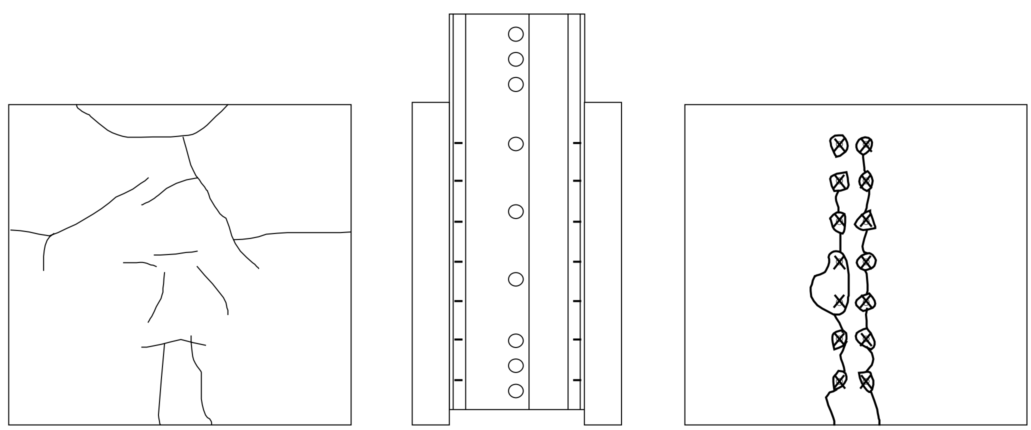
**Peak Shear Load:** 213.19 kips

**Peak Shear Load Per Screw:** 7.61 kips

**Slip at Peak Shear Load:**

| | |
|---|---|
| SC1: 0.5450 in. | SC5: 0.5591 in. |
| SC2: 0.5365 in. | SC6: 0.5707 in. |
| SC3: 0.5402 in. | SC7: 0.5701 in. |
| SC4: 0.5365 in. | SC8: 0.5664 in. |

**DAMAGE**



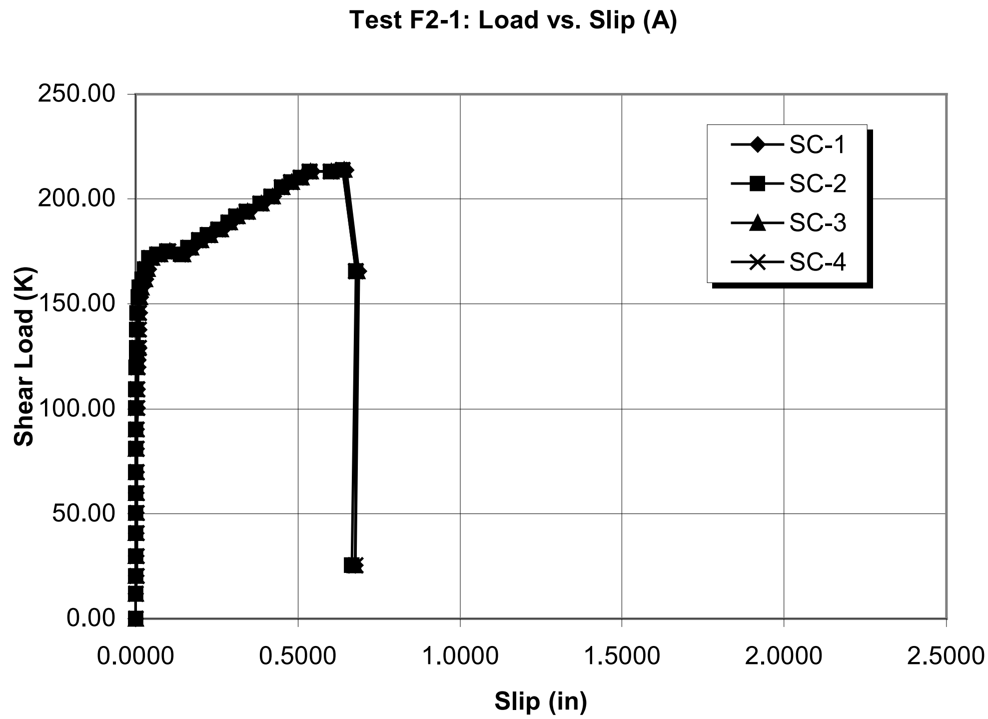
exterior, Slab A — interior, Slab B

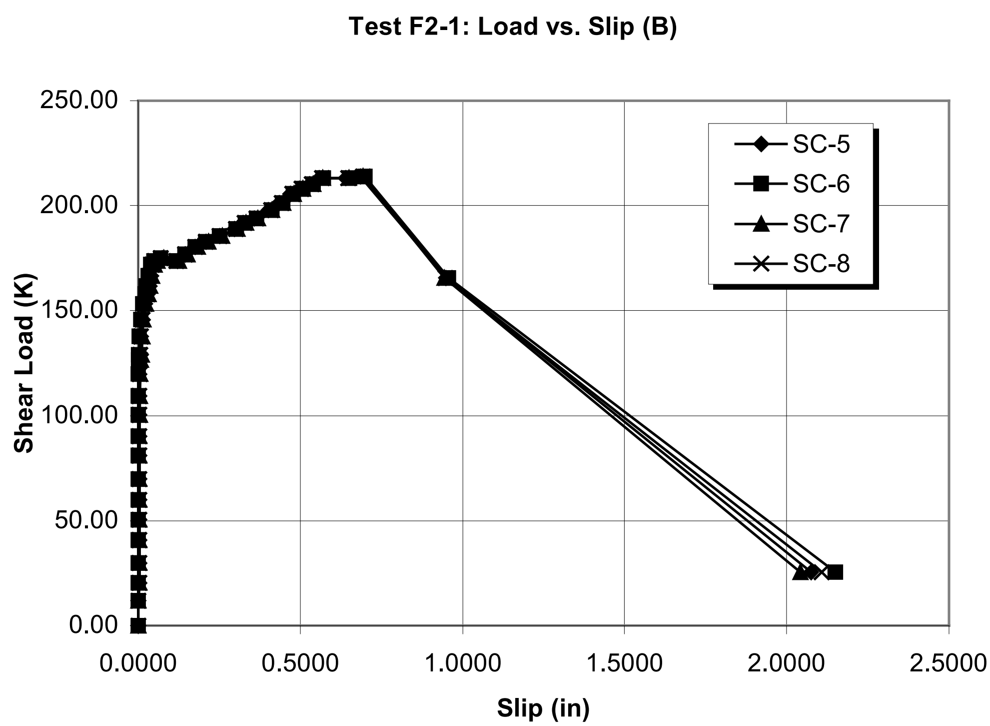
**COMMENTS**

Failure Mode: Screw Shear

Screw Rotation ≈ 30° - 40°

X = Screw sheared off


Test F2-1: Load vs. Slip (A)
Shear Load (K)
250.00
200.00
150.00
100.00
50.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
Slip (in)
SC-1
SC-2
SC-3
SC-4


Test F2-1: Load vs. Slip (B)
Shear Load (K)
250.00
200.00
150.00
100.00
50.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000
Slip (in)
SC-5
SC-6
SC-7
SC-8

**TEST F2-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 |
| 11.93 | 1.08 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20.48 | 2.15 | 0.0012 | -0.0006 | 0.0006 | 0.0031 | 0.0037 | -0.0006 | 0.0024 | 0.0024 |
| 29.90 | 3.07 | 0.0012 | -0.0006 | 0.0006 | 0.0031 | 0.0037 | -0.0006 | 0.0024 | 0.0031 |
| 40.70 | 4.04 | 0.0012 | -0.0006 | 0.0006 | 0.0031 | 0.0037 | -0.0006 | 0.0024 | 0.0024 |
| 50.50 | 4.99 | 0.0018 | -0.0006 | 0.0012 | 0.0031 | 0.0037 | -0.0006 | 0.0024 | 0.0024 |
| 59.92 | 5.94 | 0.0018 | -0.0006 | 0.0012 | 0.0031 | 0.0037 | -0.0006 | 0.0031 | 0.0031 |
| 69.72 | 6.77 | 0.0031 | -0.0006 | 0.0012 | 0.0031 | 0.0037 | 0.0000 | 0.0031 | 0.0031 |
| 81.03 | 8.10 | 0.0031 | -0.0006 | 0.0006 | 0.0031 | 0.0037 | -0.0006 | 0.0031 | 0.0031 |
| 90.20 | 8.91 | 0.0037 | -0.0006 | 0.0012 | 0.0037 | 0.0037 | 0.0000 | 0.0037 | 0.0031 |
| 100.37 | 10.02 | 0.0055 | 0.0000 | 0.0018 | 0.0043 | 0.0037 | 0.0000 | 0.0043 | 0.0037 |
| 109.42 | 10.86 | 0.0061 | 0.0006 | 0.0024 | 0.0049 | 0.0037 | 0.0000 | 0.0049 | 0.0037 |
| 119.72 | 12.05 | 0.0073 | 0.0018 | 0.0037 | 0.0067 | 0.0037 | 0.0000 | 0.0061 | 0.0043 |
| 126.50 | 13.04 | 0.0085 | 0.0031 | 0.0055 | 0.0085 | 0.0061 | 0.0012 | 0.0085 | 0.0055 |
| 128.89 | 13.25 | 0.0110 | 0.0031 | 0.0061 | 0.0092 | 0.0085 | 0.0018 | 0.0110 | 0.0067 |
| 137.68 | 13.80 | 0.0110 | 0.0031 | 0.0061 | 0.0092 | 0.0085 | 0.0037 | 0.0122 | 0.0085 |
| 145.85 | 14.59 | 0.0122 | 0.0043 | 0.0079 | 0.0092 | 0.0134 | 0.0073 | 0.0159 | 0.0128 |
| 153.14 | 15.40 | 0.0159 | 0.0079 | 0.0122 | 0.0122 | 0.0201 | 0.0140 | 0.0232 | 0.0208 |
| 157.91 | 16.14 | 0.0195 | 0.0110 | 0.0165 | 0.0146 | 0.0275 | 0.0214 | 0.0311 | 0.0281 |
| 161.68 | 16.84 | 0.0317 | 0.0208 | 0.0275 | 0.0250 | 0.0342 | 0.0256 | 0.0360 | 0.0299 |
| 166.58 | 17.27 | 0.0403 | 0.0281 | 0.0366 | 0.0317 | 0.0397 | 0.0311 | 0.0421 | 0.0348 |
| 171.85 | 17.72 | 0.0549 | 0.0409 | 0.0507 | 0.0452 | 0.0488 | 0.0397 | 0.0507 | 0.0421 |
| 173.61 | 18.33 | 0.0793 | 0.0653 | 0.0751 | 0.0696 | 0.0568 | 0.0488 | 0.0598 | 0.0507 |
| 175.12 | 18.92 | 0.1105 | 0.0964 | 0.1056 | 0.1001 | 0.0739 | 0.0690 | 0.0787 | 0.0696 |
| 173.61 | 17.59 | 0.1520 | 0.1379 | 0.1465 | 0.1410 | 0.1208 | 0.1184 | 0.1257 | 0.1178 |
| 176.88 | 18.46 | 0.1752 | 0.1617 | 0.1703 | 0.1648 | 0.1447 | 0.1440 | 0.1514 | 0.1440 |
| 180.40 | 18.90 | 0.2069 | 0.1941 | 0.2008 | 0.1953 | 0.1764 | 0.1764 | 0.1837 | 0.1764 |
| 182.78 | 19.21 | 0.2344 | 0.2216 | 0.2295 | 0.2240 | 0.2081 | 0.2081 | 0.2167 | 0.2087 |
| 185.55 | 19.52 | 0.2679 | 0.2545 | 0.2625 | 0.2551 | 0.2502 | 0.2509 | 0.2582 | 0.2509 |
| 188.81 | 19.79 | 0.2960 | 0.2856 | 0.2905 | 0.2869 | 0.2966 | 0.3027 | 0.3052 | 0.3009 |
| 191.70 | 19.97 | 0.3192 | 0.3094 | 0.3131 | 0.3107 | 0.3235 | 0.3302 | 0.3333 | 0.3284 |
| 194.09 | 20.16 | 0.3503 | 0.3412 | 0.3455 | 0.3412 | 0.3571 | 0.3656 | 0.3687 | 0.3644 |
| 197.86 | 20.38 | 0.3931 | 0.3845 | 0.3870 | 0.3839 | 0.4010 | 0.4120 | 0.4132 | 0.4089 |
| 201.38 | 20.51 | 0.4266 | 0.4175 | 0.4211 | 0.4181 | 0.4346 | 0.4456 | 0.4468 | 0.4419 |
| 205.52 | 20.58 | 0.4584 | 0.4498 | 0.4523 | 0.4498 | 0.4687 | 0.4785 | 0.4797 | 0.4749 |
| 208.16 | 20.64 | 0.4865 | 0.4779 | 0.4810 | 0.4779 | 0.4974 | 0.5078 | 0.5084 | 0.5042 |
| 210.17 | 20.70 | 0.5164 | 0.5078 | 0.5109 | 0.5078 | 0.5280 | 0.5389 | 0.5396 | 0.5347 |
| 213.19 | 21.43 | 0.5450 | 0.5365 | 0.5402 | 0.5365 | 0.5591 | 0.5707 | 0.5701 | 0.5664 |
| 213.06 | 22.35 | 0.6104 | 0.6006 | 0.6042 | 0.6000 | 0.6396 | 0.6525 | 0.6494 | 0.6476 |
| 213.81 | 22.42 | 0.6488 | 0.6390 | 0.6433 | 0.6384 | 0.6860 | 0.6995 | 0.6940 | 0.6934 |
| 165.70 | 22.70 | 0.6879 | 0.6787 | 0.6842 | 0.6793 | 0.9491 | 0.9570 | 0.9442 | 0.9473 |
| 25.50 | 8.49 | 0.6769 | 0.6671 | 0.6757 | 0.6775 | 2.0745 | 2.1502 | 2.0422 | 2.1075 |

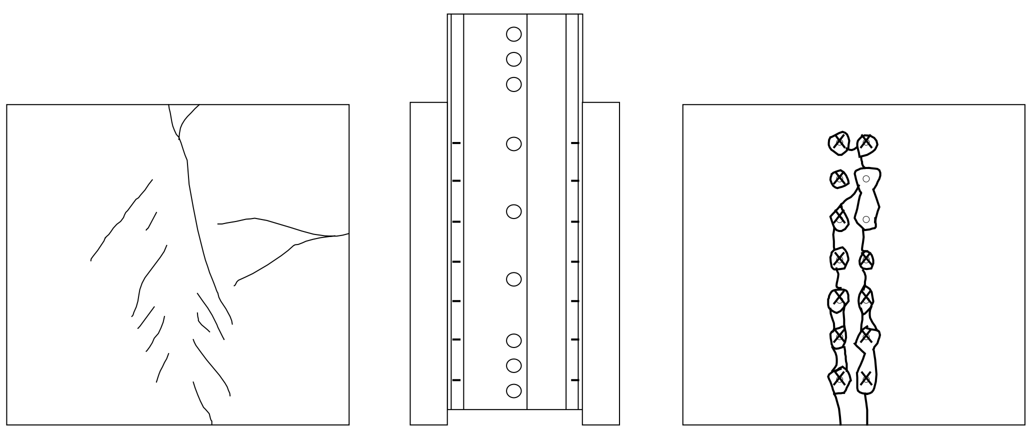
**PUSHOUT TEST SUMMARY SHEET**

Test: F2-2 Test Date: 8-Dec-98
Test Designation: SC-8-2.0-0.250-S-2.5-2

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.0 in. | No. Per Specimen: | 28 | | |
| **Deck:** | Type: | none | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | N.A. | $F_u$: | N.A. | | |
| **Base Member:** | Section: | 2L 2x2x0.250 | | | | |
| | $F_y$: | 54.5 ksi | $F_u$: | 77.4 ksi | | |
| **Slab:** | Thickness: | 2.5 in. | $f'_c$: | 3681 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W2.9xW2.9 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 204.14 kips | | | |
| **Peak Shear Load Per Screw:** | 7.29 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.5902 in. | SC5: | 0.5823 in. |
| | SC2: | 0.5499 in. | SC6: | 0.5811 in. |
| | SC3: | 0.5707 in. | SC7: | 0.5804 in. |
| | SC4: | 0.5542 in. | SC8: | 0.5609 in. |

**DAMAGE**

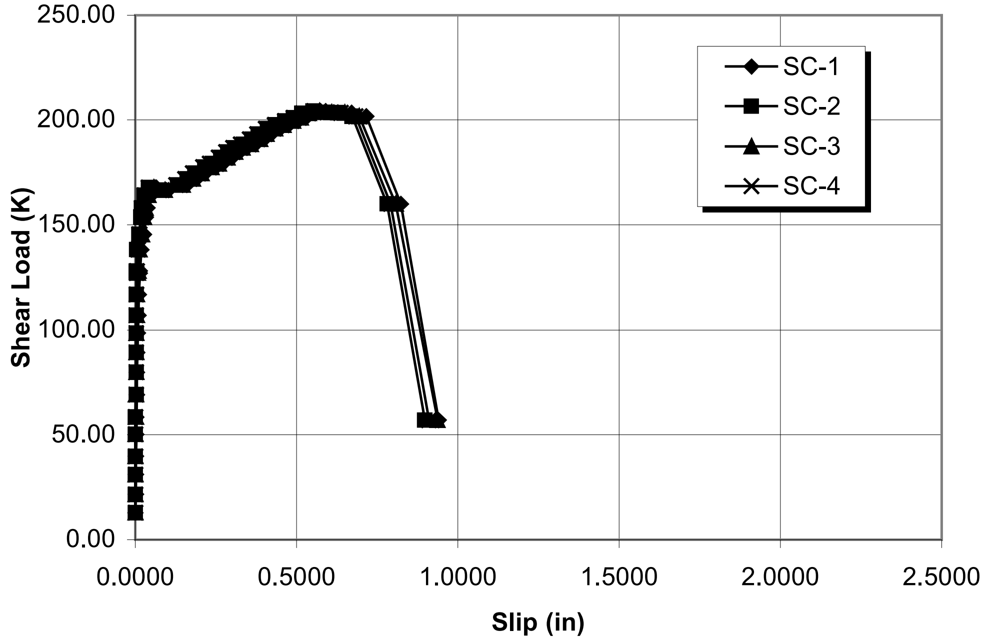


exterior, Slab A interior, Slab B

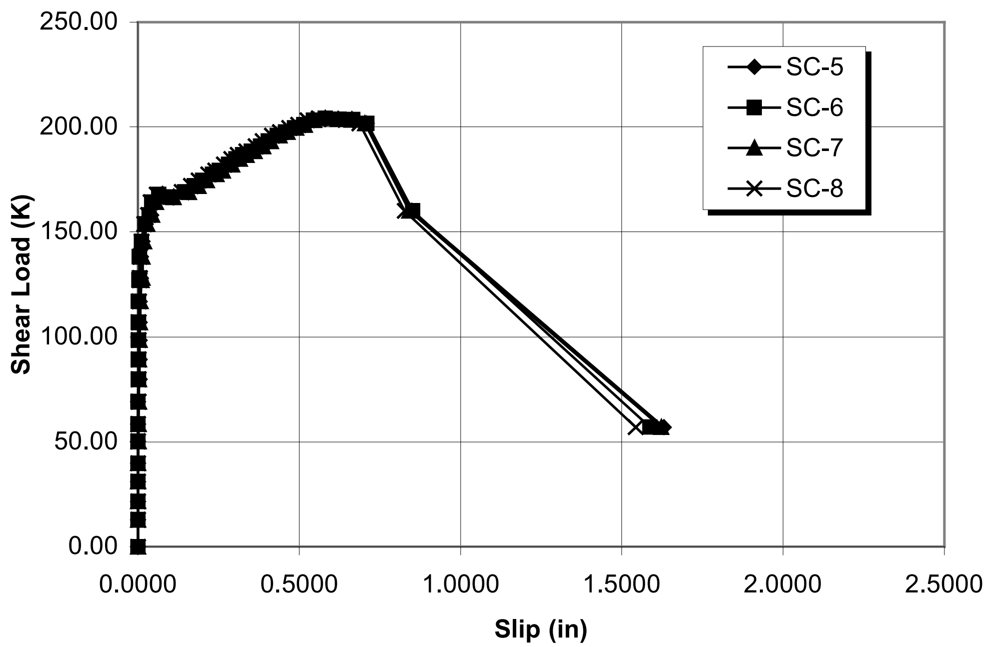
**COMMENTS**

Failure Mode: Screw Shear
Screw Rotation ≈ 30° - 40°
X = Screw sheared off

**Test F2-2: Load vs. Slip (A)**




**Test F2-2: Load vs. Slip (B)**



## TEST F2-2 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 12.81 | 1.29 | 0.0006 | 0.0000 | -0.0006 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 |
| 21.61 | 2.06 | 0.0012 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0006 | 0.0000 | 0.0000 |
| 31.03 | 3.21 | 0.0018 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0006 | 0.0000 | 0.0000 |
| 39.82 | 4.09 | 0.0018 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0006 | 0.0006 | 0.0000 |
| 50.13 | 4.99 | 0.0031 | 0.0000 | 0.0006 | 0.0000 | 0.0006 | 0.0006 | 0.0012 | 0.0006 |
| 58.42 | 6.13 | 0.0031 | 0.0000 | 0.0012 | 0.0000 | 0.0006 | 0.0006 | 0.0012 | 0.0006 |
| 69.10 | 6.99 | 0.0043 | 0.0024 | 0.0012 | 0.0018 | 0.0006 | 0.0006 | 0.0024 | 0.0012 |
| 79.77 | 8.22 | 0.0055 | 0.0024 | 0.0024 | 0.0018 | 0.0043 | 0.0018 | 0.0031 | 0.0018 |
| 89.20 | 9.10 | 0.0067 | 0.0024 | 0.0031 | 0.0018 | 0.0043 | 0.0018 | 0.0037 | 0.0018 |
| 98.37 | 10.02 | 0.0073 | 0.0024 | 0.0037 | 0.0018 | 0.0043 | 0.0018 | 0.0049 | 0.0018 |
| 106.90 | 11.03 | 0.0098 | 0.0024 | 0.0049 | 0.0018 | 0.0043 | 0.0018 | 0.0067 | 0.0018 |
| 116.95 | 11.92 | 0.0110 | 0.0024 | 0.0049 | 0.0024 | 0.0043 | 0.0018 | 0.0085 | 0.0031 |
| 127.13 | 13.17 | 0.0134 | 0.0024 | 0.0073 | 0.0031 | 0.0073 | 0.0037 | 0.0116 | 0.0049 |
| 128.01 | 13.62 | 0.0146 | 0.0024 | 0.0092 | 0.0049 | 0.0092 | 0.0049 | 0.0140 | 0.0061 |
| 138.19 | 14.38 | 0.0195 | 0.0055 | 0.0128 | 0.0079 | 0.0092 | 0.0055 | 0.0134 | 0.0061 |
| 145.47 | 15.08 | 0.0269 | 0.0116 | 0.0201 | 0.0128 | 0.0146 | 0.0116 | 0.0195 | 0.0116 |
| 153.64 | 15.75 | 0.0336 | 0.0177 | 0.0269 | 0.0189 | 0.0244 | 0.0214 | 0.0287 | 0.0195 |
| 158.16 | 16.27 | 0.0385 | 0.0189 | 0.0311 | 0.0201 | 0.0409 | 0.0348 | 0.0446 | 0.0323 |
| 164.07 | 17.14 | 0.0488 | 0.0275 | 0.0409 | 0.0281 | 0.0513 | 0.0433 | 0.0549 | 0.0397 |
| 167.71 | 17.75 | 0.0641 | 0.0409 | 0.0562 | 0.0403 | 0.0726 | 0.0641 | 0.0763 | 0.0586 |
| 166.70 | 18.79 | 0.1025 | 0.0757 | 0.0922 | 0.0739 | 0.1086 | 0.0989 | 0.1105 | 0.0903 |
| 168.96 | 18.28 | 0.1587 | 0.1306 | 0.1471 | 0.1257 | 0.1556 | 0.1459 | 0.1581 | 0.1361 |
| 171.98 | 18.76 | 0.1898 | 0.1605 | 0.1782 | 0.1550 | 0.1849 | 0.1758 | 0.1886 | 0.1642 |
| 174.62 | 19.08 | 0.2155 | 0.1849 | 0.2045 | 0.1788 | 0.2100 | 0.2008 | 0.2136 | 0.1880 |
| 177.38 | 18.83 | 0.2490 | 0.2167 | 0.2368 | 0.2100 | 0.2411 | 0.2313 | 0.2435 | 0.2179 |
| 179.14 | 19.07 | 0.2716 | 0.2374 | 0.2582 | 0.2301 | 0.2612 | 0.2527 | 0.2643 | 0.2393 |
| 182.16 | 19.35 | 0.3003 | 0.2649 | 0.2863 | 0.2582 | 0.2893 | 0.2808 | 0.2917 | 0.2667 |
| 184.79 | 19.56 | 0.3235 | 0.2875 | 0.3094 | 0.2808 | 0.3125 | 0.3040 | 0.3149 | 0.2893 |
| 186.68 | 19.74 | 0.3461 | 0.3088 | 0.3320 | 0.3021 | 0.3339 | 0.3253 | 0.3363 | 0.3101 |
| 188.44 | 19.92 | 0.3717 | 0.3339 | 0.3577 | 0.3259 | 0.3583 | 0.3516 | 0.3607 | 0.3357 |
| 190.95 | 20.10 | 0.3998 | 0.3613 | 0.3857 | 0.3552 | 0.3870 | 0.3809 | 0.3888 | 0.3644 |
| 193.34 | 20.23 | 0.4211 | 0.3821 | 0.4065 | 0.3766 | 0.4089 | 0.4034 | 0.4114 | 0.3864 |
| 195.85 | 20.38 | 0.4492 | 0.4095 | 0.4333 | 0.4041 | 0.4376 | 0.4327 | 0.4388 | 0.4150 |
| 197.61 | 20.53 | 0.4749 | 0.4352 | 0.4590 | 0.4315 | 0.4639 | 0.4584 | 0.4633 | 0.4407 |
| 199.49 | 20.74 | 0.5054 | 0.4645 | 0.4883 | 0.4633 | 0.4913 | 0.4865 | 0.4907 | 0.4687 |
| 201.13 | 20.91 | 0.5292 | 0.4901 | 0.5121 | 0.4907 | 0.5194 | 0.5151 | 0.5182 | 0.4968 |
| 203.26 | 21.12 | 0.5560 | 0.5164 | 0.5377 | 0.5188 | 0.5469 | 0.5438 | 0.5457 | 0.5249 |
| 204.14 | 21.38 | 0.5902 | 0.5499 | 0.5707 | 0.5542 | 0.5823 | 0.5811 | 0.5804 | 0.5609 |
| 203.76 | 21.69 | 0.6281 | 0.5872 | 0.6091 | 0.5945 | 0.6232 | 0.6232 | 0.6207 | 0.6012 |
| 203.39 | 22.01 | 0.6708 | 0.6281 | 0.6494 | 0.6378 | 0.6659 | 0.6665 | 0.6622 | 0.6445 |
| 201.63 | 22.30 | 0.7153 | 0.6720 | 0.6940 | 0.6830 | 0.7092 | 0.7098 | 0.7043 | 0.6873 |
| 159.92 | 18.62 | 0.8240 | 0.7806 | 0.8075 | 0.7922 | 0.8496 | 0.8527 | 0.8411 | 0.8270 |
| 57.04 | 17.92 | 0.9406 | 0.8972 | 0.9375 | 0.9106 | 1.6302 | 1.5875 | 1.6229 | 1.5429 |

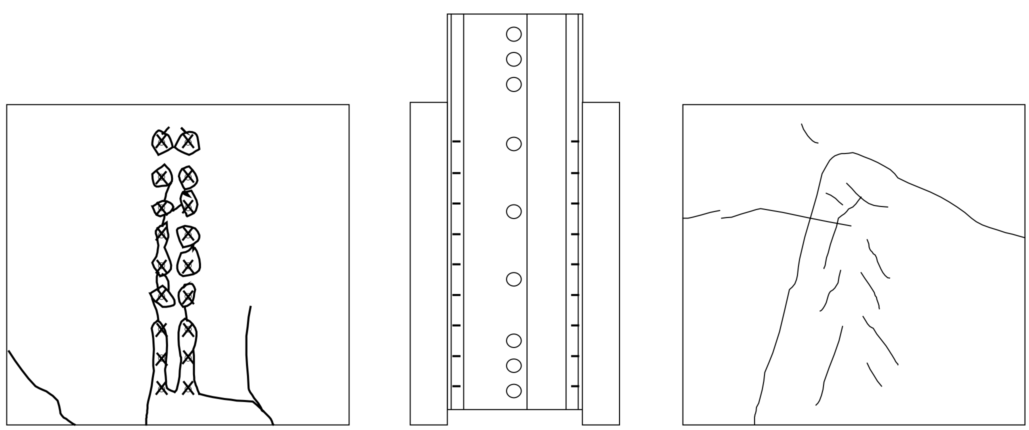
**PUSHOUT TEST SUMMARY SHEET**

Test: F3-1 Test Date: 23-Nov-98
Test Designation: SC-8-2.5-0.212-S-3.0-1

| SPECIMEN DESCRIPTION | | | | |
|---|---|---|---|---|
| **Screw:** | Height: 2.5 in. | No. Per Specimen: 36 | | |
| **Deck:** | Type: none | Width: 36 in. | Length: 36 in. | |
| | $F_y$: N.A. | $F_u$: N.A. | | |
| **Base Member:** | Section: 2L 2.5x2.5x0.212 | | | |
| | $F_y$: 54.2 ksi | $F_u$: 76.9 ksi | | |
| **Slab:** | Thickness: 3.0 in. | $f'_c$: 3793 psi | | |
| **Rebar:** | Size: No. 4 | No. Per Specimen: 8 | | |
| | | Height Above Deck: 1.0 in. | | |
| **Mesh:** | Type: WWF 4x4-W2.0xW2.0 | | | |

| TEST RESULTS | | |
|---|---|---|
| **Peak Shear Load:** | 252.38 kips | |
| **Peak Shear Load Per Screw:** | 7.01 kips | |
| **Slip at Peak Shear Load:** | SC1: 0.7007 in. | SC5: 0.6451 in. |
| | SC2: 0.7513 in. | SC6: 0.6458 in. |
| | SC3: 0.6915 in. | SC7: 0.6439 in. |
| | SC4: 0.7581 in. | SC8: 0.6256 in. |

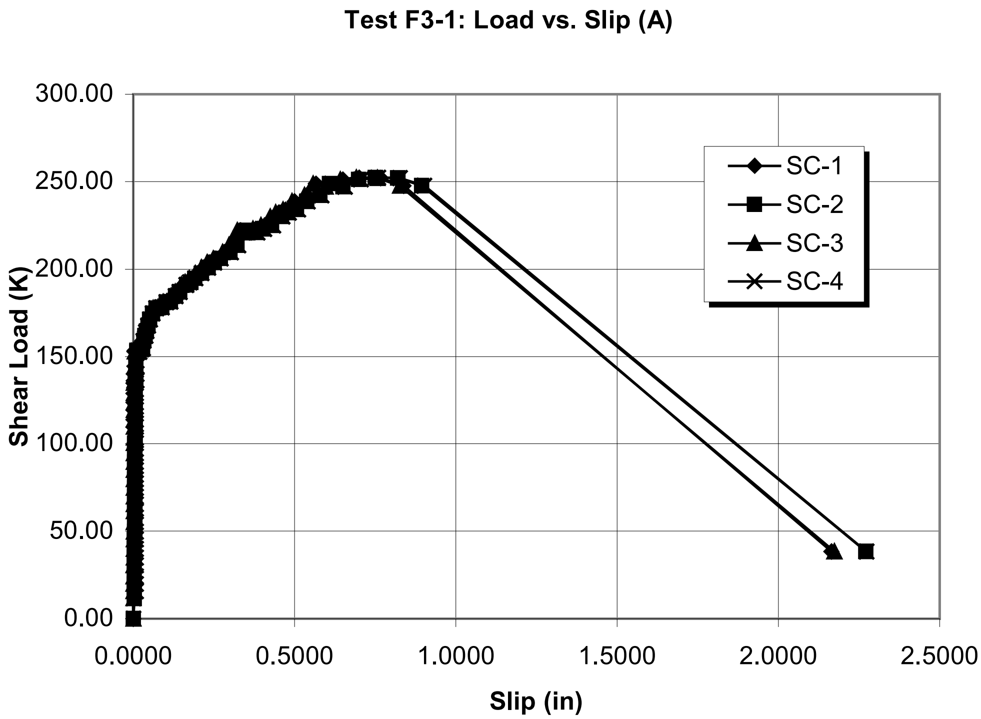
**DAMAGE**

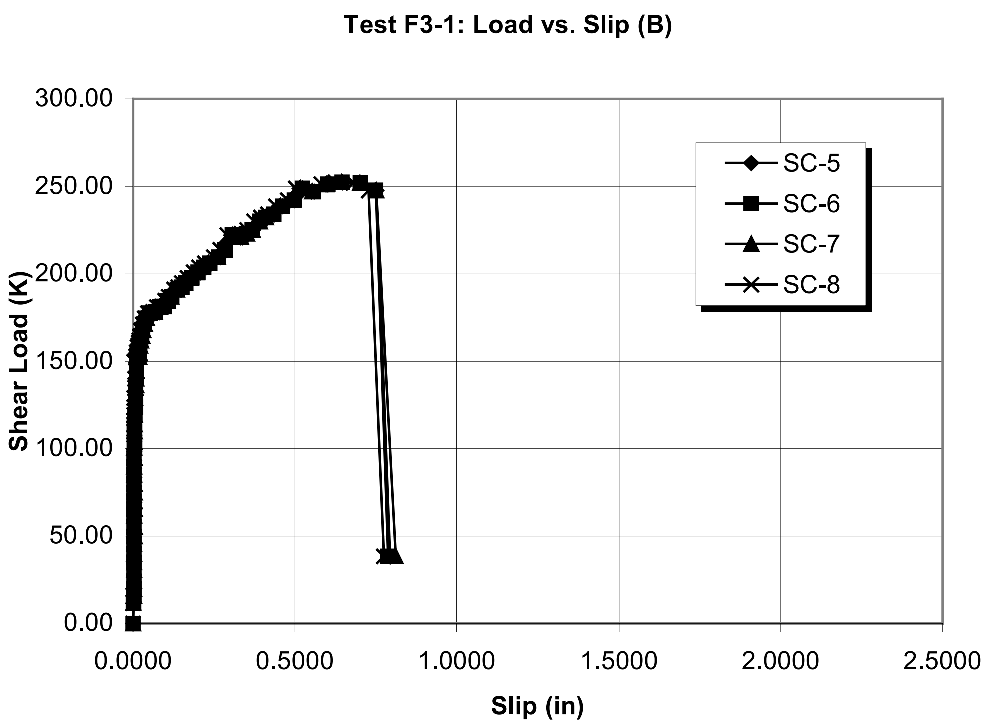


interior, Slab A exterior, Slab B

**COMMENTS**

Failure Mode: Screw Shear
Screw Rotation ≈ 30° - 40°
Significant concrete damage
X = Screw sheared off


Test F3-1: Load vs. Slip (A)
Shear Load (K)
Slip (in)
SC-1
SC-2
SC-3
SC-4
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000


Test F3-1: Load vs. Slip (B)
Shear Load (K)
Slip (in)
SC-5
SC-6
SC-7
SC-8
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0.0000
0.5000
1.0000
1.5000
2.0000
2.5000

**TEST F3-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11.56 | 1.00 | -0.0018 | 0.0024 | 0.0000 | 0.0000 | 0.0000 | 0.0012 | 0.0000 | 0.0006 |
| 15.83 | 1.48 | -0.0012 | 0.0031 | 0.0000 | 0.0073 | -0.0006 | 0.0024 | 0.0037 | 0.0018 |
| 19.85 | 1.99 | -0.0012 | 0.0037 | 0.0000 | 0.0073 | -0.0006 | 0.0024 | 0.0037 | 0.0018 |
| 24.25 | 2.46 | -0.0012 | 0.0037 | 0.0000 | 0.0079 | -0.0061 | 0.0024 | 0.0037 | 0.0018 |
| 30.65 | 3.06 | -0.0012 | 0.0037 | 0.0000 | 0.0079 | -0.0061 | 0.0031 | 0.0037 | 0.0018 |
| 34.80 | 3.52 | -0.0012 | 0.0037 | 0.0012 | 0.0079 | -0.0061 | 0.0031 | 0.0037 | 0.0018 |
| 39.82 | 3.91 | -0.0012 | 0.0037 | 0.0012 | 0.0073 | -0.0061 | 0.0031 | 0.0037 | 0.0018 |
| 45.48 | 4.50 | -0.0012 | 0.0037 | 0.0012 | 0.0079 | -0.0061 | 0.0031 | 0.0037 | 0.0018 |
| 49.87 | 5.05 | -0.0012 | 0.0043 | 0.0012 | 0.0079 | -0.0061 | 0.0031 | 0.0043 | 0.0024 |
| 55.28 | 5.68 | -0.0012 | 0.0043 | 0.0012 | 0.0073 | -0.0061 | 0.0031 | 0.0043 | 0.0018 |
| 61.31 | 6.19 | -0.0012 | 0.0043 | 0.0012 | 0.0079 | -0.0061 | 0.0031 | 0.0037 | 0.0024 |
| 65.33 | 6.67 | -0.0012 | 0.0043 | 0.0012 | 0.0073 | -0.0043 | 0.0031 | 0.0043 | 0.0024 |
| 69.97 | 7.03 | -0.0012 | 0.0043 | 0.0018 | 0.0073 | -0.0043 | 0.0031 | 0.0043 | 0.0018 |
| 74.87 | 7.97 | -0.0012 | 0.0043 | 0.0012 | 0.0079 | -0.0043 | 0.0031 | 0.0043 | 0.0024 |
| 79.77 | 8.20 | -0.0012 | 0.0043 | 0.0018 | 0.0079 | -0.0043 | 0.0031 | 0.0043 | 0.0024 |
| 84.92 | 8.57 | -0.0012 | 0.0049 | 0.0018 | 0.0079 | -0.0043 | 0.0037 | 0.0037 | 0.0024 |
| 89.70 | 9.15 | -0.0012 | 0.0049 | 0.0018 | 0.0079 | -0.0043 | 0.0037 | 0.0037 | 0.0024 |
| 94.47 | 9.67 | -0.0012 | 0.0049 | 0.0018 | 0.0079 | -0.0043 | 0.0037 | 0.0043 | 0.0024 |
| 100.37 | 10.19 | -0.0012 | 0.0055 | 0.0018 | 0.0073 | -0.0043 | 0.0043 | 0.0037 | 0.0024 |
| 103.64 | 10.63 | -0.0012 | 0.0061 | 0.0018 | 0.0079 | -0.0043 | 0.0055 | 0.0043 | 0.0024 |
| 109.79 | 11.24 | -0.0006 | 0.0061 | 0.0018 | 0.0079 | -0.0043 | 0.0055 | 0.0043 | 0.0024 |
| 113.81 | 11.54 | -0.0006 | 0.0061 | 0.0018 | 0.0079 | -0.0043 | 0.0055 | 0.0049 | 0.0024 |
| 119.34 | 12.18 | -0.0006 | 0.0061 | 0.0018 | 0.0079 | -0.0043 | 0.0067 | 0.0055 | 0.0031 |
| 123.61 | 12.55 | -0.0006 | 0.0061 | 0.0018 | 0.0079 | -0.0043 | 0.0073 | 0.0055 | 0.0037 |
| 128.76 | 13.03 | -0.0006 | 0.0067 | 0.0018 | 0.0079 | -0.0043 | 0.0073 | 0.0067 | 0.0037 |
| 134.79 | 13.65 | 0.0000 | 0.0067 | 0.0018 | 0.0079 | -0.0043 | 0.0079 | 0.0079 | 0.0061 |
| 136.30 | 14.18 | 0.0012 | 0.0079 | 0.0031 | 0.0098 | -0.0031 | 0.0085 | 0.0092 | 0.0061 |
| 139.82 | 14.43 | 0.0012 | 0.0079 | 0.0031 | 0.0098 | -0.0037 | 0.0104 | 0.0098 | 0.0067 |
| 144.34 | 14.81 | 0.0024 | 0.0079 | 0.0037 | 0.0098 | -0.0018 | 0.0110 | 0.0110 | 0.0092 |
| 152.76 | 15.13 | 0.0031 | 0.0104 | 0.0049 | 0.0122 | -0.0012 | 0.0128 | 0.0122 | 0.0098 |
| 153.26 | 15.53 | 0.0049 | 0.0116 | 0.0067 | 0.0134 | 0.0024 | 0.0153 | 0.0146 | 0.0128 |
| 152.38 | 16.06 | 0.0116 | 0.0165 | 0.0128 | 0.0189 | 0.0079 | 0.0171 | 0.0183 | 0.0146 |
| 153.89 | 16.28 | 0.0153 | 0.0220 | 0.0165 | 0.0256 | 0.0079 | 0.0177 | 0.0189 | 0.0146 |
| 154.52 | 16.24 | 0.0238 | 0.0287 | 0.0238 | 0.0299 | 0.0092 | 0.0195 | 0.0201 | 0.0153 |
| 158.79 | 16.39 | 0.0275 | 0.0323 | 0.0269 | 0.0311 | 0.0116 | 0.0208 | 0.0226 | 0.0165 |
| 161.80 | 16.54 | 0.0323 | 0.0366 | 0.0311 | 0.0372 | 0.0146 | 0.0238 | 0.0250 | 0.0195 |
| 164.44 | 16.67 | 0.0360 | 0.0403 | 0.0348 | 0.0415 | 0.0171 | 0.0262 | 0.0287 | 0.0226 |
| 167.46 | 16.89 | 0.0397 | 0.0452 | 0.0378 | 0.0452 | 0.0220 | 0.0299 | 0.0317 | 0.0256 |
| 171.23 | 17.68 | 0.0458 | 0.0507 | 0.0439 | 0.0513 | 0.0256 | 0.0348 | 0.0360 | 0.0293 |
| 174.62 | 17.93 | 0.0549 | 0.0604 | 0.0519 | 0.0604 | 0.0330 | 0.0415 | 0.0427 | 0.0360 |
| 177.38 | 18.25 | 0.0647 | 0.0708 | 0.0616 | 0.0702 | 0.0427 | 0.0513 | 0.0525 | 0.0452 |
| 178.14 | 19.00 | 0.0800 | 0.0879 | 0.0763 | 0.0879 | 0.0586 | 0.0684 | 0.0677 | 0.0610 |
| 181.03 | 18.59 | 0.0946 | 0.1025 | 0.0909 | 0.1025 | 0.0732 | 0.0830 | 0.0818 | 0.0745 |
| 181.15 | 18.79 | 0.1080 | 0.1154 | 0.1031 | 0.1147 | 0.0861 | 0.0952 | 0.0946 | 0.0873 |
| 184.54 | 19.07 | 0.1215 | 0.1306 | 0.1166 | 0.1306 | 0.1001 | 0.1080 | 0.1068 | 0.0989 |
| 186.80 | 19.25 | 0.1349 | 0.1440 | 0.1294 | 0.1434 | 0.1099 | 0.1196 | 0.1178 | 0.1093 |
| 190.82 | 19.53 | 0.1550 | 0.1660 | 0.1489 | 0.1648 | 0.1288 | 0.1373 | 0.1349 | 0.1270 |
| 192.46 | 19.70 | 0.1685 | 0.1782 | 0.1611 | 0.1758 | 0.1422 | 0.1501 | 0.1477 | 0.1392 |
| 194.72 | 19.82 | 0.1807 | 0.1910 | 0.1740 | 0.1917 | 0.1556 | 0.1630 | 0.1599 | 0.1514 |
| 197.48 | 20.48 | 0.1990 | 0.2112 | 0.1917 | 0.2118 | 0.1733 | 0.1819 | 0.1776 | 0.1685 |
| 200.87 | 20.91 | 0.2179 | 0.2313 | 0.2106 | 0.2313 | 0.1923 | 0.2014 | 0.1965 | 0.1874 |
| 203.64 | 21.07 | 0.2362 | 0.2509 | 0.2289 | 0.2515 | 0.2106 | 0.2185 | 0.2142 | 0.2045 |
| 206.15 | 21.30 | 0.2551 | 0.2704 | 0.2478 | 0.2716 | 0.2295 | 0.2368 | 0.2332 | 0.2222 |
| 209.54 | 21.55 | 0.2838 | 0.2997 | 0.2753 | 0.3027 | 0.2582 | 0.2643 | 0.2618 | 0.2496 |
| 213.44 | 22.17 | 0.3058 | 0.3223 | 0.2972 | 0.3253 | 0.2802 | 0.2844 | 0.2820 | 0.2692 |
| 222.11 | 22.60 | 0.3320 | 0.3497 | 0.3223 | 0.3516 | 0.3033 | 0.3058 | 0.3058 | 0.2911 |
| 220.97 | 23.05 | 0.3601 | 0.3802 | 0.3516 | 0.3845 | 0.3314 | 0.3326 | 0.3326 | 0.3174 |
| 222.98 | 23.15 | 0.3809 | 0.4016 | 0.3705 | 0.4047 | 0.3510 | 0.3503 | 0.3516 | 0.3345 |
| 225.00 | 23.35 | 0.4065 | 0.4291 | 0.3961 | 0.4333 | 0.3687 | 0.3680 | 0.3687 | 0.3522 |
| 229.77 | 23.89 | 0.4346 | 0.4584 | 0.4236 | 0.4620 | 0.3900 | 0.3912 | 0.3918 | 0.3741 |
| 232.16 | 23.97 | 0.4504 | 0.4785 | 0.4413 | 0.4822 | 0.4089 | 0.4108 | 0.4102 | 0.3937 |
| 234.04 | 24.78 | 0.4718 | 0.5066 | 0.4645 | 0.5109 | 0.4272 | 0.4352 | 0.4303 | 0.4163 |
| 238.56 | 24.89 | 0.4993 | 0.5377 | 0.4913 | 0.5414 | 0.4517 | 0.4614 | 0.4553 | 0.4419 |
| 241.95 | 25.10 | 0.5383 | 0.5792 | 0.5304 | 0.5835 | 0.4865 | 0.4974 | 0.4913 | 0.4779 |
| 248.86 | 25.67 | 0.5658 | 0.6091 | 0.5573 | 0.6146 | 0.5139 | 0.5231 | 0.5164 | 0.5029 |
| 246.98 | 25.88 | 0.6055 | 0.6506 | 0.5969 | 0.6555 | 0.5499 | 0.5579 | 0.5524 | 0.5383 |
| 251.25 | 26.66 | 0.6506 | 0.6995 | 0.6421 | 0.7056 | 0.5951 | 0.6012 | 0.5975 | 0.5817 |
| 252.38 | 26.83 | 0.7007 | 0.7513 | 0.6915 | 0.7581 | 0.6451 | 0.6458 | 0.6439 | 0.6256 |
| 252.13 | 27.06 | 0.7666 | 0.8209 | 0.7568 | 0.8270 | 0.6976 | 0.7025 | 0.7013 | 0.6812 |
| 247.61 | 27.29 | 0.8374 | 0.8948 | 0.8270 | 0.9027 | 0.7513 | 0.7495 | 0.7507 | 0.7281 |
| 38.44 | 28.61 | 2.1643 | 2.2717 | 2.1728 | 2.2729 | 0.7928 | 0.7874 | 0.8105 | 0.7739 |

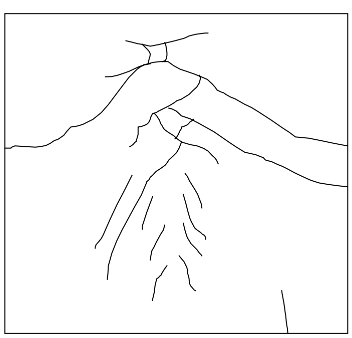
## PUSHOUT TEST SUMMARY SHEET

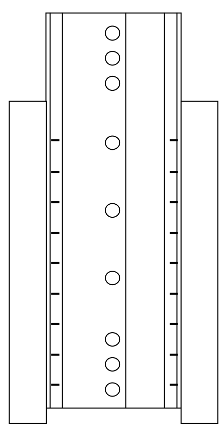
Test: F3-2 Test Date: 24-Nov-98
Test Designation: SC-8-2.5-0.212-S-3.0-2

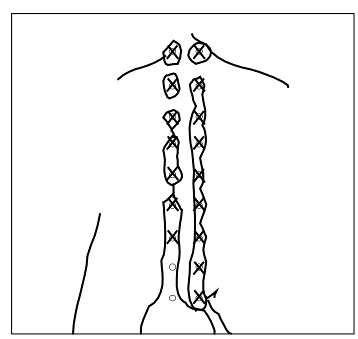
| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.5 in. | No. Per Specimen: | 36 | | |
| **Deck:** | Type: | none | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | N.A. | $F_u$: | N.A. | | |
| **Base Member:** | Section: | 2L 2.5x2.5x0.212 | | | | |
| | $F_y$: | 54.2 ksi | $F_u$: | 76.9 ksi | | |
| **Slab:** | Thickness: | 3.0 in. | $f'_c$: | 3793 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 4x4-W2.0xW2.0 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 223.24 kips | | | |
| **Peak Shear Load Per Screw:** | 6.20 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.6549 in. | SC5: | 0.7745 in. |
| | SC2: | 0.6531 in. | SC6: | 0.7074 in. |
| | SC3: | 0.6488 in. | SC7: | 0.7660 in. |
| | SC4: | 0.6732 in. | SC8: | 0.7031 in. |

**DAMAGE**


exterior, Slab A

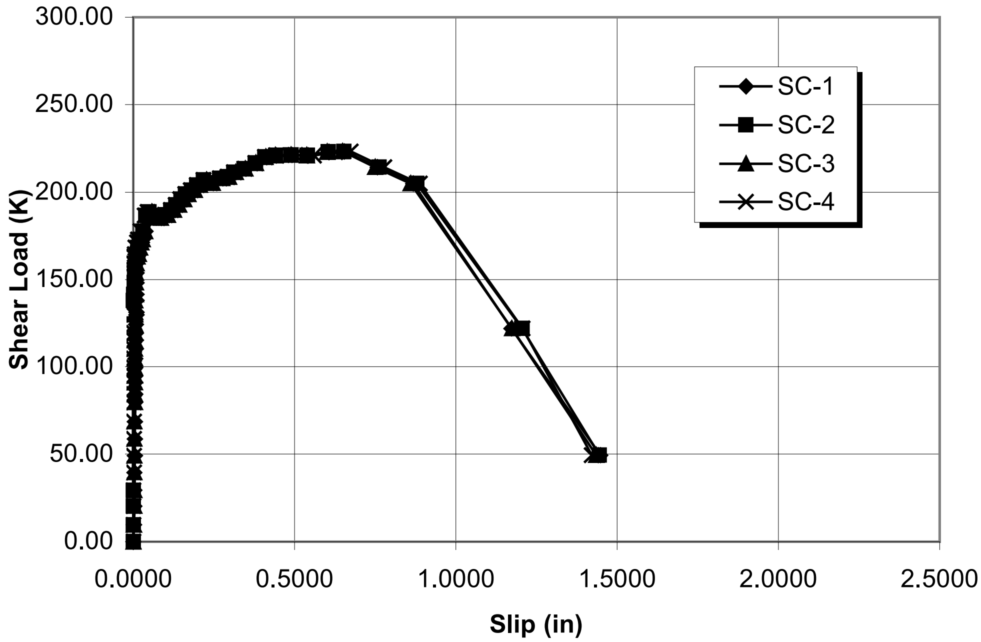



interior, Slab B

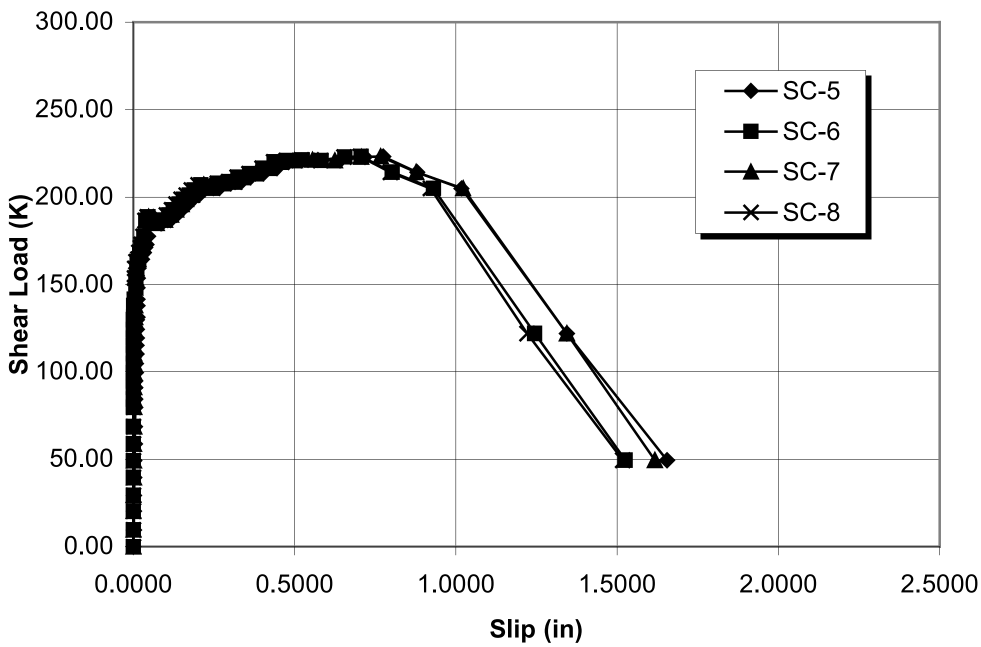
**COMMENTS**

Failure Mode: Screw Shear
Screw Rotation ≈ 30° - 40°
Significant concrete damage
X = Screw sheared off

**Test F3-2: Load vs. Slip (A)**




**Test F3-2: Load vs. Slip (B)**



**TEST F3-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | -0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0006 |
| 9.67 | 0.96 | 0.0018 | -0.0006 | 0.0018 | 0.0000 | 0.0012 | 0.0000 | 0.0000 | 0.0000 |
| 20.48 | 2.12 | 0.0024 | -0.0006 | 0.0024 | 0.0000 | 0.0012 | 0.0000 | 0.0006 | 0.0006 |
| 29.27 | 3.55 | 0.0024 | -0.0006 | 0.0024 | 0.0000 | 0.0018 | 0.0000 | 0.0006 | 0.0006 |
| 39.45 | 4.25 | 0.0037 | -0.0018 | 0.0024 | 0.0012 | 0.0024 | -0.0006 | 0.0012 | 0.0006 |
| 49.25 | 5.08 | 0.0043 | -0.0018 | 0.0031 | 0.0012 | 0.0031 | -0.0006 | 0.0012 | 0.0006 |
| 58.92 | 5.99 | 0.0049 | -0.0018 | 0.0031 | 0.0012 | 0.0043 | -0.0006 | 0.0018 | 0.0006 |
| 68.59 | 7.00 | 0.0049 | -0.0018 | 0.0037 | 0.0012 | 0.0055 | -0.0006 | 0.0024 | 0.0006 |
| 79.77 | 8.05 | 0.0061 | -0.0018 | 0.0043 | 0.0012 | 0.0061 | -0.0006 | 0.0024 | 0.0006 |
| 84.42 | 8.57 | 0.0061 | -0.0018 | 0.0043 | 0.0012 | 0.0067 | -0.0006 | 0.0024 | 0.0006 |
| 91.08 | 9.19 | 0.0061 | -0.0018 | 0.0043 | 0.0012 | 0.0067 | -0.0006 | 0.0031 | 0.0006 |
| 94.97 | 9.89 | 0.0061 | -0.0018 | 0.0043 | 0.0012 | 0.0067 | -0.0006 | 0.0031 | 0.0006 |
| 99.62 | 10.14 | 0.0067 | -0.0018 | 0.0049 | 0.0012 | 0.0085 | -0.0006 | 0.0037 | 0.0006 |
| 104.77 | 10.64 | 0.0067 | -0.0018 | 0.0049 | 0.0012 | 0.0085 | 0.0006 | 0.0037 | 0.0012 |
| 110.17 | 11.17 | 0.0073 | -0.0018 | 0.0055 | 0.0012 | 0.0092 | 0.0006 | 0.0037 | 0.0012 |
| 115.20 | 11.44 | 0.0073 | -0.0018 | 0.0055 | 0.0012 | 0.0092 | 0.0006 | 0.0037 | 0.0012 |
| 119.34 | 12.01 | 0.0079 | -0.0018 | 0.0061 | 0.0012 | 0.0110 | 0.0006 | 0.0043 | 0.0012 |
| 124.12 | 12.49 | 0.0079 | -0.0018 | 0.0067 | 0.0012 | 0.0110 | 0.0006 | 0.0043 | 0.0012 |
| 129.77 | 13.05 | 0.0092 | -0.0018 | 0.0067 | 0.0012 | 0.0116 | 0.0006 | 0.0055 | 0.0012 |
| 131.15 | 13.68 | 0.0092 | -0.0012 | 0.0067 | 0.0012 | 0.0122 | 0.0012 | 0.0061 | 0.0012 |
| 138.06 | 14.04 | 0.0092 | -0.0006 | 0.0067 | 0.0012 | 0.0122 | 0.0018 | 0.0061 | 0.0012 |
| 141.45 | 14.49 | 0.0098 | 0.0012 | 0.0079 | 0.0012 | 0.0128 | 0.0031 | 0.0061 | 0.0012 |
| 148.24 | 15.13 | 0.0098 | 0.0031 | 0.0079 | 0.0018 | 0.0128 | 0.0073 | 0.0061 | 0.0031 |
| 153.76 | 15.55 | 0.0098 | 0.0043 | 0.0079 | 0.0018 | 0.0140 | 0.0085 | 0.0073 | 0.0037 |
| 159.29 | 16.10 | 0.0098 | 0.0061 | 0.0092 | 0.0012 | 0.0165 | 0.0110 | 0.0092 | 0.0055 |
| 163.06 | 16.64 | 0.0128 | 0.0092 | 0.0122 | 0.0018 | 0.0195 | 0.0128 | 0.0110 | 0.0073 |
| 164.32 | 17.32 | 0.0183 | 0.0122 | 0.0177 | 0.0055 | 0.0275 | 0.0177 | 0.0165 | 0.0140 |
| 168.21 | 17.43 | 0.0208 | 0.0140 | 0.0201 | 0.0067 | 0.0323 | 0.0208 | 0.0201 | 0.0171 |
| 171.10 | 17.70 | 0.0269 | 0.0195 | 0.0256 | 0.0116 | 0.0360 | 0.0250 | 0.0244 | 0.0214 |
| 172.98 | 17.80 | 0.0299 | 0.0226 | 0.0287 | 0.0146 | 0.0409 | 0.0287 | 0.0281 | 0.0244 |
| 177.51 | 18.17 | 0.0378 | 0.0299 | 0.0366 | 0.0220 | 0.0458 | 0.0330 | 0.0336 | 0.0293 |
| 186.55 | 18.63 | 0.0482 | 0.0397 | 0.0470 | 0.0342 | 0.0537 | 0.0391 | 0.0403 | 0.0360 |
| 188.69 | 18.98 | 0.0592 | 0.0494 | 0.0574 | 0.0439 | 0.0616 | 0.0464 | 0.0476 | 0.0421 |
| 185.30 | 19.31 | 0.0714 | 0.0623 | 0.0702 | 0.0586 | 0.0739 | 0.0562 | 0.0586 | 0.0525 |
| 185.05 | 19.56 | 0.0867 | 0.0781 | 0.0854 | 0.0739 | 0.0879 | 0.0696 | 0.0720 | 0.0647 |
| 186.68 | 19.96 | 0.1099 | 0.0989 | 0.1080 | 0.0970 | 0.1147 | 0.0928 | 0.0977 | 0.0867 |
| 189.82 | 20.19 | 0.1288 | 0.1172 | 0.1270 | 0.1166 | 0.1337 | 0.1105 | 0.1160 | 0.1031 |
| 192.71 | 20.36 | 0.1440 | 0.1324 | 0.1416 | 0.1312 | 0.1501 | 0.1251 | 0.1318 | 0.1178 |
| 195.97 | 20.53 | 0.1593 | 0.1483 | 0.1575 | 0.1459 | 0.1691 | 0.1422 | 0.1495 | 0.1331 |
| 198.74 | 20.66 | 0.1733 | 0.1617 | 0.1709 | 0.1605 | 0.1843 | 0.1569 | 0.1642 | 0.1477 |
| 201.00 | 20.81 | 0.1929 | 0.1807 | 0.1904 | 0.1788 | 0.2032 | 0.1740 | 0.1813 | 0.1648 |
| 203.89 | 20.96 | 0.2087 | 0.1971 | 0.2069 | 0.1965 | 0.2197 | 0.1892 | 0.1978 | 0.1801 |
| 206.90 | 21.14 | 0.2289 | 0.2179 | 0.2264 | 0.2173 | 0.2405 | 0.2100 | 0.2179 | 0.2002 |
| 205.15 | 21.33 | 0.2484 | 0.2380 | 0.2466 | 0.2374 | 0.2673 | 0.2332 | 0.2435 | 0.2277 |
| 207.66 | 21.64 | 0.2771 | 0.2679 | 0.2753 | 0.2679 | 0.3009 | 0.2661 | 0.2783 | 0.2606 |
| 208.66 | 21.81 | 0.2985 | 0.2911 | 0.2966 | 0.2911 | 0.3351 | 0.2985 | 0.3119 | 0.2942 |
| 211.18 | 21.99 | 0.3186 | 0.3119 | 0.3174 | 0.3125 | 0.3625 | 0.3253 | 0.3394 | 0.3210 |
| 213.19 | 22.21 | 0.3491 | 0.3436 | 0.3467 | 0.3448 | 0.4016 | 0.3619 | 0.3784 | 0.3583 |
| 216.45 | 22.41 | 0.3827 | 0.3778 | 0.3809 | 0.3784 | 0.4456 | 0.4028 | 0.4218 | 0.3998 |
| 220.10 | 22.56 | 0.4126 | 0.4083 | 0.4102 | 0.4083 | 0.4816 | 0.4376 | 0.4578 | 0.4352 |
| 220.97 | 23.09 | 0.4437 | 0.4413 | 0.4407 | 0.4425 | 0.5212 | 0.4761 | 0.4993 | 0.4724 |
| 221.23 | 23.15 | 0.4913 | 0.4889 | 0.4883 | 0.5011 | 0.5725 | 0.5237 | 0.5554 | 0.5206 |
| 220.97 | 23.31 | 0.5432 | 0.5389 | 0.5377 | 0.5597 | 0.6403 | 0.5823 | 0.6250 | 0.5798 |
| 222.86 | 23.47 | 0.6073 | 0.6049 | 0.6012 | 0.6256 | 0.7184 | 0.6561 | 0.7068 | 0.6531 |
| 223.24 | 23.64 | 0.6549 | 0.6531 | 0.6488 | 0.6732 | 0.7745 | 0.7074 | 0.7660 | 0.7031 |
| 214.07 | 23.80 | 0.7568 | 0.7617 | 0.7489 | 0.7776 | 0.8807 | 0.8026 | 0.8765 | 0.7971 |
| 204.77 | 24.22 | 0.8679 | 0.8789 | 0.8594 | 0.8881 | 1.0180 | 0.9302 | 1.0223 | 0.9204 |
| 121.85 | 24.02 | 1.1718 | 1.2048 | 1.1730 | 1.2072 | 1.3439 | 1.2445 | 1.3446 | 1.2213 |
| 49.37 | 22.17 | 1.4483 | 1.4453 | 1.4349 | 1.4215 | 1.6552 | 1.5246 | 1.6168 | 1.5179 |

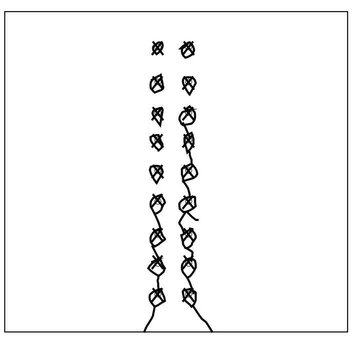
**PUSHOUT TEST SUMMARY SHEET**

Test: F4-1 Test Date: 11-Jan-99
Test Designation: SC-8-2.5-0.313-S-3.0-1

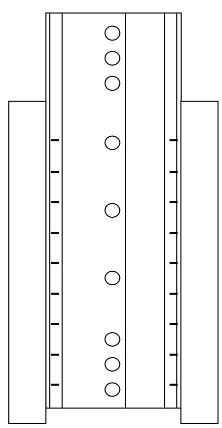
| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.5 in. | No. Per Specimen: | 36 | | |
| **Deck:** | Type: | none | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | N.A. | $F_u$: | N.A. | | |
| **Base Member:** | Section: | 2L 3x3x0.313 | | | | |
| | $F_y$: | 60.6 ksi | $F_u$: | 85.8 ksi | | |
| **Slab:** | Thickness: | 3.0 in. | $f'_c$: | 5052 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 4x4-W2.0xW2.0 | | | | |

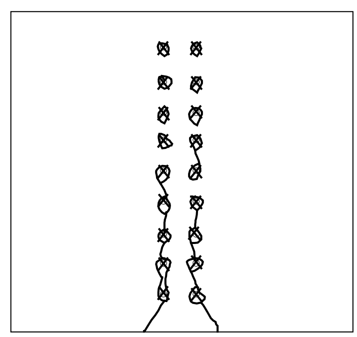
| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 216.58 kips | | | |
| **Peak Shear Load Per Screw:** | 6.02 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.2057 in. | SC5: | 0.2478 in. |
| | SC2: | 0.2179 in. | SC6: | N.A. |
| | SC3: | 0.1959 in. | SC7: | 0.2429 in. |
| | SC4: | 0.2155 in. | SC8: | 0.2374 in. |

**DAMAGE**



interior, Slab A



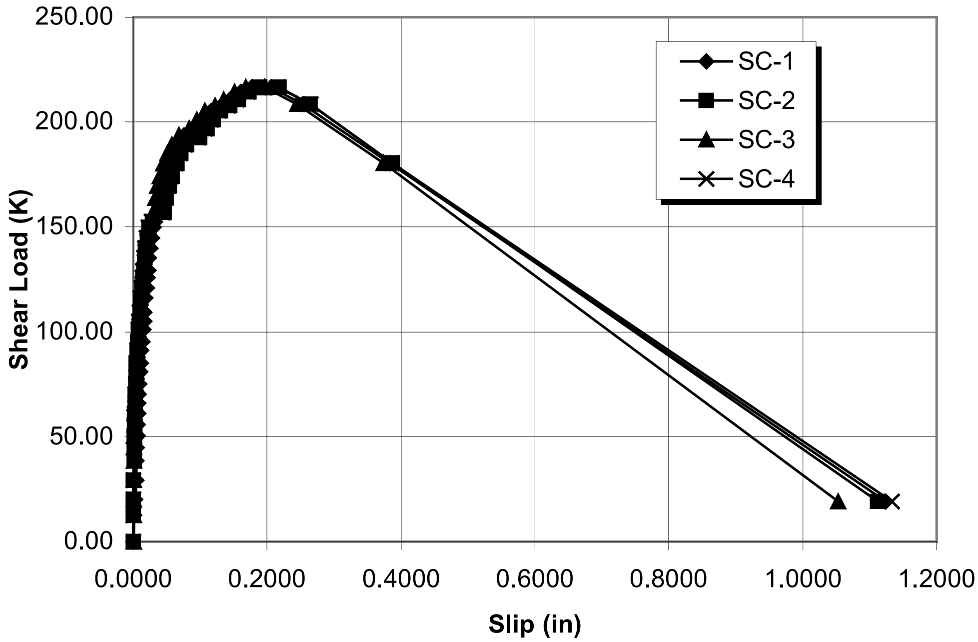


interior, Slab B

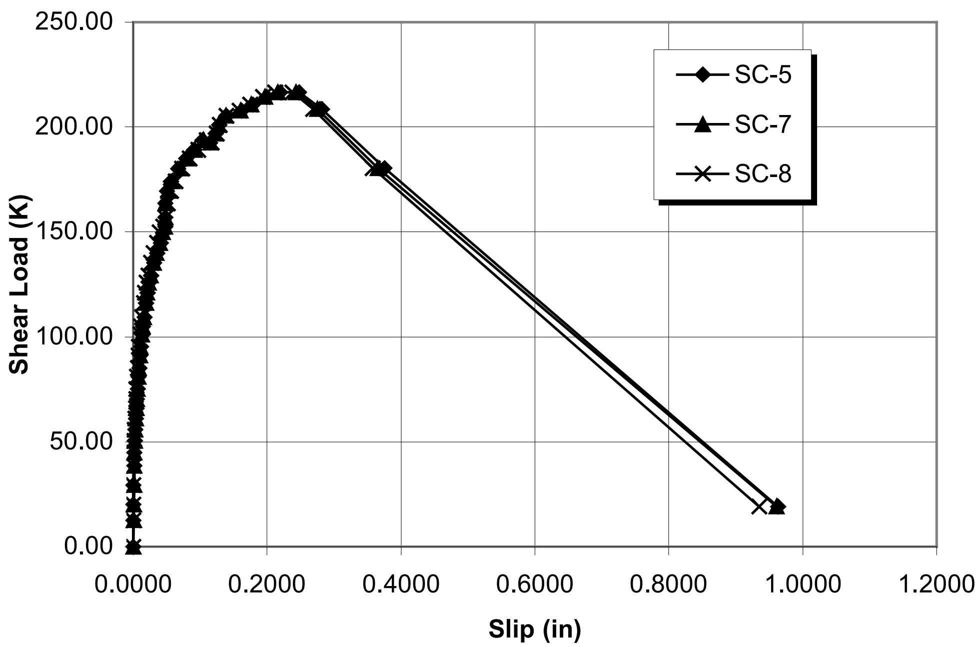
**COMMENTS**

Failure Mode: Screw Shear
Screw Rotation ≈ 10° - 20°
Significant concrete damage
X = Screw sheared off

**Test F4-1: Load vs. Slip (A)**




**Test F4-1: Load vs. Slip (B)**



## TEST F4-1 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | ~~0.0000~~ | 0.0000 | 0.0000 |
| 12.56 | 1.29 | 0.0018 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | ~~-0.0006~~ | 0.0006 | 0.0000 |
| 20.10 | 2.10 | 0.0031 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | ~~0.0006~~ | 0.0006 | 0.0000 |
| 29.40 | 3.13 | 0.0043 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | ~~0.0006~~ | 0.0012 | 0.0000 |
| 38.44 | 3.84 | 0.0049 | 0.0018 | 0.0006 | 0.0012 | 0.0012 | ~~0.0006~~ | 0.0012 | 0.0006 |
| 44.97 | 4.58 | 0.0055 | 0.0018 | 0.0006 | 0.0012 | 0.0018 | ~~0.0006~~ | 0.0018 | 0.0018 |
| 50.50 | 5.04 | 0.0067 | 0.0018 | 0.0006 | 0.0012 | 0.0024 | ~~0.0006~~ | 0.0024 | 0.0018 |
| 55.78 | 5.63 | 0.0067 | 0.0024 | 0.0012 | 0.0018 | 0.0031 | ~~0.0006~~ | 0.0031 | 0.0024 |
| 61.06 | 6.22 | 0.0073 | 0.0024 | 0.0012 | 0.0024 | 0.0037 | ~~0.0006~~ | 0.0037 | 0.0031 |
| 65.95 | 6.66 | 0.0079 | 0.0031 | 0.0018 | 0.0031 | 0.0043 | ~~0.0006~~ | 0.0049 | 0.0037 |
| 70.35 | 7.15 | 0.0085 | 0.0031 | 0.0031 | 0.0031 | 0.0055 | ~~0.0006~~ | 0.0055 | 0.0043 |
| 75.25 | 7.68 | 0.0092 | 0.0037 | 0.0037 | 0.0037 | 0.0067 | ~~0.0006~~ | 0.0061 | 0.0049 |
| 81.03 | 8.27 | 0.0104 | 0.0049 | 0.0043 | 0.0049 | 0.0079 | ~~0.0006~~ | 0.0073 | 0.0055 |
| 85.18 | 8.65 | 0.0116 | 0.0049 | 0.0049 | 0.0055 | 0.0092 | ~~0.0006~~ | 0.0085 | 0.0067 |
| 91.08 | 9.28 | 0.0122 | 0.0061 | 0.0061 | 0.0061 | 0.0104 | ~~0.0006~~ | 0.0098 | 0.0079 |
| 95.35 | 9.73 | 0.0134 | 0.0067 | 0.0067 | 0.0067 | 0.0116 | ~~0.0006~~ | 0.0110 | 0.0085 |
| 101.13 | 10.23 | 0.0153 | 0.0079 | 0.0079 | 0.0079 | 0.0134 | ~~0.0006~~ | 0.0128 | 0.0104 |
| 104.89 | 10.63 | 0.0165 | 0.0092 | 0.0092 | 0.0085 | 0.0146 | ~~0.0006~~ | 0.0140 | 0.0116 |
| 109.42 | 11.18 | 0.0165 | 0.0104 | 0.0092 | 0.0092 | 0.0165 | ~~0.0006~~ | 0.0159 | 0.0128 |
| 116.20 | 11.68 | 0.0183 | 0.0116 | 0.0110 | 0.0110 | 0.0189 | ~~0.0006~~ | 0.0189 | 0.0159 |
| 121.10 | 12.06 | 0.0201 | 0.0128 | 0.0128 | 0.0122 | 0.0214 | ~~0.0006~~ | 0.0208 | 0.0171 |
| 125.75 | 12.66 | 0.0214 | 0.0146 | 0.0140 | 0.0134 | 0.0238 | ~~0.0006~~ | 0.0226 | 0.0195 |
| 129.27 | 13.26 | 0.0226 | 0.0159 | 0.0140 | 0.0146 | 0.0262 | ~~0.0006~~ | 0.0256 | 0.0226 |
| 135.30 | 13.72 | 0.0238 | 0.0171 | 0.0153 | 0.0159 | 0.0311 | ~~0.0006~~ | 0.0305 | 0.0262 |
| 139.94 | 14.40 | 0.0256 | 0.0183 | 0.0171 | 0.0171 | 0.0354 | ~~0.0006~~ | 0.0342 | 0.0305 |
| 144.84 | 14.75 | 0.0281 | 0.0214 | 0.0183 | 0.0195 | 0.0409 | ~~0.0006~~ | 0.0397 | 0.0360 |
| 149.87 | 15.18 | 0.0305 | 0.0232 | 0.0214 | 0.0226 | 0.0452 | ~~0.0006~~ | 0.0439 | 0.0397 |
| 152.63 | 15.72 | 0.0323 | 0.0287 | 0.0238 | 0.0275 | 0.0482 | ~~0.0006~~ | 0.0470 | 0.0446 |
| 156.78 | 16.27 | 0.0360 | 0.0464 | 0.0299 | 0.0439 | 0.0476 | ~~0.0006~~ | 0.0476 | 0.0482 |
| 163.56 | 16.38 | 0.0385 | 0.0494 | 0.0330 | 0.0470 | 0.0476 | ~~0.0006~~ | 0.0482 | 0.0513 |
| 169.47 | 16.88 | 0.0427 | 0.0537 | 0.0360 | 0.0525 | 0.0500 | ~~0.0006~~ | 0.0525 | 0.0562 |
| 173.99 | 17.76 | 0.0464 | 0.0586 | 0.0397 | 0.0562 | 0.0562 | ~~0.0006~~ | 0.0586 | 0.0629 |
| 180.15 | 18.75 | 0.0519 | 0.0653 | 0.0446 | 0.0629 | 0.0671 | ~~0.0006~~ | 0.0696 | 0.0732 |
| 184.92 | 19.33 | 0.0580 | 0.0714 | 0.0507 | 0.0696 | 0.0787 | ~~0.0006~~ | 0.0800 | 0.0842 |
| 189.07 | 19.59 | 0.0659 | 0.0800 | 0.0580 | 0.0775 | 0.0909 | ~~0.0006~~ | 0.0922 | 0.0970 |
| 193.71 | 19.92 | 0.0757 | 0.0928 | 0.0684 | 0.0891 | 0.1031 | ~~0.0006~~ | 0.1050 | 0.1093 |
| 192.58 | 20.30 | 0.0830 | 0.0995 | 0.0739 | 0.0970 | 0.1147 | ~~0.0006~~ | 0.1154 | 0.1172 |
| 196.85 | 20.54 | 0.0940 | 0.1099 | 0.0836 | 0.1068 | 0.1227 | ~~0.0006~~ | 0.1221 | 0.1245 |
| 201.13 | 20.68 | 0.1050 | 0.1190 | 0.0952 | 0.1160 | 0.1282 | ~~0.0006~~ | 0.1276 | 0.1288 |
| 205.40 | 20.94 | 0.1166 | 0.1306 | 0.1074 | 0.1276 | 0.1392 | ~~0.0006~~ | 0.1385 | 0.1392 |
| 207.78 | 21.60 | 0.1312 | 0.1447 | 0.1221 | 0.1416 | 0.1617 | ~~0.0006~~ | 0.1599 | 0.1587 |
| 210.80 | 21.91 | 0.1440 | 0.1575 | 0.1355 | 0.1550 | 0.1788 | ~~0.0006~~ | 0.1764 | 0.1746 |
| 214.44 | 22.36 | 0.1599 | 0.1733 | 0.1514 | 0.1709 | 0.1990 | ~~0.0006~~ | 0.1965 | 0.1935 |
| 216.45 | 22.69 | 0.1770 | 0.1892 | 0.1678 | 0.1874 | 0.2197 | ~~0.0006~~ | 0.2155 | 0.2118 |
| 216.58 | 23.20 | 0.2057 | 0.2179 | 0.1959 | 0.2155 | 0.2478 | ~~0.0006~~ | 0.2429 | 0.2374 |
| 208.54 | 23.96 | 0.2533 | 0.2643 | 0.2448 | 0.2649 | 0.2820 | ~~0.0006~~ | 0.2747 | 0.2686 |
| 180.52 | 25.61 | 0.3827 | 0.3876 | 0.3735 | 0.3864 | 0.3754 | ~~0.0006~~ | 0.3656 | 0.3577 |
| 19.10 | 18.76 | 1.1242 | 1.1120 | 1.0528 | 1.1328 | 0.9631 | ~~0.0006~~ | 0.9607 | 0.9351 |

Note: SC-6 readings not included due to operational error

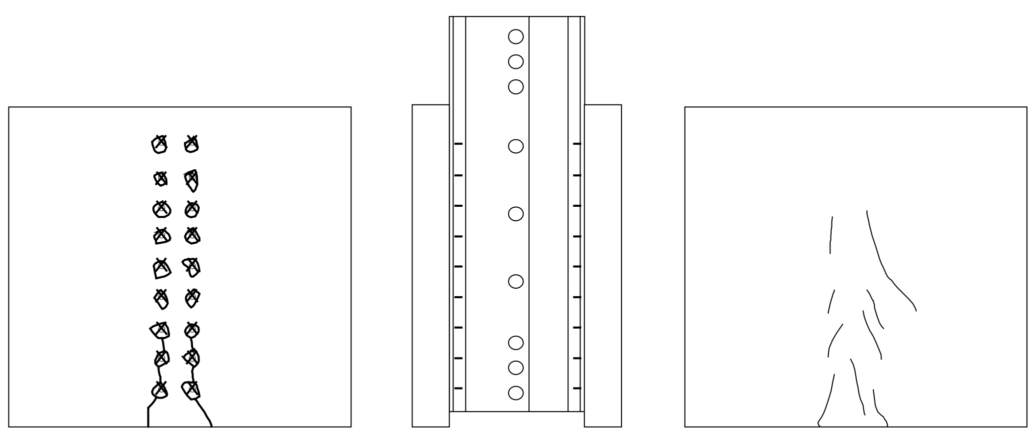
**PUSHOUT TEST SUMMARY SHEET**

Test: F4-2 Test Date: 12-Jan-99
Test Designation: SC-8-2.5-0.313-S-3.0-2

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 2.5 in. | No. Per Specimen: | 36 | | |
| **Deck:** | Type: | none | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | N.A. | $F_u$: | N.A. | | |
| **Base Member:** | Section: | 2L 3x3x0.313 | | | | |
| | $F_y$: | 60.6 ksi | $F_u$: | 85.8 ksi | | |
| **Slab:** | Thickness: | 3.0 in. | $f'_c$: | 5052 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 8 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 4x4-W2.0xW2.0 | | | | |

| TEST RESULTS | | | | | |
|---|---|---|---|---|---|
| **Peak Shear Load:** | 202.13 kips | | | | |
| **Peak Shear Load Per Screw:** | 5.61 kips | | | | |
| **Slip at Peak Shear Load:** | | SC1: | 0.2472 in. | SC5: | 0.1184 in. |
| | | SC2: | 0.2527 in. | SC6: | 0.1123 in. |
| | | SC3: | 0.2344 in. | SC7: | 0.1221 in. |
| | | SC4: | 0.2386 in. | SC8: | 0.1093 in. |

**DAMAGE**

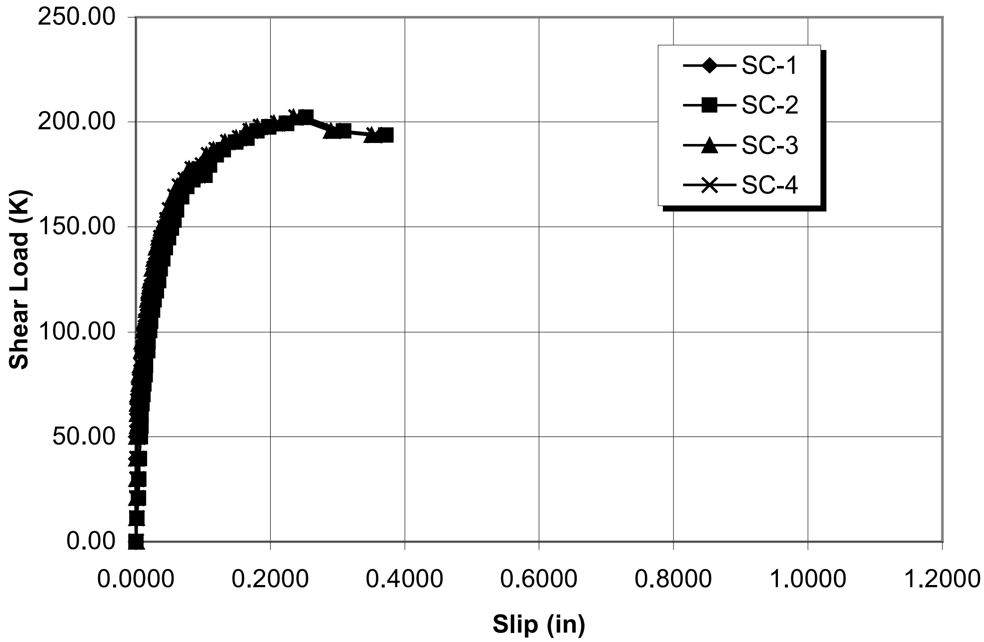


interior, Slab A exterior, Slab B

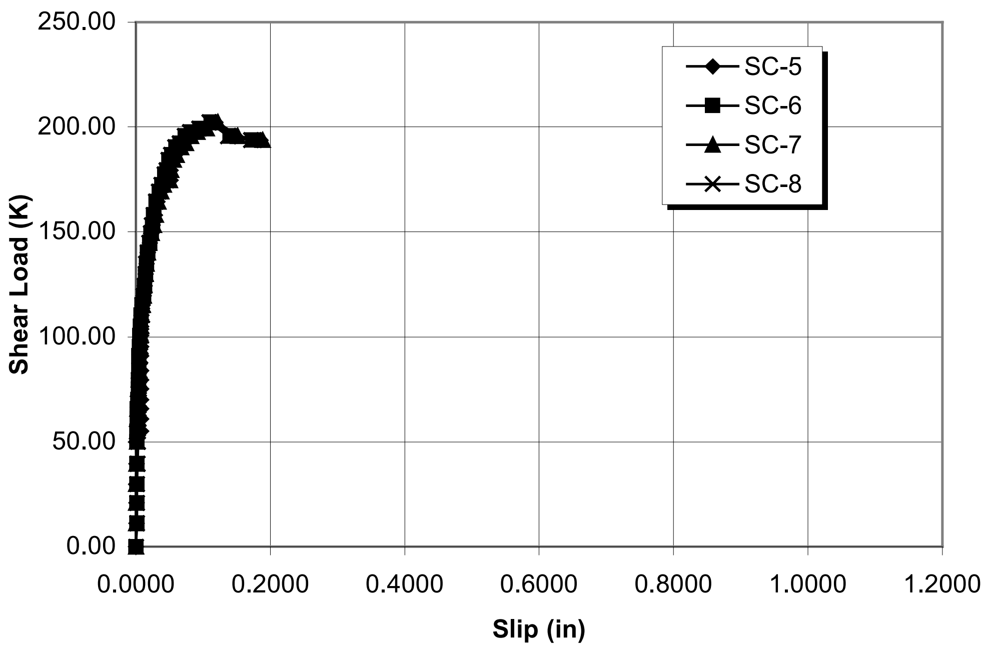
**COMMENTS**

Failure Mode: Screw Shear
Screw Rotation ≈ 10° - 20°
Significant concrete damage
X = Screw sheared off
Note: No unbalanced loading observed to cause difference in slip between slabs

**Test F4-2: Load vs. Slip (A)**




**Test F4-2: Load vs. Slip (B)**



**TEST F4-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11.06 | 1.02 | -0.0006 | 0.0018 | 0.0006 | 0.0006 | 0.0006 | 0.0012 | 0.0000 | 0.0012 |
| 20.85 | 1.97 | -0.0006 | 0.0037 | 0.0006 | 0.0006 | 0.0006 | 0.0012 | 0.0000 | 0.0012 |
| 29.77 | 2.87 | -0.0006 | 0.0043 | 0.0006 | 0.0012 | 0.0000 | 0.0018 | 0.0000 | 0.0018 |
| 39.57 | 3.86 | 0.0000 | 0.0055 | 0.0006 | 0.0018 | 0.0006 | 0.0018 | 0.0006 | 0.0024 |
| 49.87 | 4.86 | 0.0000 | 0.0067 | 0.0006 | 0.0031 | 0.0000 | 0.0018 | 0.0012 | 0.0031 |
| 55.03 | 5.52 | 0.0012 | 0.0073 | 0.0012 | 0.0031 | 0.0079 | 0.0018 | 0.0018 | 0.0031 |
| 60.93 | 6.13 | 0.0018 | 0.0079 | 0.0012 | 0.0043 | 0.0079 | 0.0024 | 0.0018 | 0.0037 |
| 65.70 | 6.56 | 0.0024 | 0.0092 | 0.0018 | 0.0049 | 0.0079 | 0.0024 | 0.0024 | 0.0037 |
| 70.10 | 7.02 | 0.0031 | 0.0104 | 0.0024 | 0.0061 | 0.0079 | 0.0031 | 0.0031 | 0.0043 |
| 75.13 | 7.52 | 0.0043 | 0.0122 | 0.0037 | 0.0073 | 0.0079 | 0.0037 | 0.0031 | 0.0049 |
| 79.52 | 8.10 | 0.0061 | 0.0134 | 0.0049 | 0.0085 | 0.0079 | 0.0037 | 0.0037 | 0.0049 |
| 83.92 | 8.58 | 0.0079 | 0.0146 | 0.0061 | 0.0085 | 0.0079 | 0.0043 | 0.0043 | 0.0055 |
| 90.83 | 9.07 | 0.0092 | 0.0171 | 0.0073 | 0.0110 | 0.0079 | 0.0049 | 0.0055 | 0.0061 |
| 95.35 | 9.63 | 0.0104 | 0.0183 | 0.0085 | 0.0116 | 0.0079 | 0.0055 | 0.0061 | 0.0067 |
| 100.75 | 10.20 | 0.0122 | 0.0208 | 0.0104 | 0.0140 | 0.0079 | 0.0061 | 0.0067 | 0.0073 |
| 105.02 | 10.68 | 0.0140 | 0.0220 | 0.0122 | 0.0153 | 0.0079 | 0.0067 | 0.0079 | 0.0079 |
| 110.42 | 11.13 | 0.0171 | 0.0250 | 0.0153 | 0.0183 | 0.0085 | 0.0079 | 0.0085 | 0.0092 |
| 115.07 | 11.64 | 0.0189 | 0.0275 | 0.0165 | 0.0195 | 0.0098 | 0.0092 | 0.0098 | 0.0098 |
| 119.47 | 12.02 | 0.0208 | 0.0305 | 0.0189 | 0.0220 | 0.0110 | 0.0116 | 0.0110 | 0.0110 |
| 124.49 | 12.46 | 0.0232 | 0.0342 | 0.0208 | 0.0250 | 0.0128 | 0.0128 | 0.0122 | 0.0128 |
| 130.02 | 13.01 | 0.0262 | 0.0360 | 0.0238 | 0.0275 | 0.0140 | 0.0140 | 0.0140 | 0.0140 |
| 134.92 | 13.52 | 0.0293 | 0.0403 | 0.0262 | 0.0311 | 0.0159 | 0.0159 | 0.0159 | 0.0153 |
| 140.07 | 14.04 | 0.0330 | 0.0439 | 0.0293 | 0.0342 | 0.0177 | 0.0177 | 0.0177 | 0.0171 |
| 144.84 | 14.47 | 0.0366 | 0.0482 | 0.0330 | 0.0372 | 0.0201 | 0.0201 | 0.0195 | 0.0195 |
| 149.37 | 15.02 | 0.0415 | 0.0531 | 0.0372 | 0.0421 | 0.0226 | 0.0226 | 0.0232 | 0.0220 |
| 153.14 | 15.44 | 0.0464 | 0.0568 | 0.0421 | 0.0464 | 0.0250 | 0.0250 | 0.0262 | 0.0238 |
| 158.16 | 16.04 | 0.0537 | 0.0604 | 0.0470 | 0.0500 | 0.0281 | 0.0269 | 0.0299 | 0.0262 |
| 164.32 | 16.57 | 0.0604 | 0.0684 | 0.0543 | 0.0580 | 0.0317 | 0.0305 | 0.0330 | 0.0299 |
| 169.34 | 17.02 | 0.0684 | 0.0757 | 0.0616 | 0.0653 | 0.0366 | 0.0348 | 0.0378 | 0.0342 |
| 172.48 | 17.52 | 0.0751 | 0.0848 | 0.0690 | 0.0739 | 0.0397 | 0.0385 | 0.0415 | 0.0378 |
| 177.51 | 17.91 | 0.0848 | 0.0946 | 0.0787 | 0.0842 | 0.0458 | 0.0433 | 0.0464 | 0.0427 |
| 174.62 | 18.22 | 0.0964 | 0.1031 | 0.0873 | 0.0928 | 0.0519 | 0.0458 | 0.0507 | 0.0452 |
| 179.52 | 18.23 | 0.1038 | 0.1099 | 0.0952 | 0.0995 | 0.0519 | 0.0464 | 0.0525 | 0.0452 |
| 184.29 | 18.59 | 0.1129 | 0.1196 | 0.1044 | 0.1086 | 0.0537 | 0.0494 | 0.0562 | 0.0488 |
| 186.68 | 18.99 | 0.1245 | 0.1306 | 0.1154 | 0.1196 | 0.0580 | 0.0537 | 0.0604 | 0.0525 |
| 190.32 | 19.60 | 0.1428 | 0.1483 | 0.1324 | 0.1373 | 0.0641 | 0.0598 | 0.0671 | 0.0586 |
| 192.33 | 19.82 | 0.1599 | 0.1654 | 0.1489 | 0.1544 | 0.0714 | 0.0659 | 0.0745 | 0.0653 |
| 195.60 | 20.11 | 0.1746 | 0.1807 | 0.1636 | 0.1703 | 0.0787 | 0.0739 | 0.0818 | 0.0726 |
| 197.73 | 20.34 | 0.1923 | 0.1978 | 0.1807 | 0.1855 | 0.0879 | 0.0824 | 0.0916 | 0.0806 |
| 199.37 | 20.82 | 0.2179 | 0.2240 | 0.2057 | 0.2112 | 0.1013 | 0.0958 | 0.1050 | 0.0940 |
| 202.13 | 21.19 | 0.2472 | 0.2527 | 0.2344 | 0.2386 | 0.1184 | 0.1123 | 0.1221 | 0.1093 |
| 195.60 | 21.88 | 0.3040 | 0.3088 | 0.2905 | 0.2942 | 0.1477 | 0.1404 | 0.1514 | 0.1373 |
| 193.84 | 22.56 | 0.3662 | 0.3717 | 0.3510 | 0.3546 | 0.1855 | 0.1740 | 0.1886 | 0.1715 |
| -0.63 | -0.13 | | | 2.4877 | 2.0635 | 0.1715 | 0.1526 | 0.1648 | 0.1678 |

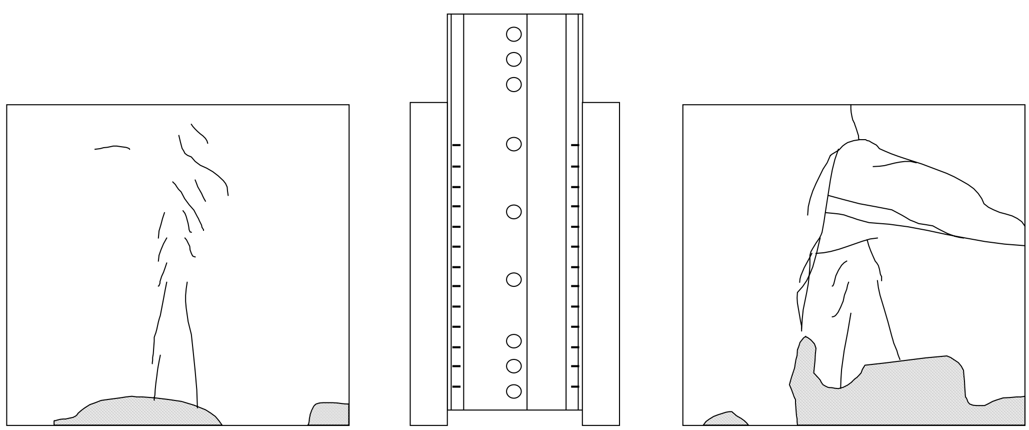
## PUSHOUT TEST SUMMARY SHEET

Test: F5-1 Test Date: 15-Jan-99
Test Designation: SC-8-3.0-0.227-S-3.5-1

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 3.0 in. | No. Per Specimen: | 52 | | |
| **Deck:** | Type: | none | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | N.A. | $F_u$: | N.A. | | |
| **Base Member:** | Section: | 2L 3x3x0.227 | | | | |
| | $F_y$: | 58.3 ksi | $F_u$: | 81.7 ksi | | |
| **Slab:** | Thickness: | 3.5 in. | $f'_c$: | 5710 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 12 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4.0xW4.0 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 300.25 kips | | | |
| **Peak Shear Load Per Screw:** | 5.77 kips | | | |
| **Slip at Peak Shear Load:** | SC1: | 0.3595 in. | SC5: | 0.2094 in. |
| | SC2: | 0.3674 in. | SC6: | 0.2728 in. |
| | SC3: | 0.3363 in. | SC7: | 0.2081 in. |
| | SC4: | 0.3644 in. | SC8: | 0.2130 in. |

**DAMAGE**

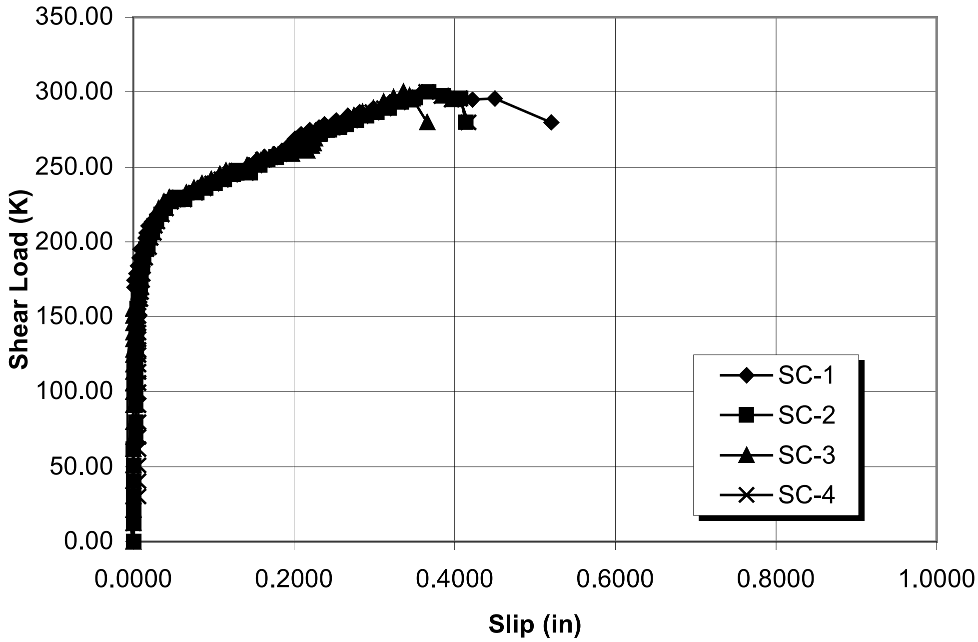


exterior, Slab A exterior, Slab B

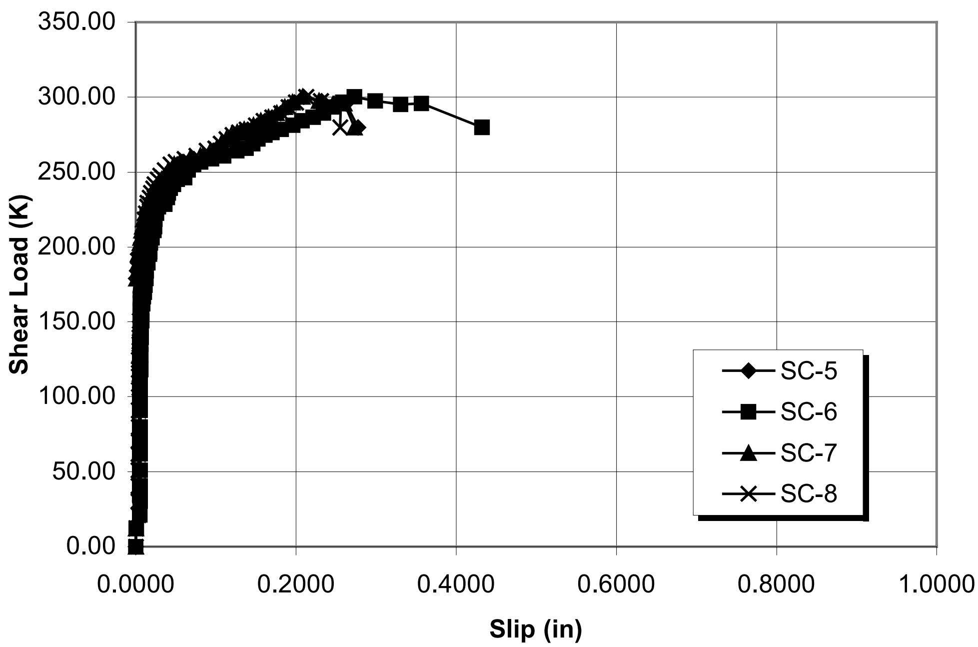
**COMMENTS**

Failure Mode: No failure observed. Test stopped to avoid equipment damage
Screw Rotation ≈ 20° - 30°
Significant concrete damage
Interior damage not available
▭ - Spalled concrete

**Test F5-1: Load vs. Slip (A)**




**Test F5-1: Load vs. Slip (B)**



**TEST F5-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | -0.0006 | 0.0006 | 0.0000 | -0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 12.31 | 1.42 | -0.0037 | 0.0006 | 0.0000 | 0.0000 | -0.0006 | 0.0006 | 0.0000 | 0.0000 |
| 21.11 | 2.01 | -0.0049 | 0.0006 | 0.0000 | 0.0000 | -0.0006 | 0.0049 | -0.0012 | 0.0031 |
| 30.28 | 3.03 | -0.0061 | 0.0006 | 0.0000 | 0.0061 | -0.0031 | 0.0055 | -0.0024 | 0.0031 |
| 40.45 | 4.10 | -0.0067 | 0.0006 | 0.0000 | 0.0061 | -0.0031 | 0.0055 | -0.0024 | 0.0031 |
| 51.01 | 5.15 | -0.0073 | 0.0006 | 0.0000 | 0.0061 | -0.0031 | 0.0055 | -0.0024 | 0.0031 |
| 61.93 | 6.14 | -0.0073 | 0.0000 | 0.0000 | 0.0061 | -0.0031 | 0.0055 | -0.0024 | 0.0031 |
| 70.10 | 7.11 | -0.0079 | 0.0031 | 0.0000 | 0.0061 | -0.0031 | 0.0055 | -0.0024 | 0.0037 |
| 79.90 | 8.07 | -0.0079 | 0.0031 | 0.0000 | 0.0061 | -0.0031 | 0.0055 | -0.0024 | 0.0037 |
| 90.83 | 9.18 | -0.0079 | 0.0031 | 0.0000 | 0.0061 | -0.0031 | 0.0055 | -0.0024 | 0.0037 |
| 99.75 | 10.24 | -0.0073 | 0.0031 | 0.0000 | 0.0061 | -0.0031 | 0.0055 | -0.0024 | 0.0037 |
| 106.03 | 10.52 | -0.0073 | 0.0031 | 0.0000 | 0.0061 | -0.0031 | 0.0055 | -0.0024 | 0.0043 |
| 113.44 | 11.12 | -0.0073 | 0.0031 | 0.0000 | 0.0061 | -0.0031 | 0.0055 | -0.0024 | 0.0037 |
| 118.21 | 11.59 | -0.0067 | 0.0031 | 0.0000 | 0.0061 | -0.0031 | 0.0061 | -0.0024 | 0.0037 |
| 124.49 | 12.54 | -0.0067 | 0.0031 | 0.0000 | 0.0061 | -0.0031 | 0.0055 | -0.0024 | 0.0037 |
| 128.01 | 13.06 | -0.0055 | 0.0037 | 0.0000 | 0.0061 | -0.0031 | 0.0061 | -0.0024 | 0.0043 |
| 135.17 | 13.52 | -0.0043 | 0.0037 | 0.0000 | 0.0061 | -0.0031 | 0.0061 | -0.0024 | 0.0043 |
| 139.44 | 14.11 | -0.0031 | 0.0043 | 0.0000 | 0.0061 | -0.0031 | 0.0067 | -0.0024 | 0.0043 |
| 145.72 | 14.51 | -0.0024 | 0.0043 | 0.0000 | 0.0061 | -0.0024 | 0.0067 | -0.0024 | 0.0049 |
| 150.75 | 15.07 | -0.0024 | 0.0043 | 0.0000 | 0.0061 | -0.0024 | 0.0073 | -0.0024 | 0.0049 |
| 155.52 | 15.61 | -0.0024 | 0.0049 | 0.0000 | 0.0073 | -0.0024 | 0.0079 | -0.0024 | 0.0061 |
| 161.93 | 16.12 | -0.0018 | 0.0061 | 0.0061 | 0.0085 | -0.0024 | 0.0092 | -0.0024 | 0.0061 |
| 166.58 | 16.62 | -0.0006 | 0.0073 | 0.0067 | 0.0098 | -0.0024 | 0.0098 | -0.0018 | 0.0067 |
| 169.72 | 17.32 | 0.0012 | 0.0085 | 0.0073 | 0.0104 | -0.0024 | 0.0110 | -0.0012 | 0.0079 |
| 174.37 | 17.59 | 0.0012 | 0.0098 | 0.0073 | 0.0110 | -0.0018 | 0.0116 | -0.0006 | 0.0079 |
| 178.76 | 18.40 | 0.0037 | 0.0098 | 0.0079 | 0.0116 | 0.0000 | 0.0128 | 0.0006 | 0.0079 |
| 183.91 | 18.64 | 0.0055 | 0.0116 | 0.0098 | 0.0122 | 0.0012 | 0.0134 | 0.0018 | 0.0079 |
| 189.44 | 18.99 | 0.0073 | 0.0134 | 0.0110 | 0.0146 | 0.0024 | 0.0153 | 0.0024 | 0.0085 |
| 195.10 | 19.47 | 0.0092 | 0.0159 | 0.0128 | 0.0165 | 0.0024 | 0.0171 | 0.0024 | 0.0092 |
| 196.60 | 20.01 | 0.0128 | 0.0183 | 0.0153 | 0.0195 | 0.0049 | 0.0177 | 0.0043 | 0.0098 |
| 202.51 | 20.35 | 0.0153 | 0.0201 | 0.0171 | 0.0214 | 0.0061 | 0.0183 | 0.0049 | 0.0098 |
| 206.15 | 20.69 | 0.0165 | 0.0238 | 0.0177 | 0.0250 | 0.0073 | 0.0201 | 0.0055 | 0.0104 |
| 210.67 | 21.18 | 0.0189 | 0.0262 | 0.0195 | 0.0269 | 0.0092 | 0.0226 | 0.0067 | 0.0104 |
| 213.56 | 21.65 | 0.0232 | 0.0293 | 0.0226 | 0.0299 | 0.0110 | 0.0232 | 0.0079 | 0.0110 |
| 218.34 | 22.10 | 0.0299 | 0.0348 | 0.0275 | 0.0354 | 0.0128 | 0.0244 | 0.0092 | 0.0110 |
| 222.48 | 22.51 | 0.0354 | 0.0397 | 0.0317 | 0.0403 | 0.0153 | 0.0262 | 0.0116 | 0.0128 |
| 226.63 | 22.97 | 0.0427 | 0.0464 | 0.0378 | 0.0470 | 0.0177 | 0.0287 | 0.0128 | 0.0140 |
| 229.64 | 23.29 | 0.0494 | 0.0531 | 0.0452 | 0.0531 | 0.0201 | 0.0305 | 0.0159 | 0.0146 |
| 228.51 | 23.67 | 0.0586 | 0.0641 | 0.0543 | 0.0635 | 0.0232 | 0.0360 | 0.0208 | 0.0171 |
| 232.78 | 23.93 | 0.0720 | 0.0793 | 0.0659 | 0.0769 | 0.0250 | 0.0391 | 0.0220 | 0.0171 |
| 235.80 | 24.30 | 0.0818 | 0.0903 | 0.0751 | 0.0879 | 0.0262 | 0.0409 | 0.0232 | 0.0189 |
| 238.94 | 24.53 | 0.0922 | 0.1019 | 0.0854 | 0.0983 | 0.0287 | 0.0433 | 0.0262 | 0.0214 |
| 241.83 | 24.60 | 0.1038 | 0.1135 | 0.0970 | 0.1093 | 0.0323 | 0.0470 | 0.0287 | 0.0238 |
| 245.10 | 24.83 | 0.1147 | 0.1245 | 0.1074 | 0.1208 | 0.0366 | 0.0519 | 0.0323 | 0.0275 |
| 247.61 | 25.09 | 0.1221 | 0.1324 | 0.1154 | 0.1282 | 0.0403 | 0.0562 | 0.0366 | 0.0305 |
| 245.97 | 25.46 | 0.1331 | 0.1459 | 0.1276 | 0.1404 | 0.0427 | 0.0610 | 0.0385 | 0.0336 |
| 251.38 | 25.63 | 0.1440 | 0.1575 | 0.1416 | 0.1514 | 0.0452 | 0.0653 | 0.0409 | 0.0360 |
| 254.89 | 25.99 | 0.1544 | 0.1678 | 0.1617 | 0.1611 | 0.0519 | 0.0726 | 0.0476 | 0.0433 |
| 256.65 | 26.26 | 0.1636 | 0.1776 | 0.1770 | 0.1709 | 0.0598 | 0.0812 | 0.0555 | 0.0494 |
| 258.54 | 26.41 | 0.1752 | 0.1892 | 0.1978 | 0.1825 | 0.0726 | 0.0946 | 0.0671 | 0.0610 |
| 260.80 | 26.62 | 0.1849 | 0.2002 | 0.2167 | 0.1929 | 0.0861 | 0.1099 | 0.0806 | 0.0757 |
| 264.19 | 26.96 | 0.1935 | 0.2112 | 0.2222 | 0.2026 | 0.0977 | 0.1263 | 0.0934 | 0.0885 |
| 265.70 | 27.17 | 0.1959 | 0.2173 | 0.2246 | 0.2094 | 0.1038 | 0.1379 | 0.1007 | 0.0989 |
| 268.84 | 27.38 | 0.2014 | 0.2246 | 0.2258 | 0.2155 | 0.1105 | 0.1459 | 0.1068 | 0.1062 |
| 271.85 | 27.67 | 0.2087 | 0.2332 | 0.2313 | 0.2252 | 0.1160 | 0.1526 | 0.1129 | 0.1129 |
| 274.74 | 27.87 | 0.2197 | 0.2441 | 0.2399 | 0.2356 | 0.1233 | 0.1611 | 0.1196 | 0.1208 |
| 276.38 | 28.22 | 0.2307 | 0.2570 | 0.2472 | 0.2484 | 0.1300 | 0.1703 | 0.1263 | 0.1288 |
| 278.39 | 28.66 | 0.2380 | 0.2655 | 0.2527 | 0.2576 | 0.1398 | 0.1813 | 0.1355 | 0.1385 |
| 281.03 | 28.97 | 0.2527 | 0.2777 | 0.2631 | 0.2704 | 0.1520 | 0.1959 | 0.1465 | 0.1501 |
| 284.29 | 29.08 | 0.2673 | 0.2905 | 0.2747 | 0.2838 | 0.1611 | 0.2075 | 0.1562 | 0.1593 |
| 286.68 | 29.33 | 0.2814 | 0.3033 | 0.2856 | 0.2972 | 0.1703 | 0.2216 | 0.1654 | 0.1703 |
| 289.07 | 29.77 | 0.2985 | 0.3186 | 0.2985 | 0.3119 | 0.1807 | 0.2344 | 0.1758 | 0.1813 |
| 293.21 | 29.96 | 0.3198 | 0.3345 | 0.3113 | 0.3296 | 0.1898 | 0.2466 | 0.1862 | 0.1904 |
| 296.48 | 30.63 | 0.3381 | 0.3510 | 0.3241 | 0.3455 | 0.1984 | 0.2582 | 0.1953 | 0.2002 |
| 300.25 | 31.10 | 0.3595 | 0.3674 | 0.3363 | 0.3644 | 0.2094 | 0.2728 | 0.2081 | 0.2130 |
| 297.48 | 31.52 | 0.3925 | 0.3864 | 0.3436 | 0.3833 | 0.2319 | 0.2991 | 0.2289 | 0.2313 |
| 294.97 | 31.65 | 0.4224 | 0.3979 | 0.3442 | 0.3961 | 0.2484 | 0.3308 | 0.2460 | 0.2441 |
| 295.85 | 31.67 | 0.4498 | 0.4077 | 0.3473 | 0.4065 | 0.2625 | 0.3571 | 0.2600 | 0.2557 |
| 279.89 | 31.54 | 0.5200 | 0.4138 | 0.3656 | 0.4169 | 0.2777 | 0.4321 | 0.2728 | 0.2551 |

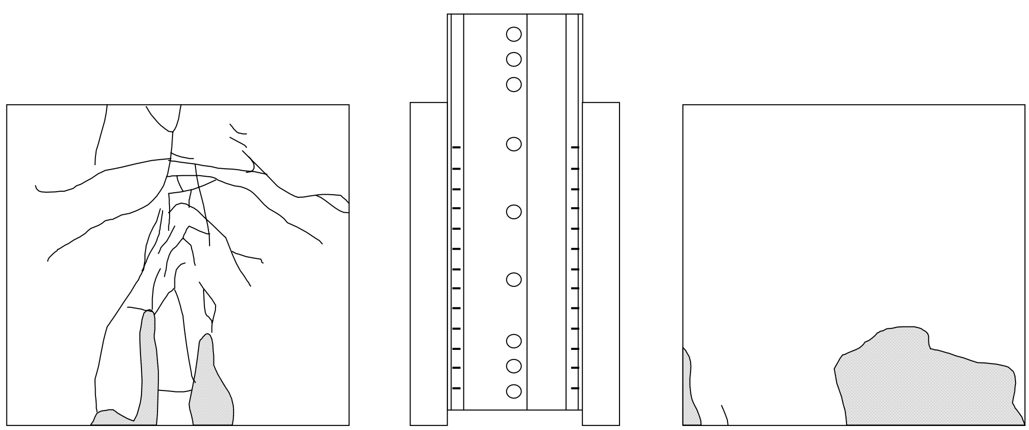
## PUSHOUT TEST SUMMARY SHEET

Test: F5-2 Test Date: 23-Jan-99
Test Designation: SC-8-3.0-0.227-S-3.5-2

| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 3.0 in. | No. Per Specimen: | 52 | | |
| **Deck:** | Type: | none | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | N.A,. | $F_u$: | N.A. | | |
| **Base Member:** | Section: | 2L 3x3x0.227 | | | | |
| | $F_y$: | 58.3 ksi | $F_u$: | 81.7 ksi | | |
| **Slab:** | Thickness: | 3.5 in. | $f'_c$: | 5710 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 12 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4.0xW4.0 | | | | |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 241.33 kips | | | |
| **Peak Shear Load Per Screw:** | 4.64 kips | | | |
| **Slip at Peak Shear Load:** | SC1: 0.2051 in. | | SC5: 0.2014 in. | |
| | SC2: 0.2527 in. | | SC6: 0.1270 in. | |
| | SC3: 0.1819 in. | | SC7: 0.1880 in. | |
| | SC4: 0.1910 in. | | SC8: 0.1251 in. | |

**DAMAGE**

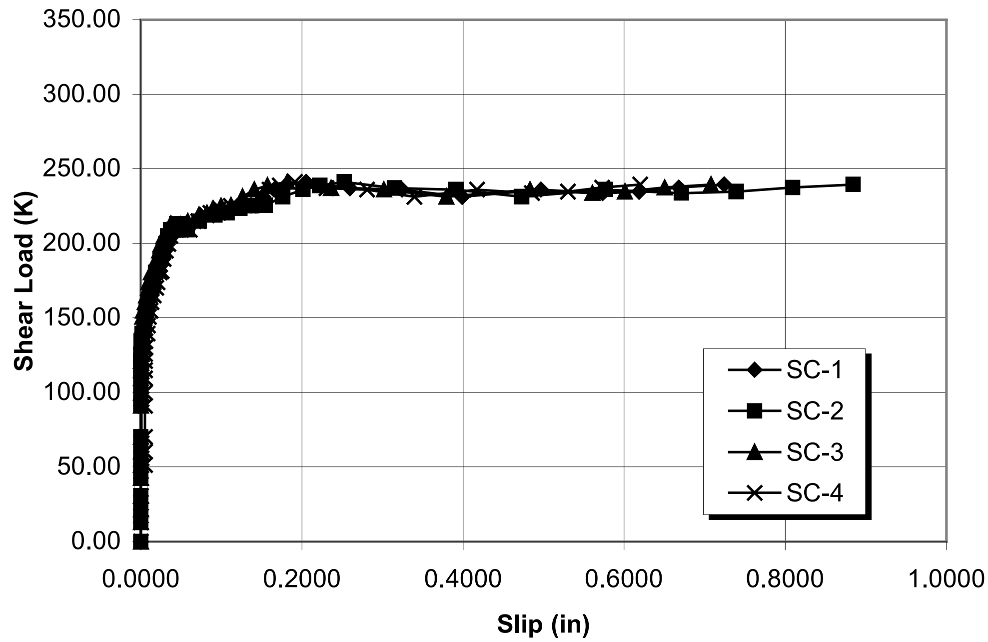


exterior, Slab A exterior, Slab B

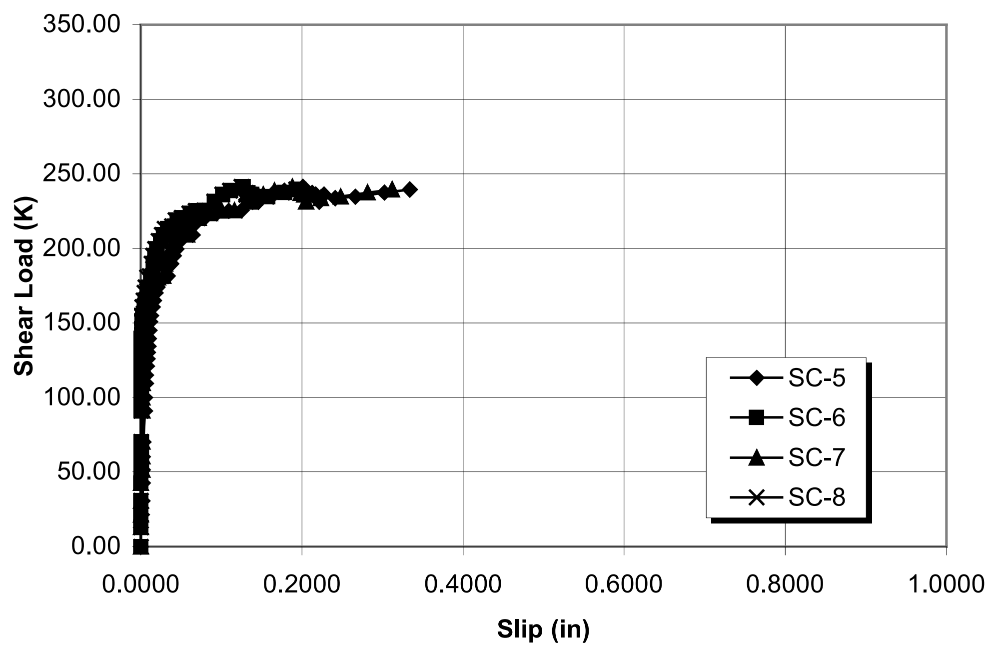
**COMMENTS**

Failure Mode: Concrete crushing (interior of slab A)
Screw Rotation ≈ 20° - 30°
Significant concrete damage
Interior damage not available
▭ - Spalled concrete

Test F5-2: Load vs. Slip (A)




Test F5-2: Load vs. Slip (B)



## TEST F5-2 DATA

| Shear Load (kips) | Normal Load (kips) | Slip (in) SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | -0.01 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 13.07 | 1.28 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 21.48 | 2.06 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0012 | 0.0000 | 0.0000 | 0.0000 |
| 30.65 | 2.68 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0018 | 0.0000 | 0.0000 | 0.0000 |
| 42.59 | 4.07 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0024 | 0.0000 | 0.0000 | -0.0006 |
| 51.38 | 5.22 | 0.0006 | 0.0000 | 0.0000 | 0.0049 | 0.0024 | 0.0006 | 0.0018 | 0.0000 |
| 60.30 | 6.17 | 0.0006 | 0.0000 | 0.0000 | 0.0049 | 0.0024 | 0.0006 | 0.0018 | 0.0000 |
| 70.23 | 7.08 | 0.0006 | 0.0000 | 0.0000 | 0.0049 | 0.0031 | 0.0006 | 0.0018 | 0.0000 |
| 91.21 | 9.17 | 0.0006 | 0.0000 | 0.0000 | 0.0049 | 0.0049 | 0.0006 | 0.0018 | 0.0000 |
| 100.00 | 10.22 | 0.0006 | 0.0000 | 0.0000 | 0.0049 | 0.0049 | 0.0006 | 0.0018 | 0.0000 |
| 109.54 | 11.25 | 0.0006 | 0.0000 | 0.0000 | 0.0049 | 0.0061 | 0.0006 | 0.0024 | 0.0000 |
| 114.82 | 11.71 | 0.0006 | 0.0000 | 0.0000 | 0.0049 | 0.0061 | 0.0006 | 0.0024 | 0.0000 |
| 121.23 | 12.32 | 0.0006 | 0.0000 | 0.0000 | 0.0049 | 0.0073 | 0.0006 | 0.0031 | 0.0000 |
| 125.75 | 12.87 | 0.0006 | 0.0000 | 0.0006 | 0.0049 | 0.0079 | 0.0006 | 0.0037 | 0.0000 |
| 130.15 | 13.21 | 0.0012 | 0.0006 | 0.0012 | 0.0055 | 0.0085 | 0.0006 | 0.0037 | 0.0000 |
| 134.42 | 13.98 | 0.0024 | 0.0006 | 0.0006 | 0.0055 | 0.0092 | 0.0006 | 0.0043 | 0.0000 |
| 139.44 | 14.55 | 0.0031 | 0.0018 | 0.0012 | 0.0079 | 0.0104 | 0.0006 | 0.0043 | 0.0000 |
| 144.84 | 14.54 | 0.0043 | 0.0043 | 0.0018 | 0.0085 | 0.0110 | 0.0012 | 0.0049 | 0.0000 |
| 150.62 | 15.07 | 0.0049 | 0.0055 | 0.0018 | 0.0104 | 0.0116 | 0.0018 | 0.0055 | 0.0006 |
| 154.77 | 15.92 | 0.0061 | 0.0067 | 0.0024 | 0.0122 | 0.0128 | 0.0024 | 0.0067 | 0.0006 |
| 160.67 | 16.29 | 0.0079 | 0.0085 | 0.0049 | 0.0134 | 0.0146 | 0.0043 | 0.0079 | 0.0018 |
| 165.07 | 16.64 | 0.0104 | 0.0116 | 0.0061 | 0.0159 | 0.0165 | 0.0055 | 0.0092 | 0.0031 |
| 170.10 | 17.24 | 0.0128 | 0.0140 | 0.0085 | 0.0189 | 0.0183 | 0.0079 | 0.0110 | 0.0043 |
| 173.86 | 17.59 | 0.0140 | 0.0159 | 0.0098 | 0.0208 | 0.0208 | 0.0092 | 0.0128 | 0.0055 |
| 180.52 | 18.54 | 0.0201 | 0.0183 | 0.0128 | 0.0232 | 0.0293 | 0.0128 | 0.0214 | 0.0073 |
| 181.53 | 18.63 | 0.0238 | 0.0214 | 0.0159 | 0.0256 | 0.0336 | 0.0146 | 0.0275 | 0.0110 |
| 189.57 | 19.08 | 0.0275 | 0.0238 | 0.0195 | 0.0287 | 0.0378 | 0.0159 | 0.0305 | 0.0134 |
| 195.10 | 19.82 | 0.0305 | 0.0275 | 0.0226 | 0.0311 | 0.0409 | 0.0177 | 0.0330 | 0.0153 |
| 199.62 | 20.58 | 0.0336 | 0.0311 | 0.0244 | 0.0342 | 0.0439 | 0.0201 | 0.0366 | 0.0177 |
| 204.89 | 21.06 | 0.0391 | 0.0336 | 0.0287 | 0.0366 | 0.0488 | 0.0244 | 0.0409 | 0.0220 |
| 209.04 | 21.26 | 0.0452 | 0.0372 | 0.0336 | 0.0403 | 0.0549 | 0.0287 | 0.0458 | 0.0256 |
| 213.19 | 21.78 | 0.0494 | 0.0446 | 0.0372 | 0.0470 | 0.0586 | 0.0336 | 0.0513 | 0.0299 |
| 209.17 | 22.71 | 0.0580 | 0.0574 | 0.0458 | 0.0604 | 0.0647 | 0.0415 | 0.0574 | 0.0360 |
| 215.07 | 23.02 | 0.0739 | 0.0726 | 0.0580 | 0.0714 | 0.0647 | 0.0415 | 0.0574 | 0.0385 |
| 219.09 | 23.28 | 0.0903 | 0.0922 | 0.0720 | 0.0812 | 0.0653 | 0.0452 | 0.0598 | 0.0427 |
| 220.22 | 23.58 | 0.1044 | 0.1074 | 0.0818 | 0.0867 | 0.0787 | 0.0525 | 0.0720 | 0.0507 |
| 223.61 | 23.84 | 0.1141 | 0.1233 | 0.0897 | 0.0977 | 0.0940 | 0.0616 | 0.0861 | 0.0598 |
| 225.00 | 24.04 | 0.1233 | 0.1379 | 0.0995 | 0.1117 | 0.1093 | 0.0708 | 0.1001 | 0.0684 |
| 225.50 | 24.26 | 0.1367 | 0.1544 | 0.1117 | 0.1343 | 0.1251 | 0.0793 | 0.1160 | 0.0781 |
| 231.40 | 24.63 | 0.1514 | 0.1764 | 0.1263 | 0.1495 | 0.1459 | 0.0916 | 0.1355 | 0.0909 |
| 235.92 | 24.97 | 0.1654 | 0.2014 | 0.1410 | 0.1599 | 0.1630 | 0.1019 | 0.1520 | 0.1007 |
| 238.94 | 25.29 | 0.1801 | 0.2222 | 0.1575 | 0.1721 | 0.1782 | 0.1117 | 0.1660 | 0.1105 |
| 241.33 | 25.84 | 0.2051 | 0.2527 | 0.1819 | 0.1910 | 0.2014 | 0.1270 | 0.1880 | 0.1251 |
| 237.18 | 26.32 | 0.2594 | 0.3149 | 0.2362 | 0.2307 | 0.2130 | 0.1331 | 0.1984 | 0.1306 |
| 236.18 | 26.77 | 0.3247 | 0.3912 | 0.3015 | 0.2808 | 0.2173 | 0.1349 | 0.2026 | 0.1306 |
| 231.28 | 23.92 | 0.3992 | 0.4730 | 0.3796 | 0.3400 | 0.2216 | 0.1349 | 0.2051 | 0.1306 |
| 235.92 | 24.97 | 0.4968 | 0.5768 | 0.4828 | 0.4175 | 0.2271 | 0.1373 | 0.2118 | 0.1331 |
| 233.54 | 25.85 | 0.5731 | 0.6714 | 0.5603 | 0.4852 | 0.2411 | 0.1428 | 0.2234 | 0.1404 |
| 234.54 | 23.78 | 0.6189 | 0.7391 | 0.6012 | 0.5304 | 0.2661 | 0.1581 | 0.2478 | 0.1556 |
| 237.43 | 24.90 | 0.6677 | 0.8093 | 0.6500 | 0.5725 | 0.3021 | 0.1788 | 0.2814 | 0.1758 |
| 239.32 | 25.52 | 0.7239 | 0.8844 | 0.7074 | 0.6201 | 0.3339 | 0.1965 | 0.3119 | 0.1923 |

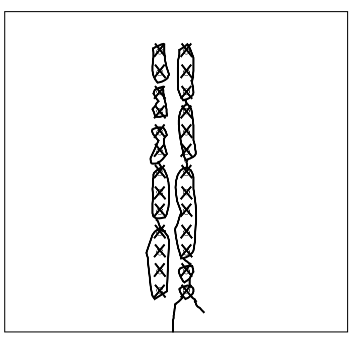
**PUSHOUT TEST SUMMARY SHEET**

Test: F6-1 Test Date: 25-Jan-99
Test Designation: SC-8-3.0-0.375-S-3.5-1

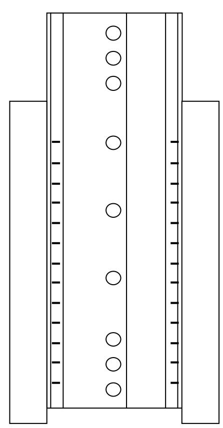
| SPECIMEN DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| **Screw:** | Height: | 3.0 in. | No. Per Specimen: | 52 | | |
| **Deck:** | Type: | none | Width: | 36 in. | Length: | 36 in. |
| | $F_y$: | N.A. | $F_u$: | N.A. | | |
| **Base Member:** | Section: | 2L 3.5x3.5x0.375 | | | | |
| | $F_y$: | 50.9 ksi | $F_u$: | 76.9 ksi | | |
| **Slab:** | Thickness: | 3.5 in | $f'_c$: | 5610 psi | | |
| **Rebar:** | Size: | No. 4 | No. Per Specimen: | 12 | | |
| | | | Height Above Deck: | 1.0 in. | | |
| **Mesh:** | Type: | WWF 6x6-W4.0xW4.0 | | | | |

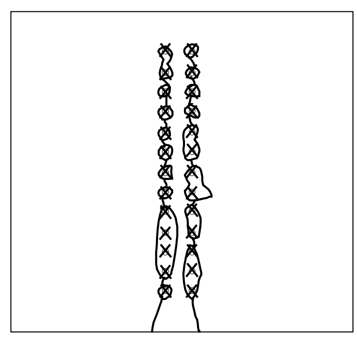
| TEST RESULTS | | | | |
|---|---|---|---|---|
| **Peak Shear Load:** | 320.60 kips | | | |
| **Peak Shear Load Per Screw:** | 6.17 kips | | | |
| **Slip at Peak Shear Load:** | SC1: 0.3113 in. | | SC5: 0.2264 in. | |
| | SC2: 0.3687 in. | | SC6: 0.2502 in. | |
| | SC3: 0.3156 in. | | SC7: 0.2277 in. | |
| | SC4: 0.3888 in. | | SC8: 0.2313 in. | |

**DAMAGE**



interior, Slab A



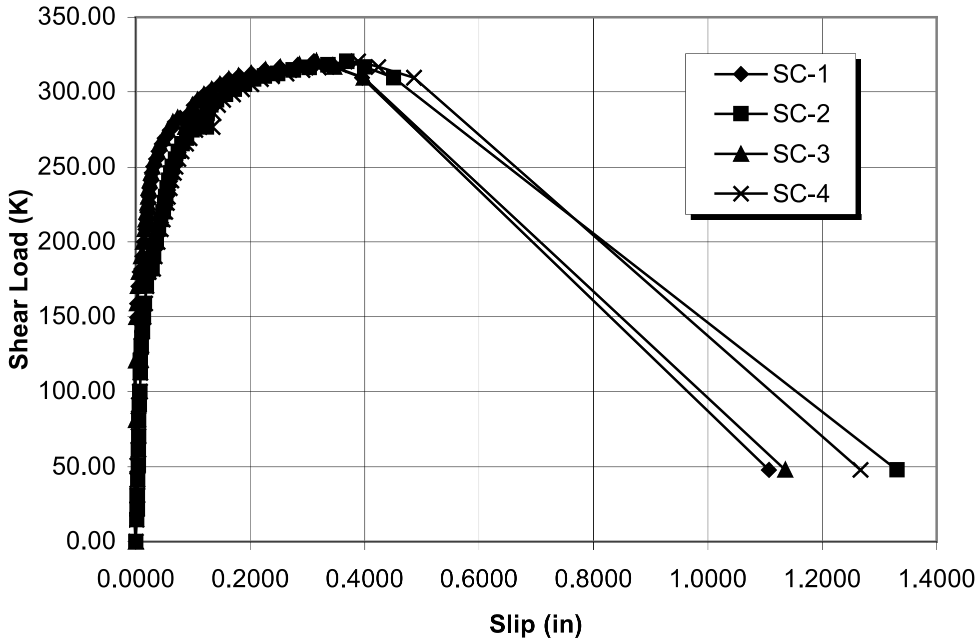


interior, Slab B

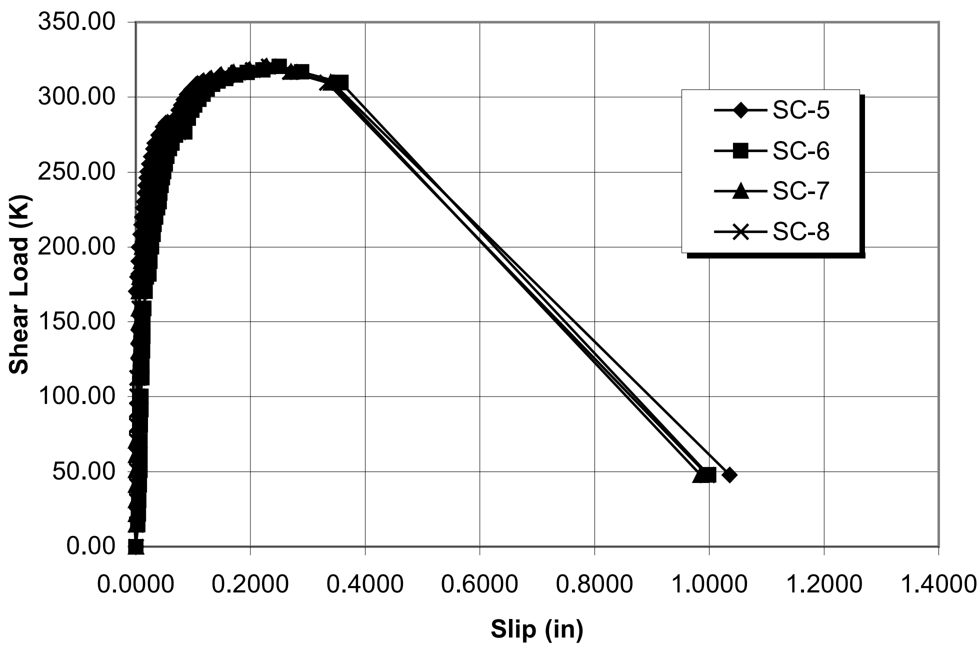
**COMMENTS**

Failure Mode: Screw shear
Screw Rotation ≈ 0° - 10°
Significant concrete damage
X = Screw sheared off

**Test F6-1: Load vs. Slip (A)**




**Test F6-1: Load vs. Slip (B)**



**TEST F6-1 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | -0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 14.57 | 0.99 | -0.0024 | 0.0018 | -0.0006 | 0.0012 | -0.0024 | 0.0037 | 0.0000 | 0.0000 |
| 21.86 | 2.15 | -0.0018 | 0.0024 | -0.0006 | 0.0018 | -0.0037 | 0.0043 | 0.0000 | 0.0000 |
| 31.03 | 3.18 | -0.0024 | 0.0031 | -0.0006 | 0.0024 | -0.0043 | 0.0055 | 0.0000 | 0.0000 |
| 40.95 | 4.39 | -0.0024 | 0.0037 | -0.0006 | 0.0031 | -0.0043 | 0.0061 | 0.0000 | 0.0000 |
| 51.01 | 5.13 | -0.0024 | 0.0043 | -0.0006 | 0.0031 | -0.0043 | 0.0067 | 0.0000 | 0.0006 |
| 61.06 | 6.17 | -0.0024 | 0.0049 | -0.0006 | 0.0043 | -0.0043 | 0.0073 | 0.0000 | 0.0006 |
| 70.60 | 7.29 | -0.0024 | 0.0055 | -0.0006 | 0.0043 | -0.0043 | 0.0073 | 0.0000 | 0.0012 |
| 81.16 | 8.06 | -0.0024 | 0.0055 | 0.0000 | 0.0049 | -0.0043 | 0.0079 | 0.0055 | 0.0012 |
| 91.21 | 9.07 | -0.0024 | 0.0061 | -0.0006 | 0.0055 | -0.0043 | 0.0085 | 0.0055 | 0.0018 |
| 100.25 | 10.13 | -0.0024 | 0.0067 | -0.0006 | 0.0067 | -0.0043 | 0.0092 | 0.0055 | 0.0031 |
| 112.56 | 11.16 | -0.0018 | 0.0079 | -0.0006 | 0.0079 | -0.0043 | 0.0104 | 0.0055 | 0.0031 |
| 120.85 | 12.18 | -0.0018 | 0.0079 | 0.0000 | 0.0085 | -0.0037 | 0.0104 | 0.0055 | 0.0043 |
| 130.77 | 13.08 | -0.0006 | 0.0098 | -0.0012 | 0.0098 | -0.0031 | 0.0116 | 0.0055 | 0.0043 |
| 140.20 | 14.04 | -0.0006 | 0.0116 | -0.0006 | 0.0110 | -0.0031 | 0.0122 | 0.0055 | 0.0043 |
| 149.87 | 15.03 | 0.0024 | 0.0134 | 0.0006 | 0.0134 | -0.0012 | 0.0128 | 0.0055 | 0.0061 |
| 158.91 | 15.94 | 0.0031 | 0.0153 | 0.0018 | 0.0159 | -0.0012 | 0.0140 | 0.0055 | 0.0061 |
| 170.35 | 17.02 | 0.0049 | 0.0189 | 0.0037 | 0.0189 | 0.0000 | 0.0159 | 0.0055 | 0.0073 |
| 180.02 | 18.10 | 0.0073 | 0.0220 | 0.0055 | 0.0220 | 0.0024 | 0.0183 | 0.0061 | 0.0104 |
| 181.90 | 18.87 | 0.0098 | 0.0281 | 0.0085 | 0.0305 | 0.0043 | 0.0232 | 0.0079 | 0.0140 |
| 190.57 | 19.28 | 0.0116 | 0.0311 | 0.0092 | 0.0330 | 0.0043 | 0.0250 | 0.0085 | 0.0153 |
| 200.12 | 19.82 | 0.0140 | 0.0354 | 0.0128 | 0.0385 | 0.0055 | 0.0275 | 0.0110 | 0.0177 |
| 208.54 | 20.90 | 0.0171 | 0.0397 | 0.0153 | 0.0433 | 0.0079 | 0.0305 | 0.0122 | 0.0208 |
| 214.82 | 21.37 | 0.0189 | 0.0433 | 0.0171 | 0.0470 | 0.0098 | 0.0317 | 0.0146 | 0.0220 |
| 219.84 | 21.81 | 0.0208 | 0.0476 | 0.0189 | 0.0519 | 0.0110 | 0.0348 | 0.0153 | 0.0250 |
| 226.00 | 22.15 | 0.0220 | 0.0507 | 0.0201 | 0.0543 | 0.0128 | 0.0378 | 0.0177 | 0.0275 |
| 230.15 | 22.92 | 0.0232 | 0.0525 | 0.0214 | 0.0562 | 0.0140 | 0.0409 | 0.0183 | 0.0299 |
| 235.92 | 23.32 | 0.0238 | 0.0555 | 0.0226 | 0.0598 | 0.0159 | 0.0421 | 0.0195 | 0.0311 |
| 241.08 | 23.61 | 0.0262 | 0.0580 | 0.0244 | 0.0623 | 0.0171 | 0.0439 | 0.0208 | 0.0330 |
| 245.97 | 23.45 | 0.0281 | 0.0610 | 0.0269 | 0.0665 | 0.0189 | 0.0464 | 0.0226 | 0.0354 |
| 250.25 | 23.58 | 0.0305 | 0.0641 | 0.0293 | 0.0696 | 0.0208 | 0.0488 | 0.0244 | 0.0372 |
| 255.27 | 23.67 | 0.0354 | 0.0690 | 0.0330 | 0.0745 | 0.0232 | 0.0513 | 0.0262 | 0.0397 |
| 260.42 | 23.72 | 0.0403 | 0.0745 | 0.0378 | 0.0800 | 0.0269 | 0.0543 | 0.0299 | 0.0427 |
| 265.45 | 23.68 | 0.0458 | 0.0806 | 0.0421 | 0.0879 | 0.0305 | 0.0586 | 0.0330 | 0.0464 |
| 269.09 | 23.65 | 0.0507 | 0.0885 | 0.0482 | 0.0940 | 0.0330 | 0.0629 | 0.0366 | 0.0500 |
| 274.74 | 23.69 | 0.0592 | 0.0983 | 0.0562 | 0.1038 | 0.0391 | 0.0690 | 0.0421 | 0.0562 |
| 280.02 | 23.74 | 0.0684 | 0.1080 | 0.0653 | 0.1154 | 0.0470 | 0.0775 | 0.0500 | 0.0641 |
| 282.91 | 23.83 | 0.0775 | 0.1166 | 0.0732 | 0.1239 | 0.0525 | 0.0812 | 0.0549 | 0.0684 |
| 276.63 | 23.37 | 0.0903 | 0.1239 | 0.0861 | 0.1343 | 0.0629 | 0.0854 | 0.0653 | 0.0745 |
| 285.80 | 23.21 | 0.0940 | 0.1245 | 0.0922 | 0.1361 | 0.0684 | 0.0916 | 0.0696 | 0.0793 |
| 291.20 | 23.17 | 0.1013 | 0.1318 | 0.0989 | 0.1440 | 0.0745 | 0.0977 | 0.0757 | 0.0854 |
| 294.72 | 23.14 | 0.1093 | 0.1410 | 0.1074 | 0.1526 | 0.0793 | 0.1031 | 0.0806 | 0.0903 |
| 298.49 | 23.13 | 0.1202 | 0.1575 | 0.1190 | 0.1697 | 0.0836 | 0.1099 | 0.0848 | 0.0964 |
| 301.88 | 23.19 | 0.1331 | 0.1727 | 0.1324 | 0.1855 | 0.0891 | 0.1172 | 0.0909 | 0.1031 |
| 305.27 | 23.21 | 0.1477 | 0.1898 | 0.1471 | 0.2020 | 0.0964 | 0.1245 | 0.0983 | 0.1117 |
| 308.54 | 23.27 | 0.1630 | 0.2063 | 0.1624 | 0.2191 | 0.1056 | 0.1337 | 0.1074 | 0.1208 |
| 310.55 | 23.30 | 0.1801 | 0.2246 | 0.1794 | 0.2386 | 0.1160 | 0.1440 | 0.1178 | 0.1294 |
| 312.43 | 23.36 | 0.2014 | 0.2484 | 0.2020 | 0.2631 | 0.1294 | 0.1569 | 0.1312 | 0.1422 |
| 314.57 | 23.47 | 0.2258 | 0.2753 | 0.2271 | 0.2911 | 0.1477 | 0.1740 | 0.1489 | 0.1587 |
| 316.33 | 23.67 | 0.2515 | 0.3027 | 0.2527 | 0.3204 | 0.1685 | 0.1947 | 0.1703 | 0.1782 |
| 317.96 | 23.80 | 0.2832 | 0.3363 | 0.2863 | 0.3558 | 0.1971 | 0.2216 | 0.1984 | 0.2039 |
| 320.60 | 23.92 | 0.3113 | 0.3687 | 0.3156 | 0.3888 | 0.2264 | 0.2502 | 0.2277 | 0.2313 |
| 316.70 | 24.11 | 0.3448 | 0.3998 | 0.3467 | 0.4236 | 0.2704 | 0.2893 | 0.2704 | 0.2692 |
| 309.54 | 24.17 | 0.3955 | 0.4510 | 0.3979 | 0.4858 | 0.3424 | 0.3577 | 0.3400 | 0.3333 |
| 47.86 | 21.65 | 1.1065 | 1.3311 | 1.1352 | 1.2670 | 1.0351 | 0.9991 | 0.9851 | 0.9961 |

## PUSHOUT TEST SUMMARY SHEET

Test: F6-2 Test Date: 27-Jan-99

Test Designation: SC-8-3.0-0.375-S-3.5-2

### SPECIMEN DESCRIPTION

| | | | | |
|---|---|---|---|---|
| **Screw:** | Height: 3.0 in. | No. Per Specimen: 52 | | |
| **Deck:** | Type: none | Width: 36 in. | Length: 36 in. | |
| | $F_y$: N.A. | $F_u$: N.A. | | |
| **Base Member:** | Section: 2L 3.5x3.5x0.375 | | | |
| | $F_y$: 50.9 ksi | $F_u$: 76.9 ksi | | |
| **Slab:** | Thickness: 3.5 in | $f'_c$: 5610 psi | | |
| **Rebar:** | Size: No. 4 | No. Per Specimen: 12 | | |
| | | Height Above Deck: 1.0 in. | | |
| **Mesh:** | Type: WWF 6x6-W4.0xW4.0 | | | |

### TEST RESULTS

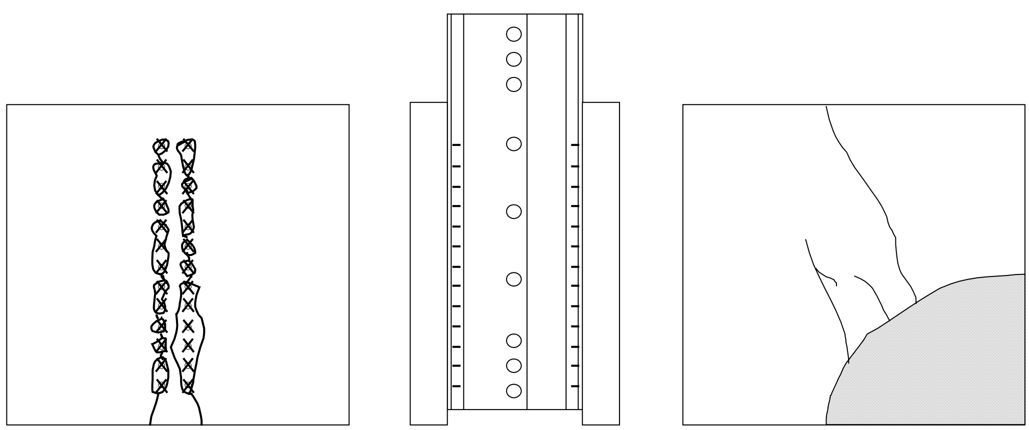
**Peak Shear Load:** 313.56 kips

**Peak Shear Load Per Screw:** 6.03 kips

**Slip at Peak Shear Load:**

| | |
|---|---|
| SC1: 0.2008 in. | SC5: 0.1996 in. |
| SC2: 0.1721 in. | SC6: 0.1398 in. |
| SC3: 0.1923 in. | SC7: 0.1947 in. |
| SC4: 0.2313 in. | SC8: 0.1306 in. |

### DAMAGE



interior, Slab A exterior, Slab B

### COMMENTS

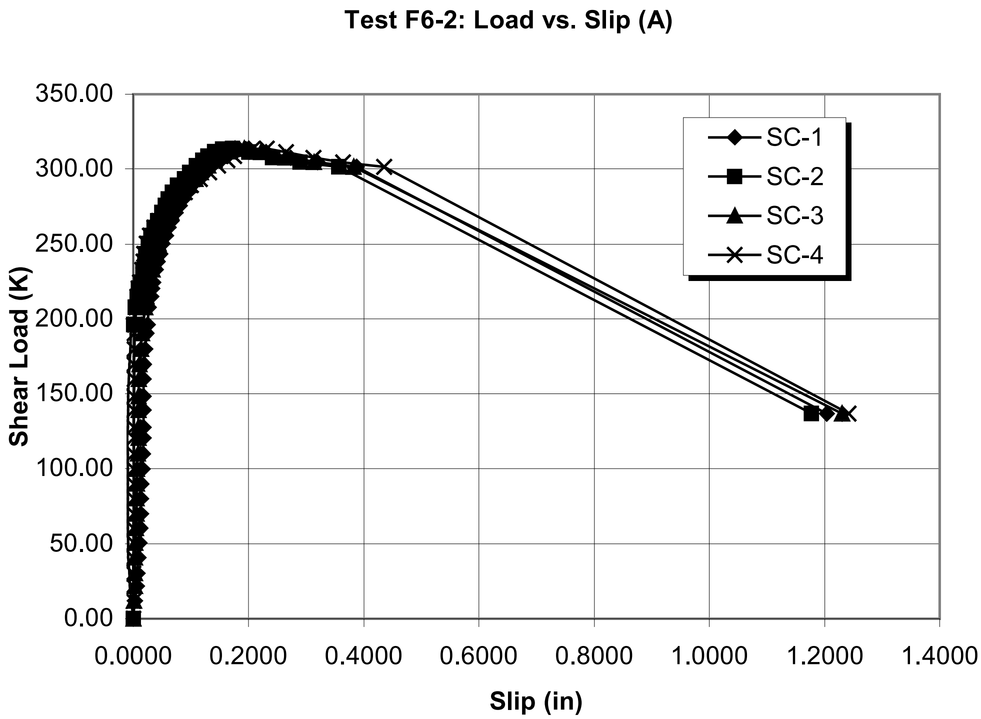
Failure Mode: Screw shear

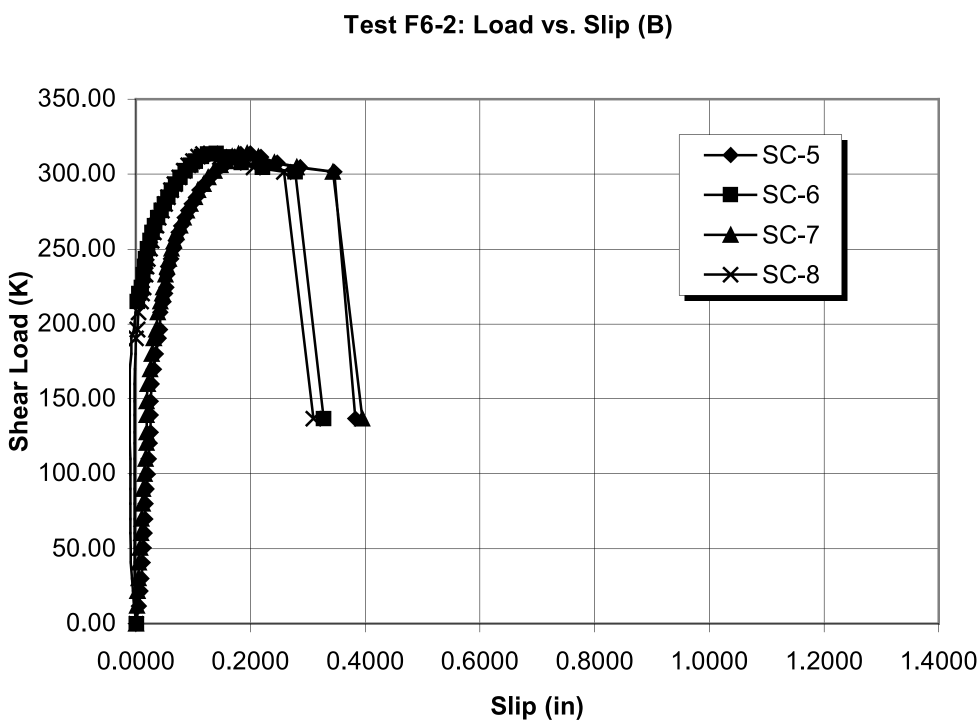
Screw Rotation ≈ 0° - 10°

Significant concrete damage

X = Screw sheared off

- Spalled concrete


Test F6-2: Load vs. Slip (A)
Shear Load (K)
Slip (in)
SC-1
SC-2
SC-3
SC-4


Test F6-2: Load vs. Slip (B)
Shear Load (K)
Slip (in)
SC-5
SC-6
SC-7
SC-8

**TEST F6-2 DATA**

| Shear Load (kips) | Normal Load (kips) | Slip (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC-1 | SC-2 | SC-3 | SC-4 | SC-5 | SC-6 | SC-7 | SC-8 |
| 0.00 | 0.00 | -0.0006 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 |
| 11.93 | 0.99 | 0.0031 | -0.0037 | 0.0012 | 0.0000 | 0.0049 | -0.0037 | 0.0018 | -0.0006 |
| 21.73 | 2.11 | 0.0061 | -0.0061 | 0.0024 | 0.0000 | 0.0079 | -0.0055 | 0.0031 | -0.0012 |
| 30.28 | 3.03 | 0.0073 | -0.0073 | 0.0031 | 0.0000 | 0.0098 | -0.0067 | 0.0043 | -0.0024 |
| 40.83 | 4.18 | 0.0092 | -0.0092 | 0.0031 | 0.0000 | 0.0116 | -0.0085 | 0.0055 | -0.0031 |
| 50.50 | 5.23 | 0.0110 | -0.0092 | 0.0037 | 0.0006 | 0.0134 | -0.0092 | 0.0073 | -0.0031 |
| 60.43 | 6.11 | 0.0122 | -0.0098 | 0.0043 | 0.0000 | 0.0146 | -0.0098 | 0.0085 | -0.0031 |
| 69.97 | 7.37 | 0.0128 | -0.0098 | 0.0049 | 0.0006 | 0.0159 | -0.0098 | 0.0098 | -0.0031 |
| 80.03 | 8.26 | 0.0134 | -0.0098 | 0.0055 | 0.0006 | 0.0171 | -0.0098 | 0.0116 | -0.0031 |
| 89.95 | 9.21 | 0.0140 | -0.0098 | 0.0061 | 0.0006 | 0.0189 | -0.0098 | 0.0128 | -0.0031 |
| 99.87 | 10.43 | 0.0159 | -0.0098 | 0.0061 | 0.0006 | 0.0208 | -0.0098 | 0.0146 | -0.0031 |
| 109.92 | 11.18 | 0.0171 | -0.0098 | 0.0079 | 0.0006 | 0.0220 | -0.0098 | 0.0165 | -0.0031 |
| 120.47 | 12.23 | 0.0177 | -0.0104 | 0.0092 | 0.0006 | 0.0238 | -0.0110 | 0.0183 | -0.0031 |
| 127.63 | 13.16 | 0.0177 | -0.0098 | 0.0092 | 0.0012 | 0.0256 | -0.0110 | 0.0183 | -0.0024 |
| 139.19 | 14.16 | 0.0177 | -0.0092 | 0.0092 | 0.0012 | 0.0256 | -0.0110 | 0.0189 | -0.0024 |
| 148.36 | 15.41 | 0.0177 | -0.0085 | 0.0092 | 0.0012 | 0.0256 | -0.0110 | 0.0189 | -0.0024 |
| 159.92 | 16.12 | 0.0177 | -0.0079 | 0.0098 | 0.0018 | 0.0275 | -0.0110 | 0.0208 | -0.0024 |
| 169.84 | 17.36 | 0.0183 | -0.0073 | 0.0110 | 0.0012 | 0.0311 | -0.0110 | 0.0244 | -0.0018 |
| 179.77 | 18.36 | 0.0201 | -0.0055 | 0.0128 | 0.0018 | 0.0348 | -0.0079 | 0.0275 | -0.0012 |
| 190.32 | 19.20 | 0.0226 | -0.0043 | 0.0153 | 0.0018 | 0.0397 | -0.0079 | 0.0311 | 0.0000 |
| 196.35 | 20.37 | 0.0244 | 0.0012 | 0.0171 | 0.0031 | 0.0415 | -0.0037 | 0.0354 | 0.0024 |
| 207.78 | 20.99 | 0.0269 | 0.0037 | 0.0201 | 0.0049 | 0.0427 | -0.0012 | 0.0385 | 0.0043 |
| 214.94 | 21.68 | 0.0305 | 0.0067 | 0.0226 | 0.0073 | 0.0482 | 0.0024 | 0.0427 | 0.0085 |
| 220.47 | 22.46 | 0.0330 | 0.0092 | 0.0244 | 0.0085 | 0.0507 | 0.0055 | 0.0458 | 0.0104 |
| 224.24 | 22.94 | 0.0348 | 0.0128 | 0.0287 | 0.0116 | 0.0531 | 0.0098 | 0.0482 | 0.0134 |
| 232.91 | 23.42 | 0.0391 | 0.0171 | 0.0336 | 0.0153 | 0.0543 | 0.0122 | 0.0513 | 0.0165 |
| 238.19 | 24.04 | 0.0421 | 0.0201 | 0.0360 | 0.0177 | 0.0562 | 0.0153 | 0.0537 | 0.0183 |
| 243.46 | 24.92 | 0.0464 | 0.0220 | 0.0403 | 0.0189 | 0.0610 | 0.0165 | 0.0580 | 0.0208 |
| 250.25 | 25.37 | 0.0507 | 0.0262 | 0.0439 | 0.0226 | 0.0653 | 0.0208 | 0.0623 | 0.0244 |
| 255.65 | 25.88 | 0.0562 | 0.0311 | 0.0488 | 0.0287 | 0.0696 | 0.0244 | 0.0665 | 0.0275 |
| 261.18 | 26.30 | 0.0610 | 0.0366 | 0.0543 | 0.0360 | 0.0745 | 0.0281 | 0.0714 | 0.0311 |
| 265.57 | 26.73 | 0.0659 | 0.0421 | 0.0592 | 0.0439 | 0.0787 | 0.0330 | 0.0769 | 0.0354 |
| 270.97 | 27.36 | 0.0732 | 0.0494 | 0.0659 | 0.0555 | 0.0854 | 0.0385 | 0.0830 | 0.0403 |
| 275.75 | 28.02 | 0.0800 | 0.0555 | 0.0720 | 0.0665 | 0.0916 | 0.0439 | 0.0891 | 0.0452 |
| 280.15 | 28.41 | 0.0867 | 0.0610 | 0.0787 | 0.0763 | 0.0977 | 0.0500 | 0.0952 | 0.0507 |
| 284.54 | 28.86 | 0.0946 | 0.0684 | 0.0861 | 0.0891 | 0.1050 | 0.0562 | 0.1025 | 0.0562 |
| 289.19 | 29.49 | 0.1025 | 0.0769 | 0.0952 | 0.1001 | 0.1111 | 0.0623 | 0.1086 | 0.0616 |
| 293.21 | 29.86 | 0.1147 | 0.0891 | 0.1074 | 0.1154 | 0.1196 | 0.0696 | 0.1178 | 0.0677 |
| 297.73 | 30.43 | 0.1263 | 0.0983 | 0.1178 | 0.1318 | 0.1294 | 0.0775 | 0.1263 | 0.0751 |
| 302.26 | 30.76 | 0.1373 | 0.1099 | 0.1300 | 0.1477 | 0.1404 | 0.0861 | 0.1367 | 0.0830 |
| 305.77 | 31.24 | 0.1489 | 0.1215 | 0.1410 | 0.1636 | 0.1508 | 0.0958 | 0.1471 | 0.0916 |
| 308.54 | 31.66 | 0.1587 | 0.1300 | 0.1501 | 0.1746 | 0.1599 | 0.1038 | 0.1569 | 0.0995 |
| 311.55 | 31.95 | 0.1709 | 0.1416 | 0.1617 | 0.1898 | 0.1721 | 0.1147 | 0.1678 | 0.1080 |
| 313.44 | 32.28 | 0.1837 | 0.1550 | 0.1764 | 0.2069 | 0.1831 | 0.1251 | 0.1794 | 0.1172 |
| 313.56 | 32.68 | 0.2008 | 0.1721 | 0.1923 | 0.2313 | 0.1996 | 0.1398 | 0.1947 | 0.1306 |
| 311.30 | 33.16 | 0.2301 | 0.2002 | 0.2216 | 0.2649 | 0.2179 | 0.1569 | 0.2136 | 0.1465 |
| 307.66 | 33.81 | 0.2728 | 0.2423 | 0.2643 | 0.3131 | 0.2466 | 0.1837 | 0.2411 | 0.1709 |
| 304.39 | 32.18 | 0.3198 | 0.2893 | 0.3137 | 0.3638 | 0.2869 | 0.2209 | 0.2802 | 0.2051 |
| 301.38 | 33.14 | 0.3876 | 0.3564 | 0.3821 | 0.4358 | 0.3461 | 0.2777 | 0.3430 | 0.2582 |
| 136.68 | 33.21 | 1.2042 | 1.1773 | 1.2304 | 1.2420 | 0.3821 | 0.3278 | 0.3949 | 0.3101 |

# VITA

James E. Webler was born on July 19, 1975 in Taipei, Taiwan. Following some moving around, he was raised in the town of Winfield, MD where he graduated from South Carroll Senior High School in 1993.

In the fall of 1993, James began his undergraduate studies at West Virginia University. In 1997, he received the degree of Bachelor of Science in civil engineering, graduating magna cum laude. After attaining his Bachelor's degree, James began his graduate studies at Virginia Polytechnic Institute and State University specializing in structural engineering.

In September 1999, James will begin employment as a structural design engineer with KCI Technologies in Hunt Valley, MD.