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Blacksburg, VA 24061

Structural Engineering

Behavior and Modeling of A Reinforced Composite Slab As Part of Partially Restrained Composite Beam-Girder Connection

by
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Research Assistant

W. Samuel Easterling, Ph.D., P.E.
Principal Investigator

Submitted to
The American Institute of Steel Construction
The American Iron and Steel Institute
The National Science Foundation
(MSS-9222064)
Innovative Steel Research For Construction Program

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Report No. CE/VPI-ST 96/13

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Research Report

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α_1 = Correction factor for reinforcing bond

α_2 = Correction factor for loading time period

A_r = Area of reinforcing steel

A_{sc} = Area of the shear stud based on the nominal shear stud diameter

C_1, C_2, C_3 = Constants for parabolic representation of Load-Strain behavior of slab

COV = Coefficient of variation

δ = Deformation

Δ = Deformation

$\delta_{0.5Qsol}$ = Stud deformation at a load of 0.5 Qsol

Δ_1 = Reference deformation for Richard Equation

DCDT = Displacement potentiometer

$\Delta\delta$ = Change in deformation

$\delta_{failure}$ = Stud deformation at failure

Δ_{last} = Deformation at last key point in multi-linear load-deformation behavior

ΔR = Change in resistance

d_{sh} = Diameter of the shear stud shank

E = Modulus of elasticity

ε = Strain

ε_1, ε_2 = Strain values at key points for Load-Strain behavior of slab

E_c = Modulus of elasticity of concrete

ε_{cr} = Concrete tensile cracking strain

f'_c = Compressive strength of the concrete

f_c = Concrete stress

f_{cr} = Tensile cracking stress of concrete

F_u = Ultimate tensile stress

F_{usc} = Shear stud steel tensile strength

F_y = Yield stress

h_r = Height of the deck rib

H_s = Shear stud height after welding

K = Elastic stiffness coefficient for Richard Equation

K_1 = Stiffness coefficient for Richard Equation

K_1, K_2 = First and second slope associated with key points for Load-Strain behavior of slab

K_i = Initial stiffness

K_p = Plastic stiffness coefficient for Richard Equation

K_{pr} = Plastic stiffness of reinforced slab

K_{ps} = Plastic stiffness of shear studs

L_1, L_2, L_3 = Lengths of reinforcing bar in regions 1, 2, and 3

L_{eff} = Effective length of reinforced concrete slab for deformation calculations

n = Curvature parameter for Richard Equation

N_r = Number of shear studs per deck rib

N_{studs} = Number of shear studs

P_1, P_2, P_3 = Loads in regions 1, 2, and 3, of a reinforcing bar

POT = Displacement potentiometer

Q = Shear stud load

Q_{base} = Basic shear stud strength for a weak position stud

Q_{sol} = The strength for a single shear stud

R = Resistance, Load

R_0 = Reference load for Richard Equation

R_1 = Reference load for Richard Equation

R_1, R_2, R_3, R_4 = Load values at key points for Load-Strain behavior of slab

R_{last} = Resistance at last key point in multi-linear load-deformation behavior

R_{oa} = Intercept of K_2 with ordinate axis

SRF = Stud reduction factor used to account for metal decking

ST = Displacement potentiometer

w_c = Unit weight of concrete

w_r = Width of the deck rib

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ABSTRACT

To determine the moment-rotation behavior of a composite partially-restrained connection the load-deformation behavior of a reinforced composite slab is required. This report develops a component model that can be used to predict this load-deformation behavior. The model is validated by comparing it to the results of four full scale experimental tests that were specially designed to isolate the load-deformation behavior of the composite slab. Behavior models for reinforcing steel, concrete tension stiffening, and shear studs are presented and / or developed to provide the necessary tools to predict the composite slab load-deformation behavior.

1. Introduction

As part of a larger research project dealing with partially-restrained composite beam-girder connections the load-deformation behavior of reinforced composite slabs is needed. The reinforced composite slab is one of two major components that make up a composite connection. The other component is the steel connection. The behavior of the steel connection is developed in a separate report.

1.1 General

The load-deformation behavior of the reinforced composite slab is required to model the moment-rotation behavior of a composite connection. The primary function of the slab with respect to the moment-rotation behavior of the connection is to provide a horizontal force at the top of the connection. This force is one part of a force couple that develops moment resistance in the connection. The opposing part of the force couple is developed by components of the steel connection. This basic relationship is shown schematically in Figure 1.

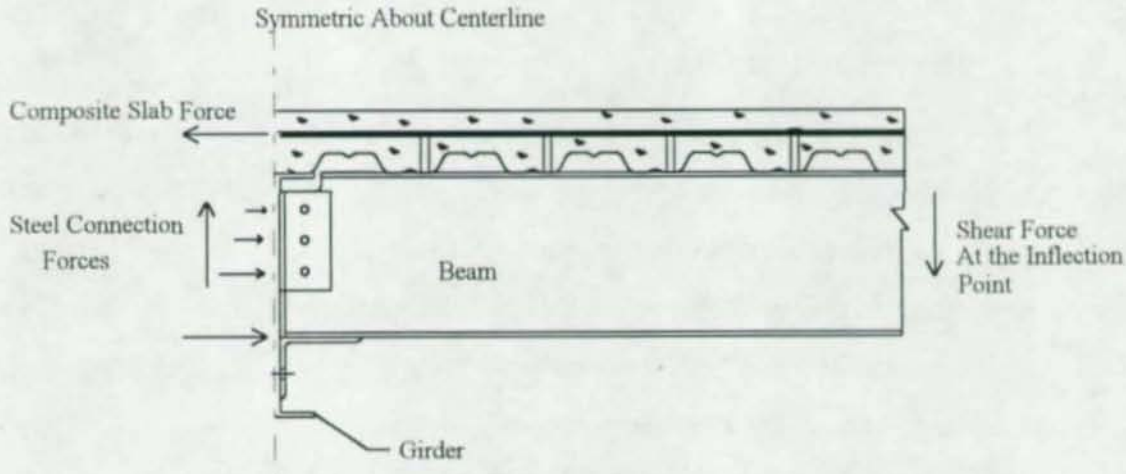

Figure 1 Fundamentals Of A Composite Beam-Girder Connection

As the beam is loaded, rotation at the end of the beam is restrained by the force couple developed between the composite slab and the steel connection. However, for typical connection details rotation is not completely eliminated. For the composite slab and the steel connection to develop forces they must undergo deformations. These deformations result in connection rotation. To properly design the attached beam the moment-rotation behavior of the connection must be understood.

The basic premise is that if we know the relationship between load and deformation for the composite slab and the components of the steel connection then the moment-rotation behavior for the connection can be modeled as an assembly of the individual components.

There are three primary load carrying components in the reinforced composite slab: reinforcing steel, concrete, and shear studs. There is typically also welded wire mesh and profiled steel decking but neither of these are considered to have significant load carrying capacity. It is assumed that if the behavior of each of the primary load carrying components in the composite slab is understood then the composite slab overall load-deformation behavior can be determined.

1.2 Review of Literature

This report focuses on the development of a method for modeling the horizontal load-deformation behavior of the reinforced composite slab. The writers are not aware of any methods for doing this that are currently in the literature. However, certain important items that are believed to control the load-deformation behavior of the composite slab have been considered by other researchers.

1. The amount and stress-strain behavior of the reinforcing steel
2. Tension stiffening behavior of the concrete
3. Number, distribution, and load slip behavior of shear studs
4. Horizontal shear lag effects

5. Longitudinal shear failure in the composite slab

Of these five the first three items are believed to be the most important and are discussed and developed later in this report. For convenience research dealing with these items will be presented at that time. The last two items are discussed below.

Shear lag is referring to the difference in load carried by reinforcing steel close to the connection compared to that carried by reinforcing steel away from connection. The reduction, or lag, in the reinforcing steel load as it gets farther away from the connection is caused by deformations in the slab. These deformations are mainly shearing deformations thus the term shear lag.

Tests on composite beam-to-girder connections have shown that there is a varying degree of shear lag present in composite connections. Research conducted at Virginia Tech (Rex and Easterling, 1995) showed that when a reasonable amount of reinforcing steel is used shear lag is not a significant factor within a 60-in. effective width. In addition, most shear lag problems can be avoided if the reinforcing steel is spaced tightly around the connection. Consequently, shear lag is not a significant concern at this time.

Longitudinal shear failure of the slab occurs when the concrete on both sides of the beam fails thus eliminating any load transfer from the shear studs into the rest of the composite slab. Longitudinal shear failure occurred in composite connection tests reported by Bernuzzi et. al. (1991). The specimens that failed all had the composite deck running parallel to the beam instead of perpendicular as is standard for filler beams. Research by Johnson and Huang (1994) showed that when the steel deck is orientated perpendicular to the composite beam it will usually provide sufficient transverse reinforcing to prevent longitudinal shear failure of the slab. In fact the steel deck was found to be more effective than transverse reinforcing in the prevention of longitudinal shear failure. Because the composite deck for beam-girder connections is almost always perpendicular to the beam, longitudinal shear failure is not a significant concern at this time.

2. Focus And Objective

The objective of this investigation is to develop a method of modeling the load-deformation behavior of a reinforced composite slab. This behavior will later be used in finite element analysis and simplified design models for the composite beam-girder connection.

An experimental investigation of the load-deformation behavior of composite slabs was conducted by the writer. Six composite slabs were tested in a manner that simulated boundary conditions associated with a composite connection. The purpose of these tests was to isolate and measure the load-deformation behavior of the composite slab without the influence of the steel connection.

There are three primary load carrying components in the reinforced composite slab: reinforcing steel, concrete, and shear studs. Behavior models are presented and/or developed for each of these components. These behavior models are then used to develop a method to predict the load-deformation behavior of the composite slab. The method developed basically assumes that the behavior of the composite slab is the sum of the behavior of the parts of the composite slab and has been termed a component model.

Finally, the component model is contrasted and compared with the experimental results. The component model is summarized and conclusions and recommendations are made with regard to the behavior of the composite slab.

3. Composite Slab Experimental Investigation

An experimental investigation was conducted to provide test data for development and verification of a load-deformation behavior model of composite slabs. The goal of the experimental investigation was to isolate and measure the load-deformation behavior of six reinforced composite slabs.

3.1 Test Specimens

There were six composite slab test specimens. Each specimen consisted of a composite slab attached to two W8x18 wide flange sections. These wide flange sections are referred to as the test beams. The general details of the specimen are shown schematically in Figure 2.

The concrete was normal weight with a measured compressive strength of 4.4 ksi. All specimens were cast from the same batch on the same day. The specimens were covered and moist cured for the first seven days and were then uncovered. Specimens were tested after 28 days of curing. Welded wire mesh (WWF 6x6 - W1.4 x W1.4) and #4 Grade 60 reinforcing steel was used to reinforce the slab.

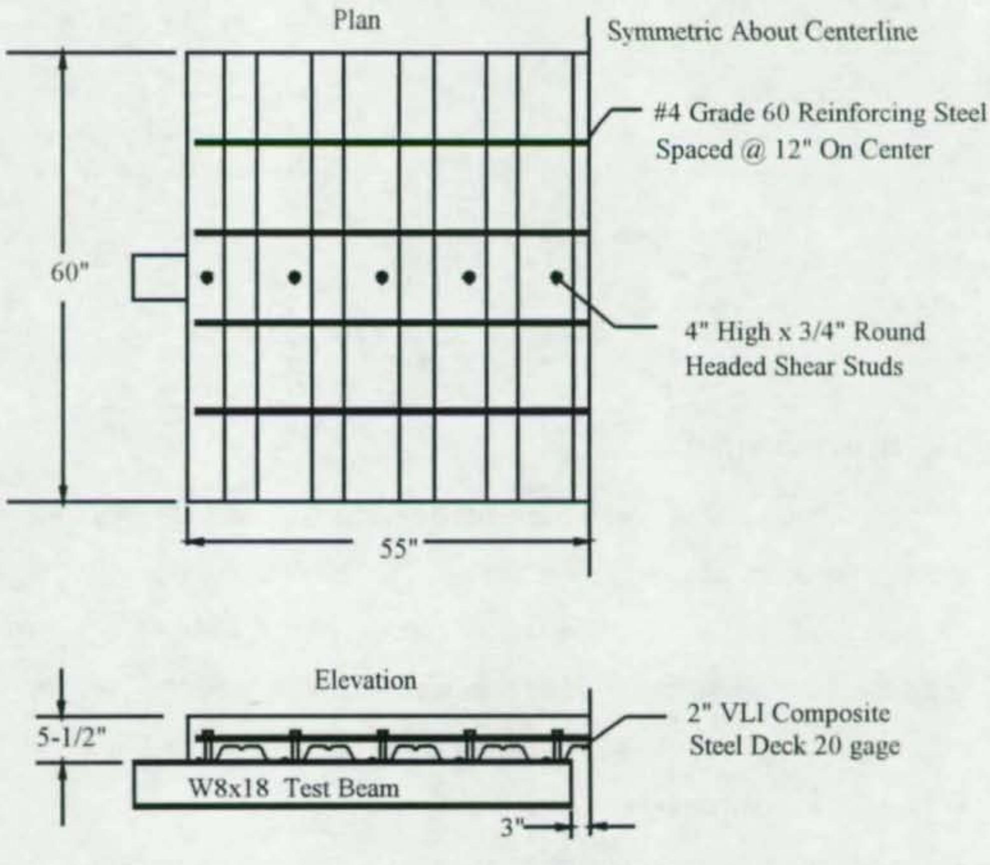

Figure 2 Test Specimens

The only variable in the composite slab test specimens was the number and location of shear studs. The shear stud positions are shown in Figure 3.

- Slab #1 5 studs in positions A, B, C, E, G
- Slab #2 5 studs in positions A, B, C, D, E
- Slab #3 4 studs in positions B, C, E, G
- Slab #4 4 studs in positions A, B, C, E
- Slab #5 3 studs in positions C, E, G
- Slab #6 3 studs in positions B, C, E

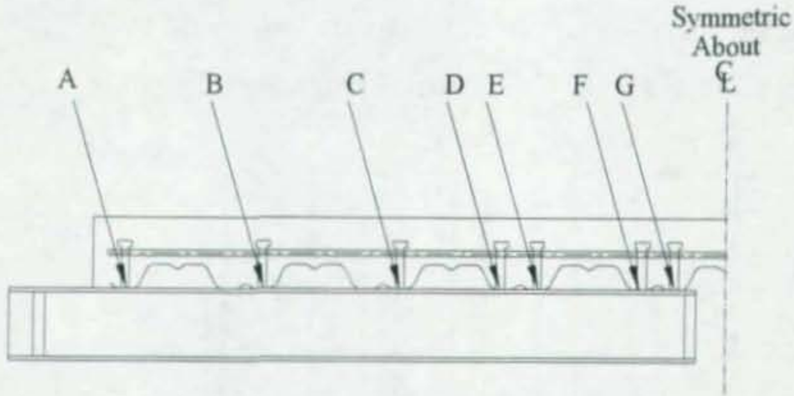

Figure 3 Shear Stud Positions

3.2 Instrumentation

Composite slab tests of this nature had never been done before. Consequently, some of the instrumentation varied from test to test in an attempt to improve the reliability of the measurements. The instrumentation used for Slab #1 is shown in Figure 4. Instrumentation details for each test specimen are presented in Appendix B. The following acronyms are used in Figure 4 and in Appendix B:

- POT, linear potentiometer
- DCDT, rotary potentiometer

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- ST, rotary potentiometer

All of these instruments are used to electronically measure displacement. The acronyms given above have been chosen based on how they are wired to a PC-based data acquisition system which was used to collect and record data. They are not (in general) reflective of the type of instrument and have been adopted merely for clarity and consistency between. These instruments were calibrated prior to being used and in general had an accuracy of +/- 0.002-in.

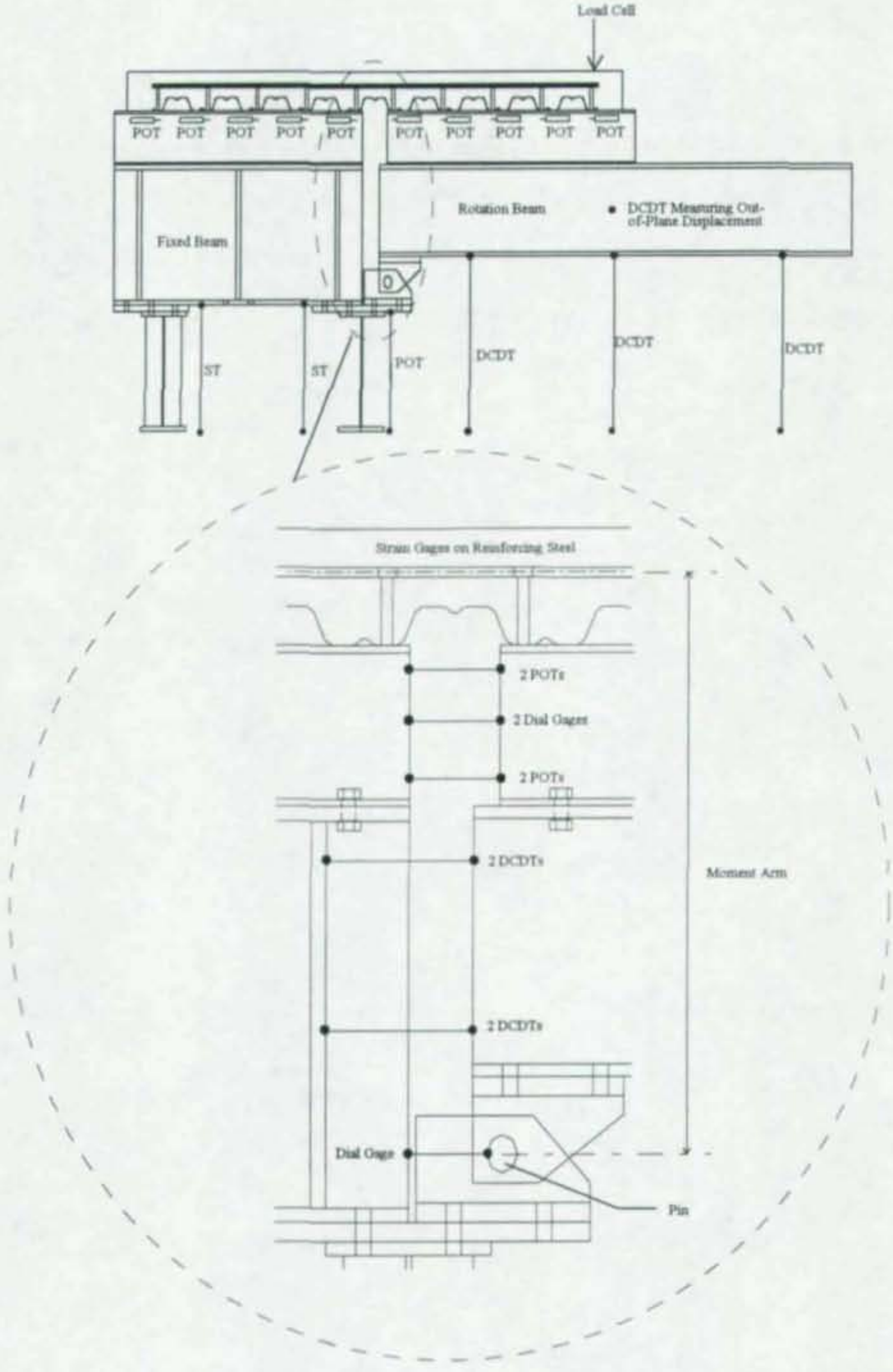

Figure 4 Test Instrumentation For Slab #1

3.2.1 Load Vs. Displacement Measurements

The primary goal of the instrumentation was to determine the load-displacement behavior for the test specimen. The hydraulic ram load was measured with a 500 kip capacity load cell. The ram load was then converted into a horizontal load in the slab by summing moments about the rotation pin.

Two measurements were needed to determine the deformation in the slab. First, the relative rotation between the fixed side of the test setup and the rotation side of the test setup had to be measured. Second, the horizontal separation of the test beams had to be measured.

DCDTs, STs, and POTs were attached to the underside of the fixed and rotation frame beams. This provided one measure of relative rotation. In addition, DCDTs were attached directly between the fixed and rotation beams providing another measure of rotation. Finally, POTS and dial gages were attached between the test beams. This provided a third measure of relative rotation as well as a measure of the horizontal separation of the test beams.

3.2.2 Reinforcing Steel Instrumentation

In an attempt to measure the load in the reinforcing steel directly, strain gages were attached at the center of each reinforcing bar. Two gages were placed on opposite sides of the bar. This combination of gages ideally eliminates bending strains so that the axial strain can be determined.

The reinforcing bars were prepared for the gages by removing the lugs in a three-in. area around the intended gage location. The gages were then installed in a normal fashion. To protect the gages from the concrete they were encased in multiple protective coatings; 1) polyurethane, 2) Teflon, 3) FB butyl rubber, 4) FN neoprene rubber, 5) aluminum tape, 6) nitrile rubber. The wires for the gages were routed through small holes in the deck near the gages. Just prior to concrete placement, the outside cover of the gages was coated in ball bearing grease to ensure the concrete did not attach itself to the outer gage covering.

Once the gages were attached and the protective coatings were in place, each bar was placed in an universal testing machine for calibration. Calibrating each reinforcing bar is believed to be the best way of determining reasonable values of the forces in each bar. Strain readings could not be directly related to forces in the bar without calibration as a result of the varying area of the bar and uncertainty of the actual alignment of the gage with respect to the longitudinal axis of the bar.

3.2.3 Other Instrumentation

Linear potentiometers (POT) were used to measure the slip between the composite slab and the test beams. The main body of the POT was attached to the top of the test beam. The plunger of the POT was then attached to a nail that had been driven into the composite slab through a small hole in the steel deck. A POT was located at every deck trough where there was a shear stud located.

3.3 General Test Setup And Testing Frames

Like the instrumentation, the test setup was modified as needed to correct problems encountered while testing. The final details of the test setup are given in Figure 5.

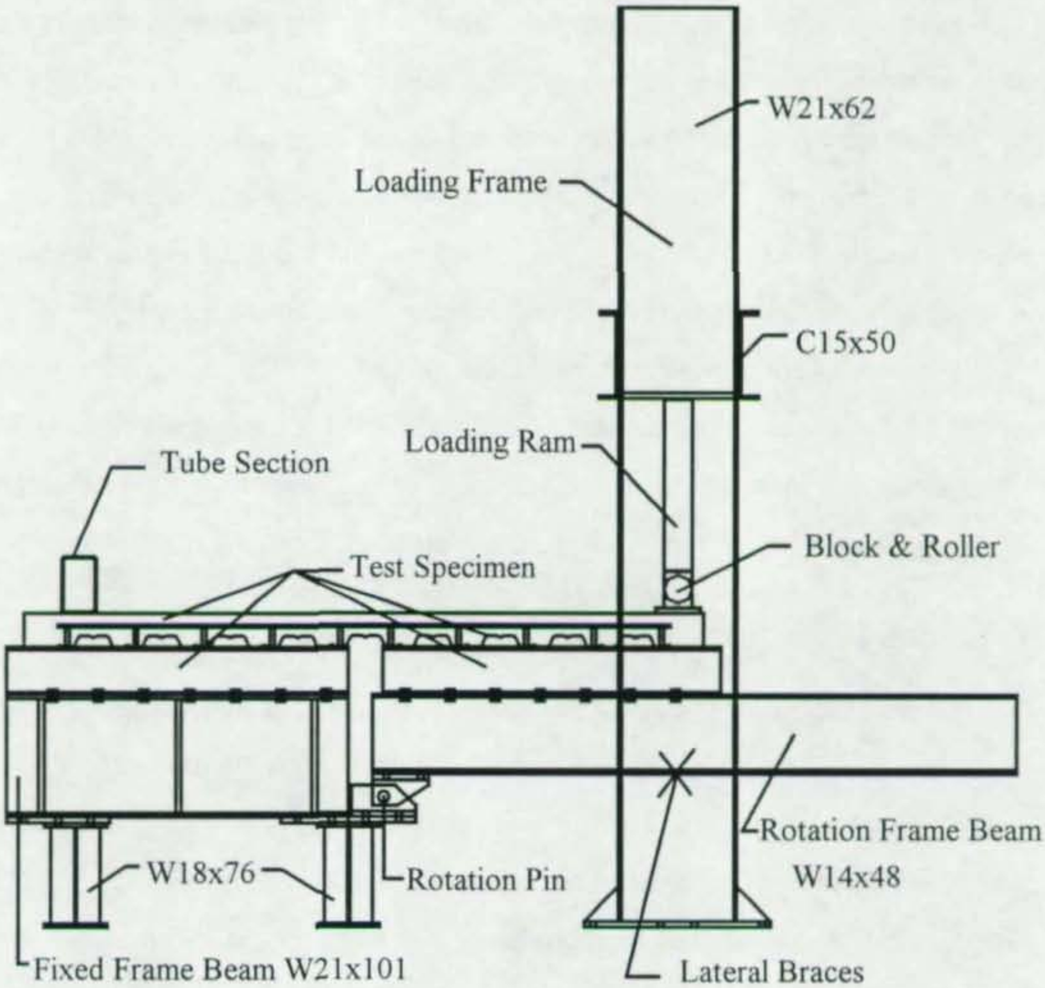

Figure 5 Test Setup

The test specimen beams were attached to the frame beams (rotation and fixed) with 28 ¾-in. diameter A325 bolts, 14 on each side. A 100 kip capacity hydraulic ram powered by an electric motor was used to load the test specimen. The ram pushed against the top of composite slab through a block and roller that rested against a 38-in. long, 8-in. wide, 1-in. thick plate.

The rotation beam was laterally braced with special lateral brace mechanisms that allow unrestrained vertical movement but prevent any lateral movement. The whole testing frame was attached to the reaction floor beams.

Slab #5 was the first of the six slabs tested. This test had the loading ram pushing against the top of the rotation beam rather than the top of the composite slab. In addition, there was no tube section across the fixed end of the composite slab. Slab #6 was the second of the six slabs tested, had the loading ram pushing against the top of the composite slab but did not have the tube section across the fixed end of the composite slab. Both of these test setups resulted in premature failure of the specimen.

The modifications made to avoid the premature failures included loading the specimen on top of the composite slab and adding a tube section at the fixed end to hold this part of the specimen down. The tube section rested against the top of the composite slab and was held down by a set of chains that were attached to the reaction floor.

3.4 Testing Procedure

The rotation beam had to be supported at its free end when a test specimen was not attached. This support was left in place until the start of the test. Typically all instrumentation would be zeroed and then the temporary support would be removed. The weight of the rotation beam and half the test specimen was carried by the composite slab at this stage. This corresponds to approximately 2.4 kips of axial load in the composite slab. The specimen would then be pre-loaded and unloaded. Occasionally after unloading some of the instrumentation would be adjusted and re-zeroed. The test loading would then start. The loading was initially controlled by load increments and later by displacement increments. Slabs #3 and #6 were unloaded after the test loading had started because of problems with instrumentation or with the test setup. The test was ended when the test was deemed to have undergone excessive deformations or when there was a shear stud failure.

4. Composite Slab Experimental Results

The following sections summarize some of the more important test results. Complete data packs with all test results are included in Appendix B.

4.1 Data Packs

Complete data packs are found in Appendix B. A typical data pack includes two figures that show the location and number of all instrumentation used for each test. The figures are followed by a table that describes each piece of instrumentation. Tables of raw data and test comments are then presented. These are followed by an equation sheet that shows how all the data calculations were made. This is followed by tables of calculated data and then finally plots of slab load vs. slab deformation and slab load vs. shear stud slip.

4.2 Test Setup Problems

As a result of test setup problems Slabs #5 and #6 failed prematurely. Slab #5 was the first test of the series. The load ram was placed beyond the end of the composite slab and pushed against the rotation frame beam directly. Consequently, nothing was forcing the composite slab to remain in contact with the test beams. As loads increased the composite slab started to separate from the test beam at the rotating end of the specimen and the shear studs were unable to develop their full horizontal shear capacity.

To correct this problem the load ram was placed on the end of the composite slab for Slab #6. As this test proceeded, it became clear that the fixed end of the specimen was separating vertically from the test beam. The test was unloaded and a tube section was placed over the fixed end of the composite slab. The tube was then secured to the reaction floor. This prevented the slab from separating vertically from the test beam. Unfortunately, this fix was implemented after the stud strength had been severely compromised by the vertical separation that occurred prior to adding the tube section.

Because vertical separation of the slab from the beam is not consistent with actual service conditions, Slabs #5 and #6 have been removed from further consideration in the test results and analysis.

4.3 Slab Load Vs. Slab Deformation

The load in the composite slab was determined by summing moments at the locations of the rotation pin. Both the dead load of the rotation end of the test setup and the ram load were multiplied by their respective horizontal distances to the rotation pin. This moment was then divided by the distance from the centerline of the reinforcing to the rotation pin. This results in the horizontal axial load in the slab. The exact details on how the slab load was calculated for each test are included in Appendix B.

The slab deformation was defined as the horizontal deformation at the level of the reinforcing steel. Various methods were used to determine the slab deformation. The method used depended on the instrumentation that was used for the test. In general, two quantities had to be determined to calculate the slab deformation. The first of these is the relative rotation between the fixed and the rotation side of the specimen. The second is the horizontal separation of the test beams. The horizontal deformation at the level of the reinforcing was then determined by similar triangles and small angle theory. The exact details on how the slab deformation was calculated for each test are included in Appendix B.

The slab load vs. slab deformation measurements for Slabs #1 through #4 are plotted in Figure 6. Load vs. deformation plots for the individual tests can be found in Appendix B.

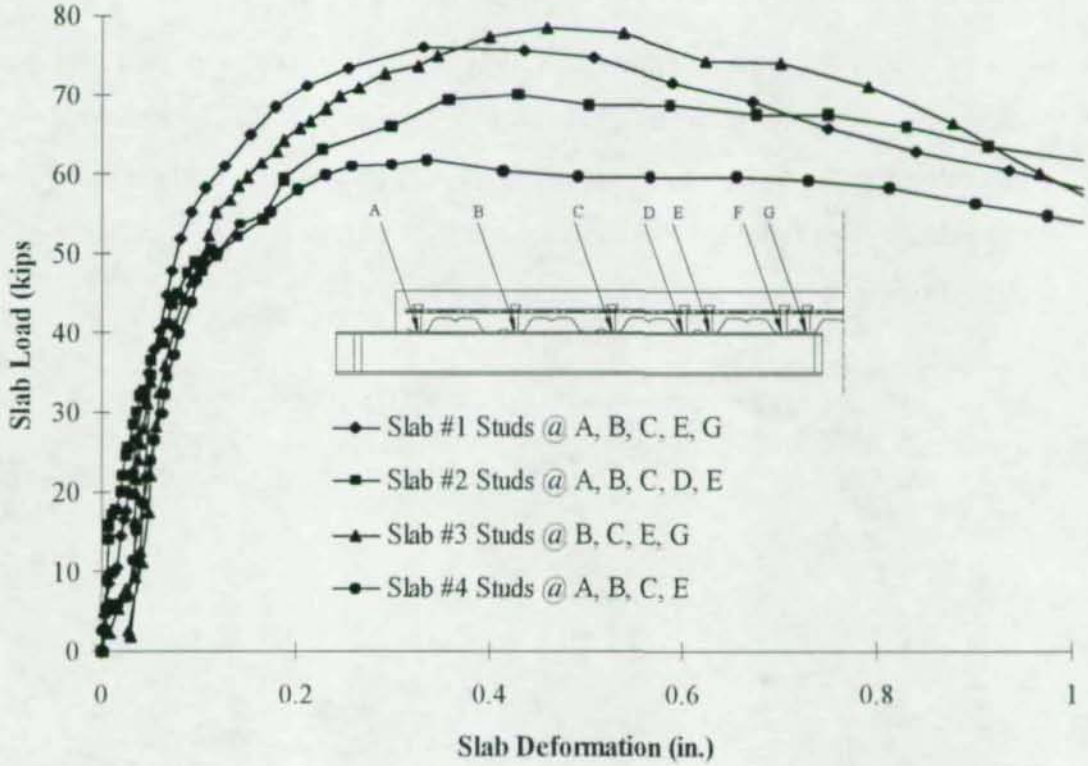

Figure 6 Test Load Vs. Deformation Behavior

The maximum test loads for Slabs #1 through #4 were 76.0, 70.0, 78.3, and 61.8 kips respectively. The reinforcing steel yielded in each test specimen; but, the maximum test load was limited by shear stud failure for all tests.

Two conclusions can be reached by considering these maximum loads and by reviewing Figure 6. First, by comparing Slab #1 to Slab #3 it is clear that the extra shear stud in position "A" in Slab #1 had little to no effect on the overall load-deformation behavior. This could also be concluded by comparing Slab #3 to Slab #4. Second, by comparing Slab #1 to Slab #2 it is clear that a shear stud in position "E" is not as effective as a shear stud in position "G".

4.4 Slab Load Vs. Shear Stud Slip

Slab load was determined as described previously and stud slip was directly measured with potentiometers as detailed in Section 3.2.3. The slab load vs. stud slip measurements for Slab #3 is shown in Figure 7. Although not identical, most load vs. stud slip relationships followed the same basic trends seen in Figure 7. Load vs. slip plots for the individual tests can be found in Appendix B.

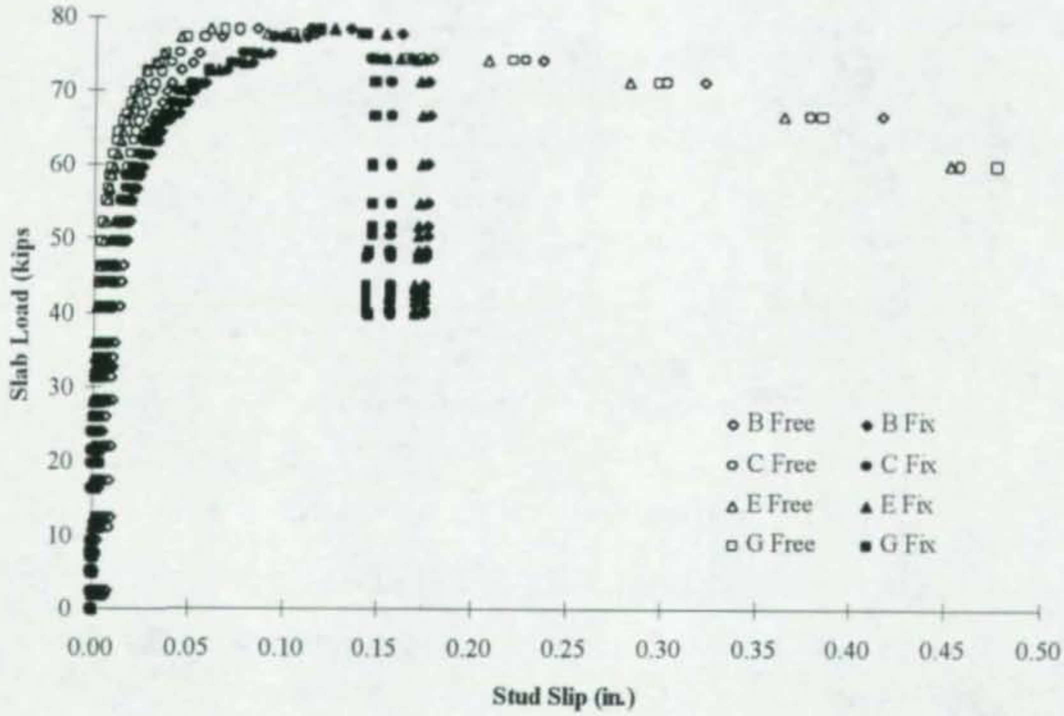

Figure 7 Slab Load Vs. Shear Stud Slip

The designations in Figure 7 refer to the stud position and which side of the test specimen the stud was on. For example "G Fix" means the stud was in location "G" on the fixed side of the test specimen.

The typical trend was for the studs on both sides of the specimen to deform fairly evenly. The stud response would start to soften at approximately 75% of the maximum

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load. The response was still fairly similar on each side of the specimen although in two cases it appeared that the side where the studs failed seemed to have a slightly stiffer response than the opposite side. After the maximum load was reached the studs on one side of the specimen would start to loose load carrying capacity and would incur large deformations (i.e. these studs failed). The opposite side maintained a constant level of deformation as the load decreased and deformation increased on the failure side.

The slab deformation measurements included deformations of both sides of the specimen. Before the maximum load was reached both sides of the specimen were deforming and the deformation measurements could be attributed to deformations on both sides. However, because of the typical behavior of one side failing and the other side not, deformation measurements taken after the maximum load was reached are mainly attributable to only one side of the specimen deforming. This observation is important for later analysis of the load-deformation behavior.

Because the load capacity of all the test specimens was limited by the load capacity of the shear studs it seems reasonable to wonder if the load-deformation behavior of the test specimen is also dominated by the shear stud load-slip behavior. Figure 8 shows the combined average stud slip compared to the measured slab deformations for Slab #3. The combined average stud slip is the sum of the two average stud slips for each side.

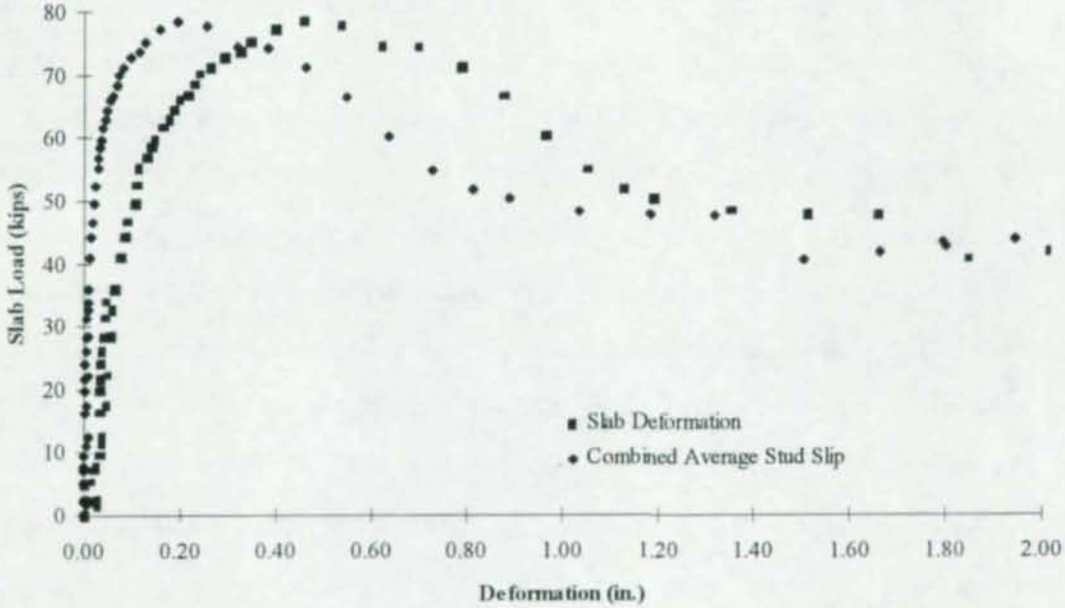

Figure 8 Total Stud Slip Vs. Slab Deformations For Slab #3

Review of Figure 8 shows two things. First the shape of the load-deformation behavior appears to be similar to shape of the load-slip behavior except the stud deformations lag behind the slab deformation. Second, it is clear that something aside from the shear studs is contributing to the overall slab deformation.

4.5 Slab Load Vs. Reinforcing Steel Load

Strain gages were attached to the reinforcing steel as discussed in Section 3.2.2. Using the average of the two gage readings and the calibration factor determined for each reinforcing bar the load in each bar was calculated. These loads were only calculated using strain readings taken before the reinforcing steel started to yield. The total load carried by the reinforcing steel was then calculated as the sum of the loads in each reinforcing bar. The total reinforcing load vs. the slab load is shown in Figure 9.

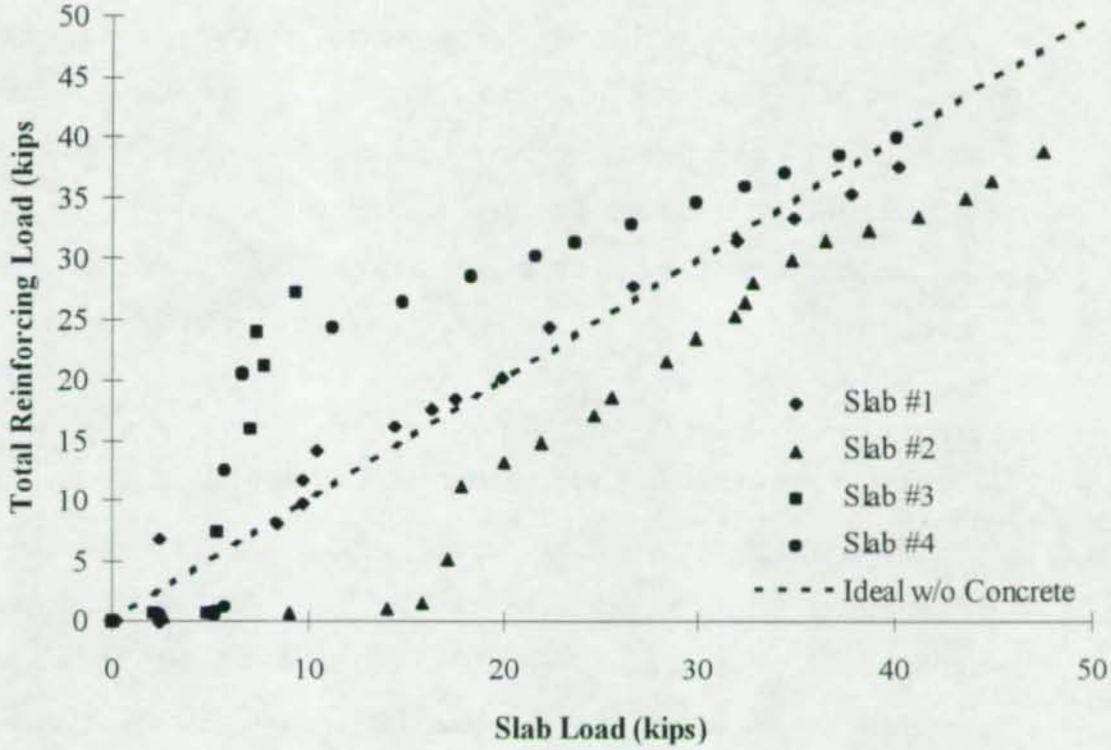

Figure 9 Measured Reinforcing Steel Load Vs. Slab Load

The dashed line in Figure 9 represents a one to one ratio between reinforcing load and slab load. Data points that lie on the dashed line are ideal reinforcing loads if the slab is cracked at the gage location (i.e. the slab load must equal the reinforcing steel load). Slab #1 seems to exhibit this behavior. However, if the slab is not cracked at the gage location then it is expected that the load in the reinforcing steel would be less than the total slab load because some of the load would be carried by the concrete. This is the case for data points that lie below the dashed line. The behavior of Slab #2 provides an excellent example of this. The load in the reinforcing steel is very low until the slab cracking starts to occur. Then the reinforcing steel load increases and slowly approaches the total slab load as concrete cracking progresses.

Points above the dashed line indicate the load in the reinforcing steel is higher than the load in the slab. This can occur when a specimen is unloaded and cracked concrete prevents the reinforcing steel from coming back to its initial state. However, if the specimen is being loaded then the only reason for calculated reinforcing loads greater than the slab load is simply inaccurate strain gage readings.

The only conclusion that can be drawn from Figure 9 is that attaching gages to reinforcing steel may or may not give you a good estimate of the actual load in the composite slab.

4.6 Typical Sequence of Composite Slab Cracking

The typical sequence of composite slab cracking was as follows. The first crack would occur very early if not right at the start of the test. This crack was typically at the center of the slab, perpendicular to reinforcing steel. Cracks parallel to and on each side of the initial crack would form soon after. These cracks result from a combination of tension and flexural stresses in the slab. Next, cracks running parallel to the line of the shear studs started to form. These types of cracks typically indicate the beginnings of longitudinal shear failure. The next cracks typically formed in the concrete under either the load ram or the tube section holding down the fixed end of the specimen. These cracks would widen and eventually the concrete in these areas would become almost completely separated from the rest of the slab. The cracks running parallel to the line of the shear studs would increase in size until the test was ended because of excessive stud deformations or a stud shear failure.

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5. Modeling Composite Slab Load-Deformation Behavior

The objective of this study is to develop a method of modeling the load-deformation behavior of a reinforced composite slab. To do this, behavior models for the three primary components of the composite slab must first be developed. Once the behavior of the reinforcing steel, concrete, and shear studs is understood then a method of modeling the composite slab load-deformation behavior can be developed. This composite slab model can then be compared to the composite slab test results for verification.

5.1 Behavior Models For Composite Slab Components

There are three primary components that determine the behavior of the reinforced composite slab: reinforcing steel, concrete, and shear studs. Methods for predicting the behavior of these three components are needed so that the behavior of the composite slab can be predicted. The component behavior for reinforcing steel, concrete, and shear studs is developed in the following three sections.

5.1.1 Reinforcing Steel

Previous research (Rex and Easterling, 1996(a)) developed a normalized stress-strain behavior for #4 Grade 60 reinforcing steel which is shown in Figure 10. This is the most common grade and size of reinforcing steel currently used in composite floor slabs.

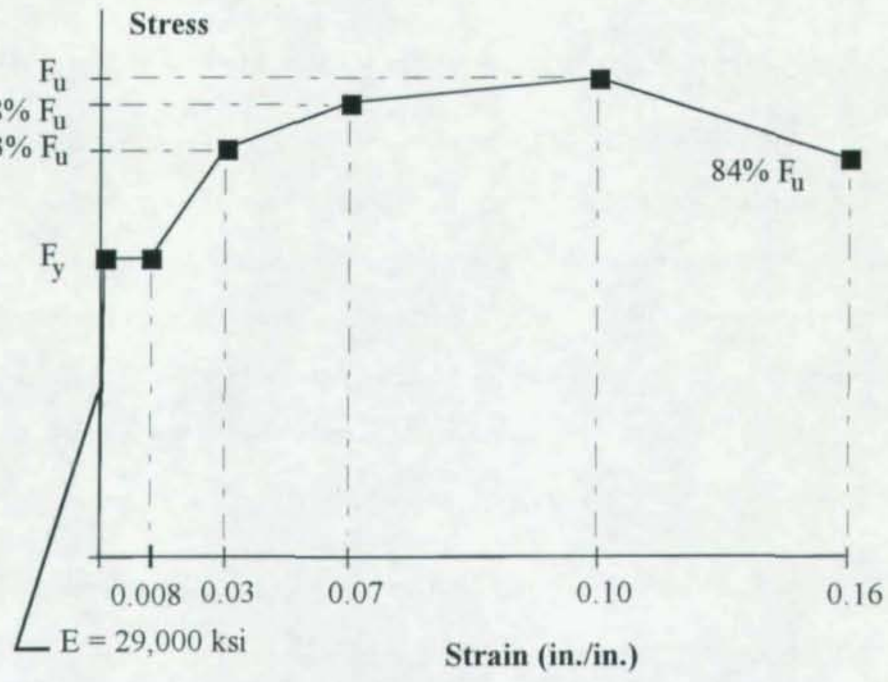

Figure 10 Multi-Linear Approximation For Reinforcing Steel Stress-Strain Behavior

Mean values of F_y and F_u were determined to be 71 ksi and 111 ksi respectively based on a mill survey of reinforcing steel. These mean values can be used when the actual yield and ultimate strengths are unknown.

5.1.2 Concrete

The concrete in a composite beam-girder connection is typically going to be in tension. This concrete is normally assumed to have no strength. In reality, the concrete has significant strength before cracking and after cracking it has a stiffening effect on the reinforcing steel.

After cracking, the concrete cannot carry load across the cracks. This load has to be carried by the reinforcing steel. However, between cracks the concrete can carry load. This reduces the load in the reinforcing steel and consequently reduces the axial deformations in the reinforcing steel. This effect on the reinforcing steel is called concrete tension stiffening.

One way to account for the stiffening effect the concrete has on the reinforcing steel is to model the concrete as an axially loaded member acting in parallel with the reinforcing steel. A special stress-strain behavior is used for the concrete and the strain in the concrete is assumed to be the same as the strain in the reinforcing steel (i.e., no slip between the reinforcing steel and the concrete surrounding it). By combining the load resisted by the reinforcing steel with the load resisted by the fictitious concrete element the real effect of concrete tension stiffening is satisfactorily represented.

One stress-strain model for concrete tension behavior both before and after concrete cracking is given by Collins and Mitchell (1991). The after cracking behavior is the tension stiffening stress-strain relation.

For: $\varepsilon_c \leq \varepsilon_{cr}$

$$f_c = E_c \, \varepsilon \qquad \text{(Eq 1)}$$

For: $\varepsilon_c > \varepsilon_{cr}$ (Tension stiffening)

$$f_c = \frac{\alpha_1 \alpha_2 f_{cr}}{1 + \sqrt{500\, \varepsilon_c}} \qquad \text{(Eq 2)}$$

Where:

$$f_{cr} = \frac{4\sqrt{1000\, f'_c}}{1000}$$

$$\varepsilon_{cr} = \frac{4\sqrt{1000\, f'_c}}{1000\, E_c}$$

$E_c = w_c^{1.5} \sqrt{f'_c}$ (*Load and*, 1993)

f'_c = Compressive strength of concrete (ksi)

w_c = Unit weight of concrete (lb/cf.)

The factor α_1 accounts for bond characteristics of reinforcement and is equal to 1.0 for deformed reinforcing bars. The factor α_2 accounts for the loading time period. It is equal to 1.0 for short-term monotonic loads and 0.7 for sustained and/or repeated loads.

The load in the concrete is determined by multiplying the stress by the area of concrete. Before cracking the area of concrete is the gross area. For a composite slab this would probably be interpreted as the gross area within the effective width of the slab. After concrete cracking the area is the effective area which is taken as a block of concrete around each reinforcing bar with a height and width of 15 times the bar diameter. It is assumed that if the full effective concrete area is not available (as would be the case for thin composite slabs) that the portion of this area that is available would be used instead.

Equation 2 is essentially a curve that was fit through test data. Equation 2 and the test data are presented in Figure 11, along with a multi-linear representation. The data for Figure 11 is based on Figure 4-16 of Collins and Mitchell (1991).

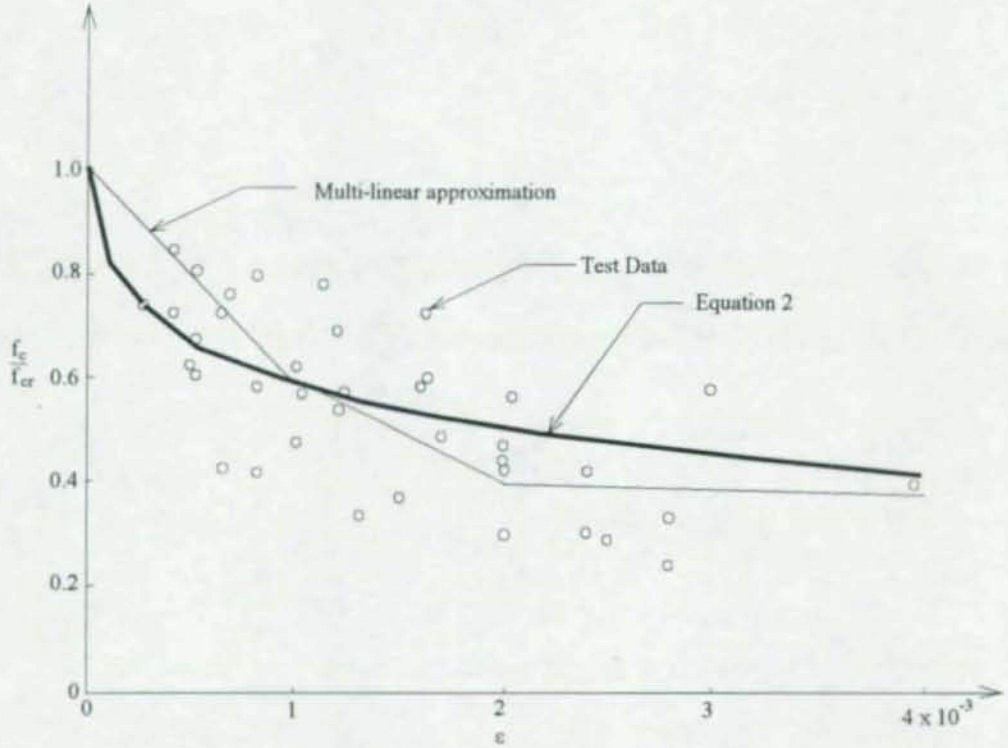

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Figure 11 Concrete Tension Stiffening Stress-Strain Behavior

Comparison of Equation 2 with the test data shows good agreement except for the very small strains where Equation 2 tends to be conservative. For this reason and the fact that a multi-linear representation of the tension stiffening stress-strain behavior may be needed for finite element analysis, the multi-linear representation given in Table 1 will be used.

Table 1 Recommended Concrete Tension Stiffening Stress-Strain Behavior

Strain	Stress
f_{cr} / E_c	f_{cr}
0.001	$0.6\ f_{cr}$
0.002	$0.4\ f_{cr}$
0.008	$0.3\ f_{cr}$
0.1	0

Note that the tension stiffening stress is slowly reduced to zero at a strain of 10%. The stress-strain behavior is forced to zero at 10% strain to ensure that the maximum load capacity of a reinforced composite slab in tension is limited by the ultimate load of the reinforcing steel. The strain at the ultimate load of the reinforcing steel is around 10%.

5.1.3 Shear Studs

Round headed shear studs are currently the most common shear connector used in composite construction. Except in cases where the combined strength of the shear connectors is far in excess of the strength of the reinforcing steel and concrete, the load-deformation behavior of the shear studs has a significant influence on the load-deformation behavior of the composite slab.

The following sections either develop or verify existing procedures to estimate both the strength and load-deformation behavior of shear studs in both weak and strong positions. These procedures are verified against test data from pushout tests that have been conducted at Virginia Tech over the last few years.

5.1.3.1 Data for Development and Verification of Shear Stud Behavior

Strength and load-deformation data for shear studs was collected from two sources. Lyons et al (1994) conducted 87 pushout tests with steel deck. Sublett et al (1992) conducted 36 pushout tests with steel deck but only 8 of these tests were designed to represent studs welded to wide flange shapes. The other tests were designed to represent studs welded to open web joists. All of these tests used normal weight concrete and ¾-in. diameter shear studs. The typical arrangement for these pushout tests is shown in Figure 12.

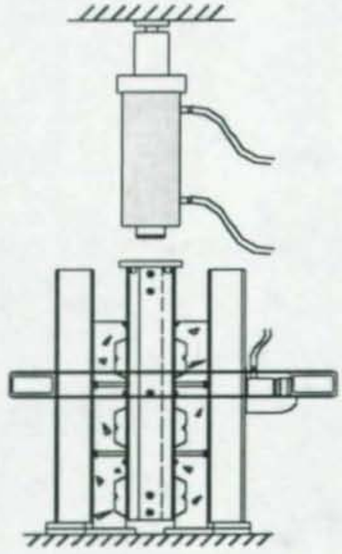

Figure 12 Typical Pushout Test (Lyons et al 1994)

Of the tests reported by Lyons et al (1994) and Sublett et al (1992) only the tests that had failure modes consistent with those expected in actual service were considered. In addition, only tests in which a single shear stud was in a strong or weak position (these positions are explained later) were considered. A summary of the tests included in this analysis is presented in Table 2. All the test parameters as well as the load-deformation data for each test was entered into a database program. The database was then used to help develop and to verify behavior models for the shear studs.

Table 2 Pushout Tests Included In Analysis

Test Number	Test Designation	Source of Data*	Stud Position**	Deck Height (in.)	Stud Height (in.)	Deck Thickness (in.)	Slab Depth (in.)	Concrete Strength (psi)	Max Stud Load (kips)
2	D2	Lyons	S	2	3.5	0.0312	5.75	4563	21.91
3	D3	Lyons	S	2	3.5	0.0312	5.75	4563	18.08
4	D4	Lyons	S	2	4	0.0312	5.75	4563	19.44
6	D6	Lyons	S	2	4	0.0312	5.75	4563	20.73
7	D7	Lyons	S	2	4.5	0.0312	5.75	4563	21.18
8	D8	Lyons	S	2	4.5	0.0312	5.75	4563	20.37
9	D9	Lyons	S	2	4.5	0.0312	5.75	4563	21.46
10	D10	Lyons	S	2	5	0.0312	5.75	4563	20.62
11	D11	Lyons	S	2	5	0.0312	5.75	4563	21.02
12	D12	Lyons	S	2	5	0.0312	5.75	4563	21.97
13	D13	Lyons	S	2	5.5	0.0312	5.75	4563	19.84
14	D14	Lyons	S	2	5.5	0.0312	5.75	4563	20.14
15	D15	Lyons	S	2	5.5	0.0312	5.75	4563	21.45
40	D40	Lyons	W	2	3.5	0.0312	5.75	2716	11.15
41	D41	Lyons	W	2	3.5	0.0312	5.75	2716	10.96
42	D42	Lyons	W	2	3.5	0.0312	5.75	2716	12.46
43	D43	Lyons	W	2	3.5	0.0363	5.75	2716	11.56
44	D44	Lyons	W	2	3.5	0.0363	5.75	2716	12.79
45	D45	Lyons	W	2	3.5	0.0363	5.75	2716	13.66
47	D47	Lyons	W	2	3.5	0.0485	5.75	2716	14.8
48	D48	Lyons	W	2	3.5	0.0485	5.75	2716	13.62
49	D49	Lyons	W	2	3.5	0.0603	5.75	2716	15.06
52	D52	Lyons	S	3	4.5	0.0363	5.75	3362	17.39
54	D54	Lyons	S	3	4.5	0.0363	5.75	3362	18.35
55	D55	Lyons	S	3	5	0.0363	5.75	3362	18.24
56	D56	Lyons	S	3	5	0.0363	5.75	3362	15.49
58	D58	Lyons	S	3	5.5	0.0363	5.75	3362	18.67
59	D59	Lyons	S	3	5.5	0.0363	5.75	3362	19.6
90	15A	Sublett	S	3	5	0.036	6	4630	18.03
91	15B	Sublett	S	3	5	0.036	6	4630	19.66
92	16A	Sublett	W	3	5	0.036	6	4324	13.66
93	16B	Sublett	W	3	5	0.036	6	4284	12.87
94	17A	Sublett	S	3	5	0.036	6	4446	14.48
95	17B	Sublett	S	3	5	0.036	6	4446	18.76
96	18A	Sublett	W	3	5	0.036	6	4228	12.92
97	18B	Sublett	W	3	5	0.036	6	4228	14.75

* Lyons et al (1994) and Sublett (1992)

** S = Strong position, W = Weak position

5.1.3.2 Strength of Shear Studs

Today almost all steel-concrete composite floor systems use a profiled steel decking. The shear studs are welded to the tops of the steel beams through the steel decking and are placed in the ribs of the decking pattern. Because of a stiffener that is present in most commonly used deck patterns, the shear stud cannot be placed in the center of the rib. Easterling et al (1993) deemed studs welded on one side of the rib weak position studs and the other side strong position studs. The designation of weak or strong depends on the relative direction of the force in the concrete. These relationships are shown schematically in Figure 13.

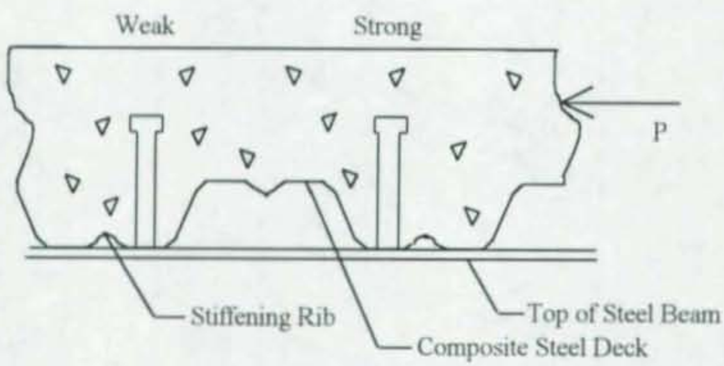

Figure 13 Weak and Strong Position Shear Stud Locations (Easterling et al 1993)

Strength prediction equations for shear studs were first developed for solid slabs. Later, when composite slabs were becoming more common, strength reduction equations were developed to account for possible reductions in strength resulting from the differences between the solid slab and the composite slab.

There are a large number of shear stud strength prediction equations and strength reduction equations available. A recent review of these equations is found in Lyons et al (1994). Lyons concluded that none of the current strength prediction equations did an adequate job of predicting the strength of studs in steel deck.

For simplicity, the current AISC Specification (*Load and,*1993) equations for shear stud strength with some modifications which are discussed and developed in the two following sections will be used.

5.1.3.2.1 Modifications to AISC Equations For Strong Position Shear Studs

Both Sublett et al (1992) and Lyons et al (1994) have shown that the current AISC Specification (*Load and,* 1993) strength prediction equations do not work well for a single stud in a composite deck trough. Two recommendations have been made to try to improve the accuracy of the prediction equations. Easterling et al (1993) recommended that an upper limit of 0.75 be used when calculating the stud reduction factor with AISC Specification (*Load and,* 1993) equation I3-1. In addition, Lyons et al (1994) recommended that the upper limit on the shear stud strength be 0.8 A_{sc} F_u rather than A_{sc} F_u as is currently given by AISC Specification (*Load and,* 1993) equation I5-1.

The test strength along with the predicted strength based on the AISC Specification (*Load and,* 1993) equations, with and without the above recommended modifications, is presented in Table 3 for all the strong position shear stud pushout tests.

Table 3 Strong Position Shear Stud Test Strength Vs. Predicted Strength

Test No.	Test Source	Test Strength (kips)	AISC (kips)	AISC Modified (kips)	Test/AISC	Test/AISC Modified
2	Lyon's	21.91	26.51	21.21	0.83	1.03
3	Lyon's	18.08	26.51	21.21	0.68	0.85
4	Lyon's	19.44	26.51	21.21	0.73	0.92
6	Lyon's	20.73	26.51	21.21	0.78	0.98
7	Lyon's	21.18	26.51	21.21	0.80	1.00
8	Lyon's	20.37	26.51	21.21	0.77	0.96
9	Lyon's	21.46	26.51	21.21	0.81	1.01
10	Lyon's	20.62	26.51	21.21	0.78	0.97
11	Lyon's	21.02	26.51	21.21	0.79	0.99
12	Lyon's	21.97	26.51	21.21	0.83	1.04
13	Lyon's	19.84	26.51	21.21	0.75	0.94
14	Lyon's	20.14	26.51	21.21	0.76	0.95
15	Lyon's	21.45	26.51	21.21	0.81	1.01
52	Lyon's	17.39	19.78	17.45	0.88	1.00
54	Lyon's	18.35	19.78	17.45	0.93	1.05
55	Lyon's	18.24	23.27	17.45	0.78	1.05
56	Lyon's	15.49	23.27	17.45	0.67	0.89
58	Lyon's	18.67	23.27	17.45	0.80	1.07
59	Lyon's	19.60	23.27	17.45	0.84	1.12
90	Sublett	18.03	26.51	21.21	0.68	0.85
91	Sublett	19.66	26.51	21.21	0.74	0.93
94	Sublett	14.48	26.51	21.21	0.55	0.68
95	Sublett	18.76	26.51	21.21	0.71	0.88
Avg:					0.77	0.96
COV					0.10	0.10

The average value of the test over predicted strength is 0.96 with a coefficient of variation of 10%. This represents a significant improvement in the prediction accuracy over the AISC strength prediction equations without modification and should be sufficient for purposes of this research.

5.1.3.2.2 Modifications to AISC Equations For Weak Position

Unfortunately, like strong position studs, the current AISC Specification (*Load and*, 1993) equations do not predict the strength of weak position studs very well (Sublett et al 1992 and Lyons et al 1994). Because weak position studs typically have concrete failures a modification to the stud reduction factor (SRF) equation seems appropriate. However, unlike the strong position studs there is an additional parameter that is not currently recognized by the AISC Specification (*Load and*, 1993) equations that has a significant effect on the strength of weak position studs.

Lyons et al (1994) suggested that the load capacity of a single stud in the weak position was a combination of load carried by the shear stud and load carried by the steel deck. The load carried by the deck was developed by the attachment of the deck to the steel beam that occurs at the weld collar around the shear stud. The author also showed that this deck strength could be approximated by using equations for spot welds found in the AISI Specification (*Load and*, 1991). For the AISI Specification (*Load and*, 1991) equations the author suggested that d (the visible diameter of the outer surface of puddle weld) be taken as 1-in. which corresponds to the diameter of the shear stud welding ferrule used for ¾-in. diameter shear studs.

A summary of the weak position pushout test loads, deck gage, and calculated deck strength is given in Table 4. The deck strength was calculated with the AISI Specification (*Load and*, 1991) equations using measured deck thickness and an average deck strength of 56.3 ksi. Note that the concrete strength for tests 40 through 49 was around 2.7 ksi while the strength for tests 92 through 97 was around 4.3 ksi.

Table 4 Weak Position Shear Stud Strength and Deck Strength

Test	Test Strength (kips)	Deck Gage	Deck Strength (kips)
40	11.15	22	2.37
41	10.96	22	2.37
42	12.46	22	2.37
43	11.56	20	3.19
44	12.79	20	3.19
45	13.66	20	3.19
47	14.8	18	5.62
48	13.62	18	5.62
49	15.06	16	7.07
92	13.66	20	3.19
93	12.87	20	3.19
96	12.92	20	3.19
97	14.75	20	3.19

Review of Table 4 indicates that the increases in the calculated deck strength seem to correlate well with the variation in the shear stud test strength which was the conclusion reached by Lyons et al (1994). Because of the significant effect the deck gage has on the weak position shear stud strength it seems reasonable to account for this parameter when predicting the shear stud strength. The method for doing this is described in the following paragraph; however, other valid methods could certainly be developed.

As Lyons et al (1994) suggested the strength of a weak position stud can be decomposed into two fundamental strengths: the strength of the shear stud and the strength of the deck. Lyons et al (1994) also pointed out that the effect of deck strength tends to deteriorate in the later stages of the load-deformation behavior. Because of this later attribute of the stud strength the current AISC Specification (*Load and*, 1993) SRF equation will be calibrated to the later strength. This calibrated strength will be called the "base strength" (Q_{base}). It seems to correlate well with the strength associated with 22 and

20 gage steel deck. The decision was arbitrarily made to calibrate Q_{base} to the strength associated with 22 gage deck.

Base strengths for all the weak position stud pushout tests were calculated by subtracting the calculated deck strength from the test strength and then adding back in the deck strength for 22 gage deck. These base strengths along with the predicted stud strength based on concrete failure using the current AISC Specification (*Load and*, 1993) shear stud strength equations are given in Table 5.

Table 5 Weak Position Shear Stud Base Strength And SRF

Test	Base Strength (kips)	AISC Strength (kips)	SRF
40	11.15	19.93	0.56
41	10.96	19.93	0.55
42	12.46	19.93	0.63
43	10.74	19.93	0.54
44	11.97	19.93	0.60
45	12.84	19.93	0.64
47	11.55	19.93	0.58
48	10.37	19.93	0.52
49	10.36	19.93	0.52
92	12.84	28.39	0.45
93	12.05	28.19	0.43
96	12.10	27.92	0.43
97	13.93	27.92	0.50

A stud reduction factor is also presented in Table 5. This factor was calculated by dividing the base strength by the predicted strength. The average stud reduction factor is 0.53. A value of 0.5 seems justifiable.

Because Q_{base} is based on the strength of studs in 22 gage deck Q_{base} would need to be modified for different deck gages. The modification factor is simply the difference in deck strength between the deck gage used and the 22 gage deck. Example modification factors are given in Table 6 for the deck gages included in this analysis. These values are based on ¾-in. diameter studs and a deck strength of 56.3 ksi.

Table 6 Weak Position Shear Stud Strength Modification Factors

Deck Gage	Modification Factor (kips)
22	0.00
20	0.82
18	3.25
16	4.70

The proposed method for determining the weak position shear stud strength is summarized as follows:

Step 1) Determine the base strength. This is the AISC strength using a maximum SRF of 0.5.

Step 2) If desired, the shear stud strength can be modified to account for the actual deck gage by adding a strength modification factor. Example modification factors are given in Table 6. Note that if these modification factors are applied it is important to insure that the weld collars around the shear studs are indeed attaching the steel deck to the beam.

Clearly, because of the way in which the above method for determining the shear stud strength was developed, comparison of the predicted value to actual value would be favorable and is consequently not warranted.

5.1.3.2.3 Concrete in Tension Vs. Compression

Almost all the equations developed and research done deals with shear studs that are in concrete which is in compression. The concrete in the region of a composite beam-girder connection is normally in tension. The effect of the concrete being in tension on the strength of shear studs is not currently well understood. Johnson et al (1969) conducted push-out tests of solid slab specimens in which the concrete was in tension. Based on the

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results of these tests a reduction in strength of 20% was suggested. Because these were solid slab specimens it is hard to say whether a similar reduction would be suitable for specimens with metal deck.

The only basis of comparing the effect of tension or compression in the concrete on the shear stud strength where the studs are in composite metal deck is by comparing typical strength values from pushout tests to the strengths determined in the composite slab tests described in Section 4. Considering pushout tests with similar parameters to those for the slab tests the average shear stud strength for strong and weak position studs is 20 kips and 12.7 kips respectively. Adding up these strengths for the weak and the strong position studs and only considering the effective studs (i.e. no studs in position "A") the estimated stud load capacity would be 80, 72.5, 80, and 60 kips for Slabs #1 through #4. The ratio of slab test loads to these simple predictions are 0.95, 0.97, 0.98, 1.03 for Slabs #1 through respectively. This would seem to indicate that the fact that the concrete is in tension has little if any detrimental effects on the shear stud strength when the studs are in composite steel deck.

5.1.3.3 Load-Deformation Behavior of Shear Studs

5.1.3.3.1 General Observations

Earlier it was shown that weak position and strong position studs have different strengths. It turns out that they also have different load-deformation behaviors. Two sets of test data showing these typical behaviors are presented in Figure 14. This data has been normalized by the maximum test load.

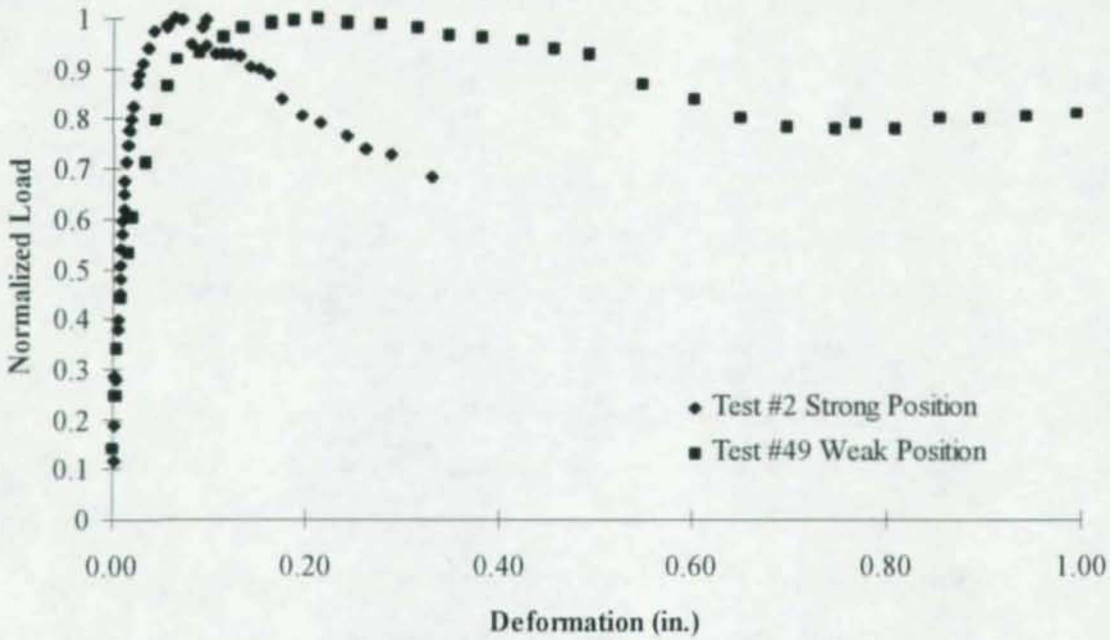

Figure 14 Load Softening of Load-Deformation Behavior

The average load-deformation behavior for a strong position stud can be characterized by five normalized load-deformation points which are presented in Table 7. The load was normalized by maximum test load and the last point is considered the failure load and deformation.

Table 7 Average Normalized Load-Deformation Points For Strong Position Shear Studs

Load	δ (in.)
50% Q_{sol}	0.009
80% Q_{sol}	0.027
94% Q_{sol}	0.06
Q_{sol}	0.18
76% Q_{sol}	0.36

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The average load-deformation behavior for a weak position stud is affected by the deck gage. In general, the average load-deformation behavior can be characterized by five normalized load-deformation points which are presented in Table 8. Note that Q_{sol} was taken as the maximum test load and the last point is considered the failure load and deformation.

Table 8 Average Normalized Load-Deformation Points For Weak Position Shear Studs

Load	δ (in.)
40% Q_{sol}	0.007
92% Q_{sol}	0.1
96% Q_{sol}	0.2
Q_{base}	0.8
Q_{base}	1.1

The effect of deck gage is accounted for by the transition from Q_{sol} to Q_{base} as the normalizing load. Because Q_{base} is smaller than Q_{sol} for deck thicker than 22 gage there is a drop in load that occurs between 0.2-in. and 0.8-in. of deformation. This load softening as well as other load-deformation characteristics that depend on the deck gage can be seen in Figure 15 where test data for four different deck gages is plotted. The test loads in Figure 15 have been normalized by the base strengths given previously in Table 5.

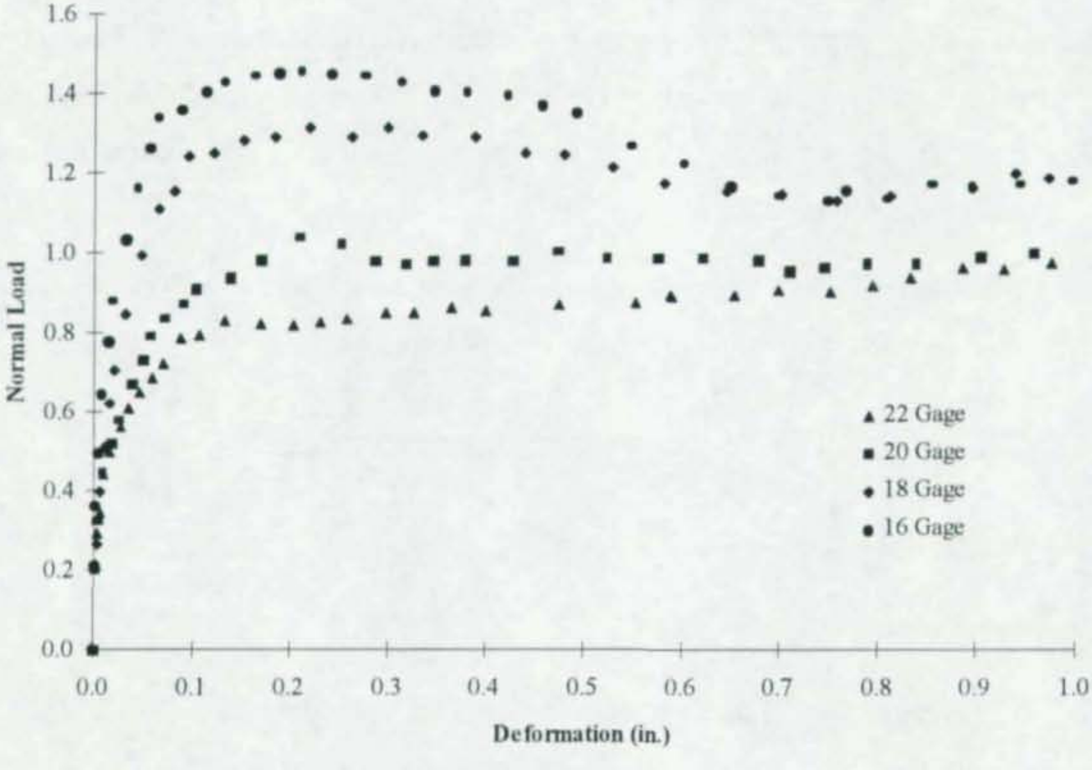

Figure 15 Effect of Deck Gage on Normalized P-Δ Behavior

Three characteristics of the load-deformation behavior for weak position studs are evident in Figure 15.

- The thicker the deck the stiffer the initial response. This is expected because of the increase in strength discussed previously.
- Decks thicker than 22 gage have a peak strength around 0.2-in. of deformation. After the peak, the strength tends to degrade. This degrading levels out around 0.8-in. of deformation.
- After 0.8-in. of deformation the stud load for all deck gages is near the base strength. Deformation continues at the base load until failure at an average deformation of 1.1-in.

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5.1.3.3.2 Existing Load-Deformation Predictions

Three analytical models for predicting the load-deformation behavior of shear studs were found. One model was developed by Buttry (1965).

$$Q = Q_{sol}\left[\frac{80\,\delta}{1+80\,\delta}\right] \qquad \text{(Eq 3)}$$

Where:

Q = Load on shear stud (Kips)

Q_{sol} = Ultimate strength of shear stud (Kips)

δ = Shear stud deformation (in.)

A second model was developed by Ollgaard, et al (1971) for continuously loaded shear studs in solid slabs.

$$Q = Q_{sol}\left[1-e^{-18\delta}\right]^{2/5} \qquad \text{(Eq 4)}$$

The third model is given by Oehlers and Coughlan (1986). Based on statistical analysis of 116 pushout tests the authors suggested a bi-linear representation of the load-deformation behavior. The authors determined that the average deformation when the pushout test was at half of the maximum test load is given by

$$\delta_{0.5\,Qsol} = (80\text{x}10^{-3} - 86\text{x}10^{-5}\, f'_c)d_{sh} \qquad \text{(Eq 5)}$$

Where:

f'_c = Concrete compressive strength (N/mm^2)

d_{sh} = Diameter of shear stud shank (mm)

The standard deviation for this equation was given as 0.026 d_{sh}. For 4000 psi concrete and ¾-in. diameter shear studs this corresponds to a coefficient of variation of around 50%. The initial stiffness is then obtained by dividing half the maximum test load by the above deformation and is given by

$$K_i = \frac{Q_{sol}}{(0.16 - 0.0017 f'_c)\, d_{sh}} \quad \text{(Eq 6)}$$

Upper and lower bounds for the initial stiffness were also given. The upper bound is obtained by substituting 0.08 for the 0.16 in the equation and the lower bound is obtained by substituting 0.24 for the 0.16.

The bi-linear model consists of the initial stiffness up to Q_{sol} and then a plastic response at Q_{sol} until the failure deformation is reached. The authors defined the failure deformation as the deformation when there was a 1% drop from the maximum test load. The failure deformation is given as

$$\delta_{failure} = (0.48 - 0.0042\, f'_c)\, d_{sh} \quad \text{(Eq 7)}$$

The units are again in N and mm. A lower bound for the failure deformation was given by substituting 0.42 for the 0.48 in the above equation. For 4000 psi concrete and ¾-in. diameter studs the failure deformation, based on Equation 9, would be 0.27-in. This value is slightly larger than the average deformation values associated with the first drop in load capacity based the pushout tests by Lyons et al (1994) and Sublett et al (1992). These values were 0.18-in. and 0.2-in. for strong and weak position studs respectively.

5.1.3.3.3 Evaluation of Existing Load-Deformation Predictions

All three of the above analytical models were evaluated against the test data for strong and weak position shear studs. Many of the pushout tests exhibited a softening in the load-deformation response after the peak load was attained but before failure. Because none of the above models attempt to include this softening only data up to the point where test softening occurred was included in the evaluation. The maximum measured test load was used for Q_{sol} in the analytical expressions. The evaluation was carried out by calculating the ratio of the test load over the predicted load for each analytical method and for each load-deformation point. The results of the evaluation are summarized in Table 9. Note that "n" is the number of load-deformation points included in the evaluation. In addition, example load-deformation plots for a weak position pushout test and a strong position pushout test are presented in Figures 16 and 17 respectively.

Table 9 Evaluation of Load-Deformation Behavior Models

	Buttry		Ollgaard		Oehlers & Coughlan	
	Weak	Strong	Weak	Strong	Weak	Strong
Mean	1.25	1.30	0.98	1.08	3.92	4.01
COV	122%	76%	17%	23%	315%	187%
n	271	595	271	595	271	595
Maximum	22.61	19.79	1.97	2.59	172.78	141.41
Minimum	0.12	0.00	0.02	0.00	0.79	0.01

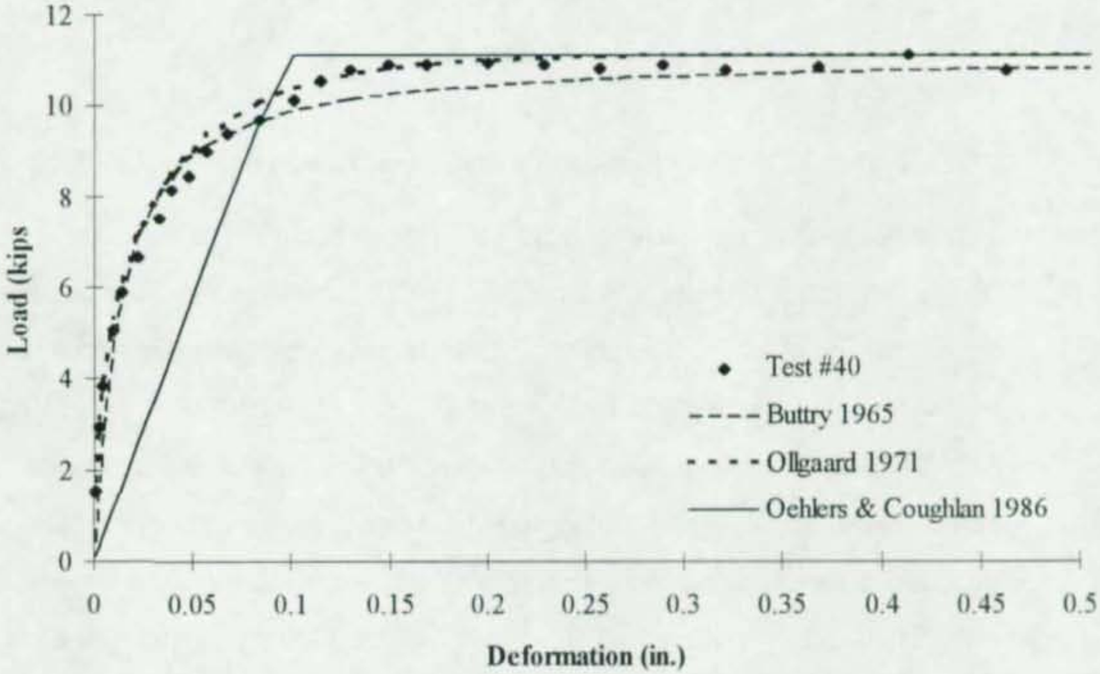

Figure 16 Weak Position Pushout Test Load-Deformation Behavior

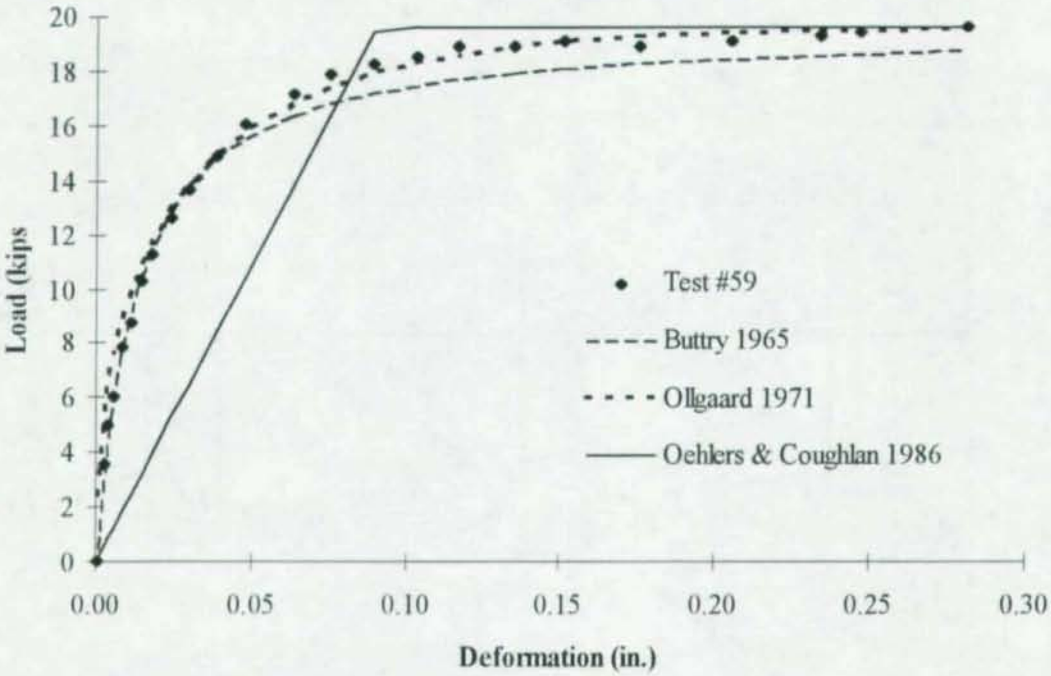

Figure 17 Strong Position Pushout Test Load-Deformation Behavior

Of the three analytical models Ollgaard (1971) appears to fit the test data the best. Both Buttry (1965) and Oehlers and Coughlan (1986) typically under predict the load. In addition the initial stiffness estimate by Oehlers and Coughlan clearly underestimates the initial stiffness seen in this test data.

If the load-deformation behavior after the initiation of softening occurs is not of interest then clearly using Ollgaard's analytical model appears to be justifiable. However, if the load-deformation behavior after initiation of softening is of interest then none of the analytical models considered so far would be suitable in the later stages of the load-deformation behavior. The refinement required to include the load softening effect is not believed necessary at this point and therefore Ollgaard's analytical model is recommended for use up to the average failure deformations of 0.36-in. and 1.1-in. for strong position and weak position studs respectively.

It should be noted that an evaluation of the previous analytical models including all test data (i.e. not just up to the point where load softening began) gave results similar to those in Table 9. This is attributed to the fact that there are far more data points taken before than after load softening occurs.

5.1.3.4 Behavior Model For Shear Studs

In summary, the behavior model suggested for shear studs is as follows. The strength is determined by using modified AISC Specification (*Load and*, 1993) equations.

$$Q_{sol} = SRF\ 0.5\ A_{sc}\ (f'_c\ E_c)^{0.5} \leq 0.8\ A_{sc}\ F_{usc} \qquad \text{(Eq 8)}$$

Where

Q_{sol} = The strength for a single shear stud (kips)

A_{sc} = Area of the shear stud based on the nominal shear stud diameter (in^2)

f'_c = Compressive strength of the concrete (ksi)

F_{usc} = Shear stud steel tensile strength (typically taken as 60 ksi)

E_c = Modulus of elasticity of concrete = $w_c^{1.5}\ \sqrt{f'_c}$ (*Load and*, 1993) (ksi)

w_c = Unit weight of concrete (lb./cf.)

SRF = Stud reduction factor which is given by

$$SRF = \frac{0.85}{\sqrt{N_r}} (w_r/h_r)[(H_s/h_r) - 1.0] \leq \begin{matrix} 0.75 \text{ For Strong Position Studs} \\ 0.5 \text{ For Weak Position Studs} \end{matrix} \qquad \text{(Eq 9)}$$

Where

N_r = Number of shear studs per deck rib

H_s = Shear stud height after welding

h_r = Height of the deck rib

w_r = Width of the deck rib

For weak position studs this strength can be modified by adding in a strength modification factor as given in Table 6 which accounts for the increased resistance from the deck weld.

The load-deformation behavior is given by Ollgaard's analytical expression repeated below.

$$Q = Q_{sol}\left[1 - e^{-18\delta}\right]^{2/5} \qquad \text{(Eq 10)}$$

When using this equation for modeling the composite slab behavior it is convenient to rearrange it so that the deformation can be determined for a given load. This is given as

$$\delta = -\frac{1}{18}\ln\left[1-\left(\frac{Q}{Q_{sol}}\right)^{2.5}\right] \qquad \text{(Eq 11)}$$

5.2 Component Model of Composite Slab

The fundamental model used to combine the behavior of the reinforcing steel, concrete, and shear studs is the three spring model shown in Figure 18. As can be seen in the figure, the concrete and reinforcing steel act in parallel and the strains in each element are assumed to be the same. The combined concrete and reinforcing steel behavior then acts in series with the shear studs.

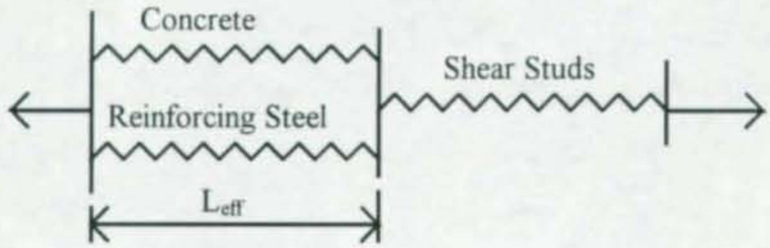

Figure 18 Spring Model Of Reinforced Composite Slab

5.2.1 Load-Strain Relation For Concrete And Reinforcing Steel

The first step in the modeling process is to develop a load-strain relationship for the combined concrete and reinforcing steel acting in parallel. The reason for developing a load-strain relationship rather than a load-deformation relationship is that the load-strain relationship will not change throughout the loading process, but because of a changing

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effective length (discussed in the next section) a load-deformation relationship would change.

Stress-strain behavior models were presented for both concrete and reinforcing steel in Section 5.1.1 and 5.1.2. To determine the load, the stresses can be multiplied by the effective area of the concrete and the nominal area of the reinforcing. The effective area of concrete is different before and after cracking. For the component model, it is recommended that the concrete area, used from start to finish, is the effective area after cracking. The details of calculating this area were given in Section 5.1.2. This simplifies the analysis and because the slab is also in flexure, it is likely that the concrete would crack before the average axial strain reached the cracking strain.

The basic outline of the load-strain relationship can be found by determining four key load-strain points.

1. Load and strain at the cracking stress of the concrete
2. Load and strain when the reinforcing steel yields
3. Load and strain at start of strain hardening in the reinforcing steel
4. Load and strain at the reinforcing steel ultimate stress

Each of these points is determined by first determining the reinforcing steel load and the corresponding strain that is compatible with the load. Because the strain in the concrete and the reinforcing steel is assumed to be equal, the reinforcing strain is then used to determine the stress in the concrete and finally the load in the concrete. By adding the loads for the reinforcing steel and concrete the total load for the calculated strain is determined. A summary of these four key points in terms of yield stress and ultimate stress of the reinforcing steel and cracking stress of the concrete and the respective elastic modulus is given in Table 10.

Table 10 Key Stress-Strain Points For Reinforcing Steel And Concrete

	Point 1	Point 2	Point 3	Point 4
Concrete Stress	f_{cr}	*0.39 f_{cr}	0.3 f_{cr}	0
Steel Stress	f_{cr} (E_s/E_c)	F_y	F_y	F_u
Strain	f_{cr}/E_c	*0.00245	0.008	0.1

* Depends on reinforcing steel yield stress, value given is for Fy = 71 ksi.

As previously mentioned, the load values can be determined by multiply the concrete and reinforcing steel stress values by the effective area of the concrete and the nominal area of the reinforcing steel respectively.

The load strain behavior between the origin and Point1, between Point 1 and Point 2, and between Point 2 and Point 3 is basically linear. The segments are not exactly linear because of the nonlinear behavior of the cracked concrete. Later it will be convenient to have defined two stiffness values

$$K_1 = R_1/\varepsilon_1 \qquad \text{(Eq 12)}$$

$$K_2 = (R_2-R_1)/(\varepsilon_2-\varepsilon_1) \qquad \text{(Eq 13)}$$

It is also convenient to define the intercept of K_2 with the ordinate axis.

$$R_{oa} = R_2 - K_2\,\varepsilon_2 \qquad \text{(Eq 14)}$$

Where

R_1 = Load at Point 1

R_2 = Load at Point 2

The load-strain behavior between Point 3 and 4 is parabolic. A parabolic interpolating function is given by

$$R = C_1\,\varepsilon^2 + C_2\,\varepsilon + C_3 \qquad \text{(Eq 15)}$$

Where

$$C_1 = 118\,(R_3 - R_4) \qquad \text{(Eq 16)}$$

$$C_2 = 23.6\,(-R_3 + R_4) \qquad \text{(Eq 17)}$$

$$C_3 = 1.1815\,R_3 - 0.1815\,R_4 \qquad \text{(Eq 18)}$$

And

R_3 and R_4 are the loads that correspond to Points 3 to 4 in Table 10.

Later it will also have been convenient to rearrange Equation 17 to solve for the strain at a given load. This is done by solving the quadratic which gives

$$\varepsilon = \frac{-C_2 \pm \sqrt{C_2^2 - 4C_1(C_3 - R)}}{2\,C_1} \qquad \text{(Eq 19)}$$

The sign on the square root is positive for strains less 10%.

5.2.2 Effective Length

To determine the deformation of the reinforcing steel and concrete there must be some effective length (L_{eff}) by which the calculated strains can be multiplied. The geometry of a typical reinforced composite is considered to determine the effective length. The important parts of this geometry are shown in Figure 19.

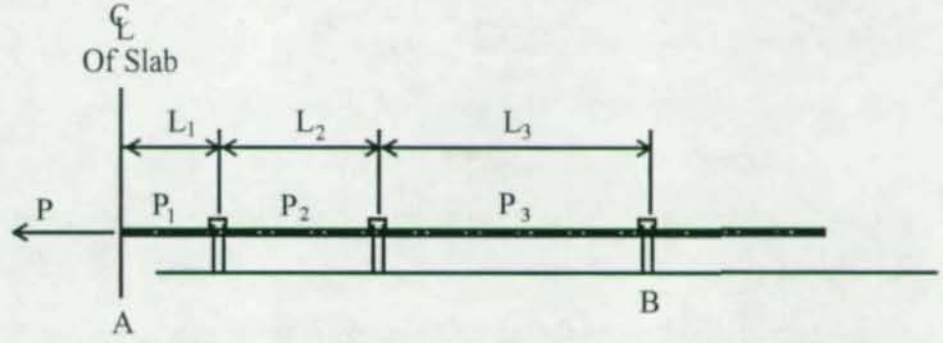

Figure 19 Typical Geometry For Elastic Effective Length of Reinforcing Steel

In Figure 19 L_1, L_2, and L_3 are the distances from the centerline of the composite slab to the first shear stud and then the shear stud spacing respectively. P_1, P_2, and P_3 represent the loads carried by the reinforcing steel in each section and P is the total load carried by the reinforcing steel at the center line of the slab.

If the load capacity of each shear stud is assumed to be that same then P_1 would be P, P_2 would be 2/3 P, and P_3 would be 1/3 P. The elastic deformations from point A to point B would then be given by

$$\delta = \frac{P}{A_r E}\frac{(3L_1 + 2L_2 + L_3)}{3} \qquad \text{(Eq 20)}$$

This could be replaced by

$$\delta = \frac{P}{A_r E} L_{eff} \qquad \text{(Eq 21)}$$

Where

$$L_{eff} = \frac{(3L_1 + 2L_2 + L_3)}{3} \qquad \text{(Eq 22)}$$

In general, for N_{studs}, L_{eff} would be given by

$$L_{eff} = [nL_1 + (n-1)L_2 + \ldots + L_n]/N_{studs} \qquad \text{(Eq 23)}$$

The same logic can be used for the concrete element as well.

The above assumes elastic deformations. For concrete when the load exceeds the cracking load and for reinforcing steel when the load exceeds the yield load the above effective length are no longer valid. For convenience it is assumed that both the concrete and reinforcing steel elements have the same effective lengths and that the above effective length is valid until the reinforcing steel yields. Consequently, any variation in effective length that would occur when the concrete cracks is ignored for purposes of this model.

Once the reinforcing steel has yielded, the above effective length can no longer be used. Because the load in the reinforcing steel and the concrete between the center of the slab and the first shear stud is the highest, the reinforcing steel will yield here first. The deformations that occur after yielding are much larger than the elastic deformations. For this reason the effective length after yielding should be assumed as L_1 until the ultimate stress of the steel is reached. Because necking of the reinforcing is typically very localized, the effective length after the ultimate stress should be taken as one or two inches if deformations beyond the ultimate stress of the reinforcing steel are desired.

5.2.3 Developing A Multi-Linear Representation of the Load-Deformation Behavior

All the tools needed to implement the spring model shown in Figure 18 have been developed.

- The load-strain curve for the combined behavior of the reinforcing steel and the concrete
- Effective length of the reinforcing steel and concrete
- Shear stud load-deformation behavior summarized in Section 5.1.3.4

The deformation in the composite slab can be determined directly for any given load using these tools and the spring model. Likewise, the load for any given deformation can also be determined; however, this is an iterative procedure because of the non-linear load-deformation behavior of each of the springs in the model.

A multi-linear representation of the composite slab load-deformation behavior can be obtained by determining a variety of key load-deformation points and then connecting them with straight line segments. Because the deformation can be calculated directly for a given load it is suggested that various key load points be picked and then the corresponding deformations be determined. The following key loads are recommended

Key loads for combined reinforcing steel and concrete

1. Load when the reinforcing steel stress is at 50% F_y
2. Load when the reinforcing steel yields
3. Load when the reinforcing steel stress is midway between F_y and F_u
4. Load when the reinforcing steel stress is at F_u

Key loads for shear studs

1. 50% of the maximum total shear stud load capacity
2. 80% of the maximum total shear stud load capacity
3. 94% of the maximum total shear stud load capacity
4. Load at a shear stud deformation of 0.36-in.

These key points were picked because they represent transition points in the typical load-deformation behavior for either of the elements. Obviously only loads up to the maximum load for either the shear studs or for the reinforcing steel and concrete would be included in the multi-linear representation.

5.2.4 Determining Richard Equation Parameters

Sometimes it is convenient to represent the composite slab load-deformation behavior with a continuous analytical curve. The parameters of the Richard Equation (Richard and Elsalti, 1991) can be determined from the multi-linear representation. A typical curve represented by the Richard Equation along with definitions of the basic equation parameters are given in Figure 20.

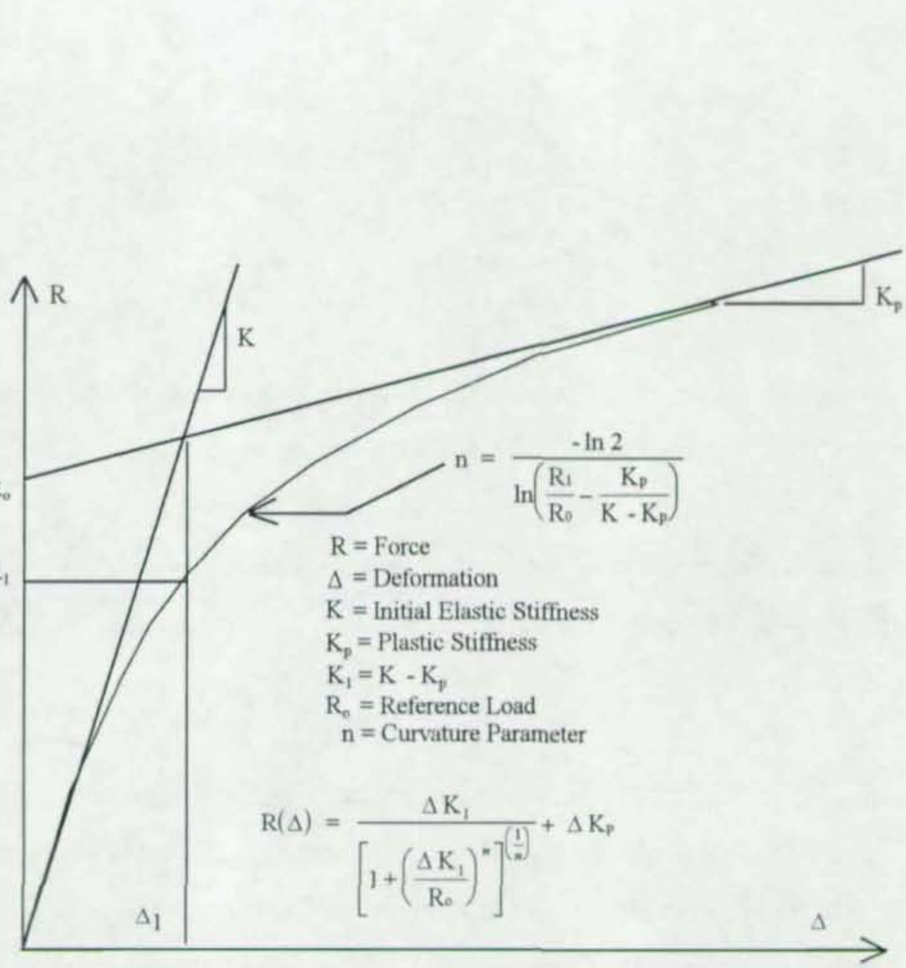

Figure 20 Richard Equation (Richard and Elsalti, 1991)

The most accurate way to determine the equation parameters would be to fit the equation through the key points of the multi-linear representation using non-linear regression. However, because the key points of the multi-linear representation are approximations to the real behavior already, it seems justifiable to use approximate methods to determine the Richard equation parameters.

The first parameter is K, the elastic stiffness. This can be approximated by the initial stiffness of the multi-linear representation. This would be done by determining the first key point (i.e. either 50% reinforcing steel yield load or 50% Qsol) and dividing the load by the deformation at that point.

The next parameter, K_p the plastic stiffness, can be approximated by the slope of the load-deformation behavior between the last two key points. If the reinforcing steel controls the maximum load capacity of the slab then the change in load and the change in deformation between the last two key points are given by

$$\Delta R = A_r (F_u - F_y)/2 \qquad \text{(Eq 24)}$$

$$\Delta\delta = 0.07\ L_{eff} \qquad \text{(Eq 25)}$$

The resulting value of the plastic stiffness when the mean values of F_u and F_y given in Section 5.1.1 are substituted into Equation 26 is given by

$$K_{pr} = 300\ A_r / L_{eff} \qquad \text{(Eq 26)}$$

Note that L_{eff} here would be the plastic L_{eff} not the elastic L_{eff}.

If the shear studs control the maximum load capacity of the slab then the plastic stiffness can be derived as

$$K_{ps} = 0.24\ Q_{sol} \qquad \text{(Eq 27)}$$

Neither K_{pr} or K_{ps} above consider the additional deformations that would occur in the slab because of the flexibility of the other component (i.e. if the shear studs control then the added flexibility from the combined concrete and reinforcing or if the reinforcing controls then the added flexibility from the shear studs). For typical combinations of reinforcing steel and shear studs the added flexibility can be accounted by dividing K_{pr} or K_{ps} by two.

To determine the reference load, R_0, the plastic stiffness (K_p) and the load (R_{last}) and deformation (Δ_{last}) associated with the last key point of the multi-linear representation must be known. Once these values are known, the reference load is calculated by

$$R_0 = R_{last} - \Delta_{last}\ K_p \qquad \text{(Eq 28)}$$

The deformation at the intercept of K and K_p is given by

$$\Delta_1 = R_0 / (K - K_p) \qquad \text{(Eq 29)}$$

The parameter R_1 is the load at deformation Δ_1. This can be determined by interpolating between points on the multi-linear representation. Typically only the first two or three key points are required to determine R_1.

Finally, the curvature parameter n is given by

$$n = \frac{-\ln 2}{\ln\left(\dfrac{R_1}{R_0} - \dfrac{K_p}{K - K_p}\right)} \qquad \text{(Eq 30)}$$

The method for determining the Richard equation parameters just outlined was verified by comparing the resulting curve to the multi-linear representation for a wide variety of composite slab variables. Overall agreement between the curve and the multi-linear representation was excellent.

5.3 Component Model Vs. Experimental Results

The component model described in Section 5.2 was used to develop multi-linear representations and Richard equation parameters for the load-deformation behavior of Slabs #1 through #4. This section compares and contrasts these two approximations to the test data.

Before any comparisons between the model and the test data could be made a couple of modifications to the test data were required. First, the initial stages of the load-deformation behavior for Slabs #1, #3 and #4 had significant jumps in the data. These jumps were caused by large slips between the rotation pin and the fixed side of the test setup. Slab #2 did not have these jumps because most of the slipping was prevented by using shims and by fully tightening the bolts attaching the frame beams to the rotation pin. These jumps in deformation were removed from the test data.

Second, the slab deformation determined from the tests represents the deformations from both sides of the specimen. This is true at least up to the point of maximum load when the shear studs in one side of the specimen would start to fail while the studs on the opposite side typically maintained a constant deformation. The proposed model considers only one side of the composite slab. Consequently, the slab deformations up to maximum load were divided by two. Increases in deformation that occurred after the maximum load can mainly be attributed to the shear studs failing on one side of the specimen. Consequently, these deformation measurements were taken at full value and simply added to the deformation at the maximum load.

Third, shear studs in position "A" were obviously ineffective based on reviewing the results presented in Section 4.3. Consequently, shear studs in position "A" were ignored for modeling purposes.

The following parameters were considered when modeling the test specimens.

- The effective concrete area was 98 in^2 based on the guidelines given in Section 5.1.2.
- The concrete was normal weight with a compressive strength of 4.4 ksi. This is based on measured concrete properties and the fact that normal weight concrete was ordered.
- The area of reinforcing steel was 0.8 in^2 based on the nominal area of four # 4 bars.
- F_y and F_u of the reinforcing was 71 and 111 ksi respectively based on the mean values for #4 Grade 60 bars given in Section 5.1.1.
- Strong and weak position shear stud strengths were 21.2 and 15.2 kips respectively. These are the nominal strengths determined using the guidelines suggested in Section 5.1.3.2.
- The stud spacing L_1 through L_4, which were described in Section 5.2.2, and the corresponding elastic and inelastic effective lengths (L_{eff}) are given in Table 11. The effective lengths were determined using the guidelines given in Section 5.2.2.

Table 11 Stud Spacing and Effective Lengths of Test Specimens

Slab	L1 (in.)	L2 (in.)	L3 (in.)	L4 (in.)	Leff Elastic (in.)	Leff Inelastic (in.)
#1	5	12	12	12	23	5
#2	17	4	8	12	27	17
#3	5	12	12	12	23	5
#4	17	12	12	N/A	29	17

The multi-linear and Richard equation representations of the load-deformation behavior are compared to the test data in Figures 21 through 23. Because studs in position "A" were ignored test Slabs #1 and #3 were considered to be the same and are consequently combined in Figure 21.

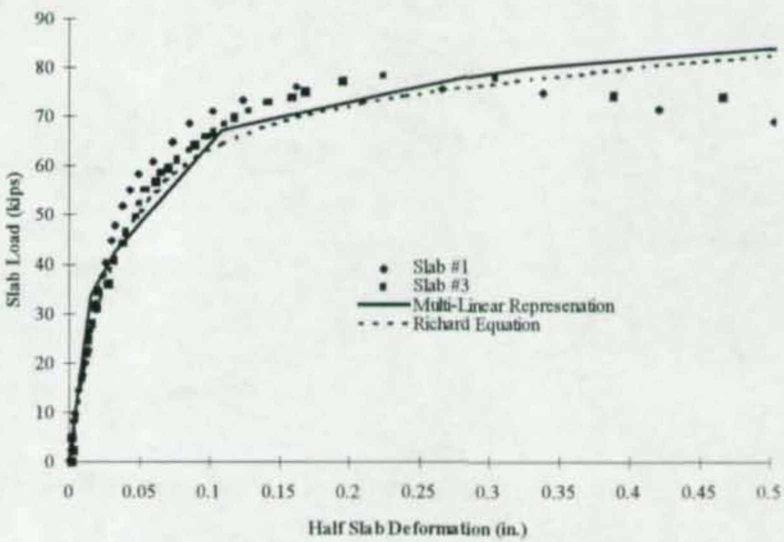

Figure 21 Model Vs. Test Results Slab #1 And #3

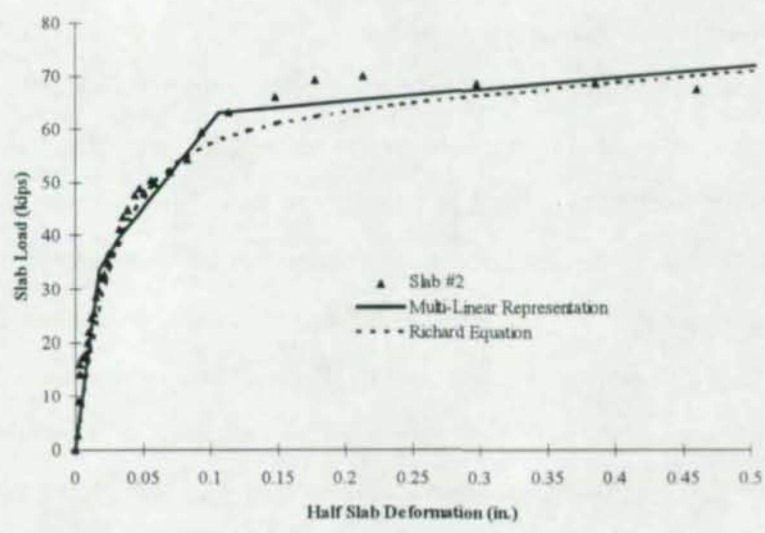

Figure 22 Model Vs. Test Results Slab #2

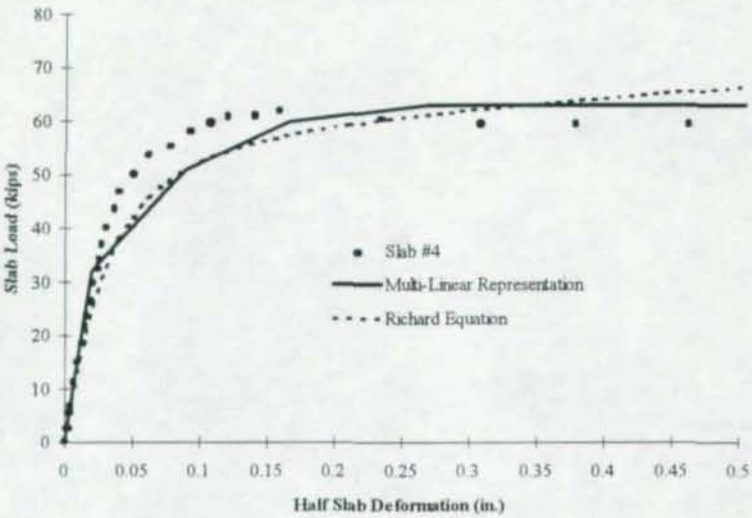

Figure 23 Model Vs. Test Results Slab #4

Review of Figure 21-23 shows favorable comparison between the model and the test results with a couple of notable exceptions. The first notable exception is that the maximum load predicted with the model was between 3% and 11% higher than the maximum load of the test. There are two sources for this difference. First, in Section 5.1.3.2.1 it was shown that the average ratio of test to predicted stud strength was 96%. Second, in Section 5.1.3.2.3 it was shown that there may be a slight drop in the stud strength because the concrete is in tension rather than compression. These combined sources of error easily explain the difference between predicted and test loads. Overall, the error is still small and refinement of the model is not deemed necessary.

The second notable exception is that the deformation at the maximum load do not agree well. This is mainly attributable to that fact the predicted test loads were higher than actual test loads. The difference in deformation is attributed to the increase in reinforcing steel and concrete element deformations that occurred between the maximum test load and the maximum predicted load.

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Based on the above comparison between the model and the test data it appears that the model provides a good estimate of the load-deformation behavior for the reinforced composite slab. However, this comparison is somewhat incomplete. All the composite slab tests failed because of shear stud failures. None of them completely failed the reinforcing steel although all of them did cause the reinforcing steel to yield.

In general there are three basic combinations of reinforcing steel and shear studs. First, the shear studs can be weak compared to the reinforcing steel. Essentially this means the shear studs fail before the reinforcing steel ever yields or is just ready to yield. The load-deformation behavior associated with this combination would mainly be determined by the shear stud behavior. Test Slab #4 falls into this category. Second, the shear stud strength could be sufficient to cause the reinforcing steel to yield and start into the strain hardening region but not sufficient to cause the reinforcing steel to fail. The load-deformation behavior associated with this combination would be determined by the combined behavior of the reinforcing steel and shear studs. Slabs #1 through #3 fall into this category. Third, the shear studs could be strong compared to the reinforcing steel which results in the reinforcing steel to failing before the studs. The load-deformation behavior associated with this combination would mainly be determined by the reinforcing steel rather than the studs. None of the tests were in this category. This means that although the model did well in the first two categories of behavior it may not do well in the third.

6. Summary, Conclusions, and Recommendations

6.1 Summary

Six composite slabs were experimentally tested in an attempt to isolate and determine the load-deformation behavior of a composite slab. This load-deformation behavior is needed to determine the moment-rotation behavior of composite beam-girder connections.

Behavior models for reinforcing steel, concrete, and shear studs were presented and / or developed. These behavior models were used to create a component model of the reinforced composite slab. A method for creating a multi-linear representation of the slab load-deformation behavior was developed. In addition, a method for determining the parameters of the Richard Equation so that it could be used to represent the slab load-deformation behavior was developed. The two representations of the load-deformation behavior compared favorably with experimental results from the composite slab tests.

6.2 Conclusions

The following conclusions were made in this report.

- Shear studs that are close to the end of a composite slab (such as those near the ends of the composite slab test specimens) cannot properly develop forces in the concrete and are in general ineffective.
- Whether the composite slab is in tension or compression seems to have little effect on the strength of the shear studs.
- Using the AISC Specification (*Load and*, 1993) shear stud strength equations with previously suggested modifications (Easterling et al 1993 and Lyons et al 1994) provides a reasonably accurate estimate of the shear stud strength for studs in profiled steel deck.
- The stud reduction factor calculated using the current AISC Specification (*Load and*, 1993) should be limited to a maximum of 0.5 for studs in the weak position.

6.3 Recommendations

The following recommendations are made for further study of the load-deformation behavior of composite slabs.

- The behavior models developed for shear studs in this report was based on a very limited number of pushout tests in which a limited number of parameters were considered. Clearly, a more comprehensive study beginning with a collection and analysis of a much larger base of data would be warranted.
- Further simplification of methods to determine a multi-linear representation of the load-deformation behavior or to determine the parameters of the Richard Equation are needed. The methods outlined in this report are still too cumbersome for use in day to day design. Most likely, the easiest way to simplify these methods would be to develop parameter equations.
- Additional composite slab tests are also recommended to provide further verification of the component model. In particular composite slab tests were the reinforcing steel fails instead of the shear studs is needed.

REFERENCES

Bernuzzi, C., Noe', S., and Zandonini, R. (1991). "Semi-Rigid Composite Joints: Experimental Studies," *Connections in Steel Structures II: Behavior, Strength, and Design*, ed. R. Bjorhovde, G. Haaijer and A. Colson, ASCE, 189-200.

Buttry, K. E. (1965). "Behavior of Stud Shear Connectors in Lightweight and Normal-Weight Concrete," *MS Thesis, University of Missouri*

Collins, M. P. and Mitchell, D. (1991). *Prestressed Concrete Structures*, Prentice Hall, 142-154.

Easterling, W. S., Gibbings, D. R. and Murray, T. M. (1993). "Strength of Shear Studs in Steel Deck on Composite Beams and Joists," *AISC Engineering Journal*, **30**(2), 44-55.

Johnson, R. P. and Huang, D. (1994). "Resistance to Longitudinal Shear of Composite Beams With Profiled Sheeting," Research Report CE48 University of Warwick Department of Engineering.

Johnson, R. P., Greenwood, R. D., and VanDalen, K. (1969). "Stud Shear Connectors in Hogging Moment Regions of Composite Beams," *The Structural Engineer*, **47**(9), 345-350.

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

LRFD Cold-Formed Steel Design Manual (1991). American Iron and Steel Institute, (AISI), Washington, D.C.

Lyons, J. C., Easterling, W. S. and Murray, T.M. (1994). "Strength Of Headed Shear Studs," Vols. I and II, Report CE/VPI-ST 94/07, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Oehlers and Coughlan (1986) "Shear Stiffness of Stud Shear Connections in Composite Beams," Journal of Constructional Steel Research, Vol. 6, p273-284.

Ollgaard, J. G., Slutter, R. G., and Fisher, J. W. (1971). "Shear Strength of Stud Connectors in Lightweight and Normal Weight Concrete." *AISC Engineering Journal*, **8**(2), 55-64.

Rex, C. O. and Easterling, W. S. (1995). "Partially Restrained Composite Beam-To-Girder Connections." *AISC Engineering Journal*, **32**(4), 145-158.

Rex, C. O. and Easterling, W. S. (1996(a)). "Behavior and Modeling of Mild and Reinforcing Steel," Report CE/VPI-ST 96/12, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Richard, R. M. and Elsalti, M. K. (1991). "PRCONN, Moment-Rotation Curves for Partially Restrained Connections." Users manual for program developed at The University of Arizona Department of Civil Engineering and Engineering Mechanics.

Sublett, C. N., Easterling, W. S. and Murray, T.M. (1992). "Strength Of Welded Headed Studs In Ribbed Metal Deck On Composite Joists," Report No. CE/VPI-ST 92/03, Virginia Polytechnic Institute and State University, Blacksburg, VA, 257 pages.

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Appendix A

Material Properties

. The yield, ultimate stress, and % elongation for tensile coupons taken from the reinforcing steel used in the composite slab experimental tests are presented in Table A-1. The first part of the designation indicates which composite slab the bar was from. The second part of the designation indicates the location number of the bar. The final part of the designation refers to the coupon if there were multiple coupons taken. For example, the designation 1-1&2a means this was coupon a from the reinforcing bar used in locations 1 and 2 in composite slab number one.

Table A-1 Reinforcing Steel Properties

Designation	Stress 2% Offset (ksi)	Ultimate Stress (ksi)	% Elongation (2" Gage)
1-1&2a	69.9	115.1	17.8%
1-3&4a	71.5	113.1	16.2%
1-3&4b	71.2	112.6	16.1%
1-3&4c	72.4	112.8	15.2%
2-1&2a	70.3	114.7	17.6%
2-1&2b	69.9	114.9	16.2%
2-1&2c	69.9	115.3	17.5%
2-3&4a	68.3	115.2	18.8%
3-1&2a	72.0	114.2	17.3%
3-1&2b	72.8	113.3	16.8%
3-1&2c	71.9	113.6	16.8%
3-3&4a	68.8	110.3	10.9%
3-3&4b	70.4	111.4	13.5%
3-3&4c	71.1	113.2	17.4%
4-1&2a	69.6	114.9	16.2%
4-3&4a	68.5	114.1	16.8%
4-3&4b	67.5	113.6	17.6%
4-3&4c	69.9	115.0	16.8%
5-1&2a	68.3	113.1	18.4%
5-3&4a	67.6	114.1	19.1%
6-3&4a	68.3	115.3	17.1%

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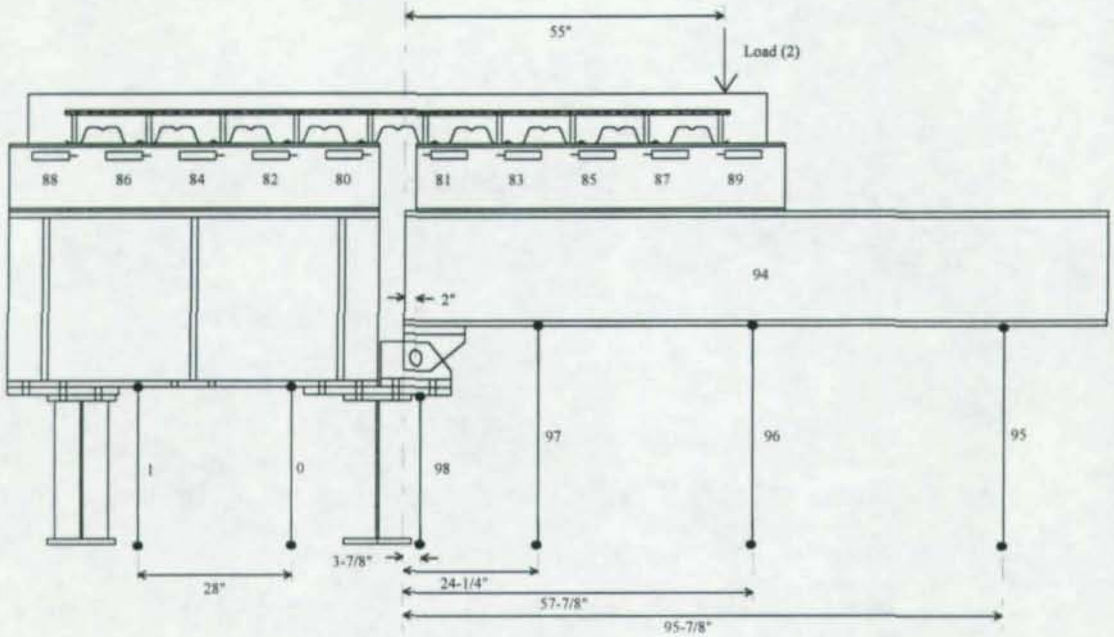
Appendix B

Data Packs For Composite Slab Tests

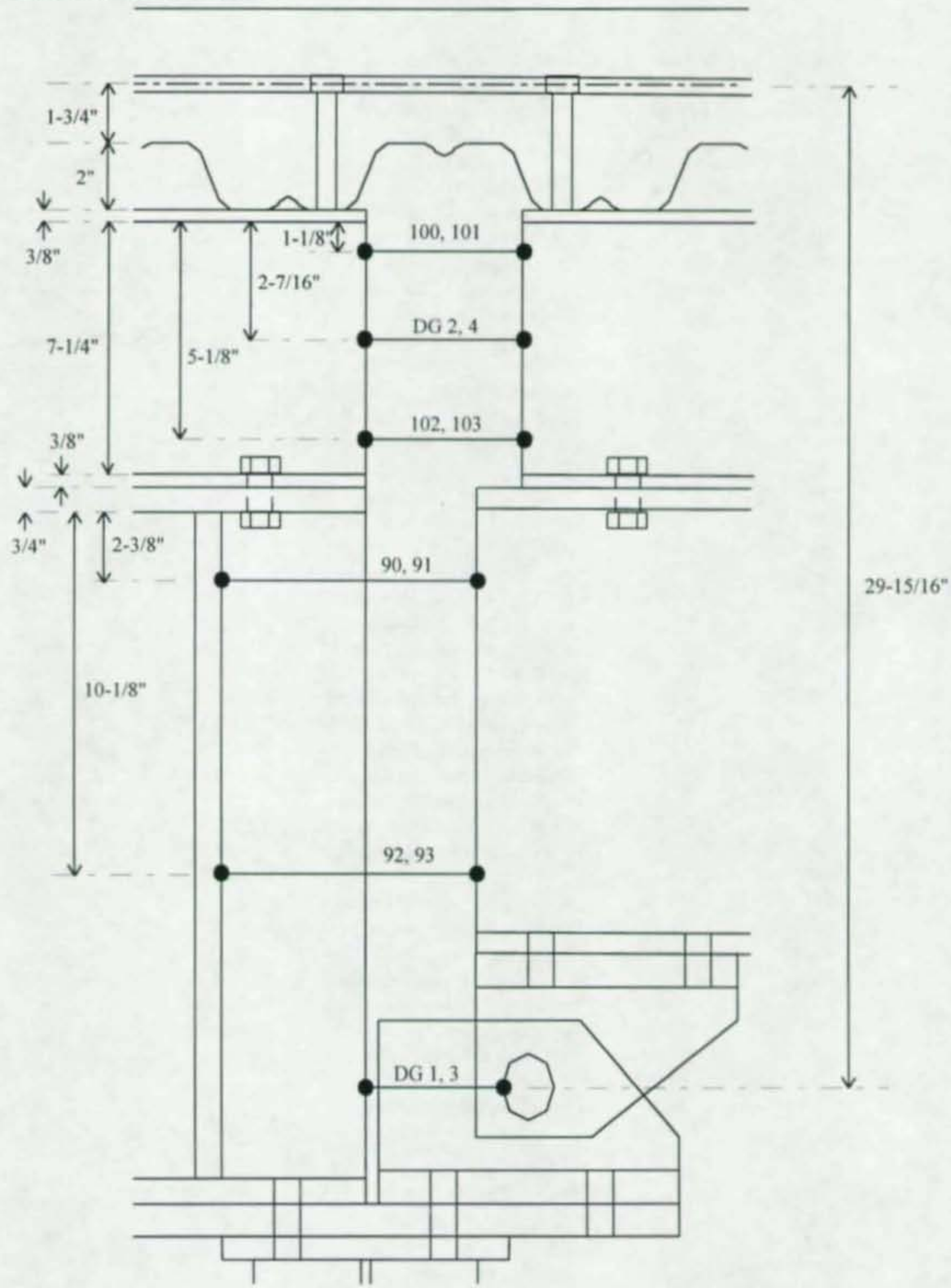
A typical data pack includes eight items:

1. Instrumentation Diagram Part A: This figure shows the overall setup for the particular test and some of the instrumentation.
2. Instrumentation Diagram Part B: This figure shows a close up of the instrumentation used near the center of the test setup.
3. Description of Instrumentation: This table links each gage number (from the instrumentation diagrams) to a description of the instrument and the particulars about the instrument.
4. Raw Data: This table presents the raw data from each instrument.
5. Test Comments: This table presents any comments that were noted during the test.
6. Data Calculations: This table presents the methods by which the raw data was manipulated to derive the calculated data.
7. Calculated Data: This table presents the calculated data of interest based on the raw data.
8. Plots: Plots showing Composite Slab Load vs. Deformation as well as Load Vs. Stud Slip are presented here

Instrumentation Diagram Part A



Instrumentation Diagram Part B



Composite Slab Axial Stiffness Tests
Test Summary

Description of Instrumentation

Gage No. Also Channel No.	Sense of Extension	Description of Measurement	Gage Type	Sensitivity	Full Scale
0	-**	Fixed Beam Rotation	ST2	1.0901	10"
1	+	Fixed Beam Rotation	ST3	1.0931	10"
2	Compression (-)	Load cell	Load Cell	1.99	500 kips
12	+	Rebar 1-1-1 Far Side	Strain Gage	4.9751 lbs/μ strain	
13	+	Rebar 1-1-2 Far Side	Strain Gage		
14	+	Rebar 1-2-1 Far Side	Strain Gage	4.9173 lbs/μ strain	
15	+	Rebar 1-2-2 Far Side	Strain Gage		
16	+	Rebar 1-3-1 Near Side	Strain Gage	5.0335 lbs/μ strain	
17	+	Rebar 1-3-2 Near Side	Strain Gage		
18	+	Rebar 1-4-1 Near Side	Strain Gage	5.2003 lbs/μ strain	
19	+	Rebar 1-4-2 Near Side	Strain Gage		
80	-**	Stud Slip Fixed Side Location G	POT		6"
81	-**	Stud Slip Free Side Location G	POT		6"
82	-**	Stud Slip Fixed Side Location E	POT		6"
83	-**	Stud Slip Free Side Location E	POT		6"
84	-**	Stud Slip Fixed Side Location C	POT		6"
85	-**	Stud Slip Free Side Location C	POT		6"
86	-**	Stud Slip Fix Side Location B	POT		6"
87	-**	Stud Slip Free Side Location B	POT		6"
88	-**	Stud Slip Fix Side Location A	POT		6"
89	-**	Stud Slip Free Side Location A	POT		6"
90	+	Frame Rotation Top Near	DCDT 10	0.94	10"
91	+	Frame Rotation Top Far	DCDT 1	0.934	10"
92	+	Frame Rotation Bottom Near	DCDT 11	0.845	10"
93	-**	Frame Rotation Bottom Far	DCDT 6	0.942	10"
94	+	Lateral Displacement At Loading Point	DCDT 4	0.471	10"
95	+	Free Beam Vertical Displacement	DCDT 9	0.701	15"
96	+	Free Beam Vertical Displacement	DCDT 8	0.947	10"
97	+	Free Beam Vertical Displacement	DCDT 3	0.47	10"
98	-**	Below Pin Vertical Displacement	POT		6"
100	-**	Test Beam Rotation Top Near	POT		6"
101	-**	Test Beam Rotation Top Far	POT		6"
102	-**	Test Beam Rotation Bottom Near	POT		6"
103	-**	Test Beam Rotation Bottom Far	POT		6"
DG1	-**	Near Pin Horizontal Displacement	Dial Gage		1"
DG2	-**	Test Beam Rotation Near Middle	Dial Gage		1"
DG3	-**	Far Pin Horizontal Displacement	Dial Gage		1"
DG4	-**	Test Beam Rotation Far Middle	Dial Gage		1"

** All data has been modified so that (+) readings indicate extension.

Composite Slab Axial Stiffness Tests
Test Summary

Slab #1

Raw Data

Channel	0	1	2	12	13	14	15	16	17	18
	(in.)	(in.)	(kips)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)
Point										
253	0.005	-0.005	-0.13	0	-1	-1	-1	-1	-1	0
254	0.000	-0.005	0.00	-1	-13	-21	-1	-1	-30	-18
255	-0.018	-0.005	-3.39	402	327	344	561	460	295	369
256	-0.014	-0.005	0.00	335	265	283	474	386	238	310
257	-0.018	-0.005	-4.15	483	397	418	674	558	360	446
258	-0.018	0.000	-4.15	563	464	489	797	710	440	554
259	-0.018	0.000	-4.52	679	565	592	975	851	504	660
260	-0.028	0.000	-6.78	776	643	687	1135	969	569	741
261	-0.028	-0.005	-7.91	838	699	752	1246	1063	640	803
262	-0.028	-0.005	-8.54	862	718	775	1291	1139	702	849
263	-0.028	-0.005	-9.92	928	776	835	1390	1274	819	944
264	-0.028	-0.005	-11.31	1033	868	958	1591	1546	1080	1188
265	-0.037	0.000	-13.69	1143	989	1098	1792	1763	1275	1354
266	-0.032	-0.005	-16.71	1214	1145	1296	2028	1991	1513	1546
267	-0.032	-0.005	-18.34	1223	1226	1433	2174	2095	1624	1629
268	-0.032	-0.005	-19.97	1131	1342	1662	2307	2202	1743	1732
269	-0.041	-0.005	-21.36	1135	1461	1979	2320	2303	1880	1866
270	-0.037	-0.005	-23.87	1216	1615	2348	2283	2441	2110	2098
271	-0.041	-0.005	-25.63	1280	1767	2449	2744	2563	2439	2334
272	-0.041	-0.005	-27.89	1164	1988	7143	831	1174	1515	2594
273	-0.041	-0.005	-29.77	1043	2157	7300	668	721	1264	2585
274	-0.050	0.000	-31.53	-135	1484	1542	669	499	1425	7114
275	-0.050	0.000	-33.04	-185	1580	1316	632	503	1461	11151
276	-0.050	-0.005	-35.30	-279	1639	972	546	496	1529	11926
277	-0.050	-0.005	-37.31	-305	1510	954	376	503	1719	12751
278	-0.046	-0.005	-38.82	-299	1467	919	211	451	1894	13040
279	-0.050	0.000	-40.08	-315	1685	938	99	385	1924	13868
280	-0.055	0.000	-41.58	-334	2074	1051	29	370	2099	5006
281	-0.055	-0.005	-41.33	-368	2024	1050	-5	380	2385	4767
282	-0.055	-0.005	-40.83	-363	2030	995	-5	364	2400	4703
283	-0.060	0.000	-39.07	-359	2027	893	58	355	2268	4635
284	-0.055	-0.005	-37.69	-350	2002	821	89	385	2301	4566
285	-0.055	-0.005	-35.80	-342	1940	888	115	383	2338	4517
286	-0.055	-0.005	-34.17	-329	1882	927	150	377	2364	4507
287	-0.055	-0.005	-32.79	-312	1840	939	162	369	2389	4539
288	-0.055	0.000	-31.28	-293	1764	950	175	349	2367	4514
289	-0.055	-0.005	-28.77	-262	1638	1012	168	292	2280	4463
290	-0.055	-0.005	-27.89	-230	1591	1093	196	274	2278	4509
291	-0.055	-0.005	-24.62	-207	1380	1121	93	255	2078	4379
292	-0.055	-0.005	-23.49	-192	1292	1062	167	254	2006	4364
293	-0.050	-0.005	-22.99	-178	1243	872	225	264	1941	4328
294	-0.055	-0.005	-22.61	-165	1233	888	266	381	1979	4137
295	-0.060	0.000	-22.24	-157	1230	880	297	332	2055	4115
296	-0.032	-0.032	-0.25	-93	-115	823	-978	278	86	3479

Composite Slab Axial Stiffness Tests
Test Summary

Raw Data

Channel	19	80	81	82	83	84	85	86	87	88
	(μ strain)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)
Point										
253	0	0.000	0.000	0.000	0.000	-0.001	-0.001	0.000	0.000	0.000
254	-4	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	0.000
255	432	0.001	0.000	0.001	0.000	0.000	0.002	0.000	0.002	0.000
256	367	0.001	0.000	0.001	0.000	0.000	0.001	0.000	0.001	0.000
257	519	0.002	0.000	0.001	0.000	0.001	0.002	0.000	0.002	0.000
258	635	0.002	-0.002	0.002	0.000	0.001	0.003	0.000	0.002	0.000
259	752	0.002	-0.004	0.002	0.001	0.001	0.003	0.000	0.003	0.000
260	841	0.002	-0.005	0.002	0.001	0.001	0.004	0.000	0.004	0.000
261	916	0.002	-0.005	0.002	0.001	0.001	0.004	0.000	0.003	0.000
262	973	0.002	-0.006	0.002	0.001	0.001	0.004	0.000	0.004	0.000
263	1081	0.002	-0.006	0.002	0.002	0.001	0.004	0.000	0.004	0.000
264	1372	0.003	-0.006	0.002	0.002	0.002	0.005	0.000	0.004	0.000
265	1559	0.003	-0.006	0.003	0.002	0.002	0.005	0.001	0.006	0.000
266	1758	0.004	-0.006	0.004	0.002	0.003	0.007	0.001	0.007	0.000
267	1833	0.004	-0.006	0.004	0.002	0.004	0.007	0.001	0.007	0.000
268	1912	0.005	-0.006	0.005	0.002	0.004	0.008	0.002	0.009	0.001
269	1985	0.006	-0.006	0.006	0.002	0.005	0.009	0.002	0.010	0.001
270	2047	0.007	-0.006	0.006	0.002	0.006	0.010	0.004	0.010	0.002
271	2067	0.007	-0.006	0.007	0.001	0.007	0.011	0.005	0.012	0.002
272	2140	0.009	-0.006	0.009	0.001	0.009	0.012	0.007	0.013	0.004
273	2157	0.010	-0.006	0.010	0.001	0.011	0.013	0.009	0.015	0.005
274	3467	0.012	-0.005	0.012	0.001	0.013	0.015	0.012	0.017	0.006
275	2288	0.016	-0.004	0.018	0.001	0.019	0.017	0.018	0.018	0.008
276	1943	0.022	-0.002	0.023	0.001	0.025	0.020	0.024	0.021	0.008
277	1862	0.027	0.000	0.028	0.001	0.030	0.022	0.029	0.023	0.009
278	1772	0.034	0.004	0.036	0.005	0.037	0.026	0.037	0.026	0.010
279	1712	0.045	0.013	0.045	0.017	0.047	0.036	0.048	0.037	0.011
280	*1665*	*0.060*	*0.038*	*0.060*	*0.042*	*0.065*	*0.061*	*0.065*	*0.057*	*0.013*
281	1518	0.071	0.093	0.069	0.096	0.074	0.121	0.076	0.109	0.015
282	1405	0.073	0.148	0.070	0.144	0.077	0.181	0.078	0.163	0.015
283	1375	0.073	0.221	0.072	0.208	0.079	0.258	0.079	0.229	0.016
284	1346	0.073	0.294	0.072	0.268	0.078	0.336	0.079	0.308	0.016
285	1327	0.073	0.367	0.072	0.329	0.078	0.413	0.080	0.382	0.016
286	1311	0.073	0.449	0.072	0.403	0.077	0.499	0.079	0.469	0.016
287	1306	0.073	0.537	0.072	0.484	0.077	0.593	0.079	0.563	0.016
288	1296	0.073	0.615	0.072	0.555	0.077	0.676	0.079	0.647	0.016
289	1289	0.073	0.749	0.072	0.683	0.076	0.822	0.078	0.793	0.016
290	1288	0.072	0.898	0.072	0.821	0.076	0.958	0.078	0.961	0.015
291	1277	0.070	1.061	0.072	0.989	0.074	1.112	0.077	1.153	0.015
292	1274	0.070	1.211	0.072	1.147	0.074	1.251	0.076	1.330	0.015
293	1273	0.068	1.350	0.072	1.296	0.074	1.380	0.076	1.492	0.016
294	1253	0.068	1.503	0.072	1.455	0.074	1.534	0.076	1.658	0.016
295	1247	0.068	1.655	0.072	1.614	0.074	1.685	0.076	1.829	0.016
296	1136	0.051	1.589	0.055	1.521	0.054	1.674	0.057	1.742	0.012

01269

Composite Slab Axial Stiffness Tests
Test Summary

Slab #1

Raw Data

Channel	89	90	91	92	93	94	95	96	97	98
	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)
Point										
253	0.000	0.001	0.001	0.001	0.002	0.002	0.000	0.000	0.000	0.000
254	0.000	-0.010	-0.008	-0.018	-0.013	0.004	-0.094	-0.049	-0.015	-0.002
255	0.003	-0.051	-0.055	-0.099	-0.082	-0.024	-0.464	-0.274	-0.114	-0.011
256	0.002	-0.051	-0.053	-0.097	-0.080	-0.024	-0.399	-0.231	-0.101	-0.006
257	0.004	-0.062	-0.065	-0.119	-0.099	-0.032	-0.551	-0.325	-0.135	-0.014
258	0.005	-0.089	-0.093	-0.168	-0.144	-0.043	-0.752	-0.442	-0.176	-0.012
259	0.005	-0.116	-0.121	-0.214	-0.186	-0.037	-0.948	-0.556	-0.227	-0.012
260	0.006	-0.132	-0.139	-0.246	-0.213	-0.037	-1.100	-0.650	-0.261	-0.014
261	0.006	-0.144	-0.152	-0.269	-0.232	-0.043	-1.216	-0.714	-0.289	-0.014
262	0.006	-0.151	-0.159	-0.284	-0.243	-0.045	-1.279	-0.753	-0.302	-0.013
263	0.006	-0.160	-0.168	-0.297	-0.258	-0.045	-1.371	-0.805	-0.323	-0.012
264	0.007	-0.169	-0.178	-0.316	-0.276	-0.045	-1.480	-0.870	-0.345	-0.009
265	0.008	-0.178	-0.184	-0.333	-0.289	-0.043	-1.593	-0.936	-0.375	-0.007
266	0.010	-0.180	-0.190	-0.346	-0.300	-0.045	-1.708	-1.005	-0.396	-0.006
267	0.010	-0.180	-0.191	-0.351	-0.304	-0.043	-1.776	-1.043	-0.409	-0.005
268	0.012	-0.181	-0.192	-0.357	-0.307	-0.052	-1.857	-1.089	-0.424	-0.004
269	0.013	-0.180	-0.191	-0.362	-0.310	-0.058	-1.946	-1.138	-0.445	-0.001
270	0.015	-0.178	-0.189	-0.363	-0.314	-0.065	-2.037	-1.194	-0.465	0.001
271	0.015	-0.176	-0.186	-0.367	-0.316	-0.067	-2.118	-1.243	-0.480	0.002
272	0.016	-0.173	-0.183	-0.372	-0.318	-0.071	-2.205	-1.297	-0.501	0.006
273	0.018	-0.169	-0.181	-0.375	-0.321	-0.078	-2.295	-1.351	-0.520	0.009
274	0.020	-0.165	-0.176	-0.379	-0.323	-0.078	-2.401	-1.410	-0.542	0.012
275	0.020	-0.154	-0.166	-0.380	-0.324	-0.084	-2.515	-1.480	-0.570	0.015
276	0.022	-0.144	-0.155	-0.380	-0.324	-0.086	-2.663	-1.564	-0.598	0.017
277	0.023	-0.135	-0.145	-0.380	-0.324	-0.091	-2.791	-1.643	-0.632	0.019
278	0.025	-0.120	-0.131	-0.379	-0.321	-0.097	-2.944	-1.729	-0.666	0.021
279	0.037	-0.100	-0.109	-0.373	-0.315	-0.099	-3.138	-1.842	-0.709	0.023
280	0.062	-0.062	-0.072	-0.357	-0.301	-0.106	-3.441	-2.020	-0.777	0.028
281	0.095	-0.011	-0.021	-0.332	-0.277	-0.112	-3.805	-2.230	-0.861	0.030
282	0.138	0.025	0.017	-0.310	-0.260	-0.112	-4.040	-2.368	-0.912	0.032
283	0.191	0.066	0.059	-0.288	-0.238	-0.112	-4.293	-2.519	-0.972	0.032
284	0.242	0.109	0.103	-0.264	-0.217	-0.112	-4.539	-2.663	-1.028	0.032
285	0.291	0.148	0.143	-0.240	-0.197	-0.119	-4.766	-2.798	-1.084	0.032
286	0.345	0.192	0.190	-0.215	-0.173	-0.119	-5.036	-2.956	-1.148	0.032
287	0.401	0.241	0.240	-0.186	-0.147	-0.119	-5.337	-3.133	-1.225	0.032
288	0.447	0.285	0.286	-0.161	-0.124	-0.119	-5.587	-3.281	-1.279	0.031
289	0.515	0.359	0.361	-0.119	-0.084	-0.112	-6.021	-3.538	-1.384	0.029
290	0.530	0.445	0.443	-0.072	-0.044	-0.086	-6.526	-3.842	-1.501	0.028
291	0.488	0.536	0.535	-0.018	0.003	-0.058	-7.041	-4.148	-1.628	0.027
292	0.477	0.618	0.617	0.029	0.044	-0.032	-7.542	-4.445	-1.752	0.026
293	0.468	0.693	0.693	0.071	0.082	-0.004	-8.015	-4.722	-1.863	0.026
294	0.482	0.775	0.773	0.117	0.122	0.022	-8.533	-4.752	-1.981	0.027
295	0.537	0.858	0.858	0.161	0.162	0.054	-9.054	-4.752	-2.107	0.028
296	0.536	0.809	0.822	0.191	0.191	-0.052	-7.949	-4.677	-1.863	0.018

Raw Data

Channel	100	101	102	103	DG1	DG2	DG3	DG4
	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)
Point								
253	0.000	0.000	0.000	0.000	-	-	-	-
254	-0.002	-0.003	-0.007	-0.007	-	-	-	-
255	-0.012	-0.017	-0.036	-0.038	-0.102	-0.024	-0.076	-0.027
256	-0.012	-0.016	-0.032	-0.035	-0.097	-0.025	-0.070	-0.025
257	-0.015	-0.019	-0.043	-0.045	-0.120	-0.030	-0.090	-0.033
258	-0.021	-0.026	-0.060	-0.063	-0.169	-0.041	-0.129	-0.043
259	-0.027	-0.032	-0.076	-0.080	-0.188	-0.053	-0.152	-0.054
260	-0.032	-0.036	-0.087	-0.089	-0.201	-0.060	-0.178	-0.061
261	-0.034	-0.038	-0.093	-0.097	-0.216	-0.066	-0.203	-0.065
262	-0.035	-0.039	-0.098	-0.101	-0.226	-0.070	-0.218	-0.068
263	-0.036	-0.040	-0.102	-0.106	-0.239	-0.073	-0.237	-0.070
264	-0.037	-0.041	-0.108	-0.112	-0.259	-0.075	-0.260	-0.074
265	-0.036	-0.041	-0.112	-0.116	-0.275	-0.077	-0.278	-0.078
266	-0.035	-0.040	-0.115	-0.119	-0.287	-0.077	-0.292	-0.080
267	-0.035	-0.039	-0.116	-0.121	-0.292	-0.077	-0.297	-0.080
268	-0.034	-0.037	-0.117	-0.123	-0.299	-0.076	-0.304	-0.080
269	-0.032	-0.034	-0.118	-0.124	-0.304	-0.076	-0.309	-0.080
270	-0.029	-0.032	-0.120	-0.125	-0.310	-0.075	-0.315	-0.079
271	-0.026	-0.029	-0.120	-0.125	-0.315	-0.074	-0.321	-0.078
272	-0.021	-0.024	-0.119	-0.123	-0.321	-0.070	-0.326	-0.075
273	-0.015	-0.018	-0.117	-0.121	-0.326	-0.066	-0.332	-0.071
274	-0.005	-0.009	-0.113	-0.116	-0.332	-0.057	-0.338	-0.065
275	0.009	0.006	-0.104	-0.106	-0.337	-0.046	-0.344	-0.052
276	0.027	0.026	-0.090	-0.093	-0.343	-0.029	-0.350	-0.036
277	0.046	0.043	-0.078	-0.081	-0.348	-0.013	-0.355	-0.021
278	0.070	0.067	-0.061	-0.066	-0.353	0.007	-0.359	0.001
279	0.105	0.103	-0.035	-0.039	-0.357	0.038	-0.364	0.031
280	0.167	0.165	0.014	0.009	-0.362	0.094	-0.370	0.085
281	0.252	0.251	0.082	0.074	-0.366	0.173	-0.374	0.159
282	0.312	0.312	0.129	0.121	-0.367	0.228	-0.375	0.212
283	0.383	0.381	0.184	0.177	-0.366	0.292	-0.376	0.275
284	0.451	0.449	0.238	0.230	-0.366	0.354	-0.376	0.335
285	0.517	0.516	0.290	0.281	-0.364	0.414	-0.376	0.394
286	0.592	0.591	0.350	0.339	-0.363	0.482	-0.376	0.461
287	0.674	0.673	0.415	0.406	-0.361	0.556	-0.376	0.534
288	0.744	0.746	0.471	0.460	-0.360	0.620	-0.376	0.598
289	0.867	0.868	0.567	0.555	-0.356	0.732	-0.376	0.707
290	1.000	1.004	0.676	0.662	-0.355	-	-0.376	-
291	1.149	1.153	0.793	0.778	-0.350	-	-0.376	-
292	1.281	1.286	0.900	0.883	-0.349	-	-0.376	-
293	1.384	1.412	0.997	0.982	-0.348	-	-0.376	-
294	1.488	1.547	1.104	1.087	-0.348	-	-0.376	-
295	1.624	1.684	1.212	1.193	-	-	-	-
296	1.505	1.564	1.138	1.117	-	-	-	-

01270

Composite Slab Axial Stiffness Tests
Test Summary

Slab #1

Test Notes

Data Point	Test Comment
253	Instrumentation zeroed while rotation beam on temporary support.
254	Temporary support removed.
255	Preload, Note that this took many attempts because of problems with load cell wiring, this may have a softening effect on initial test data.
256	Remove preload
257	Start test loading
296	End test, because of excessive stud deformations.

Composite Slab Axial Stiffness Tests **Slab #1**
Test Summary

Data Calculations

Rotation Calculations

Method

1 $\theta = \dfrac{\text{Average (90,91) - Average (92,93)}}{10.125 - 2.375}$

2 $\theta = \dfrac{\text{Average (100,101) - Average (102,103)}}{5.125 - 1.125}$

3 $\theta = \dfrac{\text{Average (DG2, DG4) - Average (102,103)}}{5.125 - 2.4375}$

4 $\theta = \theta_{\text{Free Beam}} - \theta_{\text{Fixed Beam}}$

Where: $\theta_{\text{Fixed Beam}} = \dfrac{(1) - (0)}{28}$

a $\theta_{\text{Free Beam}} = \dfrac{(97) - (96)}{58.875 - 24.25}$

b $\theta_{\text{Free Beam}} = \dfrac{(97) - (95)}{95.875 - 24.25}$

c $\theta_{\text{Free Beam}} = \dfrac{(96) - (95)}{95.875 - 57.875}$

Slab Deformation Calculations

Method

1 $\Delta = \text{Average (102,103)} + 9.25\,\theta$

2 $\Delta = \text{Average (DG2,DG4)} + 6.5625\,\theta$

3 $\Delta = \text{Average (100,101)} + 5.25\,\theta$

Slab Load Calculations

$$P = \frac{(2)\,53}{29.9375} + 2.37$$

Note: Numbers enclosed in parenthesis, i.e. (2), correspond to gage numbers.

01271

Composite Slab Axial Stiffness Tests
Test Summary

Slab #1

Calculated Data

Data Point	Load @ Centerline of Reinforcing Steel (Kips)	Rebar #1 Axial Force (kips)	Rebar #2 Axial Force (kips)	Rebar #3 Axial Force (kips)	Rebar #4 Axial Force (kips)	Rebar Total Axial Force (kips)	Rotation 1 (rad)	Rotation 2 (rad)
253	0.22	0.00	0.00	0.00	0.00	-0.01	-0.0001	0.0000
254	2.37	-0.04	-0.05	-0.08	-0.06	-0.23	0.0009	0.0010
255	8.37	1.81	2.22	1.90	2.08	8.02	0.0049	0.0057
256	2.37	1.49	1.86	1.57	1.76	6.68	0.0047	0.0048
257	9.71	2.19	2.69	2.31	2.51	9.69	0.0059	0.0067
258	9.71	2.55	3.16	2.89	3.09	11.70	0.0084	0.0095
259	10.38	3.10	3.85	3.41	3.67	14.03	0.0105	0.0120
260	14.38	3.53	4.48	3.87	4.12	16.00	0.0121	0.0136
261	16.38	3.82	4.91	4.29	4.47	17.50	0.0133	0.0148
262	17.49	3.93	5.08	4.63	4.74	18.38	0.0140	0.0157
263	19.94	4.24	5.47	5.27	5.27	20.24	0.0147	0.0165
264	22.39	4.73	6.27	6.61	6.66	24.26	0.0158	0.0177
265	26.61	5.31	7.11	7.65	7.57	27.63	0.0167	0.0189
266	31.95	5.87	8.17	8.82	8.59	31.45	0.0178	0.0199
267	34.84	6.09	8.87	9.36	9.00	33.32	0.0183	0.0204
268	37.73	6.15	9.76	9.93	9.47	35.31	0.0188	0.0212
269	40.18	6.46	10.57	10.53	10.01	37.57	0.0194	0.0219
270	44.63	-	-	-	-	-	0.0200	0.0230
271	47.74	-	-	-	-	-	0.0207	0.0237
272	51.74	-	-	-	-	-	0.0215	0.0246
273	55.08	-	-	-	-	-	0.0223	0.0256
274	58.19	-	-	-	-	-	0.0233	0.0268
275	60.86	-	-	-	-	-	0.0248	0.0280
276	64.87	-	-	-	-	-	0.0261	0.0296
277	68.42	-	-	-	-	-	0.0274	0.0309
278	71.09	-	-	-	-	-	0.0289	0.0330
279	73.32	-	-	-	-	-	0.0309	0.0352
280	75.99	-	-	-	-	-	0.0338	0.0387
281	75.54	-	-	-	-	-	0.0372	0.0434
282	74.65	-	-	-	-	-	0.0395	0.0467
283	71.54	-	-	-	-	-	0.0420	0.0503
284	69.09	-	-	-	-	-	0.0447	0.0541
285	65.76	-	-	-	-	-	0.0469	0.0577
286	62.86	-	-	-	-	-	0.0497	0.0617
287	60.42	-	-	-	-	-	0.0525	0.0658
288	57.75	-	-	-	-	-	0.0552	0.0699
289	53.30	-	-	-	-	-	0.0596	0.0765
290	51.74	-	-	-	-	-	0.0648	0.0832
291	45.96	-	-	-	-	-	0.0700	0.0913
292	43.96	-	-	-	-	-	0.0750	0.0980
293	43.07	-	-	-	-	-	0.0795	0.1021
294	42.40	-	-	-	-	-	0.0844	0.1054
295	41.74	-	-	-	-	-	0.0899	0.1128
296	2.81	-	-	-	-	-	0.0806	0.1017

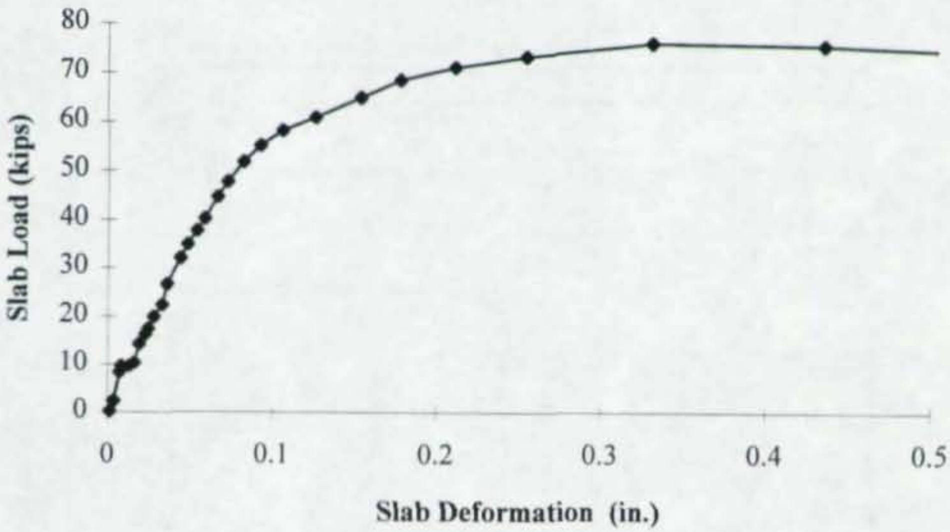
Calculate

Data Point	Rotation 3 (rad)	Rotation 4a (rad)	Rotation 4b (rad)	Rotation 4c (rad)	Rotation Average (rad)	Δ Slab 1 (in.)	Δ Slab 2 (in.)	Δ Slab 3 (in.)	Δ Slab Average (in.)
253	-	0.0003	0.0003	0.0003	0.0002	0.002	-	0.001	0.001
254	-	0.0012	0.0013	0.0013	0.0011	0.004	-	0.003	0.003
255	0.0043	0.0043	0.0044	0.0045	0.0047	0.006	0.005	0.010	0.007
256	0.0031	0.0036	0.0038	0.0041	0.0040	0.004	0.001	0.007	0.004
257	0.0047	0.0052	0.0053	0.0055	0.0056	0.007	0.005	0.012	0.008
258	0.0072	0.0073	0.0074	0.0075	0.0079	0.012	0.010	0.018	0.013
259	0.0091	0.0091	0.0094	0.0097	0.0100	0.014	0.012	0.022	0.016
260	0.0102	0.0106	0.0107	0.0109	0.0114	0.017	0.014	0.026	0.019
261	0.0110	0.0118	0.0121	0.0124	0.0126	0.021	0.017	0.030	0.023
262	0.0114	0.0126	0.0128	0.0130	0.0132	0.023	0.018	0.033	0.024
263	0.0122	0.0135	0.0138	0.0141	0.0141	0.026	0.021	0.036	0.028
264	0.0131	0.0148	0.0150	0.0152	0.0153	0.032	0.026	0.041	0.033
265	0.0136	0.0154	0.0157	0.0160	0.0160	0.034	0.028	0.046	0.036
266	0.0145	0.0171	0.0173	0.0175	0.0174	0.043	0.035	0.054	0.044
267	0.0149	0.0179	0.0181	0.0183	0.0180	0.048	0.040	0.057	0.048
268	0.0156	0.0188	0.0190	0.0192	0.0188	0.054	0.045	0.063	0.054
269	0.0159	0.0193	0.0196	0.0199	0.0194	0.058	0.049	0.069	0.059
270	0.0168	0.0205	0.0208	0.0210	0.0204	0.066	0.057	0.077	0.067
271	0.0173	0.0214	0.0216	0.0217	0.0211	0.072	0.062	0.083	0.072
272	0.0181	0.0224	0.0225	0.0226	0.0219	0.082	0.071	0.093	0.082
273	0.0188	0.0234	0.0235	0.0235	0.0228	0.092	0.081	0.103	0.092
274	0.0199	0.0240	0.0242	0.0243	0.0238	0.105	0.095	0.117	0.106
275	0.0208	0.0253	0.0254	0.0254	0.0249	0.126	0.115	0.138	0.126
276	0.0220	0.0271	0.0272	0.0273	0.0266	0.154	0.142	0.166	0.154
277	*0.0232*	*0.0284*	*0.0285*	*0.0286*	*0.0279*	*0.178*	*0.166*	*0.191*	*0.178*
278	0.0250	0.0301	0.0303	0.0305	0.0297	0.211	0.199	0.224	0.211
279	0.0265	0.0319	0.0321	0.0323	0.0315	0.254	0.241	0.269	0.255
280	0.0291	0.0350	0.0352	0.0354	0.0345	0.331	0.316	0.347	0.331
281	0.0328	0.0389	0.0393	0.0396	0.0385	0.434	0.419	0.454	0.436
282	0.0354	0.0415	0.0419	0.0422	0.0412	0.506	0.490	0.528	0.508
283	0.0383	0.0439	0.0442	0.0445	0.0439	0.586	0.571	0.612	0.590
284	0.0411	0.0468	0.0472	0.0476	0.0469	0.668	0.652	0.697	0.672
285	0.0441	0.0492	0.0496	0.0500	0.0496	0.744	0.729	0.777	0.750
286	0.0472	0.0520	0.0525	0.0529	0.0527	0.832	0.817	0.868	0.839
287	0.0501	0.0549	0.0556	0.0562	0.0558	0.927	0.911	0.967	0.935
288	0.0534	0.0576	0.0582	0.0587	0.0588	1.010	0.995	1.054	1.020
289	0.0589	0.0623	0.0629	0.0635	0.0640	1.153	1.139	1.203	1.165
290	-	0.0678	0.0684	0.0689	0.0706	1.322	-	1.373	1.347
291	-	0.0732	0.0738	0.0743	0.0765	1.493	-	1.552	1.523
292	-	0.0783	0.0790	0.0797	0.0820	1.650	-	1.714	1.682
293	-	0.0834	0.0842	0.0850	0.0869	1.793	-	1.854	1.823
294	-	0.0806	0.0897	0.0977	0.0916	1.943	-	1.998	1.970
295	-	0.0765	0.0949	0.1111	0.0970	2.100	-	2.163	2.132
296	-	0.0837	0.0850	0.0861	0.0874	1.936	-	1.993	1.965

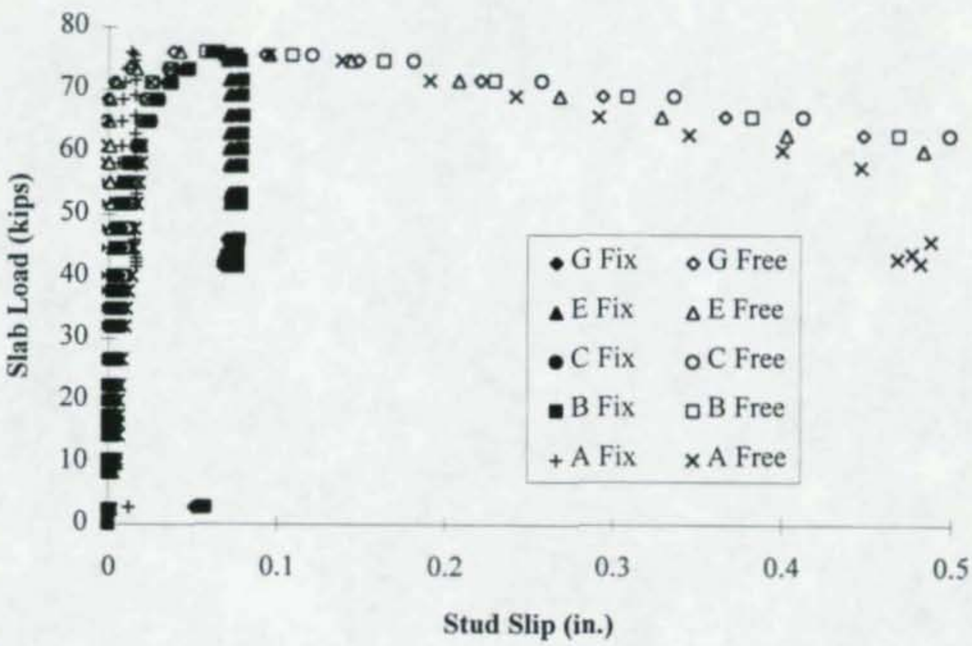
01272

Composite Slab Axial Stiffness Tests **Slab #1**
Test Summary

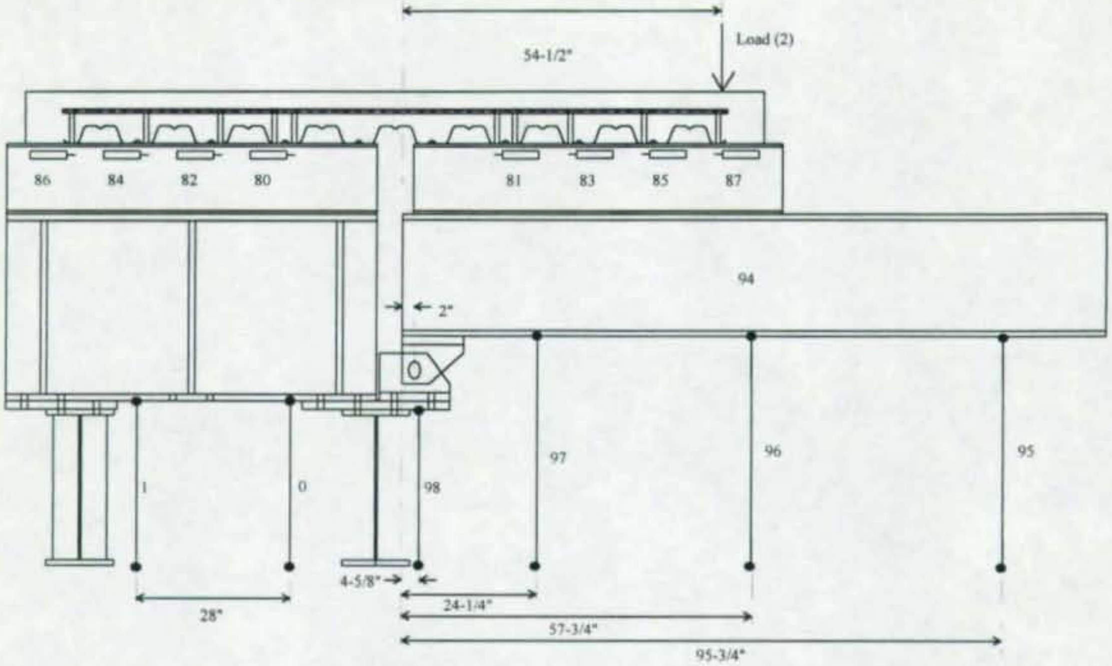
Composite Slab Load Vs. Deformation



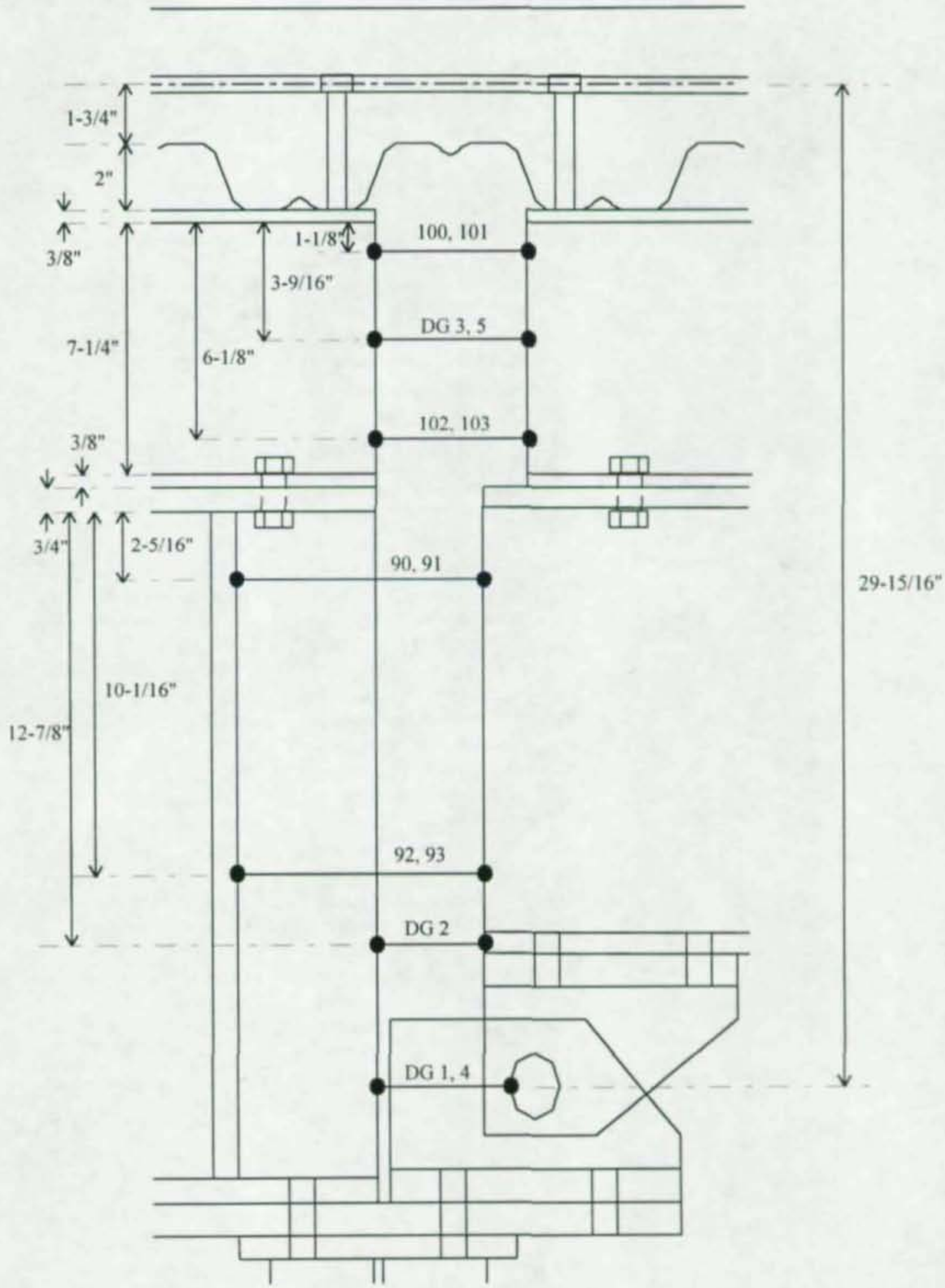
Load Vs. Stud Slip



Instrumentation Diagram Part A



Instrumentation Diagram Part B



Composite Slab Axial Stiffness Tests
Test Summary

Description of Instrumentation

Gage No. Also Channel No.	Sense of Extension	Description of Measurement	Gage Type	Sensitivity	Full Scale
0	-**	Fixed Beam Rotation	ST2	1.0901	10"
1	+	Fixed Beam Rotation	ST3	1.0931	10"
2	Compression (-)	Load cell	Load Cell	1.99	500 kips
12	+	Rebar 4-1-1 Far Side	Strain Gage	4.9189 lbs/μ strain	
13	+	Rebar 4-1-2 Far Side	Strain Gage		
14	+	Rebar 4-2-1 Far Side	Strain Gage	5.0624 lbs/μ strain	
15	+	Rebar 4-2-2 Far Side	Strain Gage		
16	+	Rebar 4-3-1 Near Side	Strain Gage	5.0049 lbs/μ strain	
17	+	Rebar 4-3-2 Near Side	Strain Gage		
18	+	Rebar 4-4-1 Near Side	Strain Gage	5.0381 lbs/μ strain	
19	+	Rebar 4-4-2 Near Side	Strain Gage		
80	-**	Stud Slip Fixed Side Location E	POT		6"
81	-**	Stud Slip Free Side Location E	POT		6"
82	-**	Stud Slip Fixed Side Location C	POT		6"
83	-**	Stud Slip Free Side Location C	POT		6"
84	-**	Stud Slip Fixed Side Location B	POT		6"
85	-**	Stud Slip Free Side Location B	POT		6"
86	-**	Stud Slip Fixed Side Location A	POT		6"
87	-**	Stud Slip Free Side Location A	POT		6"
90	+	Frame Rotation Top Near	DCDT 10	0.94	10"
91	+	Frame Rotation Top Far	DCDT 1	0.934	10"
92	+	Frame Rotation Bottom Near	DCDT 11	0.845	10"
93	+	Frame Rotation Bottom Far	DCDT 6	0.942	10"
94	+	Lateral Displacement At Loading Point	DCDT 4	0.471	10"
95	+	Free Beam Vertical Displacement	DCDT 9	0.701	15"
96	+	Free Beam Vertical Displacement	DCDT 8	0.947	10"
97	+	Free Beam Vertical Displacement	DCDT 3	0.47	10"
98	-**	Below Pin Vertical Displacement	POT		6"
100	-**	Test Beam Rotation Top Near	POT		6"
101	-**	Test Beam Rotation Top Far	POT		6"
102	-**	Test Beam Rotation Bottom Near	POT		6"
103	-**	Test Beam Rotation Bottom Far	POT		6"
DG 1	-**	Pin Near Horizontal Displacement	Dial Gage		1"
DG 2	-**	Frame Rotation Bottom Near	Dial Gage		1"
DG 3	-**	Test Beam Rotation Middle Near	Dial Gage		1"
DG 4	-**	Pin Far Horizontal Displacement	Dial Gage		1"
DG 5	-**	Test Beam Rotation Middle Far	Dial Gage		1"

** All data has been modified so that (+) readings indicate extension.

01274

Composite Slab Axial Stiffness Tests
Test Summary

Raw Data

Channel	0	1	2	12	13	14	15	16	17	18
	(in.)	(in.)	(kips)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)
Point										
206	0.005	0.000	0.00	0	0	-1	-1	0	-1	0
207	0.005	0.000	-0.13	13	13	14	9	21	15	8
208	0.005	0.000	-3.77	25	26	31	23	46	37	18
209	0.005	0.000	-0.13	14	15	16	12	27	19	10
210	0.000	0.000	-6.66	34	37	44	34	69	56	28
211	0.000	0.000	-7.66	42	46	72	74	113	92	39
212	0.000	0.000	-8.42	289	325	320	299	305	252	96
213	-0.009	0.000	-8.79	479	521	584	549	660	514	418
214	-0.005	-0.005	-10.05	539	600	691	646	779	602	499
215	-0.009	-0.005	-11.18	607	669	784	728	874	674	565
216	-0.014	0.000	-12.69	649	782	932	862	1016	780	665
217	-0.014	-0.005	-13.19	697	841	1016	936	1095	838	724
218	-0.014	0.000	-14.82	777	972	1189	1095	1265	967	848
219	-0.014	0.000	-15.70	798	1065	1306	1204	1389	1058	943
220	-0.014	-0.005	-16.83	829	1147	1393	1288	1489	1135	1020
221	-0.014	-0.005	-17.09	844	1208	1460	1349	1567	1189	1083
222	-0.014	0.000	-17.34	856	1288	1549	1428	1668	1264	1171
223	-0.014	0.000	-18.47	897	1386	1633	1510	1775	1354	1282
224	-0.023	0.000	-19.47	935	1480	1711	1583	1850	1420	1387
225	-0.023	0.000	-20.73	985	1567	1748	1643	1830	1420	1503
226	-0.023	0.000	-22.11	1024	1644	1809	1703	1883	1464	1567
227	-0.023	-0.005	-23.49	1071	1737	1874	1764	1951	1529	1680
228	-0.023	0.000	-24.25	1128	1843	1932	1839	2000	1603	1854
229	-0.023	0.005	-25.75	1223	2015	1982	1968	2090	1741	2177
230	-0.023	0.005	-26.51	1309	2139	1632	2029	2161	1828	2389
231	-0.023	0.005	-26.01	1436	2245	1238	1954	2226	1899	2422
232	-0.023	0.005	-27.39	1883	2469	1053	1933	2579	2179	3463
233	-0.023	0.005	-27.01	1941	2593	886	1952	3194	2254	6888
234	-0.032	0.005	-28.27	2025	2880	494	1610	1759	298	2719
235	-0.032	0.014	-29.52	408	1749	466	1451	1581	273	2187
236	-0.032	0.014	-32.54	302	1625	417	1432	1561	288	1961
237	-0.028	0.009	-34.67	286	1615	416	1408	1513	355	1777
238	-0.028	0.014	-36.31	264	1606	447	1280	1532	407	1631
239	-0.028	0.018	-38.19	273	1583	541	1233	1567	461	1616
240	-0.028	0.018	-38.57	313	1568	602	1124	1551	488	1594
241	-0.028	0.018	-37.81	314	1541	654	924	1499	446	1558
242	-0.028	0.018	-37.81	336	1510	702	850	1454	465	1537
243	-0.028	0.018	-37.19	337	1482	760	829	1398	449	1518
244	-0.028	0.018	-37.19	345	1459	750	770	1385	440	1502
245	-0.028	0.018	-36.31	288	1360	618	657	1354	428	1485
246	-0.028	0.018	-34.92	234	1388	613	672	1345	421	1467
247	-0.028	0.018	-33.17	291	1435	643	710	1364	493	1453
248	-0.028	0.018	-31.16	306	1448	705	720	1343	537	1431
249	-0.028	0.014	-29.65	334	1438	714	780	1339	549	1405
250	-0.028	0.018	-23.49	90	1215	556	657	1307	380	1349
251	-0.028	0.014	-18.34	-80	985	423	351	1304	277	1326
252	-0.028	0.005	-11.56	7	880	321	224	1284	235	1325

Composite Slab Axial Stiffness Tests
Test Summary

Raw Data

Channel	19	80	81	82	83	84	85	86	87	90
	(μ strain)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)
Point										
206	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
207	22	0.001	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	-0.009
208	43	0.001	-0.001	0.000	0.001	-0.001	0.001	0.000	0.000	-0.012
209	26	0.001	-0.001	0.000	0.001	-0.001	0.001	0.000	0.000	-0.012
210	63	0.001	-0.001	0.001	0.001	0.000	0.001	0.000	0.001	-0.014
211	83	0.001	0.000	0.001	0.001	0.000	0.002	0.000	0.001	-0.016
212	173	0.001	0.000	0.001	0.002	0.000	0.002	0.000	0.001	-0.018
213	708	0.002	0.000	0.002	0.002	0.000	0.002	0.000	0.001	-0.022
214	852	0.002	0.000	0.002	0.002	0.000	0.002	0.000	0.001	-0.023
215	968	0.002	0.000	0.002	0.002	0.000	0.002	0.000	0.002	-0.025
216	1146	0.002	0.000	0.002	0.002	0.001	0.002	0.001	0.003	-0.027
217	1252	0.002	0.000	0.003	0.002	0.001	0.002	0.001	0.003	-0.031
218	1456	0.004	0.001	0.004	0.002	0.002	0.003	0.001	0.004	-0.037
219	1616	0.004	0.001	0.004	0.003	0.002	0.004	0.002	0.006	-0.042
220	1743	0.004	0.001	0.004	0.004	0.002	0.004	0.002	0.006	-0.048
221	1849	0.004	0.001	0.005	0.004	0.003	0.005	0.002	0.006	-0.055
222	1978	0.004	0.001	0.006	0.004	0.004	0.005	0.002	0.007	-0.065
223	2095	0.005	0.001	0.006	0.004	0.004	0.005	0.002	0.007	-0.073
224	2164	0.005	0.002	0.006	0.004	0.004	0.005	0.003	0.007	-0.079
225	2176	0.006	0.003	0.008	0.008	0.005	0.008	0.004	0.010	-0.081
226	2246	0.006	0.004	0.008	0.009	0.006	0.009	0.004	0.011	-0.085
227	2301	0.007	0.005	0.010	0.009	0.007	0.009	0.004	0.012	-0.088
228	2325	0.009	0.006	0.010	0.010	0.008	0.010	0.004	0.013	-0.091
229	2333	0.010	0.007	0.013	0.011	0.011	0.011	0.005	0.015	-0.093
230	2321	0.013	0.008	0.015	0.012	0.013	0.012	0.007	0.015	-0.097
231	2314	0.015	0.009	0.018	0.013	0.016	0.013	0.007	0.017	-0.105
232	5117	0.017	0.010	0.021	0.013	0.019	0.015	0.007	0.017	-0.111
233	7327	0.018	0.010	0.023	0.014	0.020	0.015	0.007	0.018	-0.123
234	7311	0.022	0.012	0.028	0.015	0.026	0.017	0.008	0.020	-0.128
235	7150	0.024	0.021	0.031	0.025	0.029	0.029	0.009	0.022	-0.126
236	7284	0.026	0.026	0.033	0.032	0.032	0.036	0.010	0.023	-0.123
237	6625	0.034	0.032	0.041	0.041	0.040	0.046	0.012	0.024	-0.107
238	5147	0.045	0.048	0.056	0.061	0.056	0.068	0.019	0.024	-0.075
239	5134	0.056	0.064	0.069	0.081	0.068	0.089	0.024	0.026	-0.049
240	5027	0.068	0.090	0.085	0.111	0.082	0.124	0.028	0.026	-0.012
241	4971	0.106	0.098	0.137	0.119	0.130	0.135	0.037	0.027	0.026
242	4905	0.148	0.113	0.184	0.134	0.178	0.155	0.045	0.028	0.068
243	4794	0.175	0.140	0.214	0.160	0.208	0.188	0.050	0.029	0.105
244	4863	0.192	0.175	0.235	0.192	0.228	0.232	0.053	0.031	0.142
245	4825	0.214	0.205	0.265	0.221	0.259	0.267	0.056	0.032	0.183
246	4868	0.277	0.211	0.335	0.227	0.327	0.275	0.088	0.032	0.226
247	4905	0.416	0.213	0.486	0.228	0.474	0.277	0.150	0.032	0.309
248	4902	0.557	0.213	0.642	0.230	0.622	0.278	0.177	0.032	0.391
249	4903	0.699	0.213	0.801	0.230	0.775	0.278	0.198	0.032	0.476
250	4697	0.898	0.213	1.014	0.228	0.971	0.275	0.239	0.032	0.577
251	4445	1.107	0.213	1.208	0.225	1.160	0.272	0.272	0.032	0.665
252	4240	1.359	0.210	1.456	0.219	1.413	0.264	0.328	0.031	0.780

Composite Slab Axial Stiffness Tests
Test Summary

Slab #2

<u>Raw Data</u>

Channel	91	92	93	94	95	96	97	98	100	101
	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)
Point										
206	0.000	0.002	0.001	0.002	-0.002	0.001	0.002	0.001	0.000	0.000
207	-0.009	-0.008	-0.019	0.015	-0.089	-0.047	-0.013	-0.002	-0.002	-0.003
208	-0.014	-0.029	-0.026	0.015	-0.166	-0.099	-0.041	-0.007	-0.003	-0.004
209	-0.014	-0.021	-0.025	0.015	-0.109	-0.062	-0.026	-0.002	-0.003	-0.004
210	-0.017	-0.033	-0.032	0.006	-0.231	-0.141	-0.062	-0.010	-0.004	-0.004
211	-0.020	-0.033	-0.036	0.009	-0.259	-0.155	-0.071	-0.011	-0.004	-0.004
212	-0.022	-0.041	-0.040	0.006	-0.299	-0.178	-0.077	-0.008	-0.004	-0.003
213	-0.025	-0.048	-0.046	0.004	-0.353	-0.211	-0.092	-0.002	-0.002	0.002
214	-0.028	-0.054	-0.051	0.006	-0.401	-0.237	-0.099	-0.002	-0.001	0.002
215	-0.029	-0.059	-0.056	0.004	-0.440	-0.261	-0.114	-0.002	0.000	0.003
216	-0.034	-0.068	-0.063	0.006	-0.508	-0.301	-0.129	-0.001	0.001	0.004
217	-0.037	-0.069	-0.069	0.006	-0.553	-0.329	-0.135	0.001	0.000	0.004
218	-0.041	-0.084	-0.080	0.004	-0.641	-0.380	-0.156	0.001	0.001	0.004
219	-0.049	-0.098	-0.094	-0.002	-0.721	-0.425	-0.176	0.002	0.000	0.004
220	-0.056	-0.107	-0.104	-0.002	-0.791	-0.464	-0.191	0.002	0.000	0.004
221	-0.064	-0.124	-0.117	-0.002	-0.859	-0.505	-0.212	0.002	-0.002	0.002
222	-0.073	-0.139	-0.134	-0.004	-0.946	-0.557	-0.233	0.003	-0.004	-0.001
223	-0.083	-0.157	-0.148	-0.009	-1.031	-0.609	-0.255	0.004	-0.005	-0.002
224	-0.088	-0.171	-0.162	-0.009	-1.120	-0.658	-0.268	0.004	-0.006	-0.002
225	-0.092	-0.183	-0.173	-0.009	-1.240	-0.729	-0.296	0.007	0.000	0.004
226	-0.096	-0.193	-0.183	-0.009	-1.323	-0.778	-0.315	0.007	0.000	0.004
227	-0.100	-0.202	-0.190	-0.009	-1.395	-0.821	-0.330	0.009	0.001	0.004
228	-0.104	-0.210	-0.200	-0.009	-1.482	-0.871	-0.351	0.010	0.004	0.007
229	-0.107	-0.224	-0.210	-0.015	-1.591	-0.935	-0.371	0.012	0.008	0.011
230	-0.110	-0.234	-0.222	-0.015	-1.682	-0.989	-0.392	0.013	0.010	0.013
231	-0.118	-0.253	-0.238	-0.013	-1.785	-1.051	-0.413	0.013	0.011	0.015
232	-0.125	-0.270	-0.253	-0.015	-1.911	-1.124	-0.441	0.015	0.015	0.018
233	-0.136	-0.292	-0.276	-0.013	-2.031	-1.194	-0.467	0.015	0.015	0.017
234	-0.144	-0.317	-0.298	-0.015	-2.249	-1.320	-0.516	0.017	0.026	0.029
235	-0.143	-0.328	-0.310	-0.015	-2.434	-1.428	-0.559	0.018	0.045	0.046
236	-0.140	-0.332	-0.312	-0.015	-2.569	-1.504	-0.587	0.020	0.059	0.061
237	-0.123	-0.329	-0.314	-0.024	-2.752	-1.613	-0.636	0.023	0.089	0.090
238	-0.093	-0.319	-0.303	-0.030	-3.033	-1.778	-0.698	0.026	0.144	0.144
239	-0.067	-0.308	-0.295	-0.030	-3.275	-1.915	-0.754	0.028	0.192	0.192
240	-0.032	-0.290	-0.277	-0.035	-3.524	-2.063	-0.810	0.030	0.252	0.252
241	0.007	-0.267	-0.260	-0.035	-3.766	-2.205	-0.865	0.030	0.315	0.314
242	0.050	-0.241	-0.237	-0.035	-4.042	-2.371	-0.927	0.030	0.385	0.385
243	0.089	-0.218	-0.217	-0.035	-4.275	-2.509	-0.983	0.030	0.448	0.448
244	0.127	-0.197	-0.199	-0.035	-4.526	-2.650	-1.039	0.031	0.511	0.511
245	0.168	-0.176	-0.178	-0.035	-4.777	-2.800	-1.094	0.031	0.578	0.577
246	0.212	-0.151	-0.157	-0.037	-5.036	-2.951	-1.159	0.030	0.649	0.648
247	0.298	-0.103	-0.112	-0.030	-5.533	-3.250	-1.274	0.029	0.787	0.787
248	0.378	-0.056	-0.070	-0.015	-6.023	-3.539	-1.392	0.028	0.923	0.920
249	0.462	-0.005	-0.030	-0.004	-6.533	-3.839	-1.512	0.028	1.061	1.057
250	0.565	0.056	0.025	0.024	-7.071	-4.152	-1.645	0.025	1.226	1.219
251	0.653	0.111	0.075	0.045	-7.522	-4.419	-1.754	0.024	1.368	1.363
252	0.772	0.186	0.144	0.078	-8.084	-4.754	-1.887	0.020	1.555	1.547

Composite Slab Axial Stiffness Tests
Test Summary

Slab #2

Raw Data

Channel	102	103	DG1	DG2	DG3	DG4	DG5
	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)
Point							
206	0.000	0.000	0.000	0.000	0.000	0.000	0.000
207	-0.005	-0.007	-0.017	-0.014	-0.003	-0.005	-0.005
208	-0.009	-0.010	-0.027	-0.023	-0.006	-0.009	-0.009
209	-0.007	-0.007	-0.025	-0.017	-0.005	-0.005	-0.007
210	-0.010	-0.011	-0.032	-0.029	-0.007	-0.015	-0.010
211	-0.010	-0.013	-0.035	-0.033	-0.008	-0.019	-0.011
212	-0.012	-0.014	-0.039	-0.038	-0.009	-0.025	-0.011
213	-0.012	-0.015	-0.047	-0.046	-0.008	-0.033	-0.010
214	-0.013	-0.016	-0.052	-0.052	-0.009	-0.040	-0.010
215	-0.013	-0.017	-0.057	-0.057	-0.009	-0.045	-0.010
216	-0.015	-0.018	-0.064	-0.065	-0.009	-0.054	-0.010
217	-0.018	-0.021	-0.074	-0.074	-0.011	-0.063	-0.012
218	-0.020	-0.025	-0.087	-0.087	-0.012	-0.077	-0.014
219	-0.024	-0.029	-0.103	-0.102	-0.015	-0.093	-0.017
220	-0.028	-0.032	-0.116	-0.114	-0.017	-0.105	-0.019
221	-0.034	-0.037	-0.133	-0.129	-0.020	-0.121	-0.023
222	-0.040	-0.044	-0.155	-0.149	-0.023	-0.142	-0.028
223	-0.046	-0.050	-	-	-	-	-
224	-0.050	-0.055	-0.189	-0.181	-0.029	-0.178	-0.035
225	-0.051	-0.055	-0.203	-0.196	-0.027	-0.194	-0.032
226	-0.055	-0.058	-0.212	-0.208	-0.028	-0.204	-0.034
227	-0.057	-0.060	-0.220	-0.218	-0.029	-0.212	-0.036
228	-0.059	-0.061	-0.228	-0.229	-0.028	-0.220	-0.036
229	-0.059	-0.063	-0.237	-0.243	-0.025	-0.230	-0.035
230	-0.062	-0.066	-0.244	-0.257	-0.025	-0.237	-0.036
231	-0.066	-0.069	-0.248	-0.276	-0.027	-0.241	-0.038
232	-0.068	-0.072	-0.252	-0.293	-0.026	-0.245	-0.038
233	-0.075	-0.079	-0.255	-0.321	-0.031	-0.246	-0.043
234	-0.074	-0.078	-0.259	-0.349	-0.023	-0.251	-0.038
235	-0.066	-0.070	-0.261	-0.369	-0.010	-0.254	-0.026
236	-0.057	-0.061	-0.264	-0.375	0.002	-0.258	-0.016
237	-0.037	-0.040	-0.269	-0.378	0.028	-0.264	0.007
238	0.002	-0.002	-0.275	-0.377	0.077	-0.271	0.052
239	0.038	0.033	-0.279	-0.375	0.118	-0.275	0.091
240	0.086	0.079	-0.282	-0.368	0.171	-0.278	0.142
241	0.135	0.129	-0.282	-0.357	0.226	-0.278	0.197
242	0.190	0.183	-0.282	-0.346	0.289	-0.279	0.257
243	0.240	0.232	-0.283	-0.335	0.343	-0.278	-
244	0.288	0.279	-0.283	-0.325	0.397	-0.279	-
245	0.342	0.333	-0.283	-0.314	0.456	-0.278	-
246	0.398	0.389	-0.282	-0.300	0.518	-0.277	-
247	0.507	0.496	-0.281	-0.276	-	-0.275	-
248	0.615	0.601	-0.280	-0.251	-	-0.273	-
249	0.722	0.709	-0.279	-0.226	-	-0.271	-
250	0.853	0.836	-0.274	-	-	-0.264	-
251	0.969	0.952	-0.268	-	-	-0.257	-
252	1.118	1.099	-0.258	-	-	-0.241	-

01276

Composite Slab Axial Stiffness Tests **Slab #2**
Test Summary

Test Notes

Data Point	Test Comment
206	Instrumentation zeroed while rotation beam on temporary support.
207	Temporary support removed.
208	Preload specimen
209	Remove preload
210	Start test loading
252	Test ended because of shear stud failure

Composite Slab Axial Stiffness Tests
Test Summary

Data Calculations

Rotation Calculations

Method

1 $$\theta = \frac{\text{Average}(90,91) - \text{Average}(92,93)}{7.75}$$

2 $$\theta = \frac{\text{Average}(100,101) - \text{Average}(102,103)}{5}$$

3 $$\theta = \frac{\text{Average}(DG3, DG5) - \text{Average}(102,103)}{2.5625}$$

4 $$\theta = \theta_{\text{Free Beam}} - \theta_{\text{Fixed Beam}}$$

Where: $$\theta_{\text{Fixed Beam}} = \frac{(1) - (0)}{28}$$

a $$\theta_{\text{Free Beam}} = \frac{(97) - (96)}{33.5}$$

b $$\theta_{\text{Free Beam}} = \frac{(97) - (95)}{71.5}$$

c $$\theta_{\text{Free Beam}} = \frac{(96) - (95)}{38}$$

Slab Deformation Calculations

Method

1 $$\Delta = \text{Average}(102,103) + 10.25\,\theta$$

2 $$\Delta = \text{Average}(DG3, DG5) + 7.6875\,\theta$$

3 $$\Delta = \text{Average}(100,101) + 5.25\,\theta$$

Slab Load Calculations

$$P = \frac{(2)\,52.5}{29.9375} + 2.37$$

Note: Numbers enclosed in parenthesis, i.e. (2), correspond to gage numbers.

01277

Composite Slab Axial Stiffness Tests
Test Summary

Slab #2

Calculated Data

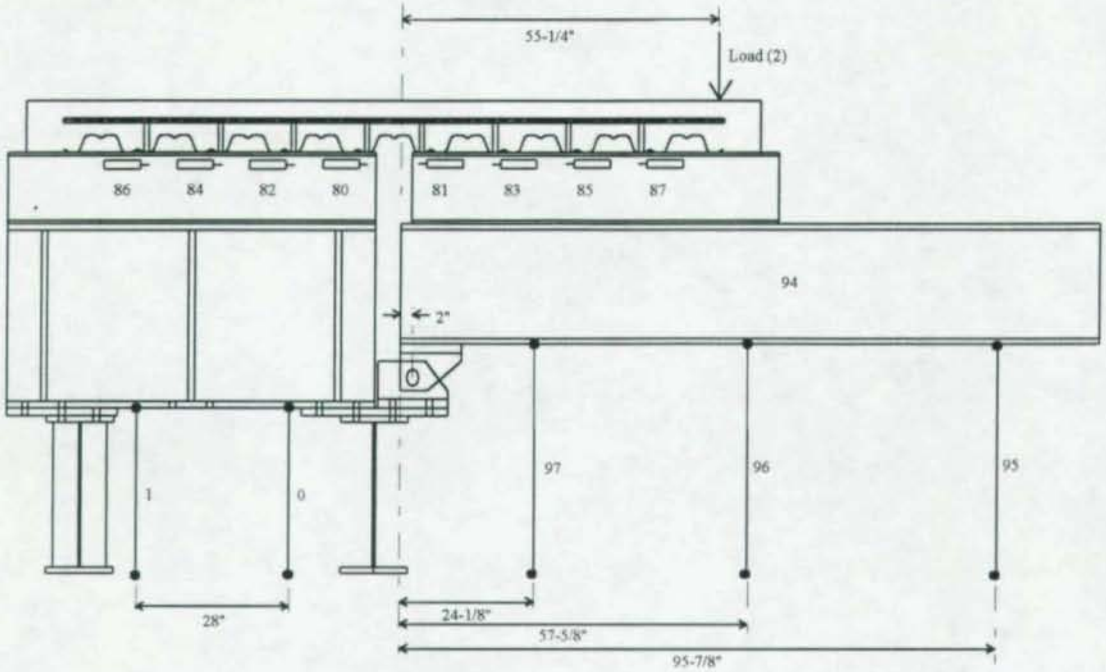
Data Point	Load @ Centerline of Reinforcing Steel (Kips)	Rebar #1 Axial Force (kips)	Rebar #2 Axial Force (kips)	Rebar #3 Axial Force (kips)	Rebar #4 Axial Force (kips)	Rebar Total Axial Force (kips)	Rotation 1 (rad)	Rotation 2 (rad)
206	0.00	0.00	0.00	0.00	0.00	-0.01	-0.0002	0.0000
207	2.59	0.07	0.06	0.09	0.08	0.29	0.0007	0.0007
208	8.98	0.13	0.14	0.21	0.16	0.62	0.0019	0.0012
209	2.59	0.07	0.07	0.12	0.09	0.35	0.0012	0.0007
210	14.05	0.17	0.20	0.31	0.23	0.91	0.0022	0.0012
211	15.81	0.22	0.37	0.51	0.31	1.41	0.0021	0.0015
212	17.13	1.51	1.57	1.39	0.68	5.15	0.0026	0.0019
213	17.79	2.46	2.87	2.94	2.84	11.10	0.0031	0.0027
214	19.99	2.80	3.39	3.46	3.40	13.05	0.0035	0.0030
215	21.98	3.14	3.83	3.87	3.86	14.70	0.0039	0.0034
216	24.62	3.52	4.54	4.49	4.56	17.12	0.0045	0.0038
217	25.50	3.78	4.94	4.84	4.98	18.54	0.0045	0.0043
218	28.37	4.30	5.78	5.59	5.80	21.48	0.0056	0.0050
219	29.91	4.58	6.35	6.12	6.45	23.51	0.0065	0.0057
220	31.89	4.86	6.79	6.57	6.96	25.17	0.0070	0.0064
221	32.33	5.05	7.11	6.90	7.39	26.44	0.0078	0.0072
222	32.77	5.27	7.54	7.34	7.93	28.08	0.0087	0.0079
223	34.76	5.61	7.95	7.83	8.51	29.90	0.0096	0.0089
224	36.52	5.94	8.34	8.18	8.95	31.40	0.0107	0.0097
225	38.72	6.28	8.58	8.13	9.27	32.26	0.0118	0.0109
226	41.14	6.56	8.89	8.38	9.61	33.43	0.0126	0.0116
227	43.57	6.91	9.21	8.71	10.03	34.85	0.0131	0.0122
228	44.89	7.31	9.55	9.02	10.53	36.40	0.0139	0.0131
229	47.53	7.96	10.00	9.59	11.36	38.91	0.0151	0.0141
230	48.86	-	-	-	-	-	0.0161	0.0151
231	47.97	-	-	-	-	-	0.0173	0.0161
232	50.40	-	-	-	-	-	0.0185	0.0172
233	49.74	-	-	-	-	-	0.0199	0.0186
234	51.94	-	-	-	-	-	0.0222	0.0207
235	54.14	-	-	-	-	-	0.0239	0.0227
236	59.43	-	-	-	-	-	0.0246	0.0238
237	63.18	-	-	-	-	-	0.0266	0.0256
238	66.04	-	-	-	-	-	0.0293	0.0287
239	69.34	-	-	-	-	-	0.0315	0.0313
240	70.00	-	-	-	-	-	0.0337	0.0339
241	68.68	-	-	-	-	-	0.0361	0.0366
242	68.68	-	-	-	-	-	0.0385	0.0397
243	67.58	-	-	-	-	-	0.0407	0.0425
244	67.58	-	-	-	-	-	0.0429	0.0453
245	66.04	-	-	-	-	-	0.0456	0.0480
246	63.62	-	-	-	-	-	0.0481	0.0510
247	60.53	-	-	-	-	-	0.0530	0.0571
248	57.01	-	-	-	-	-	0.0577	0.0627
249	54.36	-	-	-	-	-	0.0628	0.0687
250	43.57	-	-	-	-	-	0.0685	0.0756
251	34.54	-	-	-	-	-	0.0730	0.0811
252	22.64	-	-	-	-	-	0.0788	0.0885

Composite Slab Axial Stiffness Tests
Test Summary

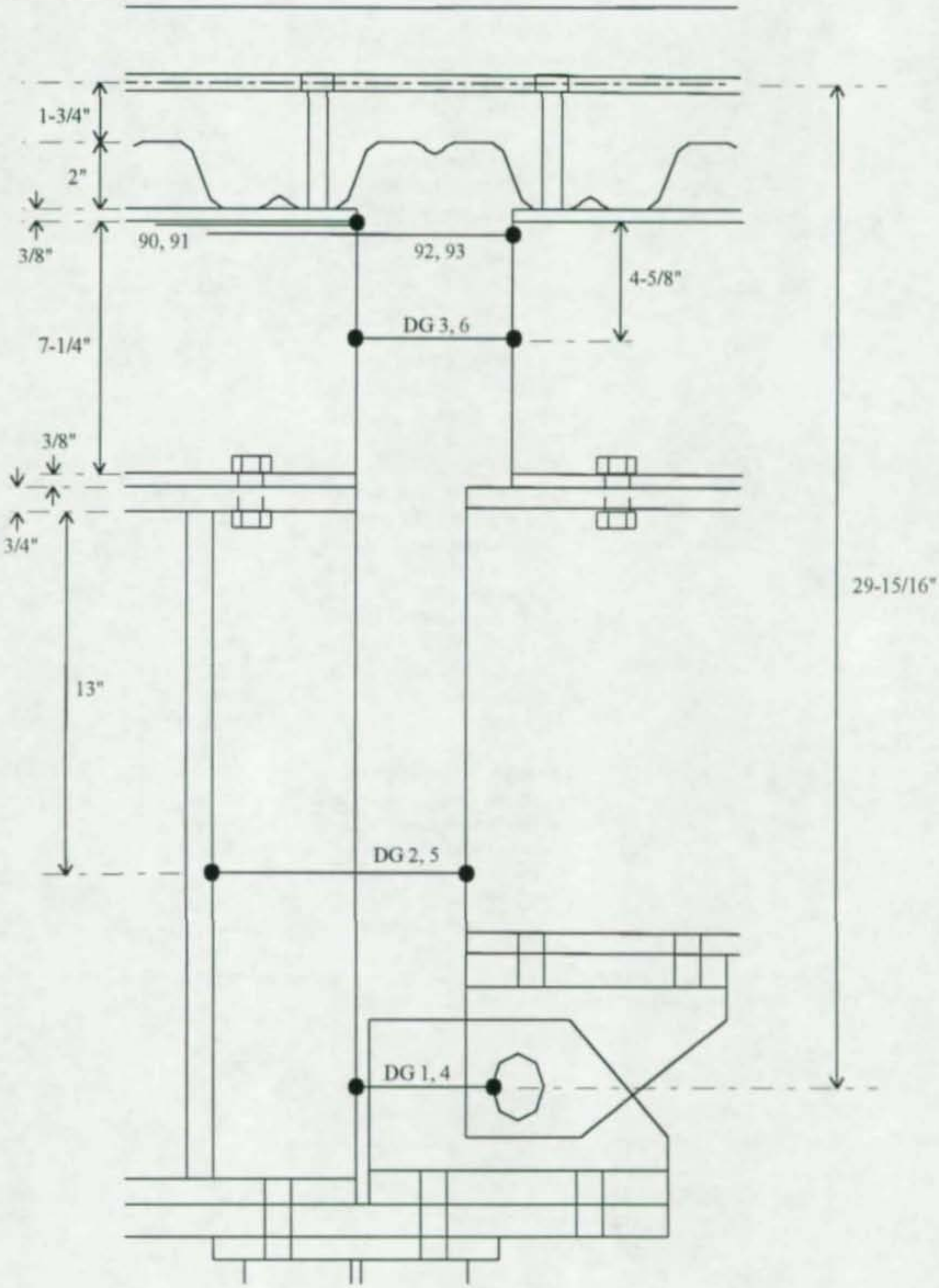
Calculate

Data Point	Rotation 3 (rad)	Rotation 4a (rad)	Rotation 4b (rad)	Rotation 4c (rad)	Rotation Average (rad)	Δ Slab 1 (in.)	Δ Slab 2 (in.)	Δ Slab 3 (in.)	Δ Slab Average (in.)
206	0.0000	0.0002	0.0002	0.0002	0.0001	0.001	0.001	0.000	0.001
207	0.0008	0.0012	0.0012	0.0013	0.0010	0.004	0.004	0.002	0.003
208	0.0008	0.0019	0.0019	0.0019	0.0016	0.007	0.005	0.005	0.005
209	0.0004	0.0013	0.0013	0.0014	0.0011	0.004	0.002	0.002	0.003
210	0.0007	0.0024	0.0024	0.0024	0.0019	0.009	0.006	0.006	0.007
211	0.0008	0.0025	0.0026	0.0027	0.0020	0.009	0.006	0.006	0.007
212	0.0012	0.0030	0.0031	0.0032	0.0025	0.013	0.009	0.009	0.010
213	0.0017	0.0032	0.0033	0.0034	0.0029	0.016	0.013	0.015	0.015
214	0.0019	0.0041	0.0042	0.0043	0.0035	0.022	0.017	0.019	0.019
215	0.0023	0.0043	0.0044	0.0045	0.0038	0.024	0.020	0.021	0.022
216	0.0027	0.0047	0.0048	0.0049	0.0042	0.027	0.023	0.025	0.025
217	0.0031	0.0055	0.0055	0.0056	0.0048	0.029	0.025	0.027	0.027
218	0.0037	0.0062	0.0063	0.0064	0.0055	0.034	0.030	0.032	0.032
219	0.0041	0.0070	0.0071	0.0073	0.0063	0.038	0.032	0.035	0.035
220	0.0048	0.0078	0.0081	0.0083	0.0071	0.042	0.036	0.039	0.039
221	0.0056	0.0084	0.0087	0.0090	0.0078	0.044	0.038	0.041	0.041
222	0.0065	0.0092	0.0095	0.0097	0.0086	0.046	0.041	0.043	0.043
223	-	0.0101	0.0104	0.0106	0.0099	0.054	-	0.048	0.051
224	0.0080	0.0108	0.0111	0.0113	0.0103	0.053	0.047	0.050	0.050
225	0.0091	0.0121	0.0124	0.0126	0.0115	0.065	0.059	0.062	0.062
226	0.0098	0.0130	0.0133	0.0135	0.0123	0.070	0.064	0.066	0.067
227	0.0101	0.0140	0.0142	0.0144	0.0130	0.075	0.068	0.071	0.071
228	0.0109	0.0147	0.0150	0.0152	0.0138	0.082	0.074	0.078	0.078
229	0.0120	0.0159	0.0161	0.0163	0.0149	0.092	0.085	0.088	0.088
230	0.0129	0.0168	0.0171	0.0173	0.0159	0.099	0.092	0.095	0.095
231	0.0137	0.0181	0.0182	0.0183	0.0169	0.106	0.098	0.102	0.102
232	0.0148	0.0194	0.0196	0.0197	0.0182	0.117	0.108	0.112	0.112
233	0.0156	0.0207	0.0209	0.0210	0.0195	0.122	0.113	0.118	0.118
234	0.0178	0.0227	0.0229	0.0231	0.0216	0.145	0.135	0.141	0.140
235	0.0196	0.0243	0.0246	0.0249	0.0233	0.171	0.161	0.168	0.167
236	0.0203	0.0257	0.0261	0.0264	0.0245	0.192	0.181	0.189	0.187
237	0.0219	0.0278	0.0283	0.0287	0.0265	0.233	0.221	0.229	0.228
238	0.0251	0.0308	0.0312	0.0316	0.0294	0.302	0.291	0.299	0.297
239	0.0268	0.0330	0.0336	0.0342	0.0317	0.361	0.348	0.359	0.356
240	0.0289	0.0358	0.0363	0.0368	0.0342	0.433	0.420	0.432	0.428
241	0.0311	0.0384	0.0389	0.0394	0.0367	0.508	0.494	0.508	0.503
242	0.0337	0.0415	0.0419	0.0423	0.0396	0.593	0.577	0.593	0.588
243	0.0419	0.0439	0.0444	0.0449	0.0430	0.677	0.674	0.674	0.675
244	0.0441	0.0464	0.0471	0.0477	0.0456	0.751	0.748	0.750	0.750
245	0.0463	0.0493	0.0499	0.0504	0.0482	0.832	0.827	0.831	0.830
246	0.0487	0.0519	0.0526	0.0532	0.0509	0.915	0.909	0.915	0.913
247	-	0.0573	0.0579	0.0584	0.0568	1.083	-	1.085	1.084
248	-	0.0625	0.0631	0.0637	0.0619	1.243	-	1.247	1.245
249	-	0.0680	0.0687	0.0694	0.0675	1.408	-	1.414	1.411
250	-	0.0732	0.0743	0.0752	0.0734	1.597	-	1.608	1.602
251	-	0.0781	0.0792	0.0802	0.0783	1.763	-	1.777	1.770
252	-	0.0844	0.0855	0.0865	0.0848	1.977	-	1.996	1.987

Instrumentation Diagram Part A



Instrumentation Diagram Part B



Composite Slab Axial Stiffness Tests
Test Summary

Slab #3

Description of Instrumentation

Gage No. Also Channel No.	Sense of Extension	Description of Measurement	Gage Type	Sensitivity	Full Scale
0	-**	Fixed Beam Rotation	ST2	1.0901	10"
1	+	Fixed Beam Rotation	ST3	1.0931	10"
2	Compression (-)	Load cell	Load Cell	1.99	500 kips
12	+	Rebar 5-1-1 Near Side	Strain Gage	4.9234 lbs/μ strain	
13	+	Rebar 5-1-2 Near Side	Strain Gage		
14	+	Rebar 5-2-1 Near Side	Strain Gage	4.8766 lbs/μ strain	
15	+	Rebar 5-2-2 Near Side	Strain Gage		
16	+	Rebar 5-3-1 Far Side	Strain Gage	4.9352 lbs/μ strain	
17	+	Rebar 5-3-2 Far Side	Strain Gage		
18	+	Rebar 5-4-1 Far Side	Strain Gage	4.995 lbs/μ strain	
19	+	Rebar 5-4-2 Far Side	Strain Gage		
80	-**	Stud Slip Fixed Side Location G	POT		6"
81	-**	Stud Slip Free Side Location G	POT		6"
82	-**	Stud Slip Fixed Side Location E	POT		6"
83	-**	Stud Slip Free Side Location E	POT		6"
84	-**	Stud Slip Fixed Side Location C	POT		6"
85	-**	Stud Slip Free Side Location C	POT		6"
86	-**	Stud Slip Fixed Side Location B	POT		6"
87	-**	Stud Slip Free Side Location B	POT		6"
90	+	Test Beam Seperation Fix Near	DCDT 6	0.942	10"
91	+	Test Beam Seperation Fix Far	DCDT 7	?	?
92	+	Test Beam Seperation Free Near	DCDT 1	0.934	10"
93	+	Test Beam Seperation Free Far	DCDT 3	0.47	10"
94	+	Lateral Displacement At Loading Point	DCDT 4	0.471	10"
95	+	Free Beam Vertical Displacement	DCDT 9	0.701	15"
96	+	Free Beam Vertical Displacement	DCDT 8	0.947	10"
97	+	Free Beam Vertical Displacement	DCDT 10	0.94	10"
DG1	-**	Near Pin Horizontal Displacement	Dial Gage*		1"
DG2	-**	Near Bottom Rotate Beam	Dial Gage*		1"
DG3	-**	Near Middle Test Beam	Dial Gage*		1"
DG4	-**	Far Pin Horizontal Displacement	Dial Gage*		1"
DG5	-**	Far Bottom Rotate Beam	Dial Gage*		1"
DG6	-**	Far Middle Test Beam	Dial Gage*		1"

* Dial gage readings not started until data point 112, while other measurements started at data point 92.

** All data has been modified so that (+) readings indicate extension.

Composite Slab Axial Stiffness Tests
Test Summary

Raw Data

Channel	0	1	2	12	13	14	15	16	17	18	19	80	81	82
	(in.)	(in.)	(kips)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(in.)	(in.)	(in.)
Point														
92	0.005	-0.005	0.00	0	-1	-1	-1	0	-1	-1	0	0.000	0.000	0.000
93	0.000	0.000	0.00	20	6	22	9	29	13	18	7	0.000	0.000	0.000
94	-0.005	0.000	-1.38	46	13	49	18	65	31	44	16	0.000	0.000	0.000
95	-0.005	0.000	0.13	41	11	43	14	59	26	40	14	-0.001	0.000	0.000
96	-0.014	0.000	-1.63	463	301	393	263	427	343	463	308	0.000	0.000	0.000
97	-0.018	0.000	-2.64	1034	701	808	579	862	715	1017	704	0.001	0.000	0.000
98	-0.023	0.000	-3.02	1432	968	1037	739	1149	944	1367	955	0.001	0.000	0.001
99	-0.023	0.000	-2.76	1648	1109	1143	816	1297	1052	1571	1091	0.001	0.000	0.001
100	-0.032	0.000	-3.89	1889	1272	1275	919	1463	1185	1777	1245	0.001	0.000	0.001
101	-0.032	0.005	-7.79	2071	1406	1372	1018	1584	1298	1901		0.002	0.000	0.002
102	-0.032	0.000	-9.80	2157	1472	1418	1073	1644	1359	1959		0.003	0.000	0.002
103	-0.032	0.005	-9.80	2121	1448	1377	1054	1601	1324	1871		0.003	0.000	0.002
104	-0.032	0.005	-10.80	2152	1476	1393	1091	1552	1274	1842		0.003	0.001	0.002
105	-0.032	0.005	-12.19	2196	1511	1414	1130	1572	1301	1863		0.003	0.001	0.002
106	-0.037	0.005	-13.32	2237	1545	1432	1164	1591	1328	1878		0.004	0.001	0.002
107	-0.041	0.005	-14.45	2289	1596	1453	1206	1613	1359	1889		0.004	0.002	0.003
108	-0.037	0.000	-16.21	2401	1713	1511	1298	1661	1421	1933		0.005	0.002	0.004
109	-0.037	0.005	-17.71	2530	1861	1573	1379	1713	1486	1974		0.007	0.002	0.005
110	-0.037	0.005	-5.65	1972	1354	1142	928	1314	1064	1543		0.004	0.002	0.004
111	-0.032	0.005	0.38	1537	1012	827	603	1007	762	1203		0.002	0.001	0.003
112	-0.032	0.005	0.00	1530	1008	823	599	1003	757	1198		0.002	0.001	0.003
113	-0.032	0.005	-4.90	1804	1213	1038	792	1216	954	1435		0.003	0.001	0.004
114	-0.032	0.005	-8.42	1996	1368	1185	938	1353	1091	1583		0.004	0.002	0.004
115	-0.037	0.005	-11.06	2128	1483	1280	1039	1443	1185	1679		0.004	0.002	0.005
116	-0.037	0.005	-14.57	2319	1659	1411	1190	1566	1318	1813		0.005	0.002	0.006
117	-0.041	0.005	-16.96	2466	1801	1508	1310	1654	1416	1903		0.007	0.002	0.006
118	-0.046	0.005	-18.84	2616	1989	1619	1429	1757	1525	2003		0.007	0.002	0.006
119	-0.046	0.005	-21.61	2684	2536	1804	1614	1936	1683	2128		0.008	0.002	0.009
120	-0.041	0.005	-23.49	5599	4800	1930	1778	2065	1792	2216		0.009	0.002	0.010
121	-0.046	0.000	-24.75	8554	8735	1994	1882	2146	1865	2263		0.010	0.003	0.012
122	-0.041	0.000	-26.51	9903	11115	2134	2268	2260	1984	2261		0.012	0.004	0.014
123	-0.050	0.005	-28.02	10473	11615	1986	2488	2403	2122	2289		0.014	0.004	0.017
124	-0.050	0.005	-29.65	11005	12016	1161	1259	3497	2585	2710		0.016	0.006	0.019
125	-0.050	0.000	-30.53	10691	12283	517	923	7148	6837	887		0.017	0.007	0.020
126	-0.050	0.005	-31.53	8828	12753	533	931	4098	7401	707		0.019	0.007	0.022
127	-0.050	0.005	-32.16	8209	13409	469	1023	1721	5253	606		0.020	0.009	0.023
128	-0.050	0.005	-33.17	7610	14029	376	979	934	4453	537		0.023	0.009	0.026
129	-0.050	0.005	-34.05	6840	14420	436	877	710	3670	478		0.026	0.011	0.030
130	-0.055	0.005	-34.80	6677	14695	454	866	597	3408	449		0.029	0.012	0.033
131	-0.055	0.005	-35.68	6902	14698	582	848	499	3042	435		0.034	0.014	0.037
132	-0.060	0.005	-36.18	5886	8050	667	827	371	2599	413		0.037	0.016	0.041
133	-0.060	0.005	-37.06	5829	7757	888	803	307	2296	435		0.042	0.019	0.045
134	-0.060	0.005	-37.94	5838	7705	1039	815	283	2075	461		0.045	0.021	0.049
135	-0.055	0.005	-38.57	5636	7503	1157	717	303	1709	463		0.051	0.024	0.055
136	-0.055	0.005	-39.57	5698	7451	1283	691	323	1280	488		0.060	0.027	0.064
137	-0.055	0.005	-40.08	5523	7226	1352	649	358	976	487		0.074	0.032	0.078
138	-0.060	0.005	-40.83	5369	7059	1575	635	371	857	490		0.081	0.037	0.086
139	-0.064	0.005	-42.09	5711	7272	1582	577	544	720	533		0.100	0.049	0.105
140	-0.064	0.005	-42.71	5710	7227	1475	547	663	714	542		0.118	0.068	0.126
141	-0.069	0.005	-42.34	5545	7123	1293	605	737	681	463		0.144	0.103	0.153
142	-0.069	0.005	-40.45	5153	6642	860	472	581	681	344		0.147	0.164	0.160
143	-0.064	0.005	-40.33	4794	6073	871	338	662	597	357		0.147	0.220	0.169
144	-0.064	0.005	-38.69	4655	5882	816	266	649	555	234		0.147	0.298	0.172
145	-0.064	0.005	-36.06	4512	5711	713	194	603	542	206		0.147	0.383	0.173
146	-0.064	0.005	-32.41	4359	5529	603	123	460	537	194		0.147	0.475	0.173
147	-0.064	0.005	-29.40	4264	5387	573	66	366	514	194		0.146	0.566	0.171
148	-0.064	0.005	-27.64	4207	5298	587	13	336	506	188		0.146	0.650	0.171
149	-0.064	0.005	-26.88	4168	5238	629	35	350	529	180		0.146	0.725	0.171
150	-0.060	-0.005	-25.75	4050	5117	736	1	406	545	171		0.145	0.871	0.171
151	-0.064	-0.005	-25.50	4034	5074	773	1	509	562	171		0.145	1.019	0.171
152	-0.064	-0.005	-25.25	4017	5037	748	1	594	576	167		0.144	1.153	0.171
153	-0.064	0.000	-21.36	3863	4813	560	1	587	535	155		0.144	1.352	0.170
154	-0.064	-0.005	-21.98	3925	4775	731	1	652	599	164		0.144	1.512	0.170
155	-0.064	-0.005	-22.99	3972	4741	871	238	600	688	174		0.144	1.644	0.170
156	-0.064	-0.005	-22.49	3947	4712	829	196	570	654	163		0.144	1.649	0.170
157	-0.064	-0.005	-23.24	4004	4699	786	290	577	805	165		0.144	1.795	0.170
158	-0.064	-0.009	-21.11	3937	4536	667	211	527	738	168		0.145	1.958	0.170

Composite Slab Axial Stiffness Tests
Test Summary

Raw Data

Channel	83	84	85	86	87	90	91	92	93	94	95	96	97	DG1
	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)
Point														
92	0.000	-0.001	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.002	0.000	0.001	0.000	-
93	0.000	-0.001	0.000	0.000	0.000	0.000	0.001	0.001	-0.001	0.041	-0.094	-0.062	-0.026	-
94	0.000	-0.001	0.000	0.000	0.001	0.012	0.006	0.007	0.001	0.039	-0.211	-0.131	-0.060	-
95	0.000	-0.001	0.000	-0.001	0.001	0.001	0.001	0.001	0.001	0.041	-0.196	-0.123	-0.058	-
96	0.000	-0.001	0.000	0.000	0.001	0.013	0.007	0.014	0.003	0.035	-0.384	-0.236	-0.106	-
97	0.000	-0.001	0.001	0.000	0.001	0.023	0.009	0.014	0.006	0.013	-0.704	-0.420	-0.183	-
98	0.000	-0.001	0.001	0.000	0.002	0.027	0.012	0.009	0.003	0.022	-0.974	-0.577	-0.245	-
99	0.000	-0.001	0.001	0.000	0.002	0.027	0.012	0.001	0.001	0.026	-1.135	-0.670	-0.282	-
100	0.000	-0.001	0.001	0.000	0.002	0.027	0.012	0.000	0.001	0.019	-1.325	-0.779	-0.324	-
101	0.000	-0.001	0.001	0.000	0.003	0.032	0.014	-0.001	0.001	0.015	-1.477	-0.868	-0.364	-
102	0.001	-0.001	0.002	0.000	0.004	0.036	0.014	0.000	0.001	0.013	-1.536	-0.906	-0.379	-
103	0.000	-0.001	0.002	0.000	0.004	0.037	0.014	-0.001	0.001	0.017	-1.562	-0.920	-0.384	-
104	0.000	-0.001	0.002	0.000	0.005	0.037	0.014	-0.001	0.001	0.015	-1.597	-0.938	-0.390	-
105	0.000	-0.001	0.003	0.001	0.006	0.040	0.014	0.002	0.001	0.009	-1.637	-0.962	-0.397	-
106	0.000	0.000	0.004	0.001	0.007	0.042	0.016	0.004	0.002	0.006	-1.669	-0.981	-0.405	-
107	0.000	0.001	0.004	0.001	0.008	0.044	0.017	0.010	0.003	0.002	-1.704	-1.003	-0.413	-
108	0.001	0.001	0.005	0.002	0.009	0.047	0.018	0.012	0.003	0.002	-1.750	-1.031	-0.422	-
109	0.001	0.002	0.007	0.004	0.010	0.050	0.018	0.016	0.006	-0.004	-1.804	-1.061	-0.433	-
110	0.001	0.002	0.006	0.003	0.009	0.041	0.015	0.009	0.004	0.037	-1.582	-0.924	-0.375	-
111	0.000	0.002	0.005	0.002	0.007	0.026	0.011	-0.003	-0.001	0.050	-1.305	-0.762	-0.309	-
112	0.000	0.002	0.005	0.003	0.007	0.026	0.011	-0.004	-0.001	0.048	-1.303	-0.761	-0.308	-
113	0.000	0.002	0.005	0.003	0.009	0.028	0.011	-0.004	0.000	0.037	-1.486	-0.868	-0.354	-0.026
114	0.000	0.002	0.005	0.002	0.009	0.034	0.013	0.000	0.001	0.024	-1.599	-0.935	-0.382	-0.039
115	0.000	0.002	0.006	0.003	0.009	0.040	0.014	0.004	0.001	0.015	-1.660	-0.972	-0.397	-0.046
116	0.001	0.002	0.007	0.003	0.010	0.045	0.017	0.012	0.004	0.002	-1.735	-1.021	-0.416	-0.055
117	0.001	0.002	0.007	0.004	0.010	0.050	0.018	0.016	0.006	-0.004	-1.789	-1.053	-0.429	-0.060
118	0.001	0.002	0.007	0.004	0.011	0.052	0.020	0.021	0.009	-0.004	-1.844	-1.084	-0.441	-0.065
119	0.002	0.004	0.009	0.007	0.013	0.055	0.020	0.028	0.011	-0.011	-1.929	-1.135	-0.458	-0.072
120	0.002	0.005	0.010	0.009	0.015	0.056	0.021	0.034	0.013	-0.015	-1.996	-1.173	-0.471	-0.077
121	0.003	0.006	0.010	0.011	0.015	0.057	0.022	0.038	0.013	-0.017	-2.044	-1.199	-0.481	-0.080
122	0.006	0.009	0.013	0.014	0.017	0.058	0.022	0.048	0.016	-0.017	-2.125	-1.246	-0.496	-0.085
123	0.006	0.012	0.013	0.016	0.018	0.060	0.022	0.055	0.018	-0.017	-2.186	-1.283	-0.510	-0.088
124	0.007	0.014	0.015	0.020	0.020	0.061	0.022	0.063	0.022	-0.024	-2.260	-1.323	-0.525	-0.093
125	0.008	0.016	0.016	0.022	0.020	0.062	0.022	0.069	0.025	-0.024	-2.314	-1.353	-0.536	-0.095
126	0.009	0.017	0.016	0.024	0.021	0.063	0.022	0.079	0.026	-0.024	-2.367	-1.382	-0.547	-0.098
127	0.010	0.020	0.017	0.026	0.022	0.067	0.023	0.084	0.029	-0.030	-2.417	-1.411	-0.558	-0.100
128	0.012	0.023	0.019	0.029	0.024	0.068	0.024	0.097	0.031	-0.030	-2.493	-1.454	-0.574	-0.103
129	0.013	0.026	0.020	0.033	0.026	0.069	0.025	0.110	0.036	-0.030	-2.574	-1.501	-0.591	-0.106
130	0.014	0.028	0.021	0.035	0.027	0.073	0.026	0.119	0.039	-0.037	-2.621	-1.532	-0.602	-0.109
131	0.016	0.032	0.023	0.039	0.030	0.074	0.026	0.130	0.043	-0.035	-2.696	-1.573	-0.618	-0.111
132	0.018	0.035	0.024	0.045	0.032	0.075	0.026	0.142	0.046	-0.037	-2.754	-1.608	-0.630	-0.114
133	0.021	0.040	0.027	0.048	0.035	0.075	0.027	0.155	0.051	-0.037	-2.831	-1.650	-0.647	-0.116
134	0.022	0.043	0.029	0.052	0.037	0.076	0.027	0.166	0.055	-0.030	-2.896	-1.688	-0.662	-0.119
135	0.024	0.050	0.032	0.058	0.040	0.078	0.026	0.181	0.060	-0.030	-2.983	-1.740	-0.681	-0.122
136	0.028	0.059	0.035	0.069	0.045	0.079	0.027	0.203	0.066	-0.024	-3.097	-1.806	-0.707	-0.125
137	0.032	0.071	0.040	0.082	0.051	0.081	0.027	0.231	0.077	-0.011	-3.232	-1.882	-0.738	-0.128
138	0.036	0.077	0.045	0.092	0.054	0.082	0.027	0.249	0.081	-0.006	-3.319	-1.934	-0.758	-0.130
139	0.045	0.094	0.057	0.112	0.067	0.087	0.027	0.295	0.095	0.015	-3.532	-2.059	-0.807	-0.135
140	0.061	0.114	0.076	0.134	0.085	0.089	0.028	0.342	0.111	0.035	-3.748	-2.183	-0.854	-0.138
141	0.090	0.140	0.111	0.162	0.116	0.090	0.028	0.409	0.132	0.056	-4.016	-2.341	-0.917	-0.140
142	0.153	0.145	0.172	0.167	0.177	0.089	0.029	0.481	0.158	0.056	-4.278	-2.491	-0.979	-0.140
143	0.208	0.153	0.227	0.174	0.236	0.090	0.029	0.545	0.177	0.054	-4.522	-2.633	-1.036	-0.140
144	0.282	0.156	0.302	0.176	0.322	0.090	0.029	0.620	0.202	0.056	-4.790	-2.794	-1.098	-0.139
145	0.364	0.156	0.378	0.177	0.416	0.087	0.029	0.691	0.226	0.056	-5.047	-2.943	-1.157	-0.138
146	0.452	0.156	0.457	0.176	0.517	0.082	0.028	0.763	0.249	0.056	-5.287	-3.084	-1.215	-0.133
147	0.544	0.156	0.539	0.176	0.618	0.080	0.028	0.838	0.278	0.050	-5.544	-3.233	-1.278	-0.130
148	0.631	0.156	0.616	0.176	0.714	0.078	0.027	0.912	0.301	0.050	-5.790	-3.382	-1.337	-0.127
149	0.705	0.156	0.686	0.176	0.796	0.078	0.027	0.975	0.324	0.050	-6.025	-3.520	-1.394	-0.126
150	0.845	0.156	0.827	0.175	0.957	0.077	0.027	1.108	0.367	0.076	-6.511	-3.810	-1.510	-0.125
151	0.983	0.156	0.978	0.175	1.120	0.077	0.027	1.246	0.412	0.110	-7.028	-4.114	-1.632	-0.123
152	1.108	0.156	1.104	0.175	1.265	0.077	0.027	1.369	0.451	0.151	-7.498	-4.389	-1.744	-
153	1.285	0.156	1.284	0.174	1.463	0.075	0.027	1.529	0.505	0.197	-8.050	-4.715	-1.881	-
154	1.447	0.156	1.435	0.174	1.623	0.075	0.027	1.668	0.548	0.231	-8.577	-5.028	-2.009	-
155	1.582	0.156	1.560	0.174	1.754	0.075	0.026	1.783	0.585	0.270	-9.019	-5.291	-2.112	-
156	1.586	0.156	1.565	0.174	1.758	0.075	0.026	1.786	0.585	0.272	-9.022	-5.292	-2.114	-
157	1.740	0.156	1.703	0.174	1.903	0.075	0.026	1.917	0.629	0.320	-9.529	-5.590	-2.233	-
158	1.913	0.156	1.855	0.174	2.067	0.075	0.027	2.051	0.674	0.361	-10.011	-5.875	-2.347	-

Raw Data

Channel	DG2 (in.)	DG3 (in.)	DG4 (in.)	DG5 (in.)	DG6 (in.)
Point					
92	-	-	-	-	-
93	-	-	-	-	-
94	-	-	-	-	-
95	-	-	-	-	-
96	-	-	-	-	-
97	-	-	-	-	-
98	-	-	-	-	-
99	-	-	-	-	-
100	-	-	-	-	-
101	-	-	-	-	-
102	-	-	-	-	-
103	-	-	-	-	-
104	-	-	-	-	-
105	-	-	-	-	-
106	-	-	-	-	-
107	-	-	-	-	-
108	-	-	-	-	-
109	-	-	-	-	-
110	-	-	-	-	-
111	-	-	-	-	-
112	-	0.000	-	0.000	-
113	-0.027	-0.005	-0.021	-0.027	-0.005
114	-0.042	-0.008	-0.032	-0.043	-0.008
115	-0.050	-0.008	-0.037	-0.050	-0.010
116	-0.059	-0.009	-0.040	-0.059	-0.012
117	-0.065	-0.009	-0.042	-0.065	-0.012
118	-0.069	-0.008	-0.044	-0.069	-0.012
119	-0.076	-0.006	-0.046	-0.076	-0.009
120	-0.080	-0.004	-0.047	-0.080	-0.006
121	-0.082	-0.002	-0.047	-0.083	-0.005
122	-0.087	0.003	-0.049	-0.088	0.000
123	-0.090	0.007	-0.049	-0.090	0.003
124	-0.094	0.001	-0.050	-0.093	0.008
125	-0.095	0.015	-0.050	-0.094	0.011
126	-0.097	0.020	-0.053	-0.095	0.015
127	-0.099	0.024	-0.056	-0.096	0.019
128	-0.102	0.033	-0.059	-0.098	0.026
129	-0.104	0.042	-0.062	-0.099	0.034
130	-0.106	0.047	-0.064	-0.101	0.039
131	-0.107	0.055	-0.066	-0.102	0.046
132	-0.108	0.063	-0.067	-0.103	0.054
133	-0.109	0.072	-0.068	-0.104	0.062
134	-0.111	0.080	-0.069	-0.106	0.070
135	-0.112	0.092	-0.069	-0.107	0.081
136	-0.113	0.108	-0.070	-0.108	0.097
137	-0.112	0.131	-0.070	-0.108	0.119
138	-0.112	0.144	-0.070	-0.108	0.131
139	-0.110	0.182	-0.071	-0.106	0.165
140	-0.106	0.223	-0.071	-0.101	0.201
141	-0.098	0.282	-0.075	-0.092	0.255
142	-0.085	0.343	-0.075	-0.079	0.315
143	-0.074	0.398	-0.075	-0.068	0.367
144	-0.060	0.463	-0.075	-0.053	0.432
145	-0.045	0.524	-0.073	-0.038	0.498
146	-0.026	0.588	-0.070	-0.020	0.564
147	-0.007	0.654	-0.065	-0.001	0.633
148	0.008	0.716	-0.063	0.015	0.679
149	0.011	0.816	-0.062	0.029	-
150	0.046	-	-0.060	0.053	-
151	0.070	-	-0.060	0.076	-
152	-	-	-	-	-
153	-	-	-	-	-
154	-	-	-	-	-
155	-	-	-	-	-
156	-	-	-	-	-
157	-	-	-	-	-
158	-	-	-	-	-

Composite Slab Axial Stiffness Tests
Test Summary

Test Notes

Data Point	Test Comment
92	Instrumentation zeroed while rotation beam on temporary support.
93	Temporary support removed.
94	Preload specimen
95	Remove preload and re-zero all DCDTs used to measure flange seperation
96	Start test loading. Small transverse crack at the slab center starting to form
101	Channel 19 offscale
110	Unload specimen to add dial gages
112	Re-zero load cell
158	Test ended. The flange seperation and beam deflection were excessive and no further loading seemed reasonable. A crack formed along the line of the shear studs between the load point and the original transverse crack. This crack allowed large shear stud deformations without a shear stud failure

Composite Slab Axial Stiffness Tests **Slab #3**
Test Summary

<u>Data Calculations</u>
Rotation Calculations

Method

4 $t = t_{\text{Free Beam}} - t_{\text{Fixed Beam}}$

Where: $t_{\text{Fixed Beam}} = \dfrac{(1) - (0)}{28}$

a $t_{\text{Free Beam}} = \dfrac{(97) - (96)}{33.5}$

b $t_{\text{Free Beam}} = \dfrac{(97) - (95)}{71.75}$

c $t_{\text{Free Beam}} = \dfrac{(96) - (95)}{38.25}$

Slab Deformation Calculations

Before Dial Gages Added

$\Delta = (92) - (90) + 4.75\,\theta$

After Dial Gages Added

$\Delta =$ Corrected Dial Gage Reading $+ 8.625\,\theta$

Where:

Corrected Dial Gage Reading

= First Dial Gage Reading +Average (DG3,DG6)

First Dial Gage Reading

= [(92)-(90) @ Data Point 112] -3.875 θ

After Dial Gages Removed

$\Delta = (92) - (90) + 4.75\,\theta$

Slab Load Calculations

$$P = \frac{(2)\ 53.25}{29.9375} + 2.37$$

Note: Numbers enclosed in parenthesis, i.e. (2), correspond to gage numbers.

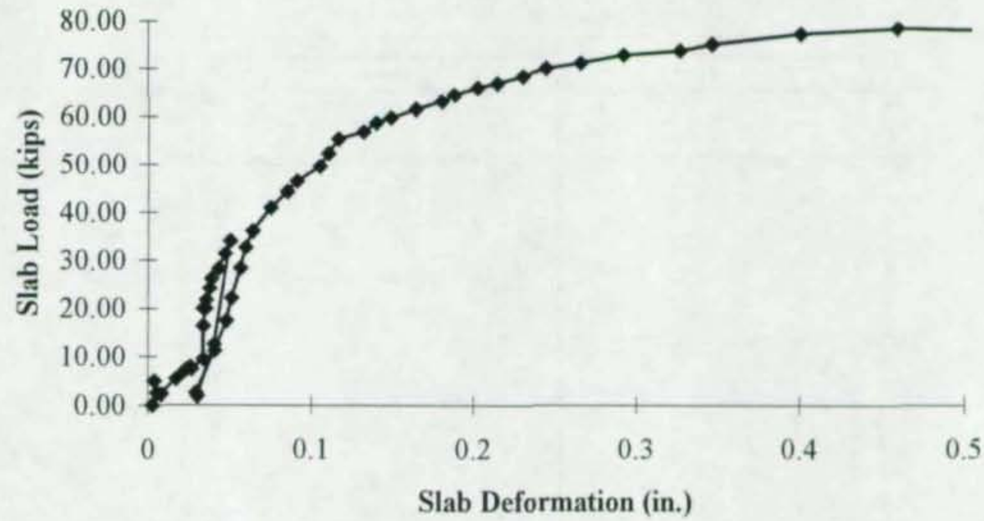
Calculated Data

Data Point	Load @ Centerline of Reinforcing Steel (Kips)	Rebar #1 Axial Force (kips)	Rebar #2 Axial Force (kips)	Rebar #3 Axial Force (kips)	Rebar #4 Axial Force (kips)	Rebar Total Axial Force (kips)	Rotation 4a (rad)	Rotation 4b (rad)	Rotation 4c (rad)	Rotation Average (rad)	Δ Slab Channel 92-90 (in.)	Δ Slab Corrected DG Readings (in.)	Δ Slab (in.)
92	0.00	0.00	0.00	0.00	0.00	-0.01	0.0003	0.0003	0.0004	0.0003	0.001	-	0.003
93	2.37	0.06	0.08	0.10	0.06	0.31	0.0011	0.0009	0.0008	0.0009	0.001	-	0.006
94	4.83	0.15	0.16	0.24	0.15	0.70	0.0020	0.0020	0.0019	0.0020	-0.005	-	0.004
95	2.15	0.13	0.14	0.21	0.14	0.61	0.0018	0.0018	0.0018	0.0018	0.000	-	0.008
96	5.27	1.88	1.60	1.90	1.93	7.31	0.0034	0.0034	0.0034	0.0034	0.001	-	0.017
97	7.06	4.27	3.38	3.89	4.30	15.84	0.0064	0.0066	0.0068	0.0066	-0.009	-	0.023
98	7.73	5.91	4.33	5.17	5.80	21.20	0.0091	0.0093	0.0096	0.0093	-0.018	-	0.026
99	7.29	6.79	4.78	5.80	6.65	24.01	0.0108	0.0111	0.0113	0.0111	-0.026	-	0.027
100	9.30	7.78	5.35	6.53	7.55	27.21	0.0124	0.0128	0.0131	0.0128	-0.027	-	0.034
101	16.22	8.56	5.83	7.11	-	-	0.0137	0.0142	0.0146	0.0142	-0.034	-	0.034
102	19.80	8.93	6.07	7.41	-	-	0.0146	0.0150	0.0153	0.0150	-0.036	-	0.035
103	19.80	8.79	5.93	7.22	-	-	0.0147	0.0151	0.0155	0.0151	-0.038	-	0.034
104	21.59	8.93	6.06	6.97	-	-	0.0151	0.0155	0.0159	0.0155	-0.038	-	0.036
105	24.05	9.12	6.20	7.09	-	-	0.0155	0.0160	0.0163	0.0159	-0.038	-	0.038
106	26.06	9.31	6.33	7.20	-	-	0.0157	0.0161	0.0165	0.0161	-0.038	-	0.039
107	28.07	9.57	6.48	7.33	-	-	0.0160	0.0164	0.0167	0.0163	-0.035	-	0.043
108	31.20	-	6.85	7.60	-	-	0.0168	0.0172	0.0175	0.0172	-0.035	-	0.047
109	33.88	-	7.20	7.89	-	-	0.0173	0.0176	0.0180	0.0176	-0.033	-	0.050
110	12.43	-	5.05	5.87	-	-	0.0149	0.0154	0.0157	0.0153	-0.032	-	0.040
111	1.70	-	3.49	4.36	-	-	0.0122	0.0126	0.0129	0.0126	-0.029	-	0.030
112	2.37	-	3.47	4.34	-	-	0.0122	0.0126	0.0129	0.0126	-0.030	-0.079	0.029
113	11.08	-	4.46	5.36	-	-	0.0140	0.0145	0.0148	0.0145	-0.033	-0.084	0.041
114	17.34	-	5.18	6.03	-	-	0.0152	0.0157	0.0161	0.0156	-0.034	-0.087	0.048
115	22.03	-	5.65	6.48	-	-	0.0157	0.0161	0.0165	0.0161	-0.036	-0.088	0.051
116	28.29	-	6.34	7.12	-	-	0.0166	0.0169	0.0172	0.0169	-0.033	-0.089	0.056
117	32.54	-	6.87	7.58	-	-	0.0170	0.0173	0.0176	0.0173	-0.033	-0.089	0.060
118	35.89	-	-	8.10	-	-	0.0174	0.0178	0.0180	0.0177	-0.031	-0.089	0.064
119	40.80	-	-	8.93	-	-	0.0184	0.0187	0.0189	0.0187	-0.027	-0.086	0.075
120	44.16	-	-	9.52	-	-	0.0193	0.0196	0.0199	0.0196	-0.022	-0.084	0.085
121	46.39	-	-	9.90	-	-	0.0198	0.0201	0.0204	0.0201	-0.019	-0.082	0.091
122	49.52	-	-	-	-	-	0.0209	0.0212	0.0215	0.0212	-0.010	-0.078	0.105
123	52.20	-	-	-	-	-	0.0211	0.0214	0.0216	0.0214	-0.005	-0.074	0.110
124	55.11	-	-	-	-	-	0.0219	0.0222	0.0225	0.0222	0.003	-0.075	0.117
125	56.67	-	-	-	-	-	0.0226	0.0230	0.0233	0.0230	0.007	-0.066	0.132
126	58.46	-	-	-	-	-	0.0230	0.0234	0.0238	0.0234	0.016	-0.062	0.140
127	59.57	-	-	-	-	-	0.0235	0.0239	0.0243	0.0239	0.017	-0.057	0.149
128	61.36	-	-	-	-	-	0.0243	0.0248	0.0252	0.0248	0.029	-0.049	0.164
129	62.93	-	-	-	-	-	0.0252	0.0257	0.0261	0.0256	0.041	-0.041	0.180
130	64.27	-	-	-	-	-	0.0256	0.0260	0.0264	0.0260	0.046	-0.036	0.188
131	65.83	-	-	-	-	-	0.0264	0.0268	0.0272	0.0268	0.056	-0.028	0.203
132	66.73	-	-	-	-	-	0.0269	0.0273	0.0277	0.0273	0.067	-0.020	0.215
133	68.29	-	-	-	-	-	0.0276	0.0281	0.0286	0.0281	0.080	-0.012	0.231
134	69.85	-	-	-	-	-	0.0283	0.0288	0.0293	0.0288	0.090	-0.004	0.245
135	70.97	-	-	-	-	-	0.0295	0.0300	0.0304	0.0299	0.103	0.008	0.266
136	72.76	-	-	-	-	-	0.0307	0.0312	0.0316	0.0312	0.124	0.024	0.292
137	73.65	-	-	-	-	-	0.0320	0.0326	0.0332	0.0326	0.150	0.046	0.327
138	74.99	-	-	-	-	-	0.0328	0.0334	0.0339	0.0334	0.167	0.059	0.346
139	77.23	-	-	-	-	-	0.0349	0.0355	0.0361	0.0355	0.208	0.095	0.401
140	78.34	-	-	-	-	-	0.0372	0.0379	0.0385	0.0378	0.253	0.133	0.459
141	77.67	-	-	-	-	-	0.0399	0.0406	0.0412	0.0405	0.320	0.190	0.539
142	74.32	-	-	-	-	-	0.0425	0.0434	0.0441	0.0433	0.393	0.250	0.624
143	74.10	-	-	-	-	-	0.0452	0.0461	0.0469	0.0461	0.455	0.304	0.701
144	71.19	-	-	-	-	-	0.0482	0.0490	0.0497	0.0490	0.530	0.369	0.791
145	66.50	-	-	-	-	-	0.0509	0.0518	0.0525	0.0517	0.604	0.432	0.878
146	60.02	-	-	-	-	-	0.0533	0.0543	0.0551	0.0543	0.681	0.497	0.965
147	54.66	-	-	-	-	-	0.0559	0.0570	0.0580	0.0570	0.758	0.565	1.056
148	51.53	-	-	-	-	-	0.0586	0.0596	0.0605	0.0596	0.834	0.619	1.132
149	50.19	-	-	-	-	-	0.0610	0.0621	0.0630	0.0621	0.897		1.192
150	48.18	-	-	-	-	-	0.0667	0.0677	0.0686	0.0677	1.031		1.353
151	47.73	-	-	-	-	-	0.0720	0.0731	0.0741	0.0730	1.169		1.516
152	47.28	-	-	-	-	-	0.0768	0.0781	0.0792	0.0780	1.292		1.663
153	40.36	-	-	-	-	-	0.0823	0.0837	0.0849	0.0836	1.455		1.852
154	41.47	-	-	-	-	-	0.0880	0.0894	0.0907	0.0894	1.593		2.018
155	43.26	-	-	-	-	-	0.0927	0.0941	0.0954	0.0941	1.708		2.155
156	42.37	-	-	-	-	-	0.0927	0.0941	0.0954	0.0941	1.711		2.158
157	43.71	-	-	-	-	-	0.0981	0.0996	0.1009	0.0995	1.842		2.315
158	39.91	-	-	-	-	-	0.1033	0.1048	0.1062	0.1048	1.977		2.474

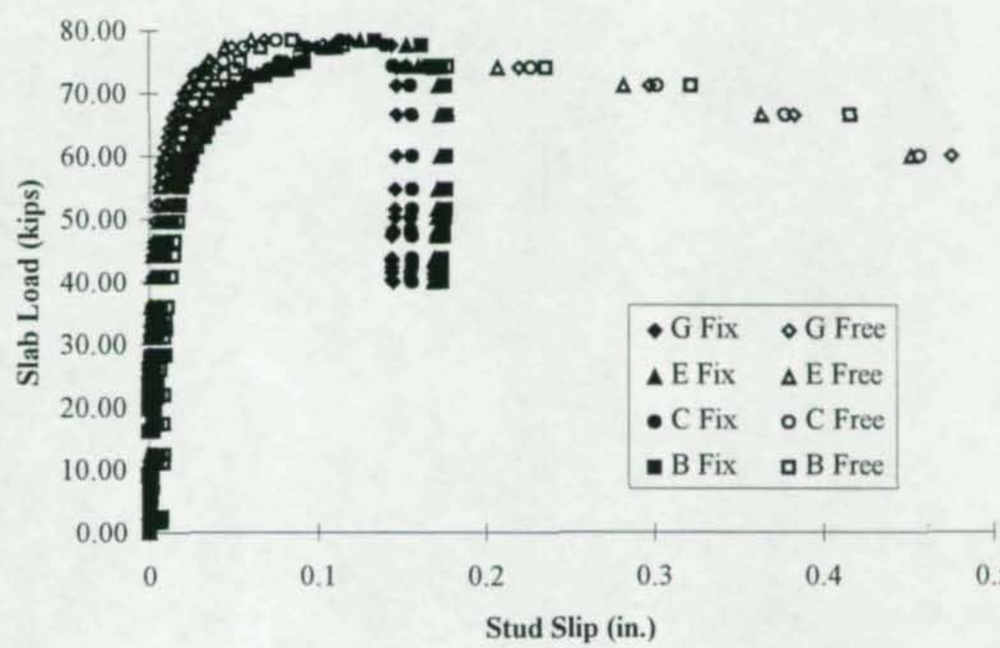
Composite Slab Axial Stiffness Tests
Test Summary

Slab #3

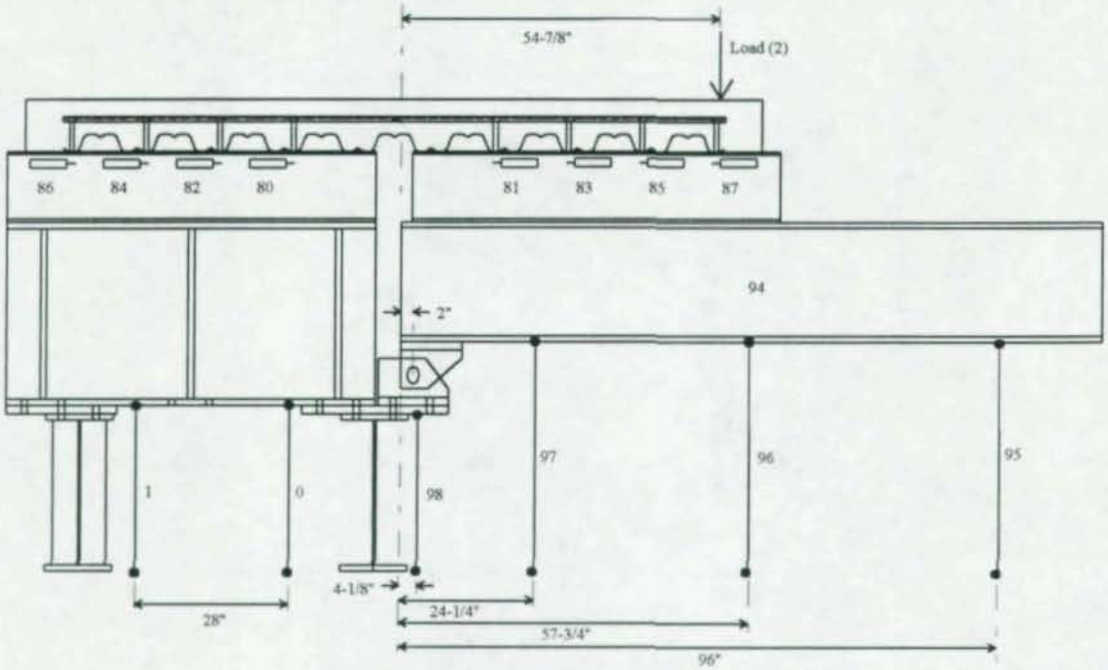
Composite Slab Load Vs. Deformation



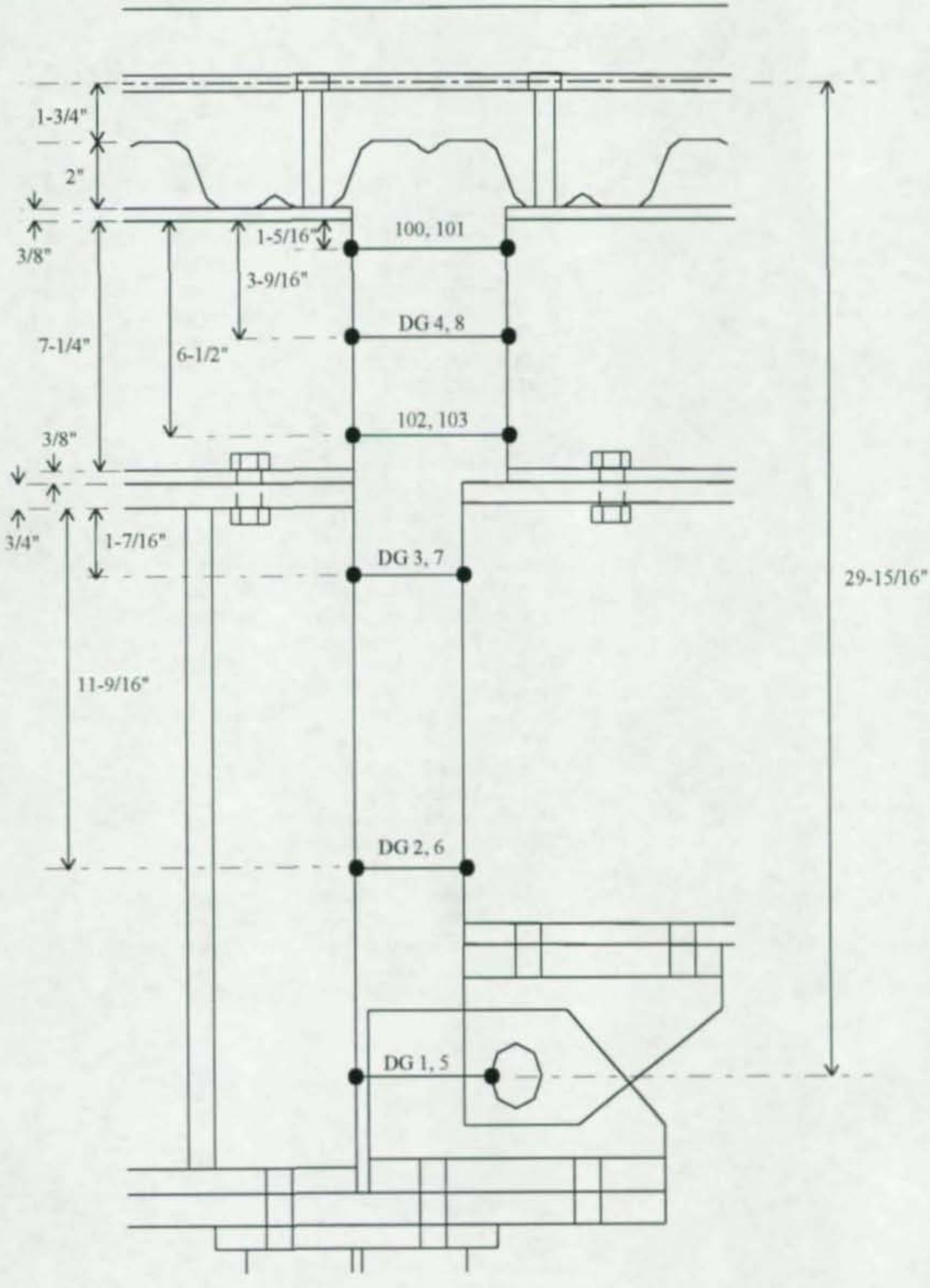
Load Vs. Stud Slip



<u>Instrumentation Diagram Part A</u>



Instrumentation Diagram Part B



Composite Slab Axial Stiffness Tests
Test Summary

Slab #4

Description of Instrumentation

Gage No. Also Channel No.	Sense of Extension	Description of Measurement	Gage Type	Sensitivity	Full Scale
0	-**	Fixed Beam Rotation	ST2	1.0901	10"
1	+	Fixed Beam Rotation	ST3	1.0931	10"
2	Compression (-)	Load cell	Load Cell	1.99	500 kips
12	+	Rebar 3-1-1 Far Side	Strain Gage	4.715 lbs/µ strain	
13	+	Rebar 3-1-2 Far Side	Strain Gage		
14	+	Rebar 3-2-1 Far Side	Strain Gage	4.96 lbs/µ strain	
15	+	Rebar 3-2-2 Far Side	Strain Gage		
16	+	Rebar 3-3-1 Near Side	Strain Gage	5.0128 lbs/µ strain	
17	+	Rebar 3-3-2 Near Side	Strain Gage		
18	+	Rebar 3-4-1 Near Side	Strain Gage	5.1864 lbs/µ strain	
19	+	Rebar 3-4-2 Near Side	Strain Gage		
80	-**	Stud Slip Fixed Side Location E	POT		6"
81	-**	Stud Slip Free Side Location E	POT		6"
82	-**	Stud Slip Fixed Side Location C	POT		6"
83	-**	Stud Slip Free Side Location C	POT		6"
84	-**	Stud Slip Fixed Side Location B	POT		6"
85	-**	Stud Slip Free Side Location B	POT		6"
86	-**	Stud Slip Fixed Side Location A	POT		6"
87	-**	Stud Slip Free Side Location A	POT		6"
94	+	Lateral Displacement At Loading Point	DCDT 4	0.471	10"
95	+	Free Beam Vertical Displacement	DCDT 9	0.701	15"
96	+	Free Beam Vertical Displacement	DCDT 8	0.947	10"
97	+	Free Beam Vertical Displacement	DCDT 3	0.47	10"
98	-**	Below Pin Vertical Displacement	POT		6"
100	-**	Test Beam Rotation Top Near	POT		6"
101	-**	Test Beam Rotation Top Far	POT		6"
102	-**	Test Beam Rotation Bottom Near	POT		6"
103	-**	Test Beam Rotation Bottom Far	POT		6"
DG1	-**	Pin Near Horizontal Displacement	Dial Gage		1"
DG2	-**	Frame Rotation Near Bottom	Dial Gage		1"
DG3	-**	Frame Rotation Near Top	Dial Gage		1"
DG4	-**	Test Beam Rotation Near Middle	Dial Gage		1"
DG5	-**	Pin Far Horizontal Displacement	Dial Gage		1"
DG6	-**	Frame Rotation Far Bottom	Dial Gage		1"
DG7	-**	Frame Rotation Far Top	Dial Gage		1"
DG8	-**	Test Beam Rotation Far Middle	Dial Gage		1"

** All data has been modified so that (+) readings indicate extension.

Composite Slab Axial Stiffness Tests
Test Summary

Raw Data

Channel	0	1	2	12	13	14	15	16	17	18	19	80
	(in.)	(in.)	(kips)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(in.)
Point												
159	0.005	0.000	0.00	-1	-1	0	-1	-1	-1	0	-1	0.001
160	0.000	0.000	0.00	20	5	6	22	0	13	17	9	0.001
161	-0.014	0.000	-1.63	50	13	12	54	1	30	43	24	0.001
162	-0.014	0.000	0.00	38	10	9	42	-1	21	33	17	0.001
163	-0.018	0.000	-1.63	53	17	34	87	10	39	40	23	0.001
164	-0.023	0.000	-1.88	59	21	75	146	23	63	46	26	0.001
165	-0.023	0.000	-1.88	728	456	607	815	447	719	693	535	0.001
166	-0.023	0.000	-2.39	1209	746	1003	1281	722	1192	1152	911	0.001
167	-0.032	0.000	-5.03	1422	877	1215	1505	865	1432	1372	1088	0.001
168	-0.032	0.000	-7.04	1530	946	1352	1617	942	1560	1484	1182	0.001
169	-0.032	0.000	-9.05	1648	1022	1475	1732	1024	1691	1602	1276	0.001
170	-0.032	0.000	-10.93	1741	1085	1566	1825	1090	1797	1695	1349	0.002
171	-0.037	0.000	-12.06	1801	1124	1607	1884	1132	1864	1755	1395	0.002
172	-0.037	0.000	-13.69	1889	1183	1686	1970	1195	1963	1842	1463	0.003
173	-0.037	0.000	-15.58	1988	1250	1789	2065	1271	2075	1945	1542	0.004
174	-0.037	0.000	-16.96	2054	1297	1883	2131	1326	2155	2016	1597	0.004
175	-0.041	0.000	-18.09	2111	1338	1936	2187	1373	2220	2078	1645	0.005
176	-0.046	0.000	-19.72	2196	1405	1994	2268	1444	2309	2171	1714	0.006
177	-0.041	0.000	-21.36	2284	1480	2040	2348	1524	2389	2267	1787	0.008
178	-0.037	-0.005	-23.49	2384	1590	2113	2442	1630	2471	2383	1877	0.010
179	-0.046	0.000	-25.13	2462	1715	2184	2525	1744	2535	2485	1961	0.013
180	-0.041	0.000	-27.01	2400	2143	2267	2611	2104	2525	2671	2158	0.017
181	-0.050	0.000	-29.02	2286	2535	2355	2702	2486	2490	2690	2250	0.022
182	-0.050	0.000	-29.90	2441	2679	2439	2756	2645	2428	6360	2385	0.026
183	-0.050	0.000	-31.53	3069	9944	2554	2670	9505	1452	1196	9203	0.030
184	-0.050	0.000	-32.54	2129	10919	73	1133	8963	1310	1058	9599	0.034
185	-0.050	0.000	-33.17	1716	11432	17	1072	8991	1244	806	10000	0.038
186	-0.050	0.000	-33.29	1591	11917	-11	1078	9000	1213	797	10469	0.043
187	-0.050	0.000	-33.67	1504	12030	-30	1038	8209	1183	770	10771	0.046
188	-0.050	0.000	-32.79	1442	12332	-28	948	7696	1190	736	10994	0.049
189	-0.050	0.000	-32.41	1363	12489	-3	925	7567	1164	699	11130	0.050
190	-0.050	0.000	-32.41	1345	12786	25	939	7627	1107	701	11631	0.051
191	-0.050	0.000	-32.41	1341	13054	35	948	7749	1133	731	12209	0.051
192	-0.050	0.000	-32.16	1325	13427	35	923	1884	1112	710	12648	0.051
193	-0.050	0.000	-31.66	1321	13760	29	900	1744	1088	705	13157	0.052
194	-0.050	0.000	-30.53	1300	13686	52	917	1657	1073	683	13360	0.052
195	-0.050	0.000	-29.65	1286	13166	38	900	1604	1069	645	13336	0.052
196	-0.050	0.000	-28.64	1269	12780	34	882	1556	1069	601	13204	0.052
197	-0.046	-0.005	-28.02	1261	12401	29	862	1533	1090	578	13162	0.052
198	-0.050	0.000	-26.88	1249	11864	38	826	1513	1105	553	13083	0.051
199	-0.050	0.000	-25.50	1238	11529	7	799	1515	1128	554	13035	0.051
200	-0.050	-0.009	-20.85	1188	11085	-169	659	1504	997	515	12769	0.051
201	-0.046	-0.014	-16.71	1172	10594	-289	618	1511	1021	496	12526	0.051
202	-0.050	-0.014	-15.83	1159	10402	-267	699	1488	1144	513	12506	0.051
203	-0.046	-0.014	-15.70	1160	10358	-209	795	1449	1211	542	12565	0.051
204	-0.050	-0.014	-15.83	1169	10437	-63	828	1429	1204	564	12685	0.051
205	-0.050	-0.014	-15.33	1180	10572	102	805	1415	1206	582	12833	0.051

Composite Slab Axial Stiffness Tests
Test Summary

Raw Data

Channel	81	82	83	84	85	86	87	94	95	96	97	98
	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)
Point												
159	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.001	0.000	0.000
160	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.032	-0.168	-0.095	-0.043	-0.004
161	0.000	0.000	0.001	0.001	0.000	0.000	0.000	-0.045	-0.384	-0.226	-0.099	-0.012
162	0.000	0.000	0.001	0.001	0.000	0.000	0.000	-0.045	-0.329	-0.197	-0.092	-0.008
163	0.000	0.000	0.001	0.000	0.001	0.000	0.000	-0.052	-0.551	-0.325	-0.139	-0.009
164	0.000	0.000	0.002	0.001	0.001	0.000	0.000	-0.058	-0.691	-0.412	-0.176	-0.010
165	0.000	0.000	0.001	0.001	0.001	0.000	0.001	-0.065	-0.983	-0.580	-0.238	-0.003
166	0.000	0.000	0.002	0.001	0.001	0.000	0.001	-0.058	-1.325	-0.789	-0.321	-0.006
167	0.000	0.000	0.002	0.000	0.001	0.000	0.001	-0.069	-1.491	-0.891	-0.358	-0.006
168	0.001	0.000	0.002	0.000	0.001	0.000	0.002	-0.071	-1.578	-0.941	-0.377	-0.004
169	0.001	0.000	0.002	0.000	0.002	0.001	0.002	-0.071	-1.674	-0.993	-0.396	-0.002
170	0.001	0.000	0.003	0.000	0.002	0.001	0.002	-0.071	-1.739	-1.031	-0.411	0.000
171	0.002	0.000	0.003	0.000	0.002	0.001	0.002	-0.071	-1.780	-1.057	-0.418	0.001
172	0.002	0.000	0.004	0.001	0.002	0.002	0.002	-0.078	-1.841	-1.093	-0.433	0.004
173	0.003	0.001	0.004	0.001	0.004	0.003	0.002	-0.080	-1.913	-1.135	-0.448	0.006
174	0.004	0.001	0.005	0.001	0.004	0.004	0.003	-0.078	-1.968	-1.167	-0.460	0.007
175	0.004	0.002	0.005	0.001	0.005	0.004	0.003	-0.078	-2.016	-1.194	-0.467	0.009
176	0.005	0.002	0.005	0.001	0.005	0.006	0.004	-0.078	-2.077	-1.230	-0.482	0.010
177	0.005	0.004	0.006	0.002	0.007	0.008	0.004	-0.078	-2.138	-1.268	-0.495	0.012
178	0.007	0.007	0.006	0.004	0.007	0.011	0.005	-0.093	-2.218	-1.318	-0.516	0.015
179	0.007	0.009	0.006	0.004	0.008	0.014	0.006	-0.093	-2.292	-1.360	-0.529	0.015
180	0.010	0.013	0.009	0.005	0.012	0.019	0.007	-0.099	-2.412	-1.430	-0.557	0.017
181	0.016	0.019	0.013	Bad	0.018	0.025	0.012	-0.099	-2.541	-1.502	-0.587	0.019
182	0.026	0.024	0.021	0.000	0.027	0.031	0.020	-0.099	-2.682	-1.582	-0.621	0.021
183	0.035	0.027	0.029	0.004	0.035	0.034	0.029	-0.106	-2.805	-1.656	-0.649	0.023
184	0.043	0.032	0.036	0.008	0.043	0.039	0.038	-0.106	-2.922	-1.727	-0.677	0.024
185	0.051	0.037	0.042	0.012	0.052	0.045	0.045	-0.106	-3.025	-1.787	-0.698	0.025
186	0.069	0.043	0.055	0.018	0.069	0.050	0.053	-0.106	-3.166	-1.866	-0.726	0.026
187	0.091	0.047	0.073	0.021	0.089	0.054	0.055	-0.106	-3.286	-1.942	-0.754	0.027
188	0.147	0.050	0.118	0.024	0.146	0.057	0.059	-0.106	-3.528	-2.083	-0.807	0.028
189	0.211	0.051	0.178	0.026	0.211	0.059	0.065	-0.106	-3.774	-2.224	-0.865	0.028
190	0.271	0.051	0.232	0.027	0.272	0.060	0.072	-0.106	-4.018	-2.365	-0.921	0.029
191	0.341	0.053	0.298	0.027	0.347	0.060	0.080	-0.106	-4.293	-2.527	-0.983	0.029
192	0.400	0.053	0.357	0.027	0.410	0.060	0.086	-0.106	-4.528	-2.665	-1.039	0.029
193	0.448	0.053	0.424	0.028	0.479	0.061	0.093	-0.106	-4.783	-2.812	-1.101	0.029
194	0.488	0.053	0.503	0.028	0.558	0.061	0.103	-0.106	-5.045	-2.972	-1.163	0.029
195	0.565	0.053	0.573	0.028	0.631	0.061	0.112	-0.106	-5.273	-3.107	-1.219	0.029
196	0.643	0.053	0.649	0.028	0.708	0.061	0.120	-0.097	-5.518	-3.253	-1.274	0.029
197	0.722	0.053	0.726	0.027	0.784	0.061	0.132	-0.099	-5.764	-3.398	-1.330	0.028
198	0.810	0.053	0.806	0.027	0.862	0.061	0.142	-0.093	-6.017	-3.546	-1.386	0.028
199	0.928	0.053	0.895	0.027	0.953	0.061	0.154	-0.086	-6.298	-3.708	-1.448	0.027
200	1.047	0.051	1.010	0.026	1.066	0.060	0.166	-0.071	-6.544	-3.857	-1.510	0.024
201	1.236	0.050	1.201	0.024	1.260	0.059	0.195	-0.052	-7.041	-4.150	-1.628	0.023
202	1.401	0.050	1.364	0.024	1.428	0.059	0.223	-0.032	-7.538	-4.446	-1.746	0.021
203	1.549	0.050	1.511	0.024	1.577	0.059	0.242	-0.006	-8.006	-4.724	-1.850	0.020
204	1.708	0.050	1.666	0.024	1.741	0.059	0.265	0.028	-8.514	-5.027	-1.975	0.019
205	1.875	0.050	1.825	0.023	1.908	0.059	0.305	0.067	-9.037	-5.335	-2.101	0.018

Composite Slab Axial Stiffness Tests
Test Summary

Raw Data

Channel	100	101	102	103	DG1	DG2	DG3	DG4	DG5	DG6	DG7	DG8
	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)
Point												
159	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	-
160	-0.005	-0.004	-0.014	-0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
161	-0.013	-0.013	-0.034	-0.028	-0.045	-0.038	-0.020	-0.008	-0.037	-0.040	-0.024	-0.010
162	-0.013	-0.012	-0.030	-0.025	-0.040	-0.031	-0.018	-0.008	-0.033	-0.033	-0.019	-0.008
163	-0.019	-0.018	-0.046	-0.043	-0.092	-0.076	-0.041	-0.019	-0.071	-0.078	-0.045	-0.019
164	-0.025	-0.024	-0.061	-0.056	-0.139	-0.110	-0.059	-0.028	-0.100	-0.113	-0.065	-0.030
165	-0.034	-0.033	-0.083	-0.082	-0.182	-0.175	-0.081	-0.044	-0.155	-0.178	-0.099	-0.045
166	-0.046	-0.045	-0.114	-0.112	-0.287	-0.255	-0.137	-0.050	-0.260	-0.259	-0.144	-0.067
167	-0.048	-0.048	-0.124	-0.121	-0.298	-0.288	-0.153	-0.051	-0.278	-0.289	-0.160	-0.074
168	-0.049	-0.049	-0.128	-0.126	-0.305	-0.301	-0.158	-0.053	-0.289	-0.303	-0.166	-0.076
169	-0.049	-0.048	-0.131	-0.129	-0.315	-0.312	-0.165	-0.054	-0.301	-0.314	-0.169	-0.078
170	-0.048	-0.047	-0.134	-0.131	-0.321	-0.319	-0.168	-0.054	-0.310	-0.322	-0.171	-0.079
171	-0.047	-0.047	-0.135	-0.132	-0.325	-0.324	-0.168	-0.054	-0.315	-0.328	-0.172	-0.079
172	-0.046	-0.045	-0.137	-0.134	-0.331	-0.330	-0.168	-0.054	-0.322	-0.333	-0.173	-0.078
173	-0.044	-0.044	-0.137	-0.135	-0.336	-0.335	-0.168	-0.054	-0.329	-0.339	-0.173	-0.078
174	-0.043	-0.042	-0.138	-0.137	-0.340	-0.339	-0.168	-0.053	-0.334	-0.342	-0.172	-0.078
175	-0.042	-0.042	-0.139	-0.137	-0.343	-0.341	-0.168	-0.053	-0.338	-0.344	-0.171	-0.078
176	-0.040	-0.040	-0.140	-0.138	-0.346	-0.344	-0.168	-0.052	-0.342	-0.347	-0.169	-0.077
177	-0.037	-0.038	-0.140	-0.138	-0.350	-0.347	-0.166	-0.050	-0.346	-0.349	-0.166	-0.074
178	-0.032	-0.034	-0.139	-0.137	-0.353	-0.350	-0.162	-0.047	-0.350	-0.351	-0.161	-0.072
179	-0.027	-0.029	-0.138	-0.136	-0.356	-0.351	-0.157	-0.044	-0.354	-0.352	-0.156	-0.069
180	-0.013	-0.015	-0.130	-0.129	-0.359	-0.351	-0.145	-0.032	-0.360	-0.352	-0.155	-0.060
181	0.004	0.002	-0.120	-0.119	-0.362	-0.350	-0.133	-0.018	-0.364	-0.351	-0.133	-0.046
182	0.026	0.023	-0.104	-0.104	-0.364	-0.347	-0.118	0.001	-0.366	-0.348	-0.116	-0.028
183	0.048	0.046	-0.088	-0.089	-0.366	-0.345	-0.103	0.020	-0.369	-0.345	-0.102	-0.008
184	0.071	0.069	-0.071	-0.072	-0.368	-0.342	-0.088	0.040	-0.372	-0.342	-0.087	0.012
185	0.092	0.089	-0.055	-0.056	-0.369	-0.338	-0.075	0.059	-0.373	-0.339	-0.073	0.030
186	0.123	0.121	-0.032	-0.032	-0.370	-0.332	-0.054	0.087	-0.375	-0.333	-0.053	0.058
187	0.153	0.152	-0.008	-0.009	-0.370	-0.326	-0.035	0.114	-0.375	-0.327	-0.034	0.084
188	0.218	0.216	0.042	0.039	-0.371	-0.313	0.004	0.170	-0.375	-0.314	0.007	0.139
189	0.282	0.279	0.092	0.088	-0.370	-0.299	0.045	0.229	-0.375	-0.300	0.047	0.196
190	0.343	0.341	0.139	0.137	-0.370	-0.287	0.084	0.284	-0.375	-0.287	0.086	0.251
191	0.414	0.411	0.195	0.193	-0.371	-0.272	0.128	0.348	-0.375	-0.272	0.130	0.314
192	0.475	0.473	0.243	0.241	-0.371	-0.259	0.168	0.404	-0.375	-0.259	0.168	0.369
193	0.543	0.541	0.297	0.293	-0.371	-0.245	0.210	0.464	-0.375	-0.245	0.211	0.429
194	0.616	0.614	0.355	0.350	-0.370	-0.228	0.256	0.531	-0.375	-0.228	0.257	0.494
195	0.678	0.677	0.404	0.399	-0.370	-0.213	0.295	0.588	-0.374	-0.214	0.297	0.549
196	0.746	0.745	0.457	0.452	-0.369	-0.198	0.338	0.648	-0.373	-0.198	0.340	0.610
197	0.813	0.810	0.510	0.504	-0.369	-0.183	0.380	0.708	-0.372	-0.184	0.382	0.670
198	0.882	0.879	0.565	0.558	-0.368	-0.167	0.423	0.769	-0.371	-0.168	0.425	0.731
199	0.959	0.957	0.624	0.619	-0.367	-0.149	0.471	0.837	-0.369	-0.150	0.474	0.800
200	1.047	1.045	0.694	0.688	-0.361	-0.123	0.505	-	-0.362	-0.123	0.534	-
201	1.199	1.196	0.816	0.810	-0.355	-0.083	-	-	-0.353	-0.083	-	-
202	1.335	1.334	0.924	0.915	-0.353	-0.051	-	-	-0.351	-0.051	-	-
203	1.459	1.457	1.022	1.014	-0.352	-0.024	-	-	-0.350	-0.024	-	-
204	1.593	1.592	1.127	1.118	-0.350	0.000	-	-	-0.349	0.002	-	-
205	1.735	1.732	1.238	1.227	-0.350	0.036	-	-	-0.347	0.033	-	-

01285

Composite Slab Axial Stiffness Tests
Test Summary

Test Notes

Data Point	Test Comment
159	Instrumentation zeroed while rotation beam on temporary support.
160	Temporary support removed.
161	Preload specimen
162	Remove preload
163	Start test loading
165	Noticed hairline transverse crack at center of slab
182	Re-zero channel 84, something went wrong with gage, the POT was replaced
205	Test ended because of excessive deformations. The concrete under the loading point was cracked so severly that it was not connected to the rest of the slab. Clearly the stud under the loading point was ineffective.

01287

Composite Slab Axial Stiffness Tests **Slab #4**

Test Summary

<u>Data Calculations</u>

Rotation Calculations

Method

2 $$t = \frac{\text{Average }(100,101) - \text{Average }(102,103)}{5.1875}$$

4 $$t = t_{\text{Free Beam}} - t_{\text{Fixed Beam}}$$

Where: $$t_{\text{Fixed Beam}} = \frac{(1) - (0)}{28}$$

a $$t_{\text{Free Beam}} = \frac{(97) - (96)}{33.5}$$

b $$t_{\text{Free Beam}} = \frac{(97) - (95)}{71.75}$$

c $$t_{\text{Free Beam}} = \frac{(96) - (95)}{38.25}$$

Slab Deformation Calculations

Method

1 $$\Delta = \text{Average }(102,103) + 10.625\,t$$

3 $$\Delta = \text{Average }(100,101) + 5.4375\,t$$

Slab Load Calculations

$$P = \frac{(2)\ 52.875}{29.9375} + 2.37$$

Note: Numbers enclosed in parenthesis, i.e. (2), correspond to gage numbers.

Composite Slab Axial Stiffness Tests
Test Summary

Calculated Data

Data Point	Load @ Centerline of Reinforcing Steel (Kips)	Rebar #1 Axial Force (kips)	Rebar #2 Axial Force (kips)	Rebar #3 Axial Force (kips)	Rebar #4 Axial Force (kips)	Rebar Total Axial Force (kips)	Rotation 2 (rad)	Rotation 4a (rad)
159	0.00	0.00	0.00	0.00	0.00	-0.01	0.0000	0.0001
160	2.37	0.06	0.07	0.03	0.07	0.23	0.0014	0.0015
161	5.25	0.15	0.16	0.08	0.17	0.56	0.0034	0.0033
162	2.37	0.11	0.13	0.05	0.13	0.42	0.0029	0.0026
163	5.25	0.17	0.30	0.12	0.16	0.75	0.0050	0.0049
164	5.70	0.19	0.55	0.21	0.19	1.14	0.0065	0.0062
165	5.70	2.79	3.53	2.92	3.18	12.42	0.0095	0.0094
166	6.59	4.61	5.66	4.80	5.35	20.42	0.0130	0.0131
167	11.25	5.42	6.75	5.76	6.38	24.30	0.0143	0.0148
168	14.80	5.84	7.36	6.27	6.91	26.38	0.0150	0.0157
169	18.35	6.29	7.95	6.81	7.46	28.52	0.0157	0.0167
170	21.67	6.66	8.41	7.24	7.89	30.20	0.0163	0.0173
171	23.67	6.90	8.66	7.51	8.17	31.23	0.0167	0.0178
172	26.56	7.24	9.07	7.92	8.57	32.80	0.0173	0.0184
173	29.88	7.63	9.56	8.39	9.04	34.62	0.0177	0.0192
174	32.32	7.90	9.95	8.72	9.37	35.95	0.0183	0.0198
175	34.32	8.13	10.22	9.01	9.65	37.01	0.0185	0.0202
176	37.21	8.49	10.57	9.41	10.08	38.54	0.0191	0.0207
177	40.09	8.87	10.88	9.81	10.51	40.08	0.0196	0.0216
178	43.86	9.37	-	-	11.05	-	0.0203	0.0228
179	46.75	-	-	-	-	-	0.0210	0.0232
180	50.07	-	-	-	-	-	0.0222	0.0246
181	53.62	-	-	-	-	-	0.0235	0.0255
182	55.18	-	-	-	-	-	0.0248	0.0269
183	58.06	-	-	-	-	-	0.0260	0.0282
184	59.84	-	-	-	-	-	0.0272	0.0295
185	60.95	-	-	-	-	-	0.0282	0.0307
186	61.17	-	-	-	-	-	0.0296	0.0322
187	61.83	-	-	-	-	-	0.0309	0.0337
188	60.28	-	-	-	-	-	0.0341	0.0363
189	59.62	-	-	-	-	-	0.0367	0.0387
190	59.62	-	-	-	-	-	0.0394	0.0413
191	59.62	-	-	-	-	-	0.0422	0.0443
192	59.17	-	-	-	-	-	0.0447	0.0467
193	58.28	-	-	-	-	-	0.0476	0.0493
194	56.29	-	-	-	-	-	0.0506	0.0522
195	54.73	-	-	-	-	-	0.0531	0.0546
196	52.96	-	-	-	-	-	0.0560	0.0573
197	51.85	-	-	-	-	-	0.0586	0.0603
198	49.85	-	-	-	-	-	0.0615	0.0627
199	47.41	-	-	-	-	-	0.0648	0.0657
200	39.20	-	-	-	-	-	0.0684	0.0686
201	31.88	-	-	-	-	-	0.0741	0.0742
202	30.33	-	-	-	-	-	0.0800	0.0793
203	30.11	-	-	-	-	-	0.0849	0.0846
204	30.33	-	-	-	-	-	0.0906	0.0898
205	29.44	-	-	-	-	-	0.0965	0.0952

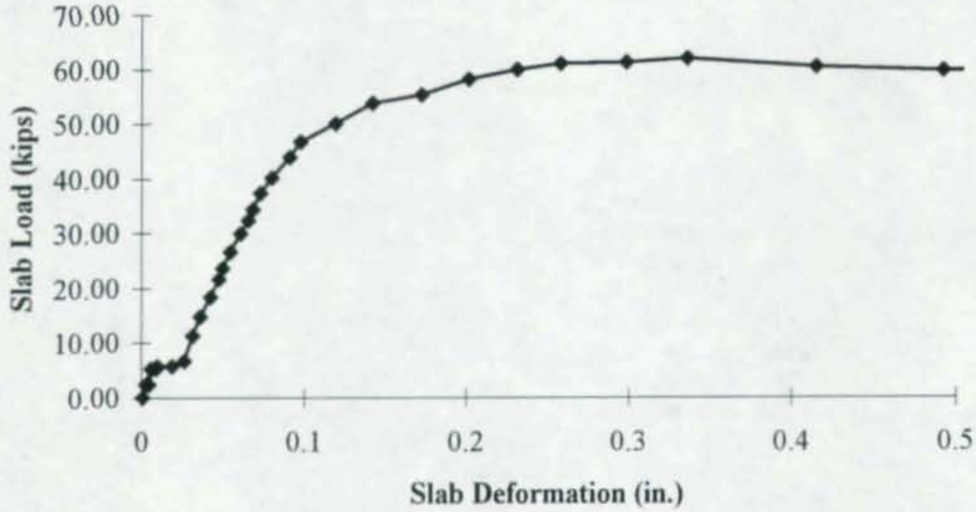
Calculate

Data Point	Rotation 4b (rad)	Rotation 4c (rad)	Rotation Average (rad)	Δ Slab 1 (in.)	Δ Slab 3 (in.)	Δ Slab Average (in.)
159	0.0002	0.0002	0.0001	0.001	0.001	0.001
160	0.0017	0.0019	0.0017	0.005	0.004	0.005
161	0.0035	0.0036	0.0035	0.006	0.006	0.006
162	0.0028	0.0030	0.0028	0.002	0.003	0.003
163	0.0051	0.0053	0.0051	0.009	0.009	0.009
164	0.0064	0.0065	0.0064	0.009	0.010	0.010
165	0.0096	0.0097	0.0095	0.019	0.019	0.019
166	0.0132	0.0132	0.0131	0.026	0.026	0.026
167	0.0146	0.0145	0.0146	0.032	0.031	0.032
168	0.0156	0.0155	0.0154	0.037	0.035	0.036
169	0.0167	0.0166	0.0164	0.044	0.041	0.043
170	0.0174	0.0174	0.0171	0.050	0.046	0.048
171	0.0177	0.0176	0.0174	0.052	0.048	0.050
172	0.0183	0.0183	0.0181	0.057	0.053	0.055
173	0.0191	0.0190	0.0188	0.063	0.058	0.061
174	0.0197	0.0196	0.0193	0.068	0.063	0.065
175	0.0201	0.0200	0.0197	0.072	0.065	0.068
176	0.0206	0.0205	0.0202	0.076	0.070	0.073
177	0.0214	0.0213	0.0210	0.084	0.076	0.080
178	0.0226	0.0224	0.0220	0.096	0.087	0.091
179	0.0229	0.0227	0.0225	0.102	0.094	0.098
180	0.0244	0.0242	0.0238	0.124	0.115	0.120
181	0.0254	0.0254	0.0250	0.146	0.138	0.142
182	0.0269	0.0270	0.0264	0.177	0.168	0.172
183	0.0282	0.0282	0.0277	0.206	0.197	0.202
184	0.0295	0.0295	0.0289	0.236	0.227	0.231
185	0.0306	0.0306	0.0300	0.263	0.253	0.258
186	0.0322	0.0322	0.0316	0.304	0.294	0.299
187	0.0335	0.0333	0.0329	0.341	0.331	0.336
188	0.0361	0.0360	0.0356	0.419	0.411	0.415
189	0.0387	0.0387	0.0382	0.496	0.488	0.492
190	0.0414	0.0414	0.0409	0.572	0.564	0.568
191	0.0443	0.0444	0.0438	0.659	0.651	0.655
192	0.0468	0.0469	0.0463	0.734	0.726	0.730
193	0.0495	0.0497	0.0490	0.816	0.809	0.812
194	0.0523	0.0524	0.0519	0.904	0.897	0.900
195	0.0547	0.0548	0.0543	0.979	0.973	0.976
196	0.0573	0.0574	0.0570	1.060	1.055	1.058
197	0.0603	0.0604	0.0599	1.144	1.137	1.140
198	0.0627	0.0628	0.0624	1.225	1.220	1.222
199	0.0658	0.0659	0.0655	1.318	1.314	1.316
200	0.0687	0.0688	0.0686	1.420	1.419	1.419
201	0.0743	0.0744	0.0743	1.602	1.601	1.601
202	0.0794	0.0795	0.0796	1.765	1.767	1.766
203	0.0846	0.0847	0.0847	1.918	1.919	1.918
204	0.0898	0.0898	0.0900	2.079	2.082	2.081
205	0.0954	0.0955	0.0956	2.249	2.254	2.251

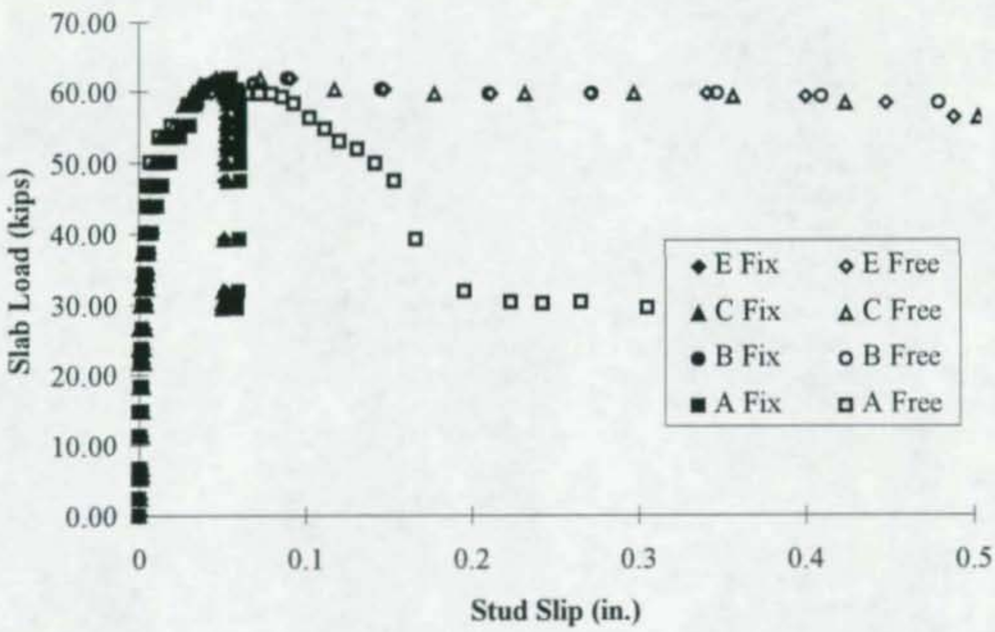
Composite Slab Axial Stiffness Tests
Test Summary

Slab #4

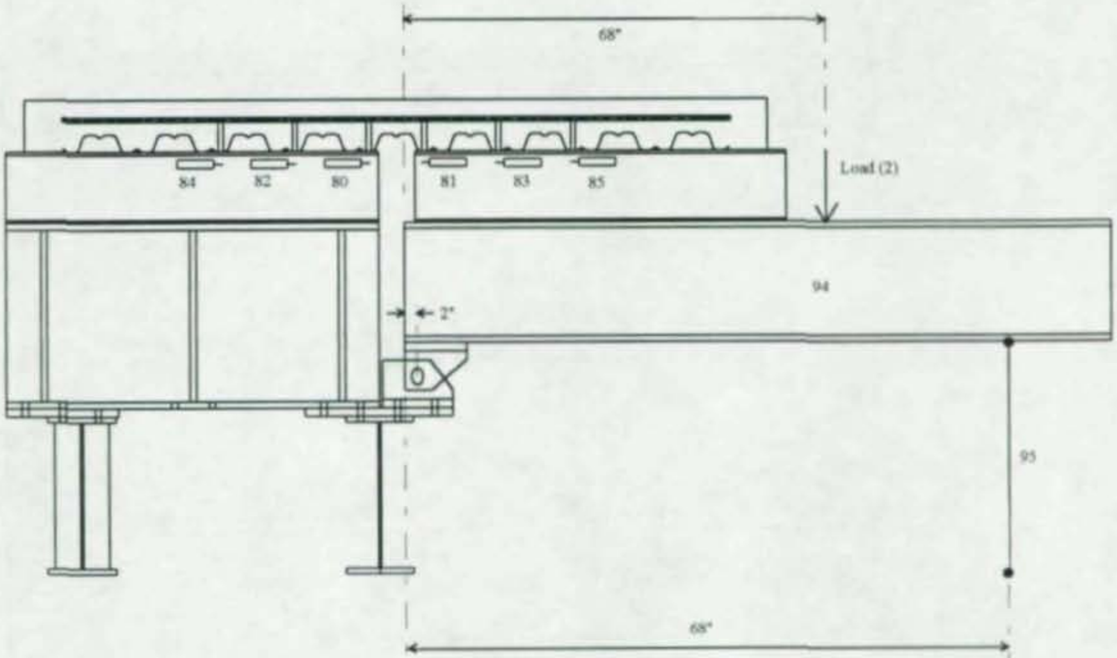
Composite Slab Load Vs. Deformation



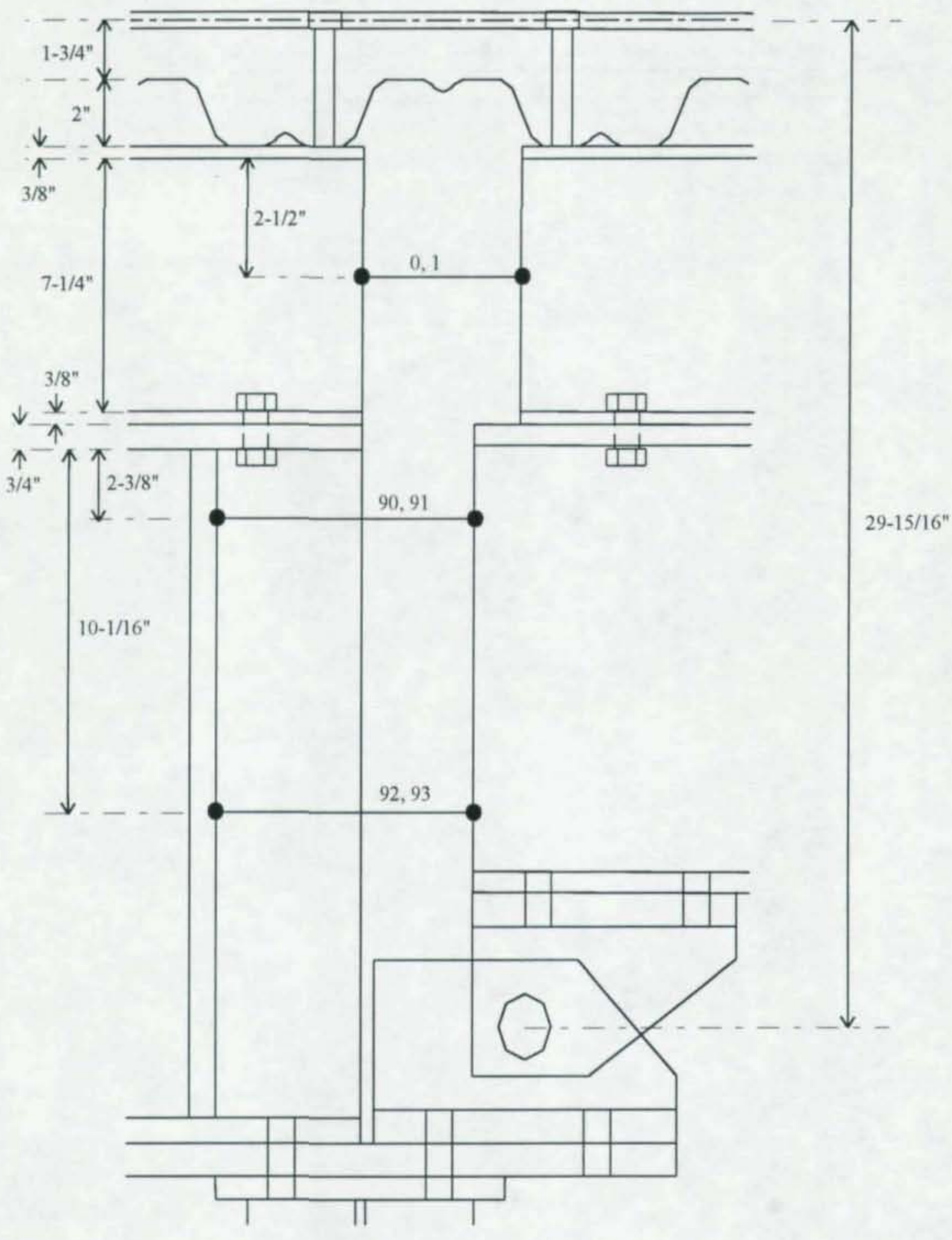
Load Vs. Stud Slip



Instrumentation Diagram Part A



Instrumentation Diagram Part B



012980

Description of Instrumentation

Gage No. Also Channel No.	Sense of Extension	Description of Measurement	Gage Type	Sensitivity	Full Scale
0	-**	Near Test Beam	ST2	1.0901	10"
1	+	Far Test Beam	ST3	1.0931	10"
2	Compression (-)	Load cell	Load Cell	1.99	500 kips
12	+	Rebar 2-1-1 Near Side	Strain Gage	5.0571 lbs/μ strain	
13	+	Rebar 2-1-2 Near Side	Strain Gage		
14	+	Rebar 2-2-1 Near Side	Strain Gage	4.9985 lbs/μ strain	
15	+	Rebar 2-2-2 Near Side	Strain Gage		
16	+	Rebar 2-3-1 Far Side	Strain Gage	4.9627 lbs/μ strain	
17	+	Rebar 2-3-2 Far Side	Strain Gage		
18	+	Rebar 2-4-1 Far Side	Strain Gage	5.0574 lbs/μ strain	
19	+	Rebar 2-4-2 Far Side	Strain Gage		
80	-**	Stud Slip Fixed Side Location G	POT		6"
81	-**	Stud Slip Free Side Location G	POT		6"
82	-**	Stud Slip Fixed Side Location E	POT		6"
83	-**	Stud Slip Free Side Location E	POT		6"
84	-**	Stud Slip Fixed Side Location C	POT		6"
85	-**	Stud Slip Free Side Location C	POT		6"
90	+	Frame Rotation Top Near	DCDT 6	0.942	10"
91	+	Frame Rotation Top Far	DCDT 3	0.47	10"
92	-**	Frame Rotation Bottom Near	DCDT 7	?	?
93	+	Frame Rotation Bottom Far	DCDT 1	0.934	10"
94	+	Lateral Displacement at loading point	DCDT 4	0.471	10"
95	+	ertical Displacement Under Loading Poi	DCDT 9	0.701	15"

** All data has been modified so that (+) readings indicate extension.

Composite Slab Axial Stiffness Tests
Test Summary

Raw Data

Channel	0	1	2	12	13	14	15	16	17	18	19	80
	(in.)	(in.)	(kips)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(in.)
Point												
3	0.000	0.005	0.13	0	0	-1	0	-1	0	-1	0	0.000
4	-0.014	-0.009	-1.76	193	409	393	379	317	266	319	225	0.000
5	-0.023	-0.023	-5.03	388	774	830	812	776	656	827	628	0.000
6	-0.023	-0.023	0.13	243	513	535	521	517	429	601	449	0.000
7	0.000	0.000	0.00	-1	-1	-1	-2	-2	-1	-1	-1	0.000
8	0.000	0.000	-5.03	174	268	310	306	278	244	250	201	0.000
9	0.000	-0.009	-7.54	-61	516	661	632	597	511	538	467	0.000
10	0.000	-0.005	-9.05	2	674	894	850	775	655	663	598	0.000
11	0.000	-0.005	-10.43	82	789	1047	998	915	773	776	704	0.000
12	0.009	0.000	-13.07	258	1031	1394	1342	1256	1057	1040	950	0.008
13	0.018	0.009	-14.82	478	1200	1658	1626	1513	1262	1229	1122	0.019
14	0.032	0.014	-15.95	936	1312	1690	1875	1673	1383	1342	1227	0.027
15	0.060	0.041	-17.96	1072	1478	1708	2067	2154	1686	1530	1401	0.047
16	0.138	0.119	-17.71	919	1026	1356	1751	1881	1435	1158	1168	0.056
17	0.174	0.160	-15.20	760	688	1018	1426	1576	1163	841	926	0.056
18	0.220	0.210	-14.57	726	510	847	1267	1434	1045	681	823	0.055
19	0.624	0.288	-14.07	707	320	685	1128	1304	946	536	742	0.056
20	0.404	0.384	-13.44	693	218	598	1064	1233	899	459	709	0.055
21	0.459	0.467	-13.07	688	139	539	1027	1192	878	406	693	0.055
22	0.550	0.549	-12.56	688	80	494	1006	1155	858	359	678	0.056
23	0.711	0.700	-12.81	687	84	483	1014	1138	859	340	673	0.055
24	0.871	0.865	-13.44	745	79	505	1073	1154	912	341	713	0.055
25	1.000	0.993	-6.03	309	24	220	719	820	561	176	469	0.053

01291

Composite Slab Axial Stiffness Tests
Test Summary

Raw Data

Channel	81	82	83	84	85	90	91	92	93	94	95
	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)
Point											
3	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.002	0.000
4	0.000	0.000	0.000	-0.001	0.002	-0.035	-0.014	-0.020	-0.064	0.002	-0.240
5	0.000	0.000	0.000	-0.001	0.004	-0.058	-0.020	-0.027	-0.110	-0.004	-0.455
6	0.000	0.000	0.000	-0.002	0.001	-0.055	-0.018	-0.022	-0.089	-0.006	-0.301
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	-0.002
8	0.000	0.000	0.000	0.002	0.002	-0.004	-0.004	-0.004	-0.022	0.000	-0.170
9	0.000	0.000	-0.001	0.007	0.006	-0.009	-0.006	-0.010	-0.046	-0.004	-0.342
10	0.000	0.000	0.000	0.009	0.009	-0.010	-0.007	-0.013	-0.056	-0.004	-0.438
11	0.000	0.000	0.000	0.012	0.012	-0.010	-0.007	-0.015	-0.061	-0.011	-0.506
12	0.000	0.000	0.000	0.021	0.017	-0.008	-0.006	-0.019	-0.073	-0.019	-0.662
13	0.000	0.000	0.000	0.033	0.024	0.000	-0.004	-0.021	-0.080	-0.017	-0.800
14	0.000	0.000	0.000	0.041	0.027	0.005	-0.004	-0.022	-0.082	-0.017	-0.880
15	0.000	0.000	0.000	0.062	0.024	0.025	0.003	-0.022	-0.081	-0.011	-1.070
16	0.001	0.000	0.000	0.072	-0.024	0.074	0.020	-0.017	-0.062	-0.011	-1.323
17	0.036	0.001	0.000	0.071	-0.021	0.100	0.029	-0.012	-0.045	-0.011	-1.397
18	0.087	0.000	0.000	0.071	-0.014	0.132	0.040	-0.008	-0.028	-0.011	-1.538
19	0.169	0.000	0.000	0.071	-0.001	0.184	0.059	-0.001	0.000	-0.011	-1.767
20	0.268	0.001	0.000	0.071	0.022	0.248	0.083	0.009	0.032	-0.011	-2.033
21	0.357	0.000	0.000	0.071	0.038	0.303	0.101	0.017	0.061	-0.011	-2.268
22	0.454	0.001	0.000	0.071	0.060	0.363	0.122	0.027	0.093	-0.013	-2.532
23	0.639	0.000	0.001	0.071	0.109	0.473	0.158	0.045	0.147	0.000	-3.022
24	0.823	0.000	0.086	0.071	0.128	0.583	0.195	0.061	0.201	0.019	-3.526
25	1.016	0.001	0.287	0.065	0.145	0.677	0.228	0.083	0.267	0.054	-3.720

Composite Slab Axial Stiffness Tests **Slab #5**

Test Summary

Test Notes

Data Point	Test Comment
3	Instrumentation zeroed while after temp support had been removed
5	Maximum preload
6	Remove preload
7	All instrumentation re-zeroed
12	Notice that slab above the free beam is uplifting with respect to the test beam. This is occuring at the locations were there are no shear studs.
15	Shear lag type cracks forming on the free side of the test slab and symmetric about the centerline of the test slab.
17	Loud pop, unsure of source, possibly stud shearing
19	Deck in front of studs at E and C positions on free end of specimen are seriously
25	End test. Stud in position G was sheared off and studs in positions E and C were severely bent

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Composite Slab Axial Stiffness Tests
Test Summary

Slab #5

Data Calculations

Rotation Calculations

Method

1 $$t = \frac{(90) - (93)}{7.6875}$$

Slab Deformation Calculations

Method

1 Δ =Average (0,1) +6.625 θ

Slab Load Calculations

$$P = \frac{(2)\,66}{29.9375} + 2.37$$

Note: Numbers enclosed in parenthesis, i.e. (2), correspond to gage numbers.

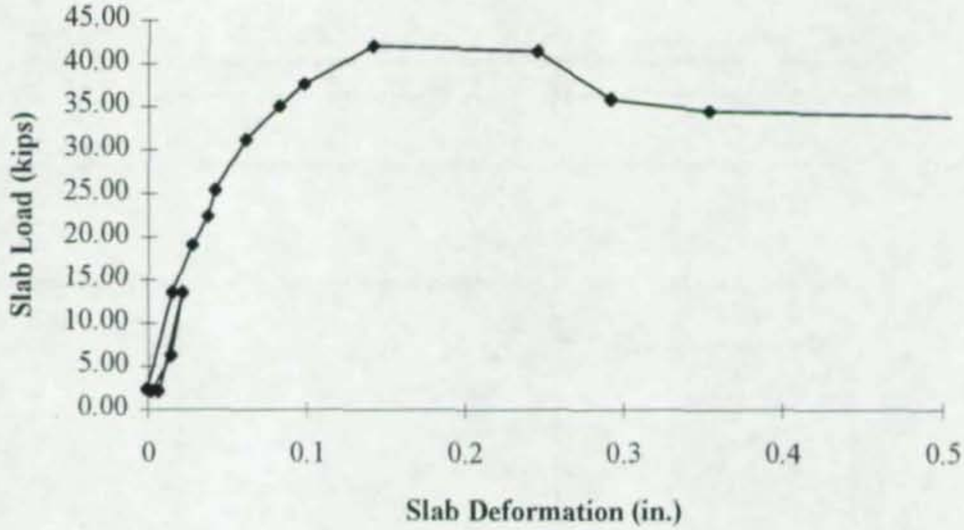
Composite Slab Axial Stiffness Tests
Test Summary

Calculated Data

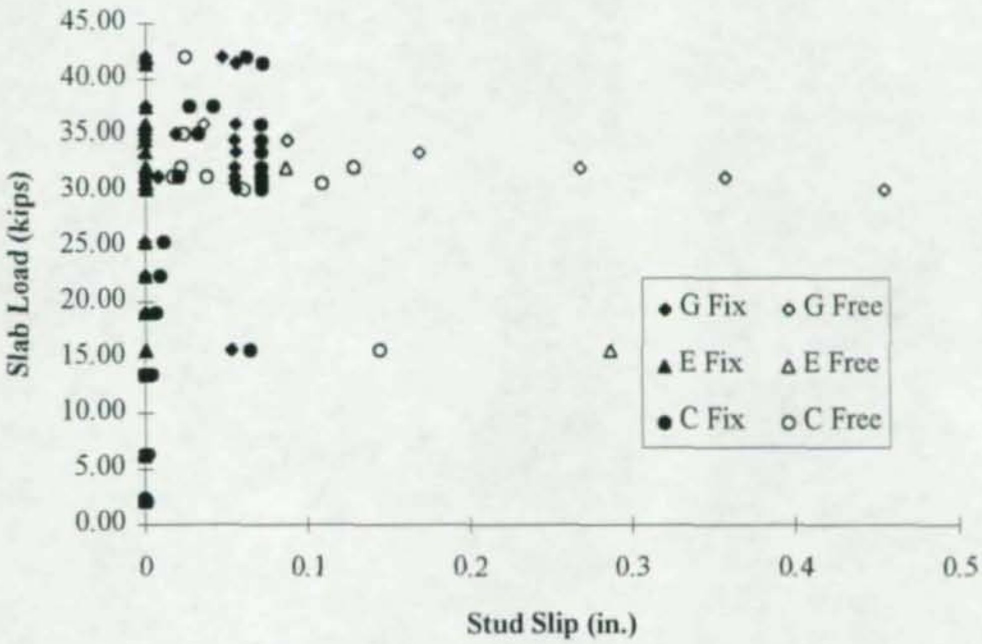
Data Point	Load @ Centerline of Reinforcing Steel (kips)	Rebar #1 Axial Force (kips)	Rebar #2 Axial Force (kips)	Rebar #3 Axial Force (kips)	Rebar #4 Axial Force (kips)	Rebar Total Axial Force (kips)	Rotation 1 (rad)	Δ Slab 1 (in.)
3	2.09	0.00	0.00	0.00	0.00	-0.01	0.0000	0.002
4	6.25	1.52	1.93	1.45	1.38	6.28	0.0039	0.014
5	13.45	2.94	4.10	3.55	3.68	14.27	0.0067	0.022
6	2.09	1.91	2.64	2.35	2.66	9.55	0.0045	0.007
7	2.37	0.00	-0.01	-0.01	0.00	-0.02	-0.0001	-0.001
8	13.45	1.12	1.54	1.30	1.14	5.09	0.0023	0.015
9	18.99	1.15	3.23	2.75	2.54	9.67	0.0048	0.027
10	22.31	1.71	4.36	3.55	3.19	12.81	0.0060	0.037
11	25.36	2.20	5.11	4.19	3.74	15.25	0.0067	0.042
12	31.17	3.26	6.84	5.74	5.03	20.87	0.0085	0.061
13	35.05	4.24	8.21	6.88	5.94	25.28	0.0104	0.082
14	37.54	5.68	8.91	7.58	6.50	28.67	0.0113	0.098
15	41.98	6.45	9.43	9.53	7.41	32.82	0.0137	0.141
16	41.42	4.92	7.76	8.23	5.88	26.79	0.0177	0.245
17	35.88	3.66	6.11	6.80	4.47	21.04	0.0188	0.292
18	34.50	3.12	5.28	6.15	3.80	18.36	0.0209	0.354
19	33.39	2.60	4.53	5.58	3.23	15.94	0.0239	0.615
20	32.00	2.30	4.16	5.29	2.95	14.70	0.0281	0.580
21	31.17	2.09	3.91	5.14	2.78	13.92	0.0315	0.671
22	30.07	1.94	3.75	4.99	2.62	13.30	0.0351	0.782
23	30.62	1.95	3.74	4.96	2.56	13.21	0.0424	0.986
24	32.00	2.08	3.94	5.12	2.67	13.82	0.0498	1.198
25	15.66	0.84	2.35	3.43	1.63	8.25	0.0533	1.349

Composite Slab Axial Stiffness Tests **Slab #5**
Test Summary

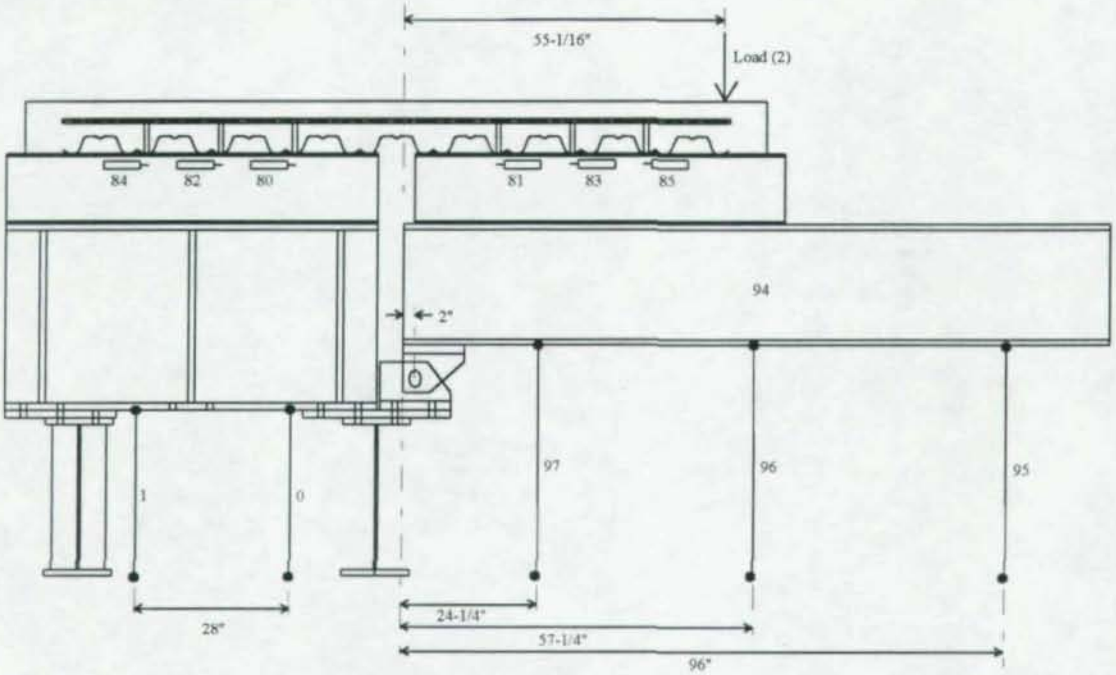
Composite Slab Load Vs. Deformation



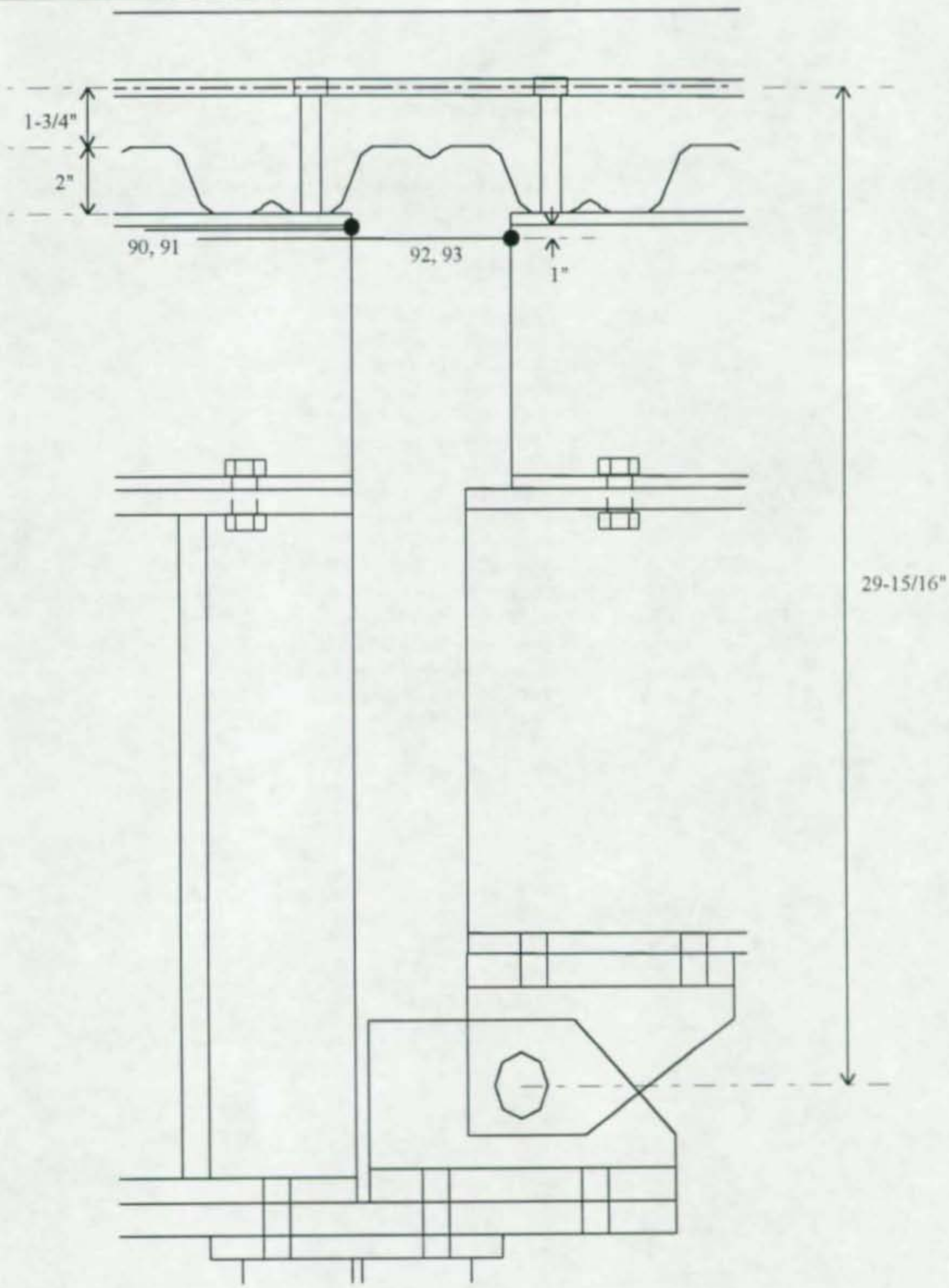
Load Vs. Stud Slip



Instrumentation Diagram Part A



Instrumentation Diagram Part B



Composite Slab Axial Stiffness Tests
Test Summary

Description of Instrumentation

Gage No. Also Channel No.	Sense of Extension	Description of Measurement	Gage Type	Sensitivity	Full Scale
0	-**	Fixed Beam Rotation	ST2	1.0901	10"
1	+	Fixed Beam Rotation	ST3	1.0931	10"
2	Compression (-)	Load cell	Load Cell	1.99	500 kips
12	+	Rebar 6-1-1 Far Side	Strain Gage	4.8068 lbs/μ strain	
13	+	Rebar 6-1-2 Far Side	Strain Gage		
14	+	Rebar 6-2-1 Far Side	Strain Gage	4.9876 lbs/μ strain	
15	+	Rebar 6-2-2 Far Side	Strain Gage		
16	+	Rebar 6-3-1 Near Side	Strain Gage	4.9963 lbs/μ strain	
17	+	Rebar 6-3-2 Near Side	Strain Gage		
18	+	Rebar 6-4-1 Near Side	Strain Gage	5.0072 lbs/μ strain	
19	+	Rebar 6-4-2 Near Side	Strain Gage		
80	-**	Stud Slip Fixed Side Location E	POT		6"
81	-**	Stud Slip Free Side Location E	POT		6"
82	-**	Stud Slip Fixed Side Location C	POT		6"
83	-**	Stud Slip Free Side Location C	POT		6"
84	-**	Stud Slip Fixed Side Location B	POT		6"
85	-**	Stud Slip Free Side Location B	POT		6"
90	+	Test Beam Seperation Fix Near	DCDT 6	0.942	10"
91	+	Test Beam Seperation Fix Far	DCDT 7	?	?
92	-**	Test Beam Seperation Free Near	DCDT 1	0.934	10"
93	+	Test Beam Seperation Free Far	DCDT 3	0.47	10"
94	+	Lateral Displacement At Loading Point	DCDT 4	0.471	10"
95	+	Free Beam Vertical Displacement	DCDT 9	0.701	15"
96	+	Free Beam Vertical Displacement	DCDT 8	0.947	10"
97	+	Free Beam Vertical Displacement	DCDT 10	0.94	10"

** All data has been modified so that (+) readings indicate extension.

Composite Slab Axial Stiffness Tests
Test Summary

Raw Data

Channel	0	1	2	12	13	14	15	16	17	18	19	80	81	82
	(in.)	(in.)	(kips)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(μ strain)	(in.)	(in.)	(in.)
Point														
26	0.005	-0.005	0.00	0	-1	0	0	-1	-1	0	-1	0.000	0.000	0.000
27	0.000	-0.005	-0.13	-1	-1	0	-1	-1	-1	1	-1	0.000	0.000	0.000
28	0.000	-0.005	-0.13	-1	-2	0	-1	-1	-1	0	-2	0.000	0.000	0.000
29	-0.005	-0.005	-2.01	214	126	200	310	271	228	176	241	0.001	0.001	0.000
30	-0.005	-0.005	-1.13	247	132	219	363	312	255	201	223	0.001	0.000	0.000
31	-0.005	-0.005	-0.13	190	87	166	299	254	205	157	148	0.001	0.000	0.000
32	-0.009	-0.005	-2.14	584	308	480	823	698	584	463	458	0.002	0.001	0.000
33	-0.018	-0.005	-2.39	846	456	721	1088	923	832	687	515	0.002	0.001	0.000
34	-0.014	-0.005	-0.13	621	285	509	815	685	620	494	264	0.001	0.001	0.000
35	-0.009	-0.005	-0.13	621	284	507	813	683	618	492	262	0.001	0.001	0.000
36	-0.014	-0.005	0.00	617	282	504	810	681	615	490	253	0.001	0.001	0.000
37	-0.009	0.000	-1.76	787	415	663	1012	859	774	638	389	0.001	0.001	0.000
38	-0.018	-0.005	-4.65	871	480	827	1019	888	878	773	336	0.003	0.001	-0.001
39	-0.018	-0.005	-7.54	926	535	887	1073	937	930	823	350	0.004	0.002	-0.005
40	-0.018	-0.005	-9.17	960	565	918	1096	961	956	854	339	0.005	0.003	-0.004
41	-0.023	-0.005	-11.43	1001	605	969	1091	979	995	884	319	0.006	0.004	-0.002
42	-0.023	-0.005	-12.94	1034	638	1016	1103	1002	1026	911	300	0.008	0.004	0.000
43	-0.023	-0.005	-14.57	1071	677	1083	1103	1022	1067	954	290	0.010	0.005	0.000
44	-0.028	-0.005	-15.70	1101	711	1134	1102	1036	1100	986	279	0.012	0.006	0.000
45	-0.023	-0.005	-17.09	1154	770	1210	1099	1055	1150	1047	273	0.014	0.007	-0.003
46	-0.032	-0.005	-18.59	1220	856	1297	1096	1074	1212	1148	254	0.016	0.007	0.000
47	-0.032	-0.005	-19.60	1281	931	1379	1108	1100	1266	1237	237	0.018	0.008	-0.001
48	-0.032	-0.005	-20.85	1344	1045	1504	1080	1120	1339	1422	193	0.021	0.009	0.000
49	-0.032	-0.005	-21.98	1386	1122	1580	1079	1141	1391	1500	183	0.024	0.010	-0.015
50	-0.032	-0.005	-22.99	1419	1220	1679	1064	1162	1453	1601	162	0.027	0.011	-4.162
51	-0.032	-0.005	-24.50	1450	1419	1870	1014	1188	1564	1797	129	0.036	0.013	0.000
52	-0.032	-0.005	-25.13	1462	1589	1980	980	1209	1657	1836	109	0.047	0.014	0.000
53	-0.032	-0.005	-25.88	1506	1680	2024	1003	1255	1732	1909	155	0.060	0.015	0.000
54	-0.032	-0.005	-24.62	1494	1719	2013	991	1275	1797	2284	180	0.088	0.016	0.000
55	-0.032	-0.005	-21.86	1425	1647	1974	937	1237	1786	2316	103	0.112	0.016	0.000
56	-0.028	-0.005	-20.23	1375	1590	1935	904	1208	1771	2289	31	0.130	0.016	0.000
57	-0.014	-0.009	0.13	363	829	1032	-293	162	824	1405	-487	0.101	0.012	0.000
58	-0.009	-0.014	0.00	189	735	903	-483	-13	667	1272	-482	0.062	0.012	0.000
59	-0.023	-0.009	-5.28	457	918	1154	-138	300	956	1526	-296	0.069	0.013	0.000
60	-0.023	-0.014	-9.05	637	1050	1309	83	506	1138	1689	-214	0.076	0.013	0.000
61	-0.032	-0.009	-14.20	880	1246	1515	382	779	1377	1922	-133	0.085	0.014	0.000
62	-0.028	-0.014	-16.96	999	1350	1614	526	910	1492	2038	-125	0.089	0.015	0.000
63	-0.032	-0.014	-19.72	1122	1462	1721	676	1039	1611	2158	-95	0.094	0.015	0.004
64	-0.032	-0.014	-21.48	1205	1540	1795	776	1125	1690	2241	-87	0.098	0.015	0.007
65	-0.037	-0.014	-23.62	1309	1644	1890	898	1228	1795	2381	-71	0.103	0.016	0.009
66	-0.037	-0.014	-25.25	1400	1747	1981	993	1307	1898	3788	41	0.108	0.017	0.012
67	-0.037	-0.014	-26.38	1454	1843	2018	1026	1363	2000	6008	-254	0.113	0.017	0.015
68	-0.037	-0.014	-27.51	1499	1955	2022	1032	1393	2087	6586	-308	0.118	0.018	0.019
69	-0.032	-0.014	-28.02	1516	2051	2020	1074	1388	2130	6705	-360	0.122	0.018	0.023
70	-0.037	-0.014	-27.89	1456	2078	924	1242	1458	2265	6868	-397	0.130	0.020	0.027
71	-0.037	-0.014	-28.39	1484	2125	378	1728	3657	4232	6953	-404	0.139	0.020	0.036
72	-0.037	-0.014	-28.27	1473	2142	167	1120	6033	6046	7068	-401	0.163	0.020	0.055
73	-0.037	-0.014	-26.51	1443	2125	128	137	6468	6504	7234	-395	0.238	0.020	0.136
74	-0.037	-0.014	-25.88	1454	2160	102	144	6729	6693	7554	-379	0.302	0.020	0.209
75	-0.037	-0.014	-25.25	1521	2207	86	206	6868	7076	8115	-337	0.387	0.020	0.299
76	-0.037	-0.014	-24.62	42	4486	68	252	7102	7368	8468	-324	0.451	0.020	0.350
77	-0.037	-0.014	-24.25	-148	2194	32	206	7469	7781	8816	-286	0.534	0.020	0.427
78	-0.037	-0.014	-23.62	-331	1575	10	233	7891	8193	9013	-335	0.624	0.020	0.514
79	-0.037	-0.014	-23.24	-427	1491	-22	241	2272	8444	9177	-344	0.689	0.020	0.588
80	-0.037	-0.014	-21.98	-464	1538	-55	293	1692	8887	9834	-298	0.852	0.020	0.753
81	-0.037	-0.014	-15.20	-457	1439	-173	-290	1484	8815	8929	-333	1.034	0.020	0.903
82	-0.037	-0.014	-14.95	-438	1595	-93	-51	1456	9112	8184	-284	1.222	0.020	1.053
83	-0.037	-0.014	-14.70	-424	1695	-43	135	1399	9583	7138	-251	1.373	0.020	1.186
84	-0.037	-0.014	-14.57	-408	1762	-17	292	1379	10318	6643	-182	1.530	0.020	1.341
85	-0.037	-0.014	-14.95	-403	1845	-6	320	1352	2318	5957	-150	1.689	0.020	1.503
86	-0.037	-0.014	-14.70	-401	1892	-7	258	1198	1981	5045	-202	1.811	0.020	1.612
87	-0.037	-0.014	-12.94	-362	1981	1	-90	1170	1924	4554	-126		0.020	
88	-0.037	-0.018	-10.93	-351	1970	-7	-444	1150	1870	4016	-527		0.020	
89	-0.037	-0.018	-10.80	-290	2052	14	-581	1205	1923	4108	-513		0.020	
90	-0.037	-0.023	-10.68	-248	2099	28	-688	1261	1906	4025	-548		0.020	

Raw Data

Channel	83	84	85	90	91	92	93	94	95	96	97
	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)
Point											
26	0.000	0.000	0.000	0.002	0.001	0.001	0.000	0.002	-0.002	0.000	-0.001
27	0.000	0.000	0.000	0.002	0.001	0.001	0.001	0.002	0.000	0.000	0.000
28	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.002	0.000	0.000	0.000
29	0.002	0.000	0.003	0.002	0.001	0.000	0.001	-0.006	-0.161	-0.104	-0.044
30	0.002	0.000	0.003	0.002	0.001	0.000	-0.002	-0.006	-0.207	-0.132	-0.056
31	0.002	0.000	0.001	0.002	0.001	0.000	-0.002	-0.006	-0.192	-0.120	-0.052
32	0.004	0.000	0.004	0.002	0.001	-0.008	-0.004	-0.032	-0.564	-0.338	-0.144
33	0.004	0.000	0.005	0.002	0.001	-0.017	-0.009	-0.032	-0.856	-0.511	-0.210
34	0.002	-0.001	0.001	0.002	0.002	-0.019	-0.012	-0.026	-0.732	-0.437	-0.182
35	0.002	-0.001	0.001	0.004	0.002	0.001	-0.012	-0.026	-0.734	-0.437	-0.182
36	0.002	-0.001	0.001	0.001	0.002	0.000	-0.014	-0.011	-0.734	-0.436	-0.182
37	0.003	-0.001	0.003	-0.005	0.004	-0.005	-0.012	-0.026	-0.835	-0.495	-0.206
38	0.004	-0.001	0.004	-0.009	0.006	-0.005	-0.012	-0.032	-1.029	-0.610	-0.251
39	0.004	-0.001	0.005	-0.008	0.005	-0.005	-0.012	-0.039	-1.142	-0.680	-0.278
40	0.005	-0.001	0.005	-0.008	0.005	-0.005	-0.012	-0.041	-1.203	-0.716	-0.293
41	0.006	-0.001	0.006	-0.008	0.005	-0.005	-0.012	-0.041	-1.279	-0.758	-0.312
42	0.007	-0.001	0.007	-0.008	0.005	-0.005	-0.012	-0.045	-1.325	-0.785	-0.318
43	0.007	-0.001	0.007	-0.008	0.005	-0.005	-0.012	-0.045	-1.373	-0.813	-0.331
44	0.008	-0.001	0.009	-0.008	0.006	-0.005	-0.012	-0.045	-1.406	-0.834	-0.339
45	0.009	0.001	0.009	-0.008	0.007	-0.005	-0.012	-0.045	-1.451	-0.862	-0.350
46	0.010	0.004	0.010	-0.008	0.007	-0.004	-0.012	-0.045	-1.512	-0.895	-0.363
47	0.010	0.005	0.010	-0.008	0.007	-0.005	-0.012	-0.043	-1.554	-0.921	-0.370
48	0.010	0.009	0.012	-0.008	0.008	-0.005	-0.010	-0.043	-1.623	-0.962	-0.387
49	0.012	0.012	0.012	-0.006	0.007	-0.004	-0.009	-0.050	-1.676	-0.993	-0.400
50	0.013	0.016	0.014	-0.006	0.008	0.000	-0.007	-0.052	-1.737	-1.025	-0.411
51	0.015	0.024	0.016	-0.006	0.008	0.011	-0.006	-0.056	-1.822	-1.079	-0.434
52	0.016	0.031	0.017	-0.004	0.009	0.026	-0.001	-0.061	-1.909	-1.131	-0.455
53	0.017	0.031	0.018	-0.004	0.009	0.043	0.004	-0.058	-1.990	-1.176	-0.473
54	0.017	0.017	0.018	-0.003	0.009	0.074	0.011	-0.058	-2.085	-1.234	-0.498
55	0.017	-0.016	0.018	-0.004	0.009	0.110	0.022	-0.058	-2.188	-1.293	-0.524
56	0.017	-0.053	0.018	-0.003	0.009	0.162	0.039	-0.065	-2.343	-1.380	-0.561
57	0.011	-0.034	0.010	0.008	0.002	0.132	0.025	-0.039	-1.543	-0.908	-0.371
58	0.010	0.030	0.010	0.014	0.000	0.092	0.008	-0.026	-1.316	-0.776	-0.315
59	0.013	0.036	0.013	0.018	-0.001	0.092	0.008	-0.080	-1.565	-0.924	-0.375
60	0.014	0.042	0.015	0.018	-0.002	0.092	0.008	-0.086	-1.708	-1.007	-0.409
61	0.015	0.054	0.016	0.019	-0.001	0.095	0.008	-0.099	-1.900	-1.117	-0.453
62	0.016	0.059	0.017	0.019	-0.001	0.104	0.008	-0.108	-1.985	-1.169	-0.472
63	0.017	0.063	0.018	0.019	-0.001	0.114	0.013	-0.115	-2.075	-1.223	-0.494
64	0.017	0.066	0.018	0.019	-0.001	0.122	0.015	-0.119	-2.136	-1.260	-0.508
65	0.018	0.072	0.018	0.021	0.000	0.136	0.017	-0.125	-2.223	-1.309	-0.528
66	0.018	0.078	0.020	0.019	0.001	0.148	0.022	-0.128	-2.301	-1.358	-0.547
67	0.020	0.084	0.020	0.021	0.001	0.160	0.027	-0.134	-2.382	-1.403	-0.564
68	0.021	0.089	0.021	0.021	0.001	0.174	0.030	-0.132	-2.458	-1.447	-0.580
69	0.022	0.095	0.021	0.021	0.001	0.182	0.034	-0.134	-2.519	-1.481	-0.594
70	0.023	0.107	0.023	0.021	0.001	0.206	0.041	-0.138	-2.619	-1.540	-0.618
71	0.024	0.121	0.024	0.021	0.001	0.223	0.047	-0.141	-2.704	-1.587	-0.636
72	0.025	0.152	0.026	0.021	0.001	0.253	0.057	-0.141	-2.824	-1.656	-0.666
73	0.026	0.230	0.026	0.021	0.001	0.322	0.078	-0.141	-3.068	-1.797	-0.723
74	0.026	0.295	0.026	0.019	0.002	0.378	0.098	-0.141	-3.277	-1.915	-0.772
75	0.026	0.385	0.026	0.021	0.002	0.454	0.121	-0.141	-3.552	-2.078	-0.838
76	0.026	0.454	0.026	0.021	0.002	0.510	0.139	-0.143	-3.761	-2.199	-0.885
77	0.026	0.537	0.026	0.023	0.001	0.583	0.165	-0.143	-4.036	-2.359	-0.949
78	0.025	0.626	0.026	0.024	0.002	0.662	0.188	-0.141	-4.319	-2.530	-1.018
79	0.025	0.691	0.026	0.023	0.002	0.719	0.207	-0.141	-4.533	-2.655	-1.070
80	0.025	0.849	0.026	0.024	0.002	0.866	0.254	-0.141	-5.062	-2.967	-1.195
81	0.024	1.005	0.025	0.025	0.001	0.996	0.296	-0.136	-5.446	-3.185	-1.284
82	0.024	1.184	0.025	0.025	0.001	1.155	0.350	-0.128	-6.030	-3.527	-1.426
83	0.024	1.333	0.025	0.025	0.001	1.283	0.390	-0.112	-6.518	-3.810	-1.541
84	0.024	1.488	0.025	0.024	0.001	1.416	0.434	-0.099	-7.030	-4.109	-1.663
85	0.024	1.644	0.025	0.025	0.001	1.551	0.479	-0.086	-7.555	-4.416	-1.787
86	0.023	1.762	0.025	0.025	0.001	1.656	0.514	-0.067	-7.943	-4.641	-1.879
87	0.023		0.025	0.025	0.000	1.881	0.585	-0.026	-8.736	-5.110	-2.072
88	0.022		0.024	0.026	-0.003	2.127	0.666	0.026	-9.608	-5.620	-2.282
89	0.022		0.024	0.028	-0.002	2.394	0.748	0.095	-10.588	-6.196	-2.519
90	0.022		0.024	0.029	-0.003	2.705	0.851	0.210	-11.765	-6.888	-2.799

01296

Composite Slab Axial Stiffness Tests **Slab #6**
Test Summary

Test Notes

Data Point	Test Comment
27	Zero before removing temporary supports
28	After release of temp support
29	Preload of 2.5 Kips, crack over center line of specimen seen transverse to the slab also a crack between the load ram and the center of the slab that is longitudinal to the slab (all very small cracks)
30	Load and specimen relaxed, no manual increase or decrease of load
31	Unload
32	Ran up to 6 k and the load dropped back to 2 k
34	Unload and re-center ram it was off about 1" to the near side and was not aligned
35	Still Unloaded and rezeoing channel 92 because wire was not in the turning wheel
36	Recenter and tighten load ram against the load frame, then re-zero load ram
37	Touch Load
40	Notice slight uplifting of the deck at the haunches near the center of the specimen (note no shear studs at these locations, both sides)
45	Secondary transverse crack about 9" toward the load ram from the center of the first transverse crack, extends all way across slab
46	Note: wonder if rotation of beam and the fact that the magnet is about 1" tall thus holding the wire about 1" off the bottom of the top flange of the test beam has an effect significant in the measurement of the flange displacement
52	Heard some popping
54	Slab starting to uplift at the end of the fixed end
56	Severe uplift of the fixed end of the slab, unloading
57	Unloaded
58	Still unloaded, put cross beam across end of fixed slab to hold it down
62	re-zeroed channel 82, and reset it since it did not seem to be responding correctly, I believe that channel 82 may not have been working correctly most of the test???
64	tansverse crack midway between original transverse crack and the end of the fixed end of the slab
66	believe rebar #4 may have yielded at least on side of the bar
71	Longitudinal cracks developing along the centerline of the specimen
81	Pop from within concrete slab, not sure what happened
83	Looks as if the stud in position e on the fixed beam is pulling out of the deck and
86	Remove pots on the fixed beam side for fear of damage
87	Studs on south side definitely failing, looks like we probaly lost the one in the e position and that the ones in the b and c positions are under severe distress as can be seen by the extreme deck bulging around these two stud locations
90	End test.

<u>Data Calculations</u>

Rotation Calculations

Method

4 $t = t_{\text{Free Beam}} - t_{\text{Fixed Beam}}$

Where: $t_{\text{Fixed Beam}} = \dfrac{(1) - (0)}{28}$

a $t_{\text{Free Beam}} = \dfrac{(97) - (96)}{33}$

b $t_{\text{Free Beam}} = \dfrac{(97) - (95)}{71.75}$

c $t_{\text{Free Beam}} = \dfrac{(96) - (95)}{38.75}$

Slab Deformation Calculations

Method

1 $\Delta = (92) - (90) + 4.75\,\theta$

Slab Load Calculations

$$P = \frac{(2)\ 53.0625}{29.9375} + 2.37$$

Note: Numbers enclosed in parenthesis, i.e. (2), correspond to gage numbers.

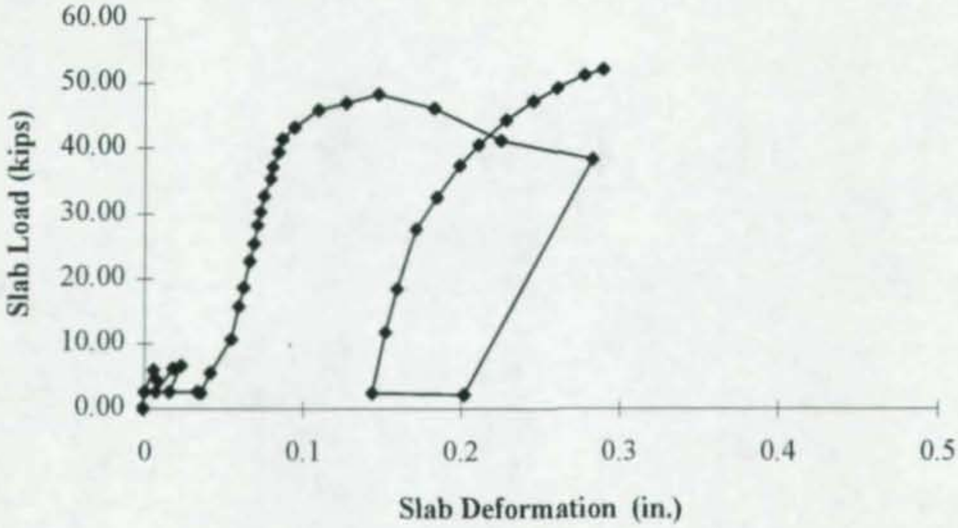
01297

Composite Slab Axial Stiffness Tests
Test Summary

Calculated Data

Data Point	Load @ Centerline of Reinforcing Steel (Kips)	Rebar #1 Axial Force (kips)	Rebar #2 Axial Force (kips)	Rebar #3 Axial Force (kips)	Rebar #4 Axial Force (kips)	Rebar Total Axial Force (kips)	Rotation 4a (rad)	Rotation 4b (rad)	Rotation 4c (rad)	Rotation Average (rad)	Δ Slab 1 (in.)
26	0.00	0.00	0.00	0.00	0.00	-0.01	0.0000	0.0000	0.0001	0.0000	-0.001
27	0.22	0.00	0.00	0.00	0.00	-0.01	0.0000	0.0000	0.0000	0.0000	-0.001
28	2.59	-0.01	0.00	0.00	0.00	-0.02	0.0000	0.0000	0.0000	0.0000	0.000
29	5.93	0.82	1.27	1.25	1.04	4.38	0.0018	0.0016	0.0015	0.0016	0.006
30	4.37	0.91	1.45	1.41	1.06	4.84	0.0023	0.0021	0.0019	0.0021	0.008
31	2.59	0.67	1.16	1.15	0.76	3.74	0.0021	0.0019	0.0018	0.0020	0.007
32	6.16	2.14	3.25	3.20	2.31	10.90	0.0059	0.0059	0.0058	0.0059	0.018
33	6.60	3.13	4.51	4.38	3.01	15.03	0.0091	0.0090	0.0089	0.0090	0.023
34	2.59	2.18	3.30	3.26	1.90	10.64	0.0077	0.0077	0.0076	0.0077	0.016
35	2.59	2.17	3.29	3.25	1.89	10.60	0.0077	0.0077	0.0077	0.0077	0.033
36	2.37	2.16	3.28	3.24	1.86	10.54	0.0077	0.0077	0.0077	0.0077	0.035
37	5.49	2.89	4.17	4.08	2.57	13.71	0.0088	0.0088	0.0088	0.0088	0.042
38	10.61	3.25	4.60	4.41	2.78	15.04	0.0109	0.0108	0.0108	0.0108	0.055
39	15.73	3.51	4.89	4.66	2.94	16.00	0.0122	0.0120	0.0119	0.0120	0.059
40	18.62	3.67	5.02	4.79	2.99	16.46	0.0128	0.0127	0.0126	0.0127	0.062
41	22.63	3.86	5.14	4.93	3.01	16.94	0.0135	0.0135	0.0134	0.0135	0.066
42	25.30	4.02	5.28	5.07	3.03	17.40	0.0142	0.0140	0.0139	0.0140	0.069
43	28.20	4.20	5.45	5.22	3.12	17.99	0.0146	0.0145	0.0144	0.0145	0.071
44	30.20	4.35	5.58	5.33	3.17	18.43	0.0150	0.0149	0.0148	0.0149	0.073
45	32.65	4.62	5.76	5.51	3.31	19.19	0.0155	0.0154	0.0152	0.0154	0.075
46	35.32	4.99	5.97	5.71	3.51	20.18	0.0161	0.0160	0.0159	0.0160	0.079
47	37.11	5.32	6.20	5.91	3.69	21.12	0.0167	0.0165	0.0163	0.0165	0.081
48	39.33	5.74	6.44	6.14	4.04	22.37	0.0174	0.0172	0.0171	0.0172	0.084
49	41.34	6.03	6.63	6.33	4.21	23.20	0.0180	0.0178	0.0176	0.0178	0.087
50	43.12	6.34	6.84	6.53	4.41	24.13	0.0186	0.0185	0.0184	0.0185	0.094
51	45.79	6.90	7.19	6.87	4.82	25.79	0.0195	0.0193	0.0192	0.0193	0.109
52	46.90	7.33	7.38	7.16	4.87	26.74	0.0205	0.0203	0.0201	0.0203	0.127
53	48.24	7.66	7.55	7.46	5.17	27.83	0.0213	0.0211	0.0210	0.0211	0.147
54	46.01	-	7.49	7.67	-	-	0.0223	0.0221	0.0220	0.0221	0.183
55	41.11	-	7.26	7.55	-	-	0.0233	0.0232	0.0231	0.0232	0.225
56	38.22	-	7.08	7.44	-	-	0.0248	0.0248	0.0248	0.0248	0.283
57	2.15	-	1.84	2.46	-	-	0.0163	0.0163	0.0164	0.0163	0.202
58	2.37	-	1.05	1.64	-	-	0.0140	0.0140	0.0139	0.0140	0.144
59	11.72	-	2.53	3.14	-	-	0.0167	0.0166	0.0165	0.0166	0.152
60	18.40	-	3.47	4.11	-	-	0.0181	0.0181	0.0181	0.0181	0.159
61	27.53	-	4.73	5.39	-	-	0.0201	0.0202	0.0202	0.0202	0.171
62	32.43	-	5.34	6.00	-	-	0.0211	0.0211	0.0211	0.0211	0.184
63	37.33	-	5.98	6.62	-	-	0.0221	0.0220	0.0220	0.0220	0.199
64	40.45	-	6.41	7.03	-	-	0.0228	0.0227	0.0226	0.0227	0.211
65	44.23	-	6.95	7.55	-	-	0.0237	0.0236	0.0236	0.0236	0.228
66	47.13	-	7.42	8.01	-	-	0.0246	0.0245	0.0243	0.0245	0.245
67	49.13	-	7.59	8.40	-	-	0.0254	0.0253	0.0253	0.0253	0.260
68	51.13	-	7.62	8.69	-	-	0.0263	0.0262	0.0261	0.0262	0.277
69	52.03	-	7.72	8.79	-	-	0.0269	0.0268	0.0268	0.0268	0.289
70	51.80	-	5.40	-	-	-	0.0279	0.0279	0.0278	0.0279	0.318
71	52.69	-	5.25	-	-	-	0.0288	0.0288	0.0288	0.0288	0.339
72	52.47	-	3.21	-	-	-	0.0300	0.0301	0.0302	0.0301	0.376
73	49.35	-	0.66	-	-	-	0.0325	0.0327	0.0328	0.0327	0.457
74	48.24	-	0.61	-	-	-	0.0346	0.0349	0.0352	0.0349	0.524
75	47.13	-	0.73	-	-	-	0.0376	0.0378	0.0380	0.0378	0.613
76	46.01	-	0.80	-	-	-	0.0398	0.0401	0.0403	0.0401	0.680
77	45.35	-	0.59	-	-	-	0.0427	0.0430	0.0433	0.0430	0.764
78	44.23	-	0.60	-	-	-	0.0458	0.0460	0.0462	0.0460	0.856
79	43.56	-	0.55	-	-	-	0.0480	0.0483	0.0485	0.0483	0.926
80	41.34	-	0.59	-	-	-	0.0537	0.0539	0.0541	0.0539	1.098
81	29.31	-	-1.16	-	-	-	0.0576	0.0580	0.0583	0.0580	1.246
82	28.87	-	-0.36	-	-	-	0.0637	0.0642	0.0646	0.0641	1.435
83	28.42	-	0.23	-	-	-	0.0688	0.0694	0.0699	0.0693	1.587
84	28.20	-	0.69	-	-	-	0.0741	0.0748	0.0754	0.0748	1.747
85	28.87	-	0.78	-	-	-	0.0797	0.0804	0.0810	0.0803	1.908
86	28.42	-	0.63	-	-	-	0.0837	0.0845	0.0852	0.0845	2.032
87	25.30	-	-0.22	-	-	-	0.0921	0.0929	0.0936	0.0928	2.297
88	21.74	-	-1.12	-	-	-	0.1011	0.1021	0.1029	0.1020	2.585
89	21.52	-	-1.41	-	-	-	0.1114	0.1125	0.1133	0.1124	2.900
90	21.30	-	-1.64	-	-	-	0.1239	0.1250	0.1259	0.1249	3.269

Composite Slab Load Vs. Deformation



Load Vs. Stud Slip