VIRGINIA POLYTECHNIC INSTITUTE
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# Structural Engineering

## Behavior and Modeling of Single Bolt Lap Plate Connections

by
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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

Report No. CE/VPI-ST 96/15

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**Research Report**

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$\alpha$ = Bolt tension coefficient

$A_b$ = Area of the bolt

$A_{bt}$ = Tensile area of the bolt

$A_{bv}$ = Shear area of the bolt

$\beta$ = Steel correction factor

BR = Bearing ration, bearing stress over net section tensile stress

$C_{bb}$ = Bolt bending stiffness coefficient

$C_{bbr}$ = Bolt bearing stiffness coefficient

$C_{bs}$ = Bolt shearing stiffness coefficient

COV = Coefficient of variation

$C_{pbr}$ = Plate bearing stiffness coefficient

$\Delta$ = Deformation

$\Delta_{max}$ = Test deformation at maximum test load

$\Delta_f$ = Failure deformation (in.)

$\Delta_{fu}$ = Deformation at which frictional resistance is considered zero

$\overline{\Delta}$ = Normalized deformation

$\overline{\Delta}_f$ = Normalized failure deformation

$d_b$ = Bolt diameter

$d_h$ = Hole diameter

$d_{m16}$ = Nominal diameter of a M16 bolt (16mm)

e = Base of natural logarithm

E = Modulus of elasticity for steel, 29,000 ksi

F = Bolt tension force

$f_{ns}$ = Net section tensile stress

$f_b$ = Bearing stress

$f_u$ = Measure ultimate stress of steel

$F_u$ = Specified ultimate stress of steel

$f_{ub}$ = Measure ultimate stress of bolt steel

$F_{ub}$ = Specified ultimate stress of bolt steel

$F_{vb}$ = Ultimate shear stress of the bolt steel

$f_y$ = Measure yield stress of steel

$F_y$ = Specified yield stress of steel

G = Shear modulus for steel, 11,200 ksi

$I_b$ = Moment of inertia of the bolt

K = Elastic stiffness parameter for Richard Equation

$K_1$ = Parameter in Richard Equation

$K_b$ = Bolt stiffness

$k_b$ = Stiffness coefficient to account for edge and bolt spacing

$K_{br}$ = Bearing stiffness

$K_f$ = Frictional stiffness

$K_{fi}$ = Frictional initial stiffness

$K_{fp}$ = Frictional final stiffness

$K_i$ = Initial stiffness

$K_p$ = Plastic stiffness parameter for Richard Equation, also plate stiffness

$K_{pb}$ = Plate bending stiffness

$K_{pbr}$ = Plate bearing stiffness

$K_{pi}$ = Plate initial stiffness

$K_{pv}$ = Plate shearing stiffness

$k_t$ = Stiffness coefficient to account for plate thickness

$\lambda$ = Regression coefficient for Fisher Equation

$L_e$ = End distance

$L_{e1}$ = End distance for plate 1

$L_{e2}$ = End distance for plate 2

$\mu$ = Regression coefficient for Fisher Equation also coefficient of friction

n = Curvature parameter for Richard Equation

$R$ = Load or force

$R_f$ = Slip load

$R_n$ = Nominal strength

$R_{nb}$ = Bolt strength

$R_{np}$ = Plate strength

$R_{np1}$ = Strength of plate 1

$R_{np2}$ = Strength of plate 2

$R_o$ = Reference load for Richard Equation

$R_{transition}$ = Transition load

$R_{ult}$ = Maximum test load

$S$ = Bolt spacing

$SR$ = Strength ratio of plate strength over bolt strength

$\tau$ = Regression coefficient for Fisher Equation

$\tau_u^p$ = Ultimate shear stress of the plate

$t$ = Thickness of main plates

$t'$ = Thickness of lap plates

$t_1$ = Thickness of the thinner of two plates in a lap plate connection

$t_2$ = Thickness of the thicker of two plates in a lap plate connection

$t_p$ = Plate thickness

## ABSTRACT

Developing analytical methods for determining the moment-rotation behavior of partially restrained beam-girder connections is the focus of a current research project. One such technique is the component method (Rex 1994; Eurocode 3 1994). This method assumes that the behavior of the connection as a whole can be determined based on the behavior of the individual parts of the connection.

One of the fundamental parts of the beam-girder connections being developed in the current research is a high strength bolt in single shear. The load-deformation behavior of this part is needed so that the component method can be used for analysis of the complete connection. It is currently believed that this behavior can be represented by the load-deformation behavior of a single bolt lap plate connection.

This report presents an analysis of single bolt lap plate connection load-deformation behavior. Each important characteristic of the behavior is evaluated and two methods for analytically approximating this behavior are developed and presented. The first of these methods is a component method, in which the behavior of the connection is assumed to be made up of the behaviors of the parts. The second method utilizes a number of parametric relationships that relate the connection parameters to coefficients of two non-linear continuous analytical curves. The test results from four independent experimental programs that investigated the behavior of single bolt lap plate connections are used in the development and verification of these methods.

# 1. Introduction

As part of a larger research project dealing with partially restrained composite beam-girder connections the moment-rotation behavior of partially restrained steel connections is needed. The localized load-deformation behavior associated with the bolts in the steel connection is needed to predict the moment-rotation behavior of the full steel connection. It is assumed that the bolt load-deformation behavior can be approximated by the load-deformation behavior of a simple single bolt lap plate connection. The basic relationship between the lap plate connection and the full steel connection is shown in Figure 1.

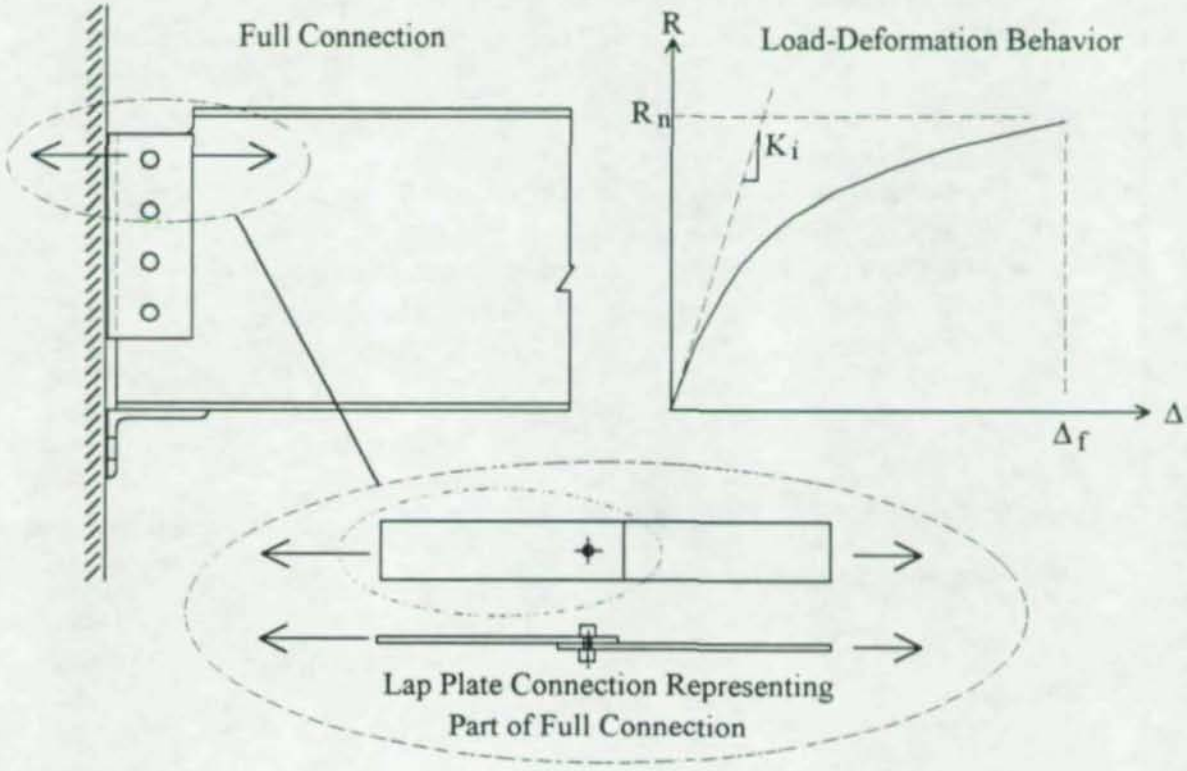


**Figure 1 Relation Of Lap Plate Connection Behavior To The Full Connection**

A typical lap plate connection load-deformation behavior with three of the important characteristics indicated is also shown in Figure 1. The load-capacity of the

connection ($R_n$), the initial stiffness of the response ($K_i$), and the deformation at failure ($\Delta_f$) define the basic boundaries within which the load-deformation behavior must lie.

There are a number of geometric and material parameters associated with the lap plate connection which are believed to affect the load-deformation behavior. The following is a lengthy although not exhaustive list of these variables, some of which are also shown in Figure 2 for definition purposes.

**Bolt Parameters**

Diameter of bolt, $d_b$
Type of bolt (A325 or A490)
Location of shear plane on the bolt (in threads, N, or shank, X)
Bolt grip length
Whether the bolt is or is not fully tensioned
Whether washers are used under bolt head and / or nut

**Plate Parameters**

Thickness of plates being bolted together, $t_1$ and $t_2$
Yield stress and ultimate strength of plates, $f_y$ and $f_u$
Bolt hole fabrication (drilled, punched)
Bolt hole diameter ($d_h$) and type (slotted, standard, oversize)
Friction coefficient of the plates being bolted together, $\mu$
Bolt end distance, $L_e$
Plate Width
Plate Edge Condition, shear cut or saw cut

There is currently very little understanding on how each individual parameter or combination of parameters influence the connection behavior.

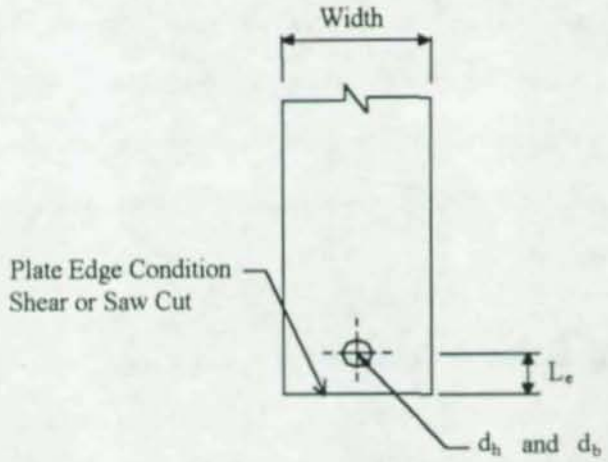


**Figure 2 Some Parameters Associated With Single Bolt Lap Plate Connection Tests**

## 1.1 Existing Bolt Load-Deformation Models

Fisher (1965) believed that the deformation associated with mechanical fasteners (rivets and bolts) generally consisted of shearing, bending, and bearing deformations of the fastener and local deformations of the plates being fastened. The author proposed a continuous non-linear expression that could be used to represent the load-deformation behavior of mechanical fasteners.

$$R = \tau\left(1 - e^{-\mu\Delta}\right)^{\lambda}$$

Where:

R = Load in fastener

$\Delta$ = Total deformation of fastener and bearing deformation of the connected material

$\tau$, $\mu$, $\lambda$ = Regression coefficients

e = Base of natural logarithm

Elemental fastener tests were conducted (Wallaert and Fisher 1965, Fisher, et al 1963). A statistical analysis of the data from these tests was used to determine the values of the regression coefficients. In all cases it was determined that the value of $\tau$ agreed well with $R_{ult}$ which is the ultimate strength of the elemental fastener test. Additional observations

were that $\lambda$ was affected only slightly by variations in the bolts and $\mu$ was mostly affected by the type of connected material. Fisher (1965) believed that these two coefficients could be related to the physical and geometric properties of the plate and bolts but never developed such relationships. The final form of the equation was given as:

$$R = R_{ult}\left(1 - e^{-\mu\Delta}\right)^{\lambda}$$

Crawford and Kulak (1971) determined values for the coefficients $\lambda$, $\mu$, and $R_{ult}$ based six identical elemental bolt tests. Single bolts were tested in double shear. The bolts were all A325 3/4-in. diameter in 13/16-in. diameter holes in 4-in. x 4-in. plates fabricated of ASTM A36 steel. The bolts had been tightened by the turn-of-the-nut method and the plates were loaded in compression. The values of the coefficients were determined to be

$\mu = 10$

$\lambda = 0.55$

$R_{ult} = 74$ +/- 2.4 Kips for 3/4-in. diameter A325 bolts in double shear

$\Delta_f = 0.34$-in. (deformation of test specimen at failure)

The equation developed by Fisher (1965) and the values of the coefficients developed by Crawford and Kulak (1971) were adopted for use by the American Institute of Steel Construction (AISC) for determining the strength of eccentrically loaded bolted connections (*Manual of* 1986; *Manual of* 1994). Despite the fact that the coefficients determined by Crawford and Kulak (1971) were based on only six identical elemental bolt tests, the same values for the coefficients of $\lambda$ and $\mu$ have been used for a wide variety of plate and bolt combinations. The value of $R_{ult}$ has generally been taken as the ultimate strength of the bolt based on current procedures for determining bolt strength as found in the AISC Specification (*Load and* 1993).

Two experimental programs were conducted at the University of Arizona to study the load-deformation behavior of bolts in single shear (Caccavale, 1975; Gillet, 1978).

An equation based on these research programs, which is referred to as the Richard equation, was developed to represent the bolt load-deformation behavior (Richard et al 1981). This equation is presented in Figure 3 along with a graphical interpretation of each parameter of the equation. The coefficients for the Richard Equation for each group of tests were reported in Richard, et al (1980). However, aside from a single equation that was proposed to determined the elastic stiffness coefficient, no methods for systematically determining the equation coefficients or discussion on how the coefficients related to the geometric and material properties was given.

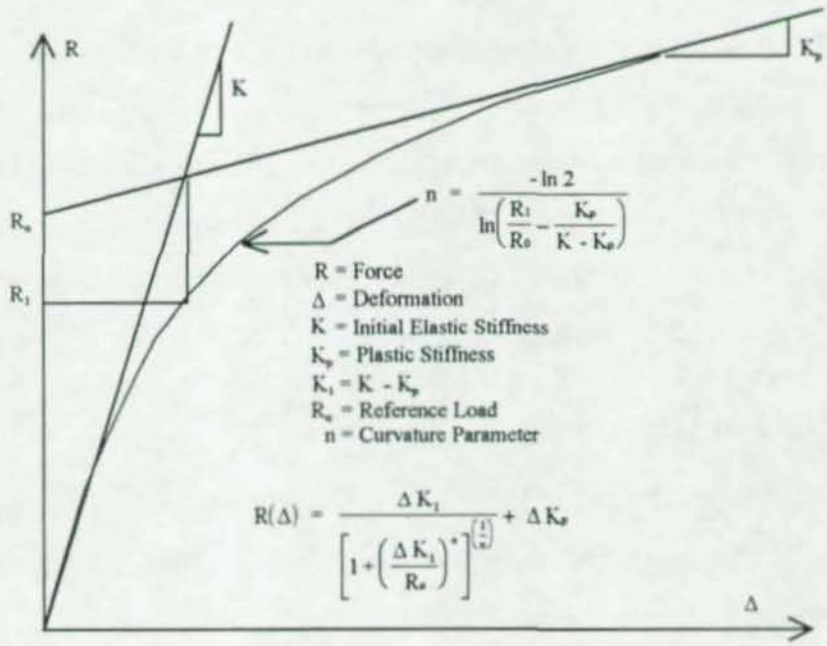


**Figure 3 The Richard Equation**

Karsu (1995) conducted a series of single bolt lap plate tests similar to those reported by Richard, et al (1981). Based on these tests Karsu recommended using four different sets of Richard Equation coefficients. The coefficients to be used depended on the plate thickness of the thinner plate in the connection ($t_1$) and / or whether bolt or plate failure occurred. The recommended coefficients are summarized in Table 1. These coefficients are based on data that was normalized by the test strength; consequently, it is

necessary to multiply the resulting value from the Richard Equation by the plate or bolt strength to obtain the estimated load.

**Table 1 Normalized Richard Equation Coefficients (Karsu, 1995)**

| Failure & Plate Thickness | K | $K_p$ | $R_o$ | n |
|---|---|---|---|---|
| **Plate Failure** | | | | |
| $t_1$ = 0.125-in. | 25.42 | -0.226 | 1.234 | 1.56 |
| $t_1$ = 0.25-in. | 20.34 | -0.0286 | 1.07 | 1.11 |
| $t_1$ = 0.375-in. | 20.14 | 0.0368 | 1.02 | 1.11 |
| **Bolt Failure** | 26.3 | 0.061 | 1.13 | 0.66 |

No other literature was identified that deals with predicting the load-deformation behavior of bolts in single shear. However, there is literature that deals with certain characteristics of this behavior such as the initial stiffness, nominal strength, and friction loads. A formal review of this literature is not presented in this part of the report. Instead, any applicable literature is presented along with the development of the particular characteristic of load-deformation behavior.

## 1.2 Focus and Objective

The focus of this report is the load-deformation behavior of a single bolt lap plate connection. The objective of this report is to develop a method or methods that can be used to predict the load-deformation behavior with reasonable accuracy.

To provide a basis for development and / or evaluation of methods to predict the load-deformation behavior, test data from 157 single bolt lap plate connection tests was collected. This data was compiled and entered into a commercial database program for ease of analysis.

The overall load-deformation behavior is very complex. In an attempt to simplify the problem, the overall behavior is broken down into more easily studied characteristics of the behavior. Three important characteristics are the initial stiffness ($K_i$), the load capacity ($R_o$), and the deformation at failure ($\Delta_f$). These characteristics are reviewed and

analyzed. Existing literature dealing with them is presented and evaluated. Methods for determining each of these characteristics are then recommended.

The final characteristic, although certainly not the least important, is the shape of the load-deformation response between the initial stiffness and failure load. As part of the development of parametric methods, a full analysis of how the various connection parameters affect this shape is conducted.

Based on the evaluation of each of the fundamental characteristics of the overall load-deformation behavior, parametric relationships between the connection parameters and the coefficients for two commonly used continuous non-linear equations are suggested. This will provide one method with which the behavior can be approximated.

Parametric solutions are commonly used for problems such as approximating the load-deformation behavior of lap plate connections. In addition to the parametric solutions, the component method for approximating the load-deformation behavior is also developed. This method assumes that the total response can be predicted by combining the behaviors of the more fundamental parts that make up the connection. For the lap plate connection these fundamental components are the plate, bolt, and friction. The behavior for each of these fundamental components is studied and methods for approximating them are developed and presented.

Finally, all of the developed and existing methods for approximating the load-deformation behavior of single bolt lap plate connections are evaluated against the experimental test data collected in this report.

## 1.3 Forward

The following eight sections of this report accomplish the following with respect to the load-deformation behavior of single bolt lap plate connections:

- Discuss the source of and any modifications to the experimental data.
- Recommend methods for approximating the basic characteristics of the response, such as the strength, initial stiffness, and failure deformation. These methods are either existing or developed herein.

- Based on experimental results, an evaluation of how the behavior is effected by many of the connection parameters is conducted
- Develop a component method and parametric methods for approximating the behavior
- Evaluate the existing and the newly developed methods for approximating the behavior against the test data

First, a discussion and presentation of the existing test data that was collected in this report is given. Next, an evaluation of methods for predicting the strength of the connection is presented. The component method is then developed. This is developed at this point in the report because the only part of this report that it relies on is the strength of the connection. In addition, because of its very fundamental nature, the component method will be used to help develop each of the subsequent sections of the report dealing with initial stiffness, failure deformation, and parametric relationships.

After the component method is developed then the initial stiffness and failure deformation will be evaluated. Next, the parametric relationships will be developed. As part of the development of the parametric relationships, a thorough evaluation of how the behavior is effected by many of the connection parameters is conducted. Finally, an evaluation of existing and newly developed methods for approximating the behavior is conducted.

## 2. Experimental Data For Single Bolt Lap Plate Connections

Four experimental investigations of single bolt lap plate connection tests were found in the literature. The experimental data including the geometric and material parameters and the raw load-deformation data from these experimental investigations was compiled and input into a commercial database program for analysis.

A schematic of a single bolt lap plate connection test is shown in Figure 4. The method in which the load was applied to the plates and the method in which deformation was measured varied depending on the experimental investigator. In general, the free ends of the connection were bolted to a testing assembly that was placed in a universal type

testing machine to apply the load. The deformation was measured as the change in the distance from one fixed point on one plate to one fixed point on the opposite plate.

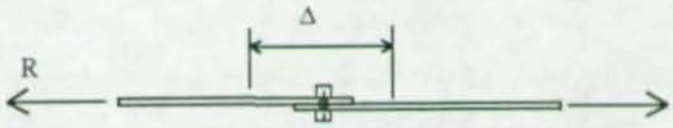


**Figure 4 Typical Single Bolt Lap Plate Connection Tests**

The following sections present a brief summary of each of the four experimental investigations. In addition, tables which summarize the test parameters and test results are presented in Appendix B through Appendix E. These tables present the test parameters and results in a uniform manner; however, in many cases there was information that could not be determined from the literature. In some of these cases it was necessary to make some assumptions so that the tests could be included in the analysis. If the information was not critical to the analysis then a question mark is used to indicate that it was unknown. The assumptions made about the tests are also discussed briefly in the following sections.

## 2.1 Lap Plate Connection Tests Reported by Karsu (1995)

Karsu (1995) reported a total of 61 lap plate connection tests. Each test actually consisted of two lap plate connections that were pulled at the same time. The average load and deformation measurements for the two connections were used.

Parameters which were varied in the experimental study included bolt diameter, plate thickness of both plates in the connection, bolt end distance, plate edge condition. Bolts included 3/4-in., 7/8-in. and 1-in. diameter A325 bolts. Plate thickness was varied from 1/8-in. to 1-in. in 1/8-in. increments. End distances of 2 $d_b$ and 1.5 $d_b$ were used. The test plates were typically fabricated at the Virginia Tech Structures & Materials Laboratory (VTSML); however, some plates were cut to length by a local steel supplier. Thinner plates that were cut by the steel supplier were sheared and the remaining plates including those cut at the VTSML were saw cut. All holes were drilled to standard sizes. Washers were placed under both the nut and bolt head.

The test specimens were assembled and put into the testing rig. The bolts were snugged up and then a pre-load was applied to the specimen. While the pre-load was applied the bolts were fully tensioned by turn-of-nut. The pre-load was then removed and the test was started from zero load. Electronic potentiometers were used to measure the deformation. This process was intended to eliminate any sudden slips in the connection during the test.

## 2.2 Lap Plate Connection Tests Reported by Gillet (1978)

Gillet (1978) reported a total of 75 lap plate connection tests. Load-deformation data was available for only 66 of these tests. Parameters varied in the experimental study included bolt grade and diameter, steel grade, plate thickness, and end distance. Both A325 and A490 bolts with 3/4-in, 7/8-in., and 1-in. bolt diameters were used. Both A36 and A572Gr50 steel was used to fabricate the plates which varied in thickness from 1/4-in. to 5/8-in. in 1/16-in. increments. End distances were 1.25-in., 1.5-in., and 1.75-in. for 3/4-in., 7/8-in., and 1-in. diameter bolts respectively.

The test plates were fabricated by a local steel fabricator. The plates were sheared and the bolt holes were punched to standard sizes. The mill scale was left in place for testing. Two dial gages were used to measure deformations, one in front and one in back of the specimen.

The test specimens were assembled and put into the testing rig. The bolts were snugged up and then a pre-load of 5 kips was applied to the specimen. While the pre-load was applied the bolts were fully tensioned by turn-of-nut. The pre-load was then removed and the test was started from zero load. This process eliminated any sudden slips in the connection during the test.

Conclusions by the author included:

- The thinner plate of the connection controlled the load-deformation relationship
- Three failure modes occurred bolt shear, plate bearing failure, plate splitting failure

Three assumptions have been made about this testing program so that the tests could be included in the analysis. First, no material properties were given for the 5/8-in.

thick plates used in the test program. It was assumed that the steel properties of these plates were consistent with other A36 steel properties given in the report and the average of the A36 steel properties given was used.

Second, in some cases the mode of failure was not clear. The mode of failure for a group of tests was reported rather than for the individual tests. In some cases two modes of failure were indicated for the same group of tests. In these cases a failure mode was assumed based on the options given for the group and a comparison of the load-deformation behaviors for the tests in the group.

Lastly, it was assumed that the bolt threads were excluded from the shearing plane. This was based on a comparison of the expected bolt shearing load to the test load reported.

## 2.3 Lap Plate Connection Tests Reported by Caccavale (1975)

Caccavale (1975) reported 11 lap plate connection tests. The plate thickness varied from 3/16-in. to 5/16-in. in 1/16 increments and was the only parameter varied. All tests used 3/4-in. diameter A325 bolt which were torqued to 350 ft-lb. Bolt holes were drilled to a 0.758-in. diameter which is a non-standard size for a bolt hole. All plate end distances were 1.25-in. Washers were placed under the nuts of the bolts.

Conclusions made by the author included:

- Connection strength did not increase linearly with plate thickness. The reason was believed to be because of the increasing eccentricity in the connection.
- The plastic slope, Kp, increases as $t_1$ (the thinner plate of the two plates in the lap plate connection) increases but not linearly because of increasing eccentricity.

The author did not specifically report failure modes of specimens. However, the author does indicate that "The test results show that under these conditions no visible mark of shear deformation occur in the bolt." This would tend to indicate some sort of plate failure. For analysis purposes it was assumed that plate bearing / tearout failures occurred.

## 2.4 Lap Plate Connection Tests Reported by Sarkar & Wallace (1992)

Sarkar and Wallace (1992) reported 16 lap plate connection tests; however, data that was supplied separately to the researchers included 19 connection tests. Parameters that were varied included the bolt type, plate thickness and end distance. The bolts were A325 or A490 ¾-in. diameter bolts in standard drilled holes. Plate thickness varied from 5/16 to 3/8 in 1/16-in. increments and end distances were either 1.5-in. or 2-in.

Conclusions by the authors included:

- Reducing plate thickness increased the deformation at failure
- Increasing the bolt grade increased deformation at failure

The report did not indicate how the bolts had been tightened. Based on a comparison to the test data from Karsu (1995) and Gillet (1978) it is believed that the bolts were only tightened to the snug condition and the tests are treated as such for analysis purposes in this report. A more detailed discussion of this is presented in the next section of this report.

## 2.5 Results

The test parameters and results of the four test programs just discussed are presented in Appendix B through Appendix E. In addition, data summaries of the tests reported by Karsu (1995) and Sarkar and Wallace (1992) are included in Appendix A and Appendix E respectively. The data summaries of the tests performed by Karsu (1995) have been included because of errors made in the original reporting of the tests in Karsu (1995). The data summaries for the tests by Sarkar and Wallace (1992) are included because this data has never been included in the literature to date. The data was received in an electronic form from Dr. Wallace. Note that the data reported in Appendix A and Appendix E is the raw data as supplied. This data does not include any modifications which are discussed in the following section.

## 2.6 Modifications, Assumptions, and Analysis of Test Data

Because important information about some of the test programs was missing it was necessary to make some assumptions about the data. These were discussed briefly in the previous sections. A more thorough discussion on some of these assumptions is presented in the following sections. In addition, it was necessary to modify the reported load-deformation data in some cases. These modifications are also discussed below. Finally, how the data was analyzed to determine initial stiffness and certain load quantities is also discussed.

### 2.6.1 Exclusion of Test Data

Because of the way that deformations were measured in the test series by Caccavale (1975) it is highly likely that the initial deformation readings included test setup deformations which were not intended to be measured. As a result, the initial stiffness values from the test data were uncharacteristically low. Both these observations were made by the author. Because of this measurement problem only the strength characteristics from this data are included in the analysis of the behavior of lap plate connections.

There were five tests reported by Karsu (1995) for which the data indicated that there were problems with the test. These tests were completely excluded from further evaluation. The test numbers were 7, 8, 9, 43, and 64.

Sarkar and Wallace (1992) reported 16 connection tests. However, test data for 19 tests was provided by Dr. Wallace. The three tests which were not reported have been excluded from all evaluation except for strength. The reason the tests were not reported is currently not known. The data from the tests are included in Appendix E. The test numbers for the three tests are 13 through 15.

### 2.6.2 Removing Elastic Plate Deformations From Data

All the techniques used to measure deformation in the above experimental investigations include elastic deformations of the plate. The deformations of interest in this research are the local bolt and plate deformations and not the overall stretching of the test plate between points of measurement. Consequently, it is desirable to remove the elastic deformations from the data. Gillet (1978) reported that elastic deformations were estimated and removed; however, the process by which this was done was not described.

The data reported by Karsu (1995) included elastic deformations. A method of estimating these deformations was developed so that they could be removed from the data. First, the length of plate between the bottom of the bolt and the point where the potentiometers were attached to the plate was divided into four regions. The length of the first region is from the top of the bolt hole to the clamping point. The length of the second, third, and fourth regions are each one-third of the bolt hole diameter. The width of the first region is the width of the plate. The width of the second region is the width of the plate minus one-third of the hole diameter. The width of the third region is the width of the plate minus two-thirds of the hole diameter. And the width of the fourth region is the width of the plate minus the hole diameter. These regions are shown schematically in Figure 5.

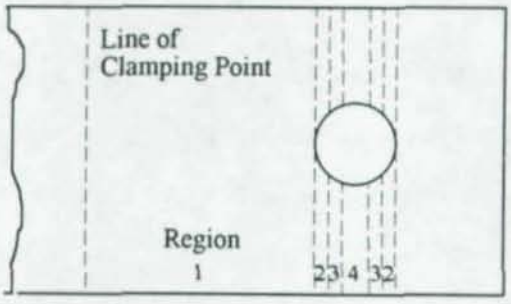


**Figure 5 Sectioning of Plate Used to Estimate Elastic Plate Deformations**

The stress area for each region was taken as the width of the region times the thickness of the plate. The load on the specimen was then divided by the stress area to determine the stress in each region. This stress was then converted to strain using a

modulus of elasticity of 29,000 ksi and then the strain was converted into deformation by multiplying the strain in each region by the length of each region. The total elastic deformation from the bottom of the bolt hole to the clamping point was then determined by adding the deformations for each region. This was done for each plate in the connection and then the estimated elastic deformations were subtracted from the raw deformation readings.

Because the distance from the centerline of the bolt to the location where the potentiometers were clamped to the plate was not given a distance had to be assumed. It was assumed that this distance was equal to the end distance of the opposite plate plus 1-in.

It should be noted that removing the elastic deformations has little or no effect on the overall load-deformation data. It primarily effects the values of the initial stiffness. If the initial stiffness values are large then removing the elastic deformations tends to have a significant impact; however, if the initial stiffness values are small then removing the elastic deformations has little impact.

Sarkar and Wallace (1992) did not report whether or not elastic deformations had been removed from the data; however as will be discussed later, the initial stiffness values associated with the tests reported by Sarkar and Wallace (1992) were typically an order of magnitude lower than those associated with the data from Karsu (1995) and Gillet (1978). Considering these low initial stiffness values modifying the data by subtracting elastic deformations would have a negligible effect on the deformation values and has consequently not been done.

### 2.6.3 Determining Initial Stiffness of Load-Deformation Behavior

There is no indisputable method for determining the initial stiffness of test data. Each set of data has to be evaluated individually and some judgment must be used to determine which data points are appropriate for measuring the initial stiffness. For this reason it is not possible to give exact details on how the initial stiffness values were

determined other than on a test by test basis. However, in general the following procedure was used to determine the initial stiffness.

The first few data points of each test were plotted and evaluated. Data points that were obviously inconsistent with the general load-deformation behavior were removed. Linear regression was then used to determine the slope, intercept, and an $r^2$ value for a best fit line through the remaining data points. The initial stiffness was taken as the slope of this line.

### 2.6.4 Shifting Data Based on Initial Stiffness

Based on the best fit line used to estimate the initial stiffness, the deformation data for each test was shifted so that the initial slope would pass through zero load and zero deformation. This was done to eliminate obvious problems with the first few deformation measurements and to provide a set of data that was consistent with the initial stiffness values.

### 2.6.5 Were Bolts Pre-tensioned or Not ?

Karsu (1995) and Gillet (1978) reported that the bolts were pre-tensioned using the turn-of-nut method. Sarkar and Wallace (1992) did not indicate if or how the bolts had been tightened. The initial stiffness values for tests with similar parameters were evaluated from each source of data. One such comparison for tests with ¾-in. bolts and ¼-in. plates is shown in Table 2.

**Table 2 Comparison of $K_i$ Values Between Experimental Investigations**

| Investigator | $L_e$ (in.) | Average $K_i$ (K/in.) |
|---|---|---|
| Karsu | 1.5 | 2890 |
| Gillet | 1.25 | 2409 |
| Sarkar & Wallace | 2 | 220 |

As can be seen in Table 2, the initial stiffness values for the tests by Sarkar and Wallace (1992) are an order of magnitude lower than those for Karsu (1995) and Gillet

(1978). Based on this comparison it was decided to treat the tests by Sarkar and Wallace (1992) as if the bolts had only been tightened to the snug condition when evaluating the load-deformation behavior of the lap plate connections.

### 2.6.6 Determining Maximum Load and Failure Load

In this report $R_{ult}$ was defined as the maximum test load and $\Delta_{max}$ is defined as the test deformation at the maximum test load. If two load-deformation data points had the same maximum load value then the first one of these was chosen to determine $\Delta_{max}$. In many cases the maximum test load was not the failure load. In these cases the load-deformation behavior peaked early then softened slightly before reaching a nearly plastic load-deformation plateau. The failure load and deformation were defined as the point where there was a sudden loss in load carrying capacity typically at the end of a plastic load-deformation plateau.

## 3. Nominal Strength

There were primarily five failure modes associated with the single bolt lap plate connections: bearing, tearout, splitting, plate buckling, bolt shear. Of these failure modes four are associated with the plate and one with the bolt. Methods of predicting the plate strength and bolt strength are presented and evaluated in the following sections.

### 3.1 Experimental Data For Evaluation of Models

Experimental strength values from the tests given by Karsu (1995), Gillet (1978), Caccavale (1975), and Sarkar and Wallace (1992) were used to evaluate the plate and bolt strength predicting methods.

### 3.2 Existing Prediction Models

For clarity, the following discussion of existing literature on plate and bolt strength is presented in separate sections.

### 3.2.1 Plate Strength

There were four basic plate failure modes that occurred in the lap plate connection tests collected in this report: plate bearing, tearout, splitting, and buckling as illustrated in Fig. 6. Most current literature dealing with plate failures recognizes all four of these failure modes. However, methods for predicting the plate strength have so far only considered bearing and tearout failure modes.

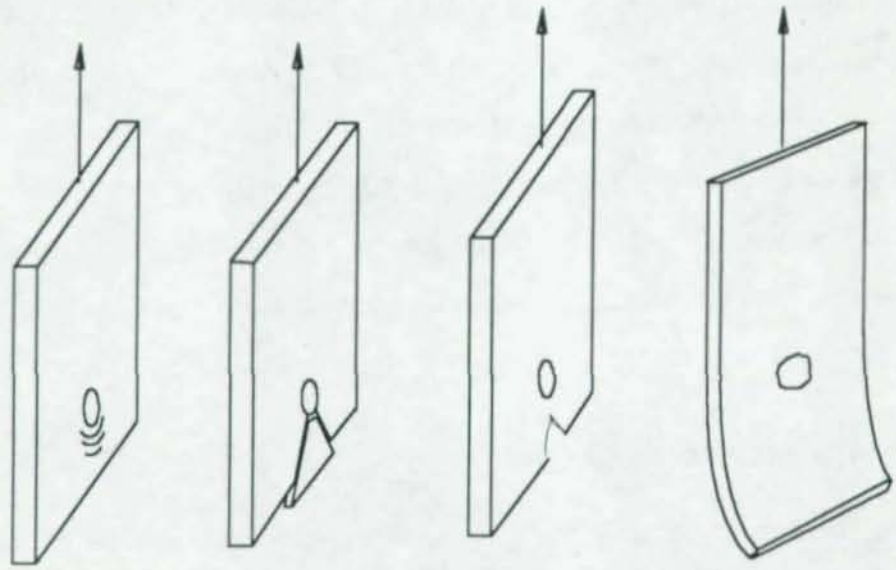


**Figure 6 Plate Failure Modes**

In the United States estimates for the tearout strength of a single bolt are based on a fairly simple lower bound physical model of the failure mode which was developed by Fisher and Struik (1974). The current equation given in the AISC Specification (*Load and*, 1993) is a simplified version of the original expression developed Fisher and Struik (1974) and is given as

$$R_n = F_u L_e t_p \qquad \text{(Eq 1)}$$

Rex and Easterling (1996) reviewed four different expressions for estimating the tearout strength of plates. It was shown that for a single bolt in a standard hole Equation

1 provided the best correlation to single plate single bolt test results. The complete expression found in the AISC Specification (*Load and*, 1993) is given as

$$R_n = F_u L_e t_p \leq 2.4 F_u t_p d_b \qquad \text{(Eq 2)}$$

The upper limit on the tearout strength is considered to be bearing failure. The current limit of $2.4 F_u t_p d_b$ is intended to limit bearing deformations to 0.25-in. before the design strength is attained and is based on the work of Perry (1981). However, if bearing deformations are not a design concern then an upper limit of $3.0 F_u t_p d_b$ is allowed instead. This later upper limit is based on the work of Fisher and Struik (1974) who (based on test results) indicated that increases in $L_e/d_b$ beyond 3.0 are accompanied by a change in failure mode from tearout to a "material piling up" type of failure (i.e. bearing failure). This "material piling up" type failure is believed to be a true upper limit on the bearing strength.

As suggested in the above paragraph, the upper limits on the tearout strength are one of two kinds: an ultimate strength limit or a deformation limit. It is convenient to discuss this upper limit in terms of bearing stress which is defined as the bearing load divided by the product of the plate thickness and bolt diameter.

With regard to an ultimate strength upper limit on the bearing stress, four suggested values were found in the literature. Fisher and Struik (1974) suggested an upper limit of $3.0 F_u$. Jones (1956) suggested an upper limit of $2.5 F_u$. As given in Perry (1981), Struik and Witterman measured bearing stresses as high as $3.5 F_u$ when they failed the main plate of a butt splice connection. Finally, based on failing the splice plates in a butt splice connection Perry (1981) suggested an upper limit of $2.8 F_u$.

With regard to upper limits imposed for deformation considerations, Jones (1956) suggested an upper limit of $2.25 F_u$. Perry (1981) suggested an upper limit of $2.4 F_u$ and $2.0 F_u$ for round holes and slotted holes respectively. The recommendations by Perry (1981) were based on using fully torqued bolts and a deformation limit of 0.25-in.

Perry (1981) also suggested an interaction between tension and bearing failures that would limit deformations to 0.25-in.

For Round Holes

$$0.0 < BR \leq 2.0 \qquad f_{ns} \leq 0.9 F_u$$

$2.0 < BR \leq 4.0$ $\quad f_b \leq (0.5 + 0.125\ BR)\ 2.4\ F_u$

$4.0 < BR$ $\quad f_b \leq 2.4\ F_u$

For Slotted Holes

$0.0 < BR \leq 1.5$ $\quad f_{ns} \leq 0.9\ F_u$

$1.5 < BR \leq 4.0$ $\quad f_b \leq (0.5 + 0.125\ BR)\ 2.0\ F_u$

$4.0 < BR$ $\quad f_b \leq 2.0\ F_u$

Where BR is the bearing ratio which is defined as

$$BR = \frac{\text{Bearing Stress}}{\text{Net Section Tensile Stress}}$$

and $f_{ns}$ is the tensile stress in the steel at the net section. Some bearing ratios for the tests considered in this report were as low as three. However, as will be shown later, the AISC Specification (*Load and*, 1993) model is conservative for all modes of failure when considering the ultimate strength of the connection; and, the model is very accurate when considering the bearing strength at a deformation limit of 0.25-in. for tests failing by bearing / tearout. Consequently, using the suggested interaction equations above would be overly conservative and no further consideration of the interaction equations is given in this report.

### 3.2.2 Bolt Strength

In general the shear strength of the bolt is given as the bolt ultimate shearing stress times the bolt shearing area. The ultimate shearing stress of a single bolt was found experimentally (Wallaert and Fisher, 1965) to be 62% and 68% of the bolt tensile strength for shear tests where the plates were in tension and compression respectively. Fisher and Struik (1974) recommended using the 62% value for design as it represented a lower bound on the ultimate shearing stress. Kulak et al (1987) also recommended using 62%. The AISC Specification (*Load and*, 1986) adopted a value of 60% to be consistent with other shearing failure models. The AISC Specification (*Load and*, 1993) adopted a value of 50% of the nominal minimum tensile strength of the bolt to account for the lack of equal load distribution seen in long joints with multiple bolts.

The reduction in bolt shearing stress associated with longer joints appears to be based on the work of Fisher et al (1963). Fisher et al (1963) conducted a series of butt

joint tests which showed that compact joints had bolt shear capacities similar to that obtained from single bolt tests. Joints were considered compact up to about 10-in long. As the joints got longer than 10-in. there was a drop in the average shear capacity of the bolts in the joint. This reduction in strength was seen to level out at around 80% of the shear strength based on single bolt tests. In the longer joints the strength of the steel was also seen to influence the bolt shear strength. The stronger the steel the higher the average bolt strength.

The shearing area is assumed to be the gross area of the bolt shank if the shearing plane passes through the bolt shank. If the shearing plane passes through the bolt threads then the shearing area is assumed to be the root area of the threads. Fisher and Struik (1974) recommend a root area equal to 75% of the gross area of the bolt. Kulak et al (1987) recommended a root area of 70% of the gross area of the bolt. The AISC Specification (*Load and*, 1986) uses a root area of 75% of the gross area. The AISC Specification (*Load and*, 1993) uses a root area of 80% of the gross area.

The experimental work that has investigated bolt ultimate shearing stress has mainly been conducted with test specimens where the bolts are in double shear. Munse et al (1954) conducted a series of two bolt lap (bolts in single shear) and butt (bolts in double shear) splice connection tests. The results showed that the shearing strength of the bolts in lap connections were 10% higher than the shearing strength of the bolts in the butt connection. This was explained by the angle of shear failure seen in the bolts from the two types of connections. The bolts in the butt connections failed at a right angle to the main axis of the bolt while the bolts in the lap connections failed at an angle slightly inclined from a right angle to the axis of the bolt. The inclination of the shear failure angle is caused by the deformed shape in the lap plate connection near failure. Because the lap plate connection is not symmetric moments in the plates cause the bolt and the plate near the bolt to slightly incline with respect to the main loading axis. This inclination is the reason for the inclined shear failure plane. The inclined shear failure plane results in a

slightly larger shearing area than when the shear plane is at a right angle to the axis of the bolt.

The results of the tests by Munse et al (1954) are in contrast to the test results discussed by Fisher and Struik (1974). Fisher and Struik (1974) indicated that based on single bolt lap connection tests that there was a 10% decrease in the shearing strength of the bolts compared to bolts in similar butt connection tests. It was reasoned that the cause of this decrease was an increase in bolt tension resulting from the plate bending discussed previously. Based on these two sources it appears that the cause for an increased shearing strength may also be a cause for a decrease in shearing strength.

Fisher et al (1978) did a statistical study of the shear strength of high strength bolts. The results showed that the average shear resistance of a high strength bolt with a single shear plane was given by

$$R_n = \alpha A_b F_{ub} \qquad \text{(Eq 3)}$$

Where $\alpha$ was 0.75 and 0.67 for A325 and A490 bolts respectively. The coefficient of variation was determined as 10% and 7% for A325 and A490 bolts respectively. The variation for the A490 bolts was less than that for the A325 because there are specified upper and lower limits on the ultimate strength for A490 bolts while there is only a lower limit on the ultimate strength for A325 bolts (Kulak et al 1987).

## 3.3 Evaluation of Existing Models

For clarity evaluation of plate strength and bolt strength are separated into the two following sections.

### 3.3.1 Plate Strength

There are currently no definitive rules for how plate strength should be determined experimentally. In most research programs the maximum load carried by the test specimen before the end of the test is assumed to be the test strength. However, there are cases where this strength would not be indicative of the true plate strength. For example, when thin plates and fully tightened bolts are used the maximum test load typically far

exceeds all reasonable estimates of the plate strength because of the additional load carried by friction. In addition, some test programs end the test at a fixed deformation limit which would, in some cases, result in maximum test loads below the true plate strength.

Another possible definition of plate strength would be the load carried by the test specimen when a particular plate failure mode occurs. However, because plate bearing and buckling failures have usually been defined by arbitrary deformation limits it is difficult to decide at exactly what point these failures occur. In addition, the initiation of plate splitting can occur very early in the test without any impact on the load-deformation behavior. Consequently using the test load associated with the initiation of plate splitting may be severely underestimating the plate strength.

Because of the above problems (as well as others not mentioned here) it is difficult to separate plate strength from the general load-deformation behavior. Consequently, the writer has decided to make comparisons between the predicted loads and the test loads at various test deformations as well as the maximum test load. In addition, because each of the test programs considered in this report were quite different comparisons are also made which consider one test program at a time so that the influence of the test program can be evaluated as well. Finally, because splitting failures are physically very different than the bearing or tearout failures the strength comparisons are also separated with respect to failure mode to see what if any influence there may be.

Plate strength predictions are based on the AISC Specification (*Load and*, 1993) which has been previously shown to provide the best correlation with single bolt single plate test data (Rex and Easterling, 1996). It should be noted that only one of the tests evaluated here had an end distance exceeding 2.4 $d_b$. Consequently, no evaluation of the current upper limits for tearout strength can be made.

A comparison of test load over predicted load is presented in Table 3. Comparisons are made against the test load at four different deformation limits as well as the maximum test load. The first deformation limit of 0.16-in. was chosen because it was the approximately the minimum deformation that any test attained prior to failure. The

second deformation limit of 0.25-in. is based on the recommended deformation limit given by Perry (1981). The third deformation limit of 0.34-in. is based on the current deformation limit recommended for use in the ultimate strength analysis approach for eccentrically loaded bolted connections given in the AISC Manual Vol. II (*Load and*, 1993). In addition, 0.34-in. appeared to be the approximate deformation limit that Gillet (1978) used to end the lap plate tests. The last deformation limit of 0.5-in. was chosen somewhat arbitrarily.

Tests which attained maximum loads before 0.16-in. of deformation are not considered in this evaluation. This is primarily because test loads in this range of deformations are still highly influenced by the load carried by friction and are not indicative of plate failure loads. Because of this requirement, none of the tests that failed by plate buckling (3 total) are included in the evaluation.

## Table 3 Evaluation of Plate Strength

| | | Δ 0.16-in. | Δ 0.25-in. | Δ 0.34-in. | Δ 0.5-in. | Max Test Load |
|---|---|---|---|---|---|---|
| *All Plate Failures* | | | | | | |
| **All Researchers** | Mean | 0.90 | 0.94 | 0.98 | 0.99 | 1.02 |
| | COV | 15.5% | 12.3% | 9.7% | 8.9% | 12.8% |
| | No. Tests | 64 | 63 | 35 | 26 | 64 |
| **Gillet** | Mean | 0.87 | 0.92 | 0.94 | | 0.94 |
| | COV | 19.2% | 14.5% | 3.3% | | 15.1% |
| | No. Tests | 28 | 27 | 2 | | 28 |
| **Karsu** | Mean | 0.94 | 0.96 | 0.98 | 1.01 | 1.09 |
| | COV | 9.8% | 8.3% | 7.6% | 7.5% | 6.4% |
| | No. Tests | 24 | 24 | 24 | 24 | 24 |
| **Caccavale** | Mean | 0.94 | 1.03 | 1.08 | | 1.09 |
| | COV | 5.8% | 3.6% | 4.3% | | 6.2% |
| | No. Tests | 10 | 10 | 7 | | 10 |
| **Sarkar & Wallace** | Mean | 0.61 | 0.71 | 0.77 | 0.83 | 0.88 |
| | COV | 20.0% | 17.2% | 15.0% | 11.4% | 5.6% |
| | No. Tests | 2 | 2 | 2 | 2 | 2 |
| *Bearing / Tearout Failures* | | | | | | |
| **All Researchers** | Mean | 0.91 | 0.97 | 1.02 | 1.02 | 1.06 |
| | COV | 9.9% | 8.6% | 8.4% | 8.7% | 9.3% |
| | No. Tests | 31 | 31 | 21 | 14 | 31 |
| **Gillet** | Mean | 0.81 | 0.89 | | | 0.92 |
| | COV | 4.5% | 4.3% | | | 4.7% |
| | No. Tests | 7 | 7 | 0 | 0 | 7 |
| **Karsu** | Mean | 0.93 | 0.96 | 0.99 | 1.02 | 1.10 |
| | COV | 10.4% | 9.1% | 8.7% | 8.7% | 6.2% |
| | No. Tests | 14 | 14 | 14 | 14 | 14 |
| **Caccavale** | Mean | 0.94 | 1.03 | 1.08 | | 1.09 |
| | COV | 5.8% | 3.6% | 4.3% | | 6.2% |
| | No. Tests | 10 | 10 | 7 | 0 | 10 |
| *Splitting Failures* | | | | | | |
| **All Researchers** | Mean | 0.89 | 0.92 | 0.94 | 0.96 | 0.98 |
| | COV | 19.7% | 15.2% | 9.7% | 8.2% | 14.9% |
| | No. Tests | 33 | 32 | 14 | 12 | 33 |
| **Gillet** | Mean | 0.89 | 0.93 | 0.94 | | 0.95 |
| | COV | 21.1% | 16.4% | 3.3% | | 17.1% |
| | No. Tests | 21 | 20 | 2 | 0 | 21 |
| **Karsu** | Mean | 0.95 | 0.96 | 0.97 | 0.98 | 1.07 |
| | COV | 9.5% | 7.4% | 5.8% | 4.9% | 6.5% |
| | No. Tests | 10 | 10 | 10 | 10 | 10 |
| **Sarkar & Wallace** | Mean | 0.61 | 0.71 | 0.77 | 0.83 | 0.88 |
| | COV | 20.0% | 17.2% | 15.0% | 11.4% | 5.6% |
| | No. Tests | 2 | 2 | 2 | 2 | 2 |

The following observations are made based on review of Table 3.

- All but one of the tests that exhibited plate failure achieved at least 0.25-in. of deformation before failure.
- Approximately half of the tests did not achieve 0.34-in. of deformation before the test was ended. It is seen that most of the tests that did not achieve the 0.34-in. of deformation were conducted by Gillet (1981). In many cases it is not clear whether these tests were just ended or whether some failure occurred resulting in a loss of load carrying capacity.
- Bearing / Tearout failures had mean strengths about 8% higher than splitting failures. This is partly attributable to the very low test strengths reported by Sarkar and Wallace (1992).
- Evaluation of bearing / tearout failures shows the predicted strength is about 6% conservative. A comparison of the specification equation to bearing / tearout strength for single bolt single plate specimens showed an average ratio of 0.998 (Rex and Easterling, 1996). This may be an indication of a slight increase in plate strength associated with the single bolt lap plate connections compared to the single plate single bolt type specimens. One possible reason for the increased strength is the confinement of the steel in front of the bolt provided by the bolt nut and head and washers if present. Another reason may be that some load was being carried by friction between the two plates which leads to calculated bearing stresses higher than the real bearing stresses (Fisher and Struik, 1974). However, it should be noted that the upper limit on the bearing stress was shown by Perry (1981) to be unaffected by bolt tension.
- Considering all the researchers there is good correlation between the maximum test load and the predicted load. However, when considering the individual research programs it is seen that the maximum test loads reported by Gillet (1978) and Sarkar and Wallace (1992) have mean test values of 6% and 12% below the predicted values respectively; while, the test loads reported by Karsu (1995) and Caccavale (1975) have mean test values of 9% above the predicted values.

- When considering the maximum test load vs. the predicted load most of the variation results from the tests conducted by Gillet (1978).
- When considering all failure modes and researchers there appears to be approximately an 8% increase in strength associated with the maximum test load compared to the test load at 0.25-in. of deformation.
- Splitting failures are physically very different than tearout failures. The current expression given in the AISC Specification (*Load and*, 1993) is based on the physical behavior associated with tearout. Despite this, the expression appears to correlate very well with the test strengths associated with splitting failures as well.

The only general conclusion that can be made based on this evaluation is that the current expression given in the AISC Specification (*Load and*, 1993) for determining tearout strength correlates well with all the test data considered. These tests included bearing / tearout and splitting failures. However, it should be restated that an evaluation of the upper limit on the tearout strength (representing the bearing strength) has not been evaluated in this study.

### 3.3.2 Bolt Strength

Based on the literature there are basically five bolt shear strength models that have been recommended over the last 25 years. The basic differences in these models lie in the value of the ultimate shearing stress and the value of the root area in the threaded portion of the bolt. These models are summarized in Table 4 along with statistical results from the comparisons of the maximum test load over predicted values. Note that because the maximum test load almost always occurred just prior to shearing of the bolt it is believed that the maximum test load is a good indicator of the bolt shearing strength. There were a total of 71 single bolt lap plate tests that failed by bolt shear.

**Table 4 Evaluation of Bolt Shear Strength Models**

| Model | $F_{vb}/F_{ub}$ | $A_{bv}/A_b$ | Average Test/Predict | COV |
|---|---|---|---|---|
| Fisher & Struik (1974) | 0.62 | 0.75 | 1.05 | 12% |
| Fisher et al (1978) | 0.75 / 0.67* | ** | 0.89 | 12% |
| AISC (1986) | 0.60 | 0.75 | 1.09 | 12% |
| Kulak et al (1987) | 0.62 | 0.70 | 1.07 | 14% |
| AISC (1993) | 0.50 | 0.80 | 1.28 | 11% |

* A325 / A490 Bolts

** Was not recommended. Assumed to be 0.70 for evaluation purposes.

Considering the ratio of test strength over predicted strength all the models except Fisher et al (1978) were conservative. The latest edition of the AISC Specification (LRFD 1993) is over conservative as would be expected because the single bolt lap plate connection would be considered compact and the new model assumes long joint behavior. Overall the model suggested by Fisher and Struik (1974) compared the best but predictions using the AISC Specification (*Load and*, 1986) are also satisfactory. The coefficient of variation for all the models except perhaps that recommended by Kulak et al (1987) are in line with the expected coefficient of variation of 10% (Fisher et al, 1978).

A more detailed statistical analysis of the test loads compared to the predicted load based on the AISC Specification (*Load and*, 1986) is presented in Table 5. This analysis is similar to that done for plate failures and includes a breakout of the different research programs as well as different deformation limits.

**Table 5 Evaluation of Test over Predicted Bolt Shear Capacity**

| | | Δ 0.16-in. | Δ 0.25-in. | Δ 0.34-in. | Δ 0.5-in. | Max Test Load |
|---|---|---|---|---|---|---|
| *Bolt Shear Failures* | | | | | | |
| **All Researchers** | Mean | 0.97 | 1.04 | 1.11 | 1.16 | 1.09 |
| | COV | 11.9% | 9.5% | 6.4% | 3.9% | 11.4% |
| | No. Tests | 69 | 46 | 19 | 7 | 69 |
| **Gillet** | Mean | 0.92 | 0.99 | | | 0.98 |
| | COV | 9.1% | 9.4% | | | 9.9% |
| | No. Tests | 30 | 19 | 0 | 0 | 30 |
| **Karsu** | Mean | 1.02 | 1.07 | 1.09 | 1.12 | 1.15 |
| | COV | 13.2% | 8.1% | 6.6% | 1.6% | 5.7% |
| | No. Tests | 22 | 15 | 10 | 2 | 22 |
| **Sarkar & Wallace** | Mean | 0.98 | 1.08 | 1.13 | 1.17 | 1.20 |
| | COV | 11.0% | 9.0% | 6.1% | 4.0% | 4.9% |
| | No. Tests | 17 | 12 | 9 | 5 | 17 |

The following observations are based on review of Table 5.

- The majority of the variation when comparing maximum test load to predicted appears to result from the tests conducted by Gillet (1978). Recall that it was assumed that, for the tests reported by Gillet (1978), bolts had the threads excluded from the shear plane of the connection. Because this detail was not reported, it is possible that some of the tests did and some did not include the threads in the shear plane. This would lead to an increased scatter between predicted and test values.
- When considering all researchers the predicted load capacity appears to be about 9% conservative. However, when considering the individual research programs it is seen that the test loads reported by Karsu (1995) and Sarkar & Wallace (1992) are 15% and 20% respectively higher than predicted; while, the test loads reported by Gillet (1978) agree well with predicted. The lower average value for the tests reported by Gillet (1978) may be at least partially explained with the same reasoning for the increased scatter in the test vs. predicted given above.
- Bolt strength appears to increase with test deformation. The highest strengths corresponding with the largest test deformation. This may possibly be the result of

increased out-of-plane deformations which would increase the angle of failure in the bolt.

Because the actual tensile strengths of the bolts is unknown and in some cases the shear plane condition (X or N) is unknown any conclusions about the relative shearing strength of bolts in single shear compared to the strength of bolts in double shear (like in butt connections) cannot conclusively determined. However, based on the above comparison it does appear that the average shearing strength of the bolts in the single bolt lap connections is slightly higher than would be expected based on equations developed from double shear bolt tests. One possible reason for this is an inclined shearing angle. A visual inspection of the bolts that sheared in the tests reported by Karsu (1995) showed that the shearing angle was inclined similar to the tests reported by Munse et al (1954). A second possible reason for the increased load may be frictional forces between the plates resulting from tension in the bolt. The bolt tension could be a result of the original pre-tensioning or the result of prying forces developed by the deforming plates or some combination of these two.

Without additional testing and analysis, trying to include either of these possible effects to increase the bolt load capacity does not seem justifiable at this time. In general, it is believed that the model given in AISC Specification (*Load and*, 1986) is sufficiently accurate and precise for purposes of the current research.

# 4. Component Modeling of Load-Deformation Behavior

The fundamental idea of component modeling is that the behavior of the individual parts of a connection can be combined to simulate the behavior of the complete connection. For a single bolt lap plate connection there are three primary component behaviors: plates, bolts, and friction. This concept is shown schematically in Figure 7.

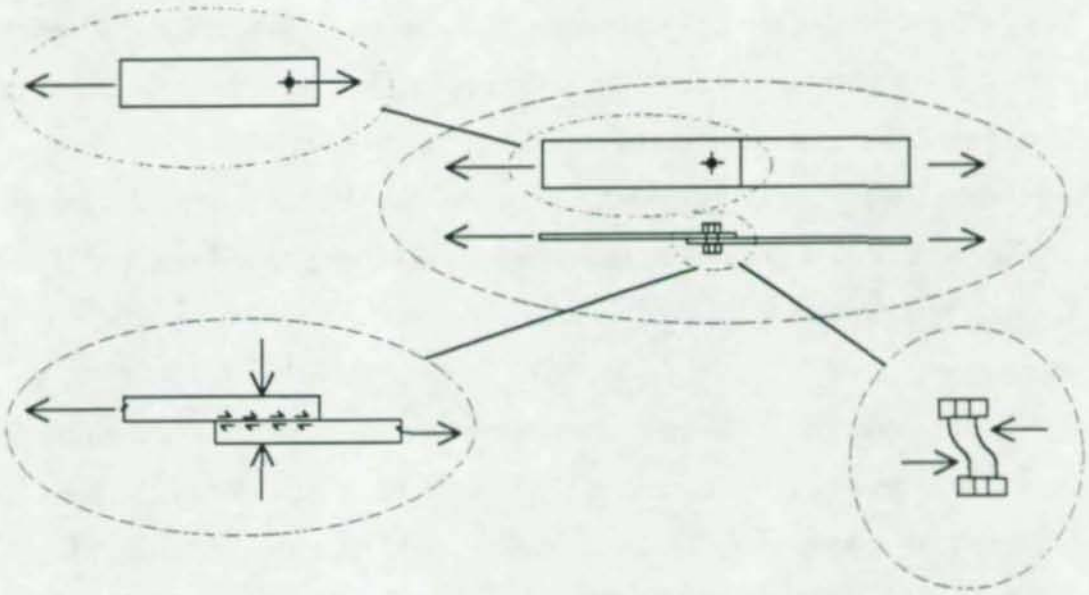

**Figure 7 Primary Components of Single Bolt Lap Plate Connection**

If the load-deformation behavior for each of these components can be approximated then the load-deformation behavior of the complete connection can be approximated by combining the component behaviors in series and in parallel as shown in Figure 8.

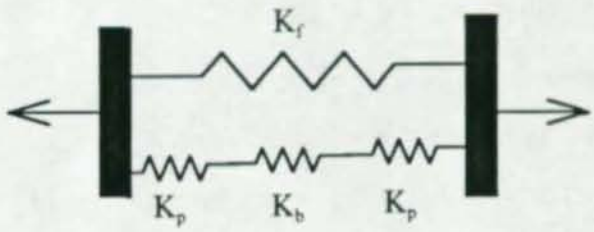


**Figure 8 Combination of Components To Simulate Complete Connection Behavior**

The first step in developing this procedure is to isolate and develop methods of approximating the load-deformation behavior of each component. Because of the high degree of interaction between the components it is extremely difficult to experimentally isolate the individual behaviors. In fact, it can be very easily argued that by isolating the components there will be inconsistencies between the isolated behavior and the behavior observed in the complete connection which cannot be eliminated.

The following sections present the development of methods for approximating the individual component behaviors. In an attempt to minimize the previously mentioned inconsistencies the isolated behaviors will first be identified and characterized based on experimental work from other research programs which do not specifically consider single bolt lap plate connections. Next, this behavior will be verified and modified as necessary to provide reasonable agreement with the experimental results for single bolt lap plate connections.

The development of these components is broken into two sections. The first section considers lap plate connections with snug tight bolt. When the bolts are only brought to the snug tight condition it is assumed that the frictional component is negligible. This allows the plate and bolt components to be evaluated independent of the friction component. The second section considers lap plate connections with fully tensioned bolts. Based on the methods for approximating bolt and plate behavior developed in the first section the frictional behavior can be isolated and evaluated.

## 4.1 Plate and Bolt Behavior Developed With Respect to Lap Plate Connections With Snug Tight Bolts.

The simplest single bolt lap plate connections are those with snug tight bolts. In these connections the frictional resistance between the plates is assumed to be small and can be ignored. This means that there are essentially only two unknown behaviors; the plate and bolt. Because there are two unknown behaviors but only one source of verification (lap plate connection tests with snug tight bolts) at least one behavior has to be determined from a separate experimental program. Of the two, plate behavior is believed to be more easily isolated and evaluated than bolt behavior.

### 4.1.1 Plate Load-Deformation Behavior

The load-deformation behavior of plates in the local vicinity of a bolt was the topic of a separate report on single bolt single plate behavior (Rex and Easterling, 1996). In this report both experimental and analytical methods were used to develop an approximation

to the plate load-deformation behavior. One form of this behavior is given in a normalized equation as

$$\frac{R}{R_n} = \left(1 - e^{-0.2\bar{\Delta}}\right)^{0.5} \qquad \text{(Eq 4)}$$

This equation can be easily rearranged so that the deformation is a function of load.

$$\bar{\Delta} = -5 \ln\left\{1 - \left(\frac{R}{R_n}\right)^2\right\} \qquad \text{(Eq 5)}$$

Where

$R$ = Plate load

$R_n$ = Plate strength

$\bar{\Delta}$ = Normalized deformation = $\Delta \beta K_i / R_n$

$\Delta$ = Local plate deformation

$\beta$ = Steel correction factor = 30% / %Elongation (for typical steels taken as 1)

$K_{pi}$ = Initial stiffness given by

$$K_{pi} = \frac{1}{\frac{1}{K_{pbr}} + \frac{1}{K_{pb}} + \frac{1}{K_{pv}}} \qquad \text{(Eq 6)}$$

Where

$K_{pbr}$ = Plate bearing stiffness = $120 F_y t_p d_b^{0.8}$ (units are kips and inches)

$K_{pb}$ = Plate bending stiffness = $32 E t_p (L_e/d_b - 0.5)^3$

$K_{pv}$ = Plate shearing stiffness = $6.67 G t_p (L_e/d_b - 0.5)$

The experimental single bolt single plate strength, $R_n$, was found to correlate very well with predicted strength based on the AISC Specification (*Load and*, 1993). The experimental plate strength for the lap plate connections was shown to also correlate very well with the predicted strength based on the AISC Specification (*Load and*, 1993) in Section 3 of this report.

There are some inconsistencies between the plate behavior in the isolated tests and the plate behavior in a lap plate connection. First, in the lap plate connections there is an eccentricity that induces moments into the plates. This moment is not present in the

isolated plate tests. Second, the bolt in the isolated tests imposes a symmetric bearing pressure with respect to the plate planes of symmetry. In the lap plate connections, the bolt imposes a non-symmetric bearing pressure on the bolt hole going from a maximum pressure at the shear plane to a minimum pressure under the bolt head or nut. At this time, no attempt will be made to modify the approximation to the plate behavior to account for these inconsistencies. However, subsequent refinements of the approximate behavior should address these issues.

### 4.1.2 Bolt Load-Deformation Behavior

Assuming that the plate behavior can now be sufficiently approximated then the only unknown behavior in the lap plate connections with snug tight bolts is that of the bolt itself. The bolt behavior will first be identified and characterized based on the work reported by Wallaert and Fisher (1965), Fisher (1965), and Karsu (1995) along with the guidelines given in EC3 Annex J (1994). Next, the approximate behavior will be verified and modified as necessary against the single bolt lap plate connection tests reported by Sarkar and Wallace (1992).

#### *4.1.2.1 Identification And Characterization of Behavior*

Wallaert and Fisher (1965) ran 174 elemental bolt shear tests. Single bolts were tested in double shear. The primary goal of this testing was to determine the double shear strength of high strength bolts and to establish what parameters effected this. A secondary goal was to establish complete load-deformation behaviors for the bolts. Fisher (1965) developed the following expression to represent the load-deformation behavior of the bolt shear tests conducted by Wallaert and Fisher (1965).

$$R = R_{ult} [1-e^{-\mu\Delta}]^{\lambda}$$

The equation parameters $R_{ult}$, $\mu$, and $\lambda$ were determined for a number of the bolt shear tests and these values were reported in Fisher (1965). A summary of these curve parameter values as well as test parameters is given in Table 6.

**Table 6 Summary Of Bolt Shear Tests by Wallaert and Fisher (1965)**

| Test Index | Bolt Type | Bolt Lot | Bolt %Elong | $F_{ub}$ (ksi) | $d_b$ (in.) | Steel Grade | $f_y$ (ksi) | $f_u$ (ksi) | $R_{ult}$ (kips) | $\mu$ | $\lambda$ | $\Delta r$ (in.) | Sense of Test |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A325 | 8A | 25.3 | 128.5 | 0.875 | A440 | 43 | 76 | 98.6 | 23 | 1 | 0.187 | Tension |
| 2 | A325 | 8A | 25.3 | 128.5 | 0.875 | A440 | 43 | 76 | 102.3 | 23 | 1 | 0.2 | Comp |
| 3 | A325 | 8B | 21 | 117.1 | 0.875 | A440 | 43 | 76 | 92.5 | 25 | 0.95 | 0.2 | Tension |
| 4 | A325 | 8B | 21 | 117.1 | 0.875 | A440 | 43 | 76 | 104 | 22 | 1 | 0.239 | Comp |
| 5 | A325 | H | 19.1 | 126.1 | 0.875 | A440 | 43 | 76 | 95.2 | 22 | 1 | 0.22 | Tension |
| 6 | A325 | H | 19.1 | 126.1 | 0.875 | A440 | 43 | 76 | 103 | 22 | 1 | 0.236 | Comp |
| 7 | A325 | C | * | * | 0.875 | A7 | * | * | 98.5 | 18 | 1 | 0.238 | Tension |
| 8 | A325 | C | * | * | 0.875 | A7 | * | * | 106.9 | 18 | 1 | 0.291 | Comp |
| 9 | A325 | D | 18.3 | 123.1 | 0.875 | A7 | * | * | 101.8 | 18 | 1 | 0.279 | Tension |
| 10 | A325 | D | 18.3 | 123.1 | 0.875 | A7 | * | * | 102.5 | 18 | 1 | 0.3 | Comp |
| 11 | A354BC | CC | 21.6 | 134.8 | 0.875 | A440 | 43 | 76 | 103.7 | 20 | 0.4 | 0.178 | Tension |
| 12 | A354BC | CC | 21.6 | 134.8 | 0.875 | A514 | 110 | 120 | 101.1 | 25 | 0.4 | 0.137 | Tension |
| 13 | A354BC | DC | 22.6 | 137 | 1 | A440 | 43 | 76 | 138.2 | 20 | 0.5 | 0.212 | Tension |
| 14 | A354BC | DC | 22.6 | 137 | 1 | A514 | 110 | 120 | 131.5 | 25 | 0.5 | 0.156 | Tension |
| 15 | A354BD | ED | 16.6 | 168 | 0.875 | A440 | 43 | 76 | 123.9 | 25 | 0.4 | 0.174 | Tension |
| 16 | A354BD | ED | 16.6 | 168 | 0.875 | A514 | 110 | 120 | 123.2 | 25 | 0.4 | 0.113 | Tension |
| 17 | A354BD | FD | 16.7 | 164 | 1 | A440 | 43 | 76 | 157.7 | 21 | 0.5 | 0.248 | Tension |
| 18 | A354BD | GD | 18.8 | 164 | 0.875 | A440 | 43 | 76 | 122.4 | 23 | 0.5 | 0.173 | Tension |
| 19 | A354BD | GD | 18.8 | 164 | 0.875 | A514 | 110 | 120 | 123.4 | 25 | 0.35 | 0.152 | Tension |
| 20 | A490 | KK | 20 | 169 | 0.875 | A440 | 43 | 76 | 124.4 | 23 | 0.4 | 0.202 | Tension |
| 21 | A490 | JJ | * | 164 | 1 | A514 | 110 | 120 | 151.7 | 28 | 0.35 | 0.155 | Tension |

*Properties not given in literature.

The authors recognized that $R_{ult}$ corresponded well with the maximum test load. They also recognized that the parameter $\mu$ was primarily influenced by the type of connected material and that $\lambda$ was basically unaffected by the type of connected material.

The first step in characterizing the bolt component behavior is to determine the deformation in the bolt at failure. Considering test specimens with A514 steel plates it is assumed that the majority of the deformation at failure is deformation in the bolt and not in the plate (because of the extremely high plate strength). Four of these tests are summarized in Table 7.

**Table 7 Bolt Shear Tests in A514 Steel Wallaert and Fisher (1965)**

| Test | $d_b$ (in.) | $f_{ub}$ (ksi) | %Elongation | $R_{ult}$ (kips) | $\Delta_f$ (in.) |
|---|---|---|---|---|---|
| 12 | 7/8 | 135 | 21.6 | 101 | 0.137 |
| 14 | 1 | 137 | 22.6 | 131 | 0.156 |
| 16 | 7/8 | 168 | 16.6 | 123 | 0.113 |
| 21 | 1 | 164 | * | 152 | 0.155 |

*Not reported.

Two observations are based on review of Table 7.

- As bolt grade increases (indicated by increasing $f_{ub}$) bolt deformations at failure should ideally decrease because of the decreased ductility of the bolt steel; however, because test loads increase the deformations in the plates increase which creates a situation where there is little change in the overall deformation at failure. This observation was suggested by the authors; however, it should be noted that in all of these tests the plate strength was many times greater than the bolt strength.
- As bolt diameter increases the deformation at failure increases because the bolt deformation at failure will most likely remain constant but the plate deformations will increase because of the increased failure load. This is also explained by the fact that shearing area increases faster than bearing area with increasing bolt diameter.

Based on these observations it is assumed that a reasonable value of the bolt deformation at failure can be approximated by the average of the deformations for the 7/8-in. diameter bolts which was 1/8-in. Measurements were made on sheared bolts from the tests conducted by Karsu (1995). These measurements confirmed that for A325 bolts a bolt deformation of about 1/8-in. was indeed a reasonable value.

The next step in trying to characterize the bolt component behavior is to determine the basic shape of the load-deformation behavior. It was reported by Wallaert and Fisher (1965) that tests with snug tight bolts and fully tensioned bolts were conducted. However, it was not indicated in any of the literature which condition existed for the tests reported in Table 6. The tests with snug tight bolts should provide a close approximation to the load-deformation behavior of the bolt component (i.e. closer than the tests with fully tensioned bolts because of the lack of frictional resistance). Consequently, it was

necessary to determine which bolt condition was most likely associated with each of the reported tests.

To do this, each of the 21 tests reported in Table 6 were plotted and evaluated. Based on this evaluation it was very evident that the tests which had $\lambda$ values of around 1.0 had snug tight bolts while those with $\lambda$ values below 0.5 had fully tensioned bolts. The most indicative difference between the two was the initial stiffness. The tests with $\lambda$ values at and below 0.5 had initial stiffness values typically an order of magnitude above the tests with $\lambda$ values of around 1. This difference in initial stiffness is similar to the difference in initial stiffness observed between the single bolt lap plate connection tests with snug and fully tensioned bolts collected in this report.

The load-deformation behavior for the tests (conducted by Wallaert and Fisher 1965) with snug tight bolts should be primarily comprised of the bolt and plate component behaviors (i.e. the same assumption as for the lap plate connections with snug tight bolts). The following procedure was used to isolate the bolt behavior from the test data.

Using the curve parameters given for Test 3 from Table 6 the load vs. deformation for this test was plotted. Next, using the approximate plate component behavior discussed previously and the plate properties reported in the literature, the load-deformation behavior of the plates for Test 3 was determined. For each load the estimated plate deformations were subtracted from the test deformations (assumed given by the curve parameters). The remaining load-deformation behavior was then assumed to be that associated with the bolt alone. These load-deformation points were analyzed and curve parameters were determined using non-linear regression. It was determined that a value of $\mu$ of approximately 34 and a value of $\lambda$ of 1.0 seemed appropriate.

When $\lambda$ has a value of 1.0 it can be shown that $\mu$ is a scaling factor for the initial stiffness of the load-deformation response (i.e. the initial stiffness is $\mu$ times the bolt strength $R_{ult}$). EC3 Annex J (1994) gives a estimate for initial bolt stiffness for a snug tight bolt in single shear. The exact expression given in EC3 Annex J (1994) can be rearranged in terms of bolt shear strength. When this is done the scaling factor for the

initial stiffness is given as 52.2. The basis for the expression in EC3 Annex J (1994) is currently not known. Based on these analysis it appears that a value of $\mu$ somewhere between 34 and 52.2 and a value of $\lambda$ of 1.0 seems justifiable. To determine the most appropriate value of $\mu$ the single bolt lap plate connection tests with snug tight bolts are evaluated in the next section.

#### *4.1.2.2 Verification And Modification of Behavior*

The final value of $\mu$ was determined by calibration of the predicted load-deformation behavior for single bolt lap plate connections against the test data reported by Sarkar and Wallace (1992). All of the tests that were reported and which had bolt shear failures were used (14 total). The load-deformation response for each of these tests was simulated using the plate-bolt-plate spring series previously shown in Figure 8. The plate behavior was simulated using the plate component behavior discussed previously. The bolt behavior was simulated using the exponential equation developed by Fisher (1965) with the value of $\lambda$ equal to 1, the value of $R_{ult}$ equal to the test bolt shear strength, and the value of $\mu$ left variable. The best value of $\mu$ was then determined through visual and numerical analysis. Based on this analysis, a final value of $\mu$ equal to 50 seemed most appropriate and agrees well with the value derived from EC3 Annex J (1994).

#### *4.1.2.3 Summary of Behavior*

In summary, it is convenient to express the bolt component load-deformation relationship in terms of a normalized deformation. This is given as

$$\frac{R}{R_n} = 1 - e^{-6.25\bar{\Delta}} \qquad \text{(Eq 7)}$$

Where

$$\bar{\Delta} = \Delta / \Delta_f$$

And

$$\Delta_f = 1/8\text{-in.}$$

It is recognized that in reality the load-deformation behavior of the bolt is most likely dependent on many parameters which are not included in the above expression. However, for the scope of the current research the suggested simple representation of this behavior is believed satisfactory.

## 4.2 Frictional Behavior Developed With Respect to Lap Plate Connections With Fully Tensioned Bolts.

Based on the previous section it is assumed that the plate and bolt component behavior can now be sufficiently approximated. With this assumption, the only unknown behavior in the lap plate connections with fully tensioned bolts is that of the frictional resistance between the plates. This component behavior will first be identified and characterized based on the work reported by Frank and Yura (1981) and by Fisher et al (1978) and others. Next, the approximate behavior will be further developed by calibrating it against the single bolt lap plate connection tests reported by Karsu (1995) and Gillet (1978).

### 4.2.1 Identification and Characterization of Behavior

In the following sections the primary characteristics of the frictional behavior are identified based on literature dealing with topics other than the single bolt lap plate connections.

#### *4.2.1.1 General Load-Deformation Behavior*

Frank and Yura (1981) ran 77 elemental slip tests using steel plates with blasted surfaces and single bolts in double shear. These tests were run to provide a control basis for later tests with coated steel surfaces. In these tests a special hydraulic system was used to apply a known tension in the bolt and the plates and bolt were arranged such that the bolt would not bear against the bolt hole until after significant slipping had occurred. Consequently, the only resistance to load was the frictional resistance between the plates. A typical load-deformation response for a slip test using blasted steel plates was presented

in Figure 19 of Frank and Yura (1981). This figure has been reproduced and is presented in Figure 9 below. In addition to the load-slip behavior a schematic of the basic test specimen is also shown.

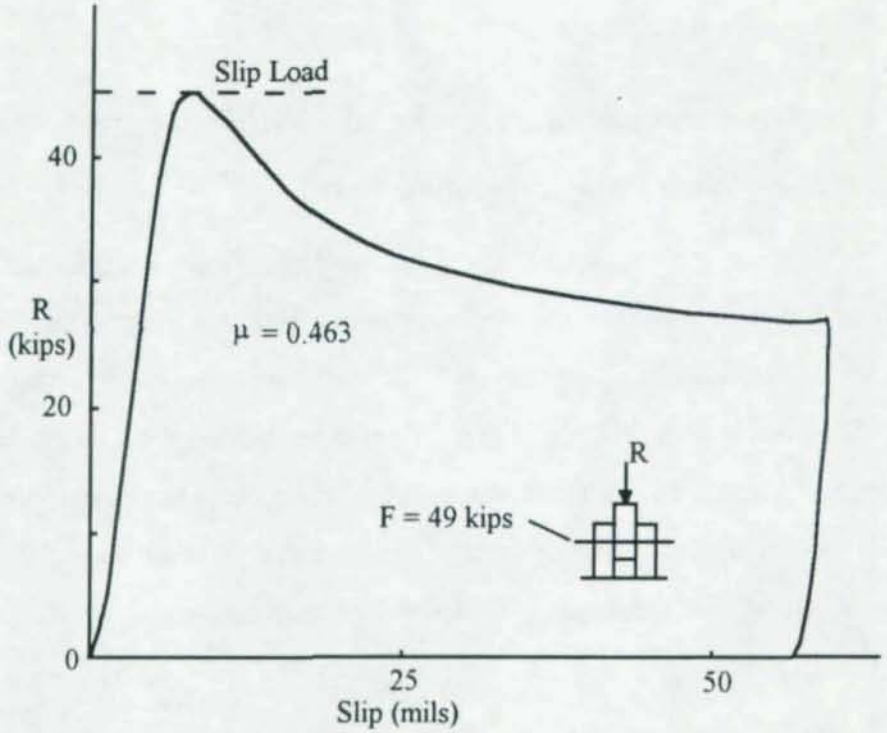


**Figure 9 Frictional Load-Slip Behavior Reported by Frank and Yura (1981)**

There are two important observations based on the test behavior presented in Figure 9. First, the test specimen exhibited a linear behavior up to very near the slipping load. Second, after the slipping load was reached the load resistance degraded with increased slip. Based on these observations it appears that there are at least two and possibly three characteristic behaviors associated with the load-slip response: initial stiffness, slip load, and post slip behavior. The only literature found at this time deals with the slip load which is discussed in the following section. No literature dealing with the pre and post slip load behavior was found.

#### *4.2.1.2 Slipping Load*

The simplest model used to determine the slipping load in a bolted connection is the bolt pretension multiplied by the frictional coefficient. For clean mill scale surfaces the frictional coefficient has been shown (Frank and Yura, 1981; Fisher et al, 1963) to be around 0.32 to 0.34. Both of these investigations utilized fairly thick plates with the bolts in double shear. The effect of the bolts being in single shear and the effect of using thinner plates on the slipping load is not well understood. Kulak et al (1987) indicated that some tests with the bolts in single shear had showed that slip resistance was not noticeably different than tests with the bolts in double shear. Kulak et al (1987) also indicated that short grip large diameter bolts may be inadequately tensioned using the 1/3 turn-of-nut method and that the method should be calibrated in these situations. The short grip would be associated with thin plate combinations.

Fisher et al (1978) did a statistical study of the slip resistance associated with the use of high strength bolts. The results showed that the average slip resistance of a high strength bolt with a single shear plane in mild steels with clean mill scale surfaces and where the bolts had been tightened by turn-of-nut method was given by

$$R_n = \alpha A_{bt} F_{ub} \qquad \text{(Eq 8)}$$

Where $\alpha$ was 0.33 and 0.29 for A325 and A490 bolts respectively. The coefficient of variation was determined as 24% for both A325 and A490 bolts. $A_{bt}$ is the tension area of a bolt usually taken as 0.75 of the gross area of the bolt $A_b$.

The current AISC Specification (*Load and*, 1993) specifies that the minimum bolt tension should be 70% of the minimum tensile strength of the bolt. Based on this and some additional assumptions, which are not completely described, the slip load for A325 and A490 bolts in standard holes under service loads and for steel with clean mill scale surfaces is given as 17 $A_b$ and 21 $A_b$ respectively. Where $A_b$ is the gross area of the bolt in $in.^2$ and the constants of 17 and 21 have units of ksi. When designing for factored loads the constants for the slipping load change to 23.5 and 29.4 for A325 and A490 bolts respectively.

### 4.2.2 Calibration Against Lap Plate Connection Tests With Fully Tensioned Bolts

Based on comparisons between the simulated and the test load-deformation behavior for lap plate connections with snug tight bolts it is assumed that the plate and bolt component behaviors developed previously are valid. With this assumption and with the spring model previously presented in Figure 8 it is possible to isolate the frictional component behavior from the experimental load-deformation behavior reported for lap plate connections with fully tensioned bolts. The following procedure was used to isolate the frictional behavior.

Plate behavior was simulated using the component behavior model previously described. The plate strength was taken as that given by the current AISC Specification (*Load and* 1993). Bolt behavior was simulated using the component behavior previously developed. The bolt strength was taken as the test strength if the test failed by bolt shear otherwise it was taken as that given by the AISC Specification (*Load and* 1986). This inconsistency in the assumed bolt shear strength was necessary because of the lack of agreement between the predicted strength and the test strength that was discussed in Section 3 of this report. It was believed that a more accurate picture of the frictional behavior would be obtained by using actual test strength rather than calculated strength. This refinement was not believed necessary for tests that exhibited plate failures because of the general good agreement between plate strength and the calculated strength also discussed in Section 3 of this report.

Using the plate-bolt-plate spring series shown in Figure 8 and the approximate component behaviors just described the load carried by the plates and bolts through bearing could be estimated for each test deformation. This load was then subtracted from the test load. The resulting load-deformation response is ideally the frictional component behavior. A typical friction load vs. connection deformation is presented in Figure 10 along with the three characteristic quantities that describe the basic behavior.

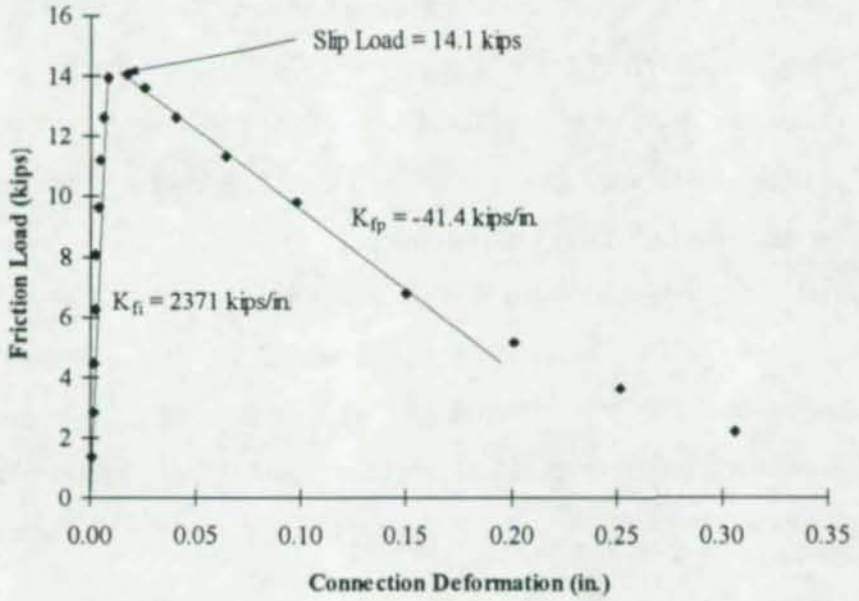


**Figure 10 Experimental Friction Load-Deformation Behavior Test 4 Reported by Gillet (1978)**

As can be seen in Figure 10 the basic shape of the load-deformation response is similar to that reported by Frank and Yura (1981). The only significant difference between the above isolated behavior and that reported by Frank and Yura (1981) is that the post slip load resistance continues to degrade until there is little or no frictional load transfer.

The reason for this degradation of the frictional load capacity is not clear at this time. However, there are a couple of possible theories that may explain the behavior. First, as the tension load in the plates increases poison's effect would tend to reduce the thickness of the plates. This reduction in thickness would be accompanied by a relaxation in the bolt and consequently a reduction in the axial load in the bolt and thus frictional resistance. Second, research (Wallaert and Fisher, 1965) has shown that bolts which are fully tensioned and bolts which are only snug tight have essentially the same shear capacity. Two reasons for this have been given. First, it is believed that most of the bolt elongation that occurs when pre-tensioning is from the elongation of the threaded portion

of the bolt. However, most of the bolt shear tests with fully tensioned bolts have the shear plane passing through the shank of the bolt which would be under a much lower stress. Second, it is believed that during the test plastic flow of the bolt steel allows the bolt to relax and that by the time the shear capacity is reached that there is very little axial tension still in the bolt and thus very little frictional resistance.

The frictional component behavior was isolated for each of the tests reported by Karsu (1995) and Gillet (1978). For each test the initial stiffness ($K_{fi}$), the post stiffness ($K_{fp}$), and the slipping load ($R_f$) were determined. These quantities were entered into a database program and analyzed to determine if there were correlation's between the values and the test parameters. Based on this analysis three parametric equations were developed.

$$R_f = 0.11\ F_{ub}\ A_b\ + 5.1 \text{ (kips)} \qquad \text{(Eq 9)}$$

$$K_{fi} = 15.7\ F_{ub}\ A_b + 887 \text{ (k/in.)} \qquad \text{(Eq 10)}$$

$$K_{fp} = t_1\ [2.81\ (F_{ub}\ A_b) - 0.0122\ (F_{ub}\ A_b)^2] \text{ (k/in.)} \qquad \text{(Eq 11)}$$

In addition to the above parametric equations more rational expressions for predicting these three quantities were also developed. This method will be referred to as the "rational method" for lack of a fancier name at this time. First, based on a combination of the AISC Specification (*Load and*, 1993) requirements for bolt tightening and the recommended coefficients for A325 vs. A490 bolts given by Fisher et al (1978) the following expression for slipping load can be derived.

$$R_f = \alpha\ (0.7\ F_{ub})\ (0.75\ A_b)\ \mu \qquad \text{(Eq 12)}$$

Where

$\alpha$ = 1.0 for A325 bolts and 0.88 for A490 bolts

$\mu$ = Friction coefficient (0.33 for clean mill scale surfaces)

Next, the connection deformation when slip started to occur was determined to have an average value of 0.0076-in. with a COV of 46%. The initial frictional stiffness ($K_{fi}$) could then be determined as the slipping load divided by 0.0076-in. Finally, it was noticed that the post slip slope ($K_{fp}$) was related to the combined thickness of $t_1$ and $t_2$. This

relationship was best represented by developing a method for determining the deformation at which the frictional resistance could be assumed to be zero ($\Delta_{fu}$). A tri-linear prediction model for approximating $\Delta_{fu}$ seemed to work best.

$$\Delta_{fu} \begin{cases} (t_1 + t_2) < 0.5" & \Delta_{fu} = 0.4" \\ .0.5" \le (t_1 + t_2) \le 1.5" & \Delta_{fu} = 0.4" - (t_1 + t_2 - 0.5)\ 0.3 \\ 1.5" < (t_1 + t_2) & \Delta_{fu} = 0.1" \end{cases} \quad \text{(Eq 13)}$$

The post slip slope is then determined by dividing the slip load by $\Delta_{fu}$. The resulting bi-linear approximation to the friction load-deformation behavior is shown in Figure 11.

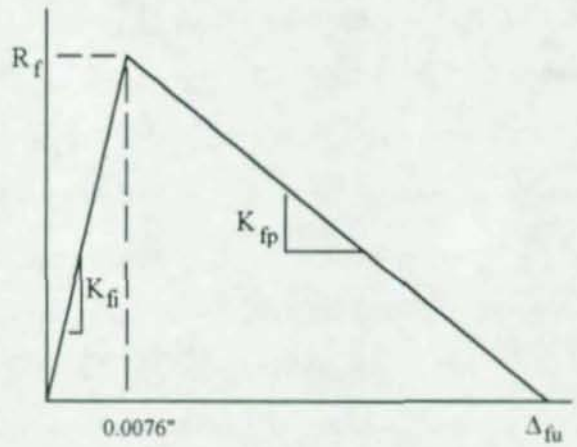


**Figure 11 Bi-Linear Representation of Friction Load-Deformation Behavior**

### 4.2.3 Evaluation of Models for Calculating Frictional Behavior

As developed in the previous section there are three characteristic values that basically describe the frictional component behavior: $R_f$, $K_{fi}$, and $K_{fp}$. So far, five methods for determining $R_f$ have been discussed and two methods for determining $K_{fi}$ and $K_{fp}$ have been discussed. A comparison of these various methods for calculating the characteristic quantities against the values determined from the test data is needed so that an appropriate method for calculating these quantities may be recommended. Such a comparison is presented in Table 8. Each of the methods discussed for calculating the frictional component characteristic quantities are presented along with the average of test over predicted value and the associated coefficient of variation.

**Table 8 Evaluation of Methods For Determining Characteristic Frictional Behavior Values**

| Method | $R_f$ | | $K_{fi}$ | | $K_{fp}$ | |
|---|---|---|---|---|---|---|
| | Average | COV | Average | COV | Average | COV |
| Fisher et al (1978) | 0.76 | 22% | N/A | N/A | N/A | N/A |
| AISC Service Loads (1993) | 1.31 | 23% | N/A | N/A | N/A | N/A |
| AISC Factored Loads (1993) | 0.95 | 23% | N/A | N/A | N/A | N/A |
| Parametric | 1.00 | 20% | 1.00 | 40% | 1.00 | 45% |
| Rational | 1.09 | 22% | 1.02 | 42% | 1.00 | 29% |

With regard to slip load, $R_f$, the method suggested for factored loads given in the AISC Specification (*Load and*, 1993), the parametric, and the rational methods show generally sufficient accuracy. Considering the coefficient of variation, all the methods had values within the 24% value given previously by Fisher et al (1978). With regard to pre and post slipping stiffness, it appears that the parametric and rational methods are equally accurate and for the pre slipping stiffness are equally precise. However, for the post slipping stiffness the rational method appears to provide better precision than the suggested parametric method. Note, in reality the rational method for post slipping stiffness is parametric in nature but is based on a more physical understanding of the frictional component behavior.

Based on the above analysis the rational method for calculating the frictional component characteristic values is recommended.

## 5. Initial Stiffness

The initial stiffness of the load-deformation behavior is one of the two most important quantities needed to provide reliable predictions of this behavior. Unfortunately, it is also the hardest quantity to predict and measure. In the following sections existing models for predicting the initial stiffness of the load-deformation response are reviewed. In addition, a parametric equation based on the test data collected

in this report is developed. Finally, an evaluation of the various methods against the test data is presented.

## 5.1 Data For Evaluation of Models

The initial stiffness values determined from the experimental studies presented in Section 2 were used for the development and / or evaluation of models that predict the initial stiffness. As discussed previously, linear regression of the test data was used to determine the initial stiffness values. The initial stiffness values are presented in Appendix B through Appendix E. Note that the data reported by Caccavale (1975) is not included in this analysis because of the problems with test measurements previously described.

## 5.2 Existing Initial Stiffness Models

Four analytical models for determining the initial stiffness of bolted or riveted connections were found in the literature. The first of these was given in EC3 Annex J (1994). This was developed for the purpose of determining the initial stiffness of the moment-rotation behavior of bolted joints where the bolts are in shear and not fully tightened. By applying the basic methodology (the component method) behind the model the initial stiffness for a single bolt lap plate connection is given by a series combination of plate bearing and bolt stiffness values.

$$K_i = \frac{1}{\frac{1}{K_{pbr1}} + \frac{1}{K_b} + \frac{1}{K_{pbr2}}} \qquad \text{(Eq 14)}$$

Where:

$$K_{pbr} = 24\, k_b\, k_t\, d_b\, F_u \quad \text{(Plate Bearing Stiffness)} \qquad \text{(Eq 15)}$$

$$K_b = \frac{16\, F_{ub}\, d_b^{\,2}}{d_{m16}} \quad \text{(Bolt Stiffness)} \qquad \text{(Eq 16)}$$

And:

$k_b$ = Minimum $(L_e / (4d_b) + .5$ or $S / (4d_b) + .375) \leq 1.25$

$k_t = 1.5\, t_p / d_{m16} \leq 2.5$

$d_{m16}$ = Nominal diameter of a M16 bolt (16mm)

The 1 and 2 subscripts on the plate bearing stiffness values, $K_{pbr}$, indicate plate 1 or plate 2 of the lap plate connection.

The second model is given by Richard et al (1980). The model was developed for predicting the initial stiffness of single bolt lap connections with fully tensioned bolts and was based on unpublished Chance Vought tests.

$$K_i = 2E \frac{t_1 t_2}{t_1 + t_2} \qquad \text{(Eq 17)}$$

Tate & Rosenfeld (1946) developed a method for analyzing the load distribution between the bolts in a long bolted connection. In doing so the authors developed an expression for estimating the stiffness of bolts. The initial stiffness is based on a series combination of bolt and plate stiffness values and is given by

$$K_i = 1 / ( C_{bs} + C_{bb} + C_{bbr} + C_{pbr}) \qquad \text{(Eq 18)}$$

Where:

$$C_{bs} = \frac{t + t'}{6GA_b} \qquad \text{(Bolt Shearing Stiffness)} \qquad \text{(Eq 19)}$$

$$C_{bb} = \frac{t'^3 + 4tt'^2 + 4t't^2 + t^3}{384EI_b} \qquad \text{(Bolt Bending Stiffness)} \qquad \text{(Eq 20)}$$

$$C_{bbr} = \frac{(t + t')}{Ett'} \qquad \text{(Bolt Bearing Stiffness)} \qquad \text{(Eq 21)}$$

$$C_{pbr} = \frac{(t + t')}{Ett'} \qquad \text{(Plate Bearing Stiffness)} \qquad \text{(Eq 22)}$$

And:

t' = Combined outside splice plate thickness

t = Inside pull plate thickness

Fisher (1965) reported that Vogt (1947) developed a theoretical model for the initial stiffness of riveted assemblies. Although not explicitly stated in Fisher (1965), it is

assumed that the model was developed for butt splice connections. The initial stiffness is given as

$$\frac{1}{K_i} = \frac{1.125t'^3 + 3.75tt'^2 + 5t't^2 + 2t^3}{240\, I_b\, E} + \frac{t + t'}{11.03\, G\, A_b\, E} + \frac{0.375}{d_b E} + \frac{1.3}{E}\left(\frac{t + t'}{t\, t'}\right) \quad \text{(Eq 23)}$$

The writer was unable to obtain a copy of Vogt's paper. However, comparisons between the expression developed by Vogt (1947) and the expression developed by Tate & Rosenfeld (1946) show striking similarities. Based on this comparison it appears that Vogt (1947) used an approach similar to that used by Tate & Rosenfeld (1946). In addition, the terms on the right side of Equation 23 are assumed to be the bolt bending stiffness, bolt shearing stiffness, bolt bearing stiffness, and plate stiffness reading from left to right.

## 5.3 Parametric Functions

The experimental initial stiffness values were evaluated against the geometric and material parameters. A variety of parameter and parameter combinations were considered. Three of the best functions are given in Table 9. Because of a large amount of scatter in the data with respect to any parameter or parameter combination linear functions were found to provide accuracy similar to higher order functions. Consequently, linear functions were used instead of higher order functions for simplicity.

**Table 9 Parametric Functions For $K_i$**

| Parameter | Data | Parametric Function (Kips and Inches) |
|---|---|---|
| $t_1$ | Gillet | $K_i = 4119\, t_1 + 1875$ |
| | Gillet & Karsu | $K_i = 5299\, t_1 + 1075$ |
| | Sarkar & Wallace | $K_i = 430\, t_1 + 80$ |
| $t_1\, d_b$ | Gillet Data | $K_i = 4541\, t_1 d_b + 1979$ |
| | Gillet & Karsu | $K_i = 5751\, t_1 d_b + 1213$ |
| | Sarkar & Wallace | $K_i = 573\, t_1 d_b + 80$ |
| $f(t_1)f(d_b)$ | Gillet Data | $K_i = (18.6\, t_1 + 20)\,(155.9\, d_b - 1.4)$ |
| | Gillet & Karsu | $K_i = (35.0\, t_1 + 8.8)\,(109.4\, d_b + 46.3)$ |
| | Sarkar & Wallace | $K_i = (29.0\, t_1 + 5.4)\,(843\, d_b - 618)$ |

Recall that the tests reported by Gillet (1978) and Karsu (1995) had fully tensioned bolts while those reported by Sarkar and Wallace (1992) had snug tight bolts. Separate parametric functions for the tests reported by Gillet were found for later comparisons to the expected variation. The accuracy of these functions is evaluated in the following section.

## 5.4 Evaluation of Models for Predicting Initial Stiffness

An evaluation of the existing and parametric methods for predicting the initial stiffness of the load-deformation response was conducted by comparing calculated stiffness values to the measured stiffness values. The component method developed in Section 4 of this report is also included in the evaluation.

Both Gillet (1978) and Sarkar and Wallace (1992) ran duplicate tests. These tests allow some insight into the natural variation associated with the test specimen and testing procedure. For each identical group of tests the average initial stiffness for the group was calculated. The ratio of the test value over the average value was then calculated for each test. The mean and coefficient of variation were then determined for these ratios. The value of the coefficient of variation represents the minimum variation possible for any method of predicting the initial stiffness (i.e. if a method could have predicted the exact average value for each group then the variation associated with that method would be this value). This variation is used as a benchmark for evaluating the variation associated with each method and is referred to as the "expected variation."

To be able to make a fair comparison to expected variation two evaluations were conducted for tests with fully tensioned bolts. One considers only the tests reported by Gillet (1978). This evaluation is used to make comparisons to the expected variation which was based on these tests. The second considers tests reported by both Gillet (1978) and Karsu (1995) for a more general evaluation of the method.

The results of the evaluation are presented in Table 10. The mean value of the test over predicted value as well as the coefficient of variation are presented.

**Table 10 Evaluation of Models For Predicting $K_i$**

| Method | Fully Tensioned | | | | Snug Tight | |
|---|---|---|---|---|---|---|
| | Gillet & Karsu | | Gillet Only | | Sarkar & Wallace | |
| | Mean | COV | Mean | COV | Mean | COV |
| EC3 Annex J | 6.50 | 36% | 7.49 | 31% | 0.54 | 19% |
| Richard | 0.26 | 33% | 0.29 | 27% | 0.02 | 19% |
| Tate & Rosenfeld | 1.78 | 38% | 1.91 | 25% | 0.13 | 19% |
| Vogt | 1.45 | 48% | 1.53 | 30% | 0.09 | 19% |
| Component | 1.19 | 32% | 1.39 | 23% | 0.49 | 19% |
| Parameter $t_1$ | 1.00 | 26% | 1.00 | 23% | 1.00 | 18% |
| Parameter $t_1 d_b$ | 1.00 | 25% | 1.00 | 22% | 1.00 | 18% |
| Parameter $f(t_1)$ $f(d_b)$ | 1.00 | 26% | 1.00 | 21% | 1.00 | 18% |
| Expected Variation | | N/A | | 16% | | 10% |

First, consider the comparison to the tests reported by Gillet (1978). Excluding the parametric methods, the most accurate and precise method appears to be the component method. Of the parametric methods, the most precise is that given as a function of $t_1$ and $d_b$. The variations of 23% and 21% associated with the component and parametric methods respectively compare well with the expected variation of 16%. When considering tests reported by both Gillet (1978) and Karsu (1995) the most accurate and precise is again the component method if the parametric methods are excluded. Evaluation of the parametric methods shows each of them to be equally precise.

Next, consider the tests reported by Sarkar and Wallace (1992). Again, excluding the parametric methods, all the methods appear to result in approximately equal precision; however, the component method and EC3 Annex J (1994) method (which is actually also a component method with different coefficients) gave the best accuracy. All of the parametric methods resulted in equal precision. Note that the variation associated will all the methods is about twice the expected variation. This is probably a result of the small number of tests conducted (16 total).

Because it was assumed that the tests by Sarkar and Wallace (1992) had snug tight bolts it is not clear whether the comparisons to their data are valid. In addition because of

the few number of tests (16) definite conclusions would be premature. Additional testing of lap connections with snug tight bolts should be conducted.

Based on the above evaluation it would be recommended that if analytical models are to be used then using the component method results in equal or improved accuracy and precision compared to the existing methods. The parametric functions provided similar if not better precision than the analytical models. In addition, the accuracy is of course perfect because of the way in which the functions are determined. If parametric functions are to be used then the functions using $t_1 d_b$ as a variable would be recommended for both fully tensioned and snug tight bolts. However, because of the rather severe discrepancy between the analytical and test values it is questionable if the test data truly represents the behavior associated with snug tight bolts. Bearing this in mind some caution should be used when using the parametric function for snug tight bolts.

# 6. Deformation At Failure

To be able to evaluate the ductility of lap plate connections (and eventually of actual beam-girder connections) it is important to know what deformations can be attained without significant loss of load carrying capacity. First, the source of test data and how failure deformations were defined is discussed. Next, a component method and a parametric method for predicting the deformation at failure are developed and discussed. Finally, the developed methods are evaluated against the test data.

## 6.1 Data For Evaluation and Development of Models

The deformation at failure was determined for each set of test data reported by Karsu (1995), Gillet (1978), and Sarkar and Wallace (1992). The data reported by Caccavale (1975) was not included because of the problems with deformation measurements described in Section 2 of this report. The deformation at failure was defined as the test deformation just prior to a significant loss in load carrying capacity resulting from a plate or bolt failure.

When a bolt failure occurs the deformation at failure is easily defined. However, when plate failure occurs the deformation at failure is less easily defined because of the long plastic plateaus. In addition, many of the tests were stopped before any reduction in load carrying capacity was observed. These tests do not provide useful data for evaluating the deformation at failure. Consequently, it is convenient to separate the tests into bolt failures and plate failures. When considering bolt failures, all of the failure deformations were used in the evaluation and development of models. When considering plate failures, only the tests with bearing/tearout or splitting failures were considered. Of these only the tests reported by Karsu (1995) were used. This is because all but two of the tests reported by Sarkar and Wallace (1992) failed by bolt shear and the tests reported by Gillet (1978) were typically stopped at a deformation limit of around 0.3-in. In many of the tests reported by Gillet (1978) it is believed that additional deformations could have been sustained without loss of load.

## 6.2 Existing Models

No existing models were found in the current literature with the possible exception of the deformation limit of 0.34-in. used currently in the AISC Manual (*Load and*, 1993) for the ultimate strength approach to determining eccentrically loaded bolted connection strength. However, it should be recalled that this limit was based on only six identical tests conducted by Crawford and Kulak (1971).

## 6.3 Component Model

Based on the component behaviors developed and discussed in Section 4 of this report it is possible to estimate the deformation at failure of the connection. First, the failure load needs to be determined. This is simply the maximum load that can be carried by plate 1, plate 2, or the bolt in the connection. Next, using the load-deformation behaviors developed for each of the components it is possible to determine the deformation in each component at the failure load. The connection deformation at failure is then the sum of these component deformations.

There is one problem with the above method. Because the load-deformation behaviors are expressed as exponential functions the deformation associated with the component that limits the connection strength cannot be determined from the load-deformation behaviors (it would be infinity using the exponential models). Consequently, it is necessary to explicitly define the deformation at failure for the limiting component. A reasonable value for the bolt deformation at failure was determined in Section 4 as 0.125-in. However, the deformation of the plate at failure has not been discussed.

Based on using the Richard Equation normalized load-deformation behavior developed for the single bolt single plate behavior (Rex and Easterling, 1996) it is possible to determine the plate deformation associated with the maximum plate load. In normalized form this deformation is given as

$$\overline{\Delta}_f = 22.87 \qquad \text{(Eq 24)}$$

It is assumed that this deformation is a reasonable estimate of the plate deformation at failure.

In summary, the failure load for the connection needs determined. The deformation for the component that is expected to fail first is given by 0.125-in. for bolt failure or $\overline{\Delta}_f = 22.87$ for plate failure. The remaining component deformations are determined using the component behaviors developed in Section 4. The connection deformation at failure is then the sum of all the component deformations.

## 6.4 Parametric Model

Based on the same principles applied in the component method just described it is possible to derive a simplified equation for estimating the connection deformation at failure in the situation where one of the plate strengths limits the connection strength.

$$\Delta_f = -0.26 \frac{L_{e1}}{d_b} \ln\left(1 - \frac{0.63\, R_n}{R_{np1}}\right) - 0.26 \frac{L_{e2}}{d_b} \ln\left(1 - \frac{0.63\, R_n}{R_{np2}}\right) - 0.125 \ln\left(1 - \frac{0.63\, R_n}{R_{nb}}\right) \qquad \text{(Eq 25)}$$

Where:

$\Delta_f$ = Failure deformation (in.)

$L_{e1}$ = End distance for plate 1

$L_{e2}$ = End distance for plate 2

$R_{np1}$ = Strength of plate 1

$R_{np2}$ = Strength of plate 2

$R_{nb}$ = Bolt strength

$R_n$ = Connection strength

The three terms in Equation 25 represent the three components (two plates and a bolt). The first two terms are the plate behaviors while the last term is the bolt behavior. The first part of each term is the approximate failure deformation for that component while the second part of each term is an exponential function accounting for the non-linear load-deformation behavior of each component.

For connections that are limited by bolt failure a much simpler expression was determined.

$$\Delta_f = \frac{0.2}{(S.R. - 1)^{0.2}} \leq 0.7 \text{ in.} \qquad \text{(Eq 26)}$$

Where:

SR = Plate Strength / Bolt Strength

This equation was based on observations from the test data which are discussed later in Section 7. The upper limit of 0.7-in. is simply based on the maximum deformation measured for tests failing by bolt shear.

## 6.5 Evaluation of Models

There are just two models to evaluate: the component and the parametric models. Because the parametric model distinguishes between bolt and plate failures two evaluations will be considered.

### 6.5.1 Plate Failures

Failure deformations for tests failing by plate bearing/tearout or splitting and reported by Karsu (1995) were calculated using the component and parametric methods. Test values vs. predicted values are plotted in Figure 12. Points lying on the plotted line

(which is at a one to one slope) represents perfect agreement between test and predicted values. Points to the left of this line indicate test over predicted above one while those to the right represent test over predicted below one.

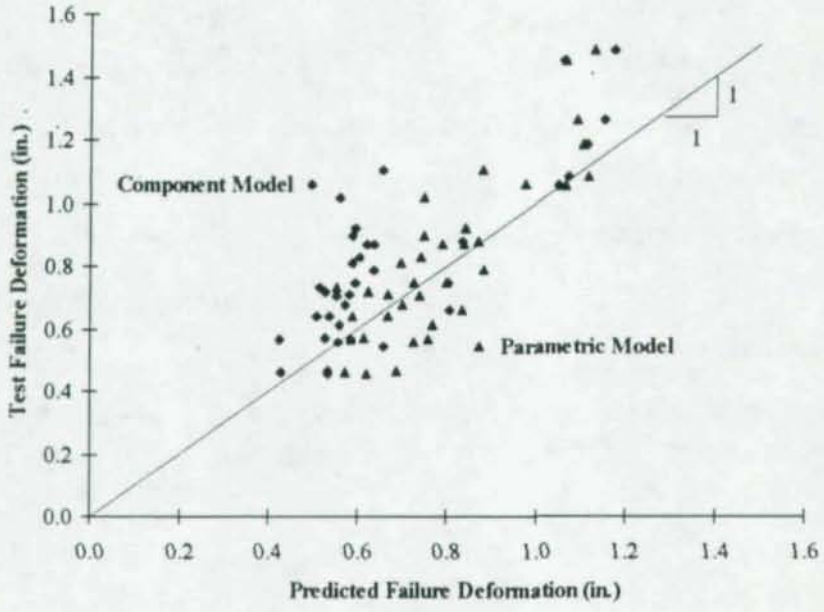


**Figure 12 Test Vs. Predicted Failure Deformations For Plate Failures**

Review of Figure 12 shows that there is medium degree of scatter around the one to one slope line. In general, the component model is more conservative than the parametric model with the majority of the test points lying to the left of the line. The average test over predicted for the component model was 1.23 with a coefficient of variation of 23%. The average test over predicted for the parametric model was 1.01 with a coefficient of variation of 19%.

### 6.5.2 Bolt Failures

Failure deformations for tests failing by bolt shear and reported by Karsu (1995), Gillet (1978), and by Sarkar and Wallace (1992) were calculated using the component and parametric methods. Test and predicted failure deformations are plotted with respect to the ratio of plate strength over bolt strength in Figure 13. There is clearly a large amount of scatter in the test results; however, the general trend of the data appears to agree with

both the component and parametric models. The average test over predicted for the component model was 1.06 with a coefficient of variation of 47%. The average test over predicted for the parametric model was 1.05 with a coefficient of variation of 50%.

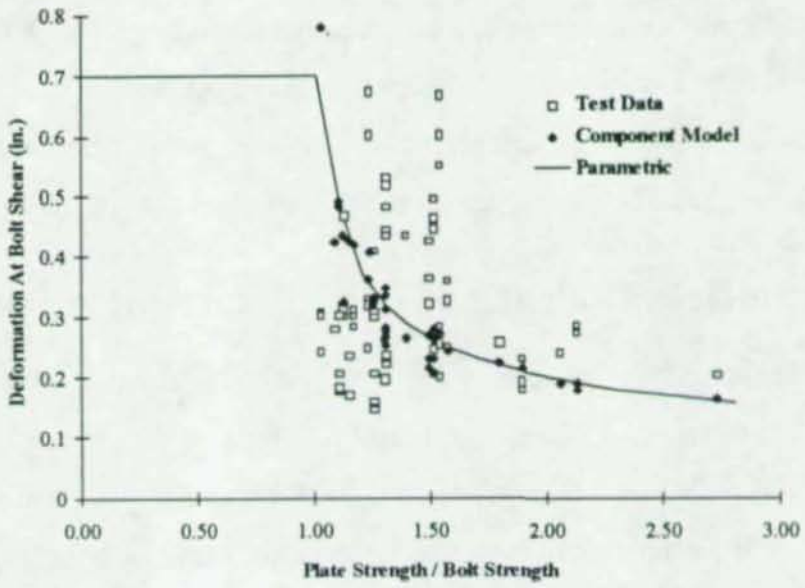


**Figure 13 Test Vs. Predicted Failure Deformations For Bolt Failures**

For bolt failures the variation among identical tests was around 12% based on the tests reported by Gillet (1978) and Sarkar and Wallace (1992). Because the predicted values based on the component and parametric methods had COV values significantly higher than this a new parametric study was conducted based on the more typical approach of throwing all the variables into a power equation and determining what comes out. Based on this approach the following parametric equation was derived using non-linear regression.

$$\Delta_f = 0.0887 \{d_b^{1268} + t_1^{-1.26} + t_2^{0.91}\} \qquad \text{(Eq 27)}$$

This expression had a COV around 30% which is still approximately three times the variation seen for identical tests but represents a significant improvement over the original parametric and the component methods.

## 6.6 Summary

A component model and three parametric models have been developed and discussed in the previous sections. For plate failures Equation 25, which was based on the component model, provides the best accuracy and precision. For bolt failures Equation 27 provides the best accuracy and precision. Although not as accurate or precise as Equations 25 and 27 the component model does provide reasonable estimates and provides a more fundamental approach to the problem.

# 7. Parametric Modeling of Load-Deformation Behavior

The component method of modeling load-deformation behavior, discussed in Section 4 of this report, is ideally applicable to a broad spectrum of parameter values and is not, in general, restricted to the range of parameters for which there are tests. However, this flexibility comes at the price of increased complexity; and, a computer program would be needed to readily implement the component method. Parametric equations are typically easy to use but are limited to the range of parameters tested. However, given the large number of tests collected in this report and the wide range and number of parameters included in the tests the development of parametric equations seems like a reasonable way of providing a second method by which the load-deformation behavior can be approximated.

Methods for determining many of the important characteristics of the load-deformation behavior have already been discussed and / or developed. These characteristics include load capacity, the initial stiffness, and the deformation at failure. In some cases, the methods developed for determining these characteristics were parametric.

The simplest method of representing the non-linear load-deformation behavior of the single bolt lap plate connections is with a continuous non-linear parametric equation. Two such equations have been discussed so far: the Richard Equation and the equation developed by Fisher (1965) which will be referred to from here out as the Fisher Equation. The Richard Equation has four parameters and the Fisher Equation has three parameters

which determine the shape of the curve. The following sections will discuss and develop ways of relating the connection parameters to the equation parameters.

The first step in this development is to examine the influence of each connection parameter as seen from the experimental results. Based on an understanding of this influence then relationships between the connection parameters and the equation parameters can be formulated.

## 7.1 Influence of Parameters Based on Experimental Results

The majority of the test data collected in this report is for lap plate connections with fully tensioned bolts. Of this data only that reported by Karsu (1995) and Gillet (1978) will be considered. The data reported by Caccavale (1975) is not considered because of the problems with deformation measurement described previously in Section 2 of this report. Because of the severe difference in behavior between connections with fully tensioned bolts and those with snug tight bolts the analysis of the parameter effects for the two bolt conditions will be considered separately. Because most of the test data is for connections with fully tensioned bolts observations from this data will be considered first. Observations based on the limited number of tests with snug tight bolts (Sarkar and Wallace, 1992) will then be made and be included with those found for the tests with fully tensioned bolts.

In the following evaluation of parameter effects the load-deformation data has been normalized. The load has been normalized by the expected load capacity based on calculations using the methods given in the AISC Specification (*Load and*, 1993) for plate strength and in the AISC Specification (*Load and*, 1986) for bolt strength. It was decided to normalize the load by the calculated strength rather than the test strength because normalizing by the test strength is dependent on the method chosen to define test strength; and, such a method has not been clearly defined for plate failures.

To give a somewhat consistent evaluation of the effect of each parameter some terminology that will be used needs to be defined. First, the "transition load" is the load at which the load-deformation behavior starts to deviate significantly from the initial behavior

(i.e. the start of the transition from initial to final behavior). Note that the transition load does not necessarily correspond (and in general does not) with the slipping load previously discussed. The plastic slope is the slope of the load-deformation curve in the later stages of the test response. The deformation at failure refers to the test deformation associated with a sudden loss in load carrying capacity associated with either a plate or bolt failure. Finally, stiffer or softer behavior refers to the overall load-deformation curve. If a curve lies below another curve then the first curve is softer than the second and if it lies above then the first curve is stiffer than the second. As a final note; because the data has been normalized it is important to realize that the observations are relative to the normalized behavior. As such, the fact that the transition load for one test appears lower than for another does not mean that the actual load value (before normalizing) is consistent with this observation.

### 7.1.1 Connections With Fully Tensioned Bolts

There were five parameters that were varied in a manner which allowed the effect of the parameter to be determined for connections with fully tensioned bolts. These are $t_1$, $t_2$, $d_b$, $L_e$, and bolt grade. The influence of these parameters on the load-deformation behavior is somewhat dependent on whether the plate or the bolt fails. Consequently, the influence of each parameter is considered for both types of failures.

#### *7.1.1.1 Effect Of $t_1$*

The parameter $t_1$ is the thickness of the thinner of the two plates that make up the lap plate connection. Three tests that had plate failures and which had identical parameters except for $t_1$ are plotted in Figure 14. There are two important observations. First, as $t_1$ increases so does the plastic slope. This is consistent with observations made by Caccavale (1975). For the 1/8-in. thick plate the slope is negative. For the 1/4-in. plate the slope is zero to slightly positive and for the 3/8-in. plate the slope is definitely positive. Second, the transition load decreased with increasing $t_1$.

Three tests that had bolt failures and which had identical parameters except for $t_1$ are plotted in Figure 15. The most consistent observation was that as $t_1$ increased the deformation at failure decreased. A second observation, although less consistent, was that as $t_1$ increased the plastic slope increased.

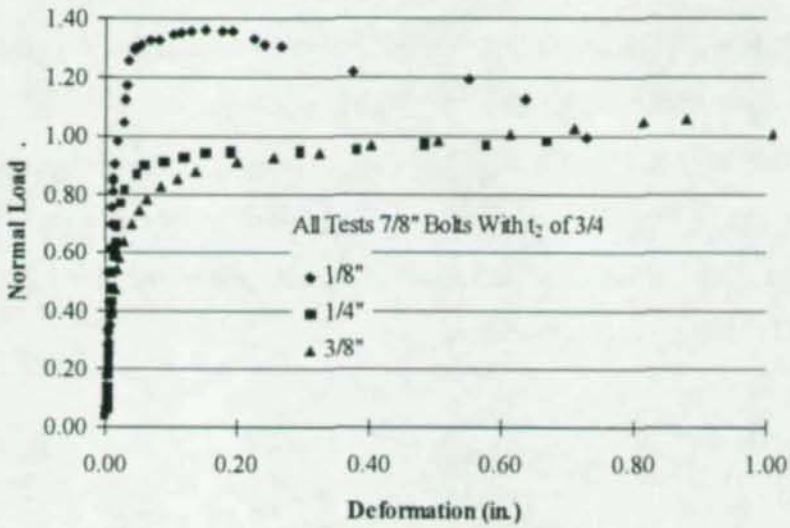


**Figure 14 Effect of $t_1$ On Plate Failure Behavior**

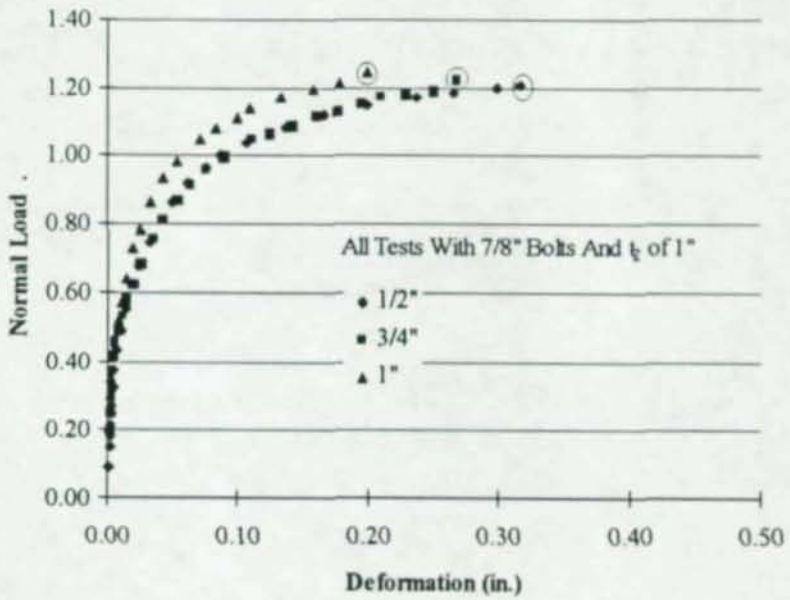


**Figure 15 Effect of $t_1$ On Bolt Failure Behavior**

### *7.1.1.2 Effect Of $t_2$*

The parameter $t_2$ is the thickness of the thicker of the two plates that make up the lap plate connection. Five tests that had plate failures and which had identical parameters except for $t_2$ are plotted in Figure 16. In general, there was little or no effect of $t_2$ unless $t_2$ was equal to $t_1$. If $t_2$ was equal to $t_1$ then there was typically a reduction in the transition load compared to tests with larger $t_2$ values and in general the overall load-deformation response was softer compared to tests with larger $t_2$ values.

Four tests that had bolt failures and which had identical parameters except for $t_2$ are plotted in Figure 17. The only fairly consistent observations was that as $t_2$ increased the deformation at failure decreased. Occasionally the load-deformation response increased in stiffness as $t_2$ was increase.

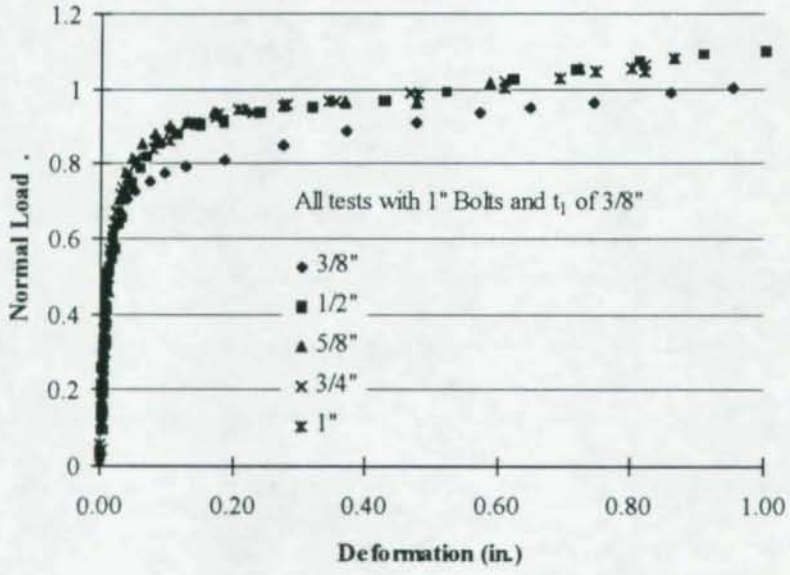


**Figure 16 Effect of $t_2$ On Plate Failure Behavior**

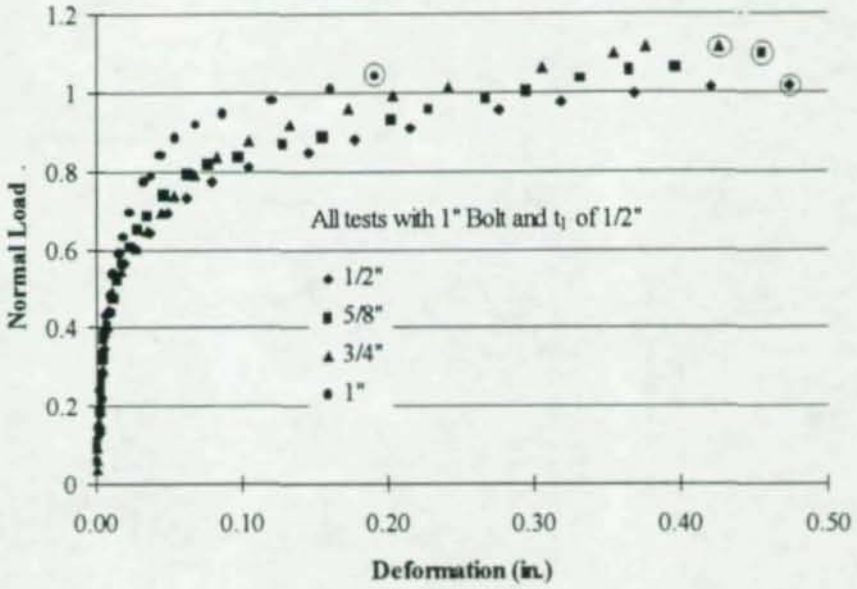


**Figure 17 Effect of $t_2$ On Bolt Failure Behavior**

### *7.1.1.3 Effect Of $L_e$*

The parameter $L_e$ is the distance from the center of the bolt hole to the end of the plate. In particular, this section will be referring to the end distance associated with the thinner plate of the two plates that make up the connection. Two tests that had plate failures and which had identical parameters except for $L_e$ are plotted in Figure 18. There were three fairly consistent observations. First, the transition load decreased with increasing end distance. Second, the plastic slope increased with increasing end distance. Last, the load-deformation behavior softened with increasing end distance.

Three tests that had bolt failures and which had identical parameters except for $L_e$ are plotted in Figure 19. In general, the deformation at failure decreased and the load-deformation response stiffened with increasing end distance.

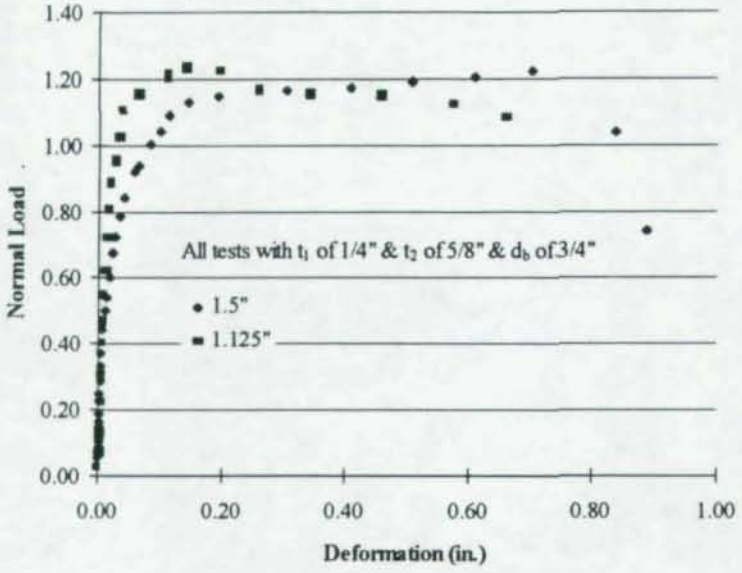


**Figure 18 Effect of $L_e$ On Plate Failure Behavior**

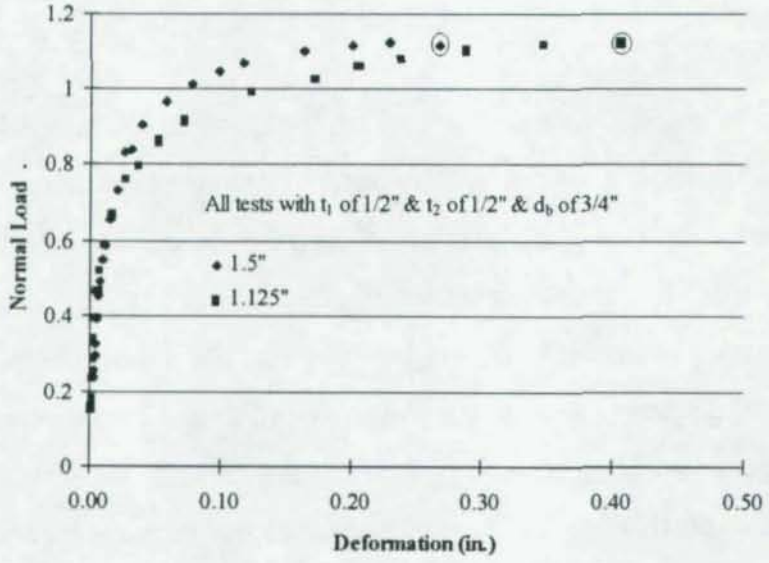


**Figure 19 Effect of $L_e$ On Bolt Failure Behavior**

### *7.1.1.4 Effect Of $d_b$*

The parameter $d_b$ is the diameter of the bolt in the lap plate connection. There were no consistent series of tests that varied the bolt diameter while maintaining all other

parameters constant. Typically, increases in the bolt diameter were accompanied by increases in the end distance. Consequently, it is difficult to ascertain the exact influence of bolt diameter on the load-deformation response. However, based on the effect of end distance, which was just discussed, it is possible to estimate the probable influence of the bolt diameter.

Three tests that had plate failures and which had identical parameters except for $d_b$ and $L_e$ are plotted in Figure 20. The load-deformation response was previously shown to soften with increasing end distance. However, review of Figure 20 shows that this trend has reversed or been negated by increasing bolt diameter. Physically, it is expected that the load-deformation response to would stiffen with increasing bolt diameter because of the increased bearing and shearing areas. However, one would also expect a softening of the load-deformation for a given end distance and increasing bolt diameter because of the reduced distance from the edge of the bolt hole to the end of the plate. Based on review of 14 different combinations of bolt tests there was in general no consistent effect of increasing bolt diameter observed. This would indicate that the effect of increasing bolt diameter and increasing end distance essentially offset each other.

Three tests that had bolt failures and which had identical parameters except for $d_b$ and $L_e$ are plotted in Figure 21. It was previously shown that increasing the end distance resulted in decreased deformation at failure and an increase in the load-deformation stiffness. However, review of Figure 21 shows that these trends have been reversed. In general there was an increase in the deformation at failure, a decreased load-deformation stiffness, and a reduction in the transition load with increasing bolt diameter. There was one other fairly consistent observation. As bolt diameter increased the ratio of the test failure load over the calculated failure load decreased. In many cases a 10% or even 20% decrease was noticed going from 3/4-in. bolts to 1-in. bolts.

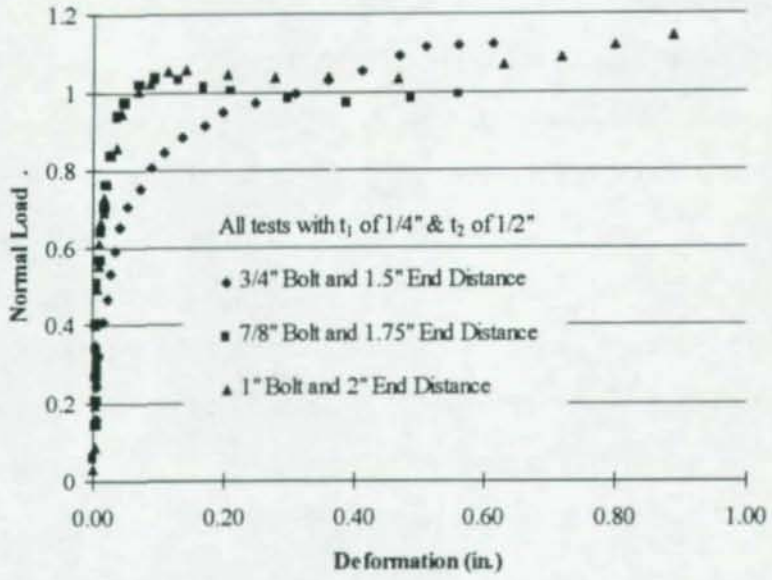


**Figure 20 Effect of $d_b$ and $L_e$ On Plate Failure Behavior**

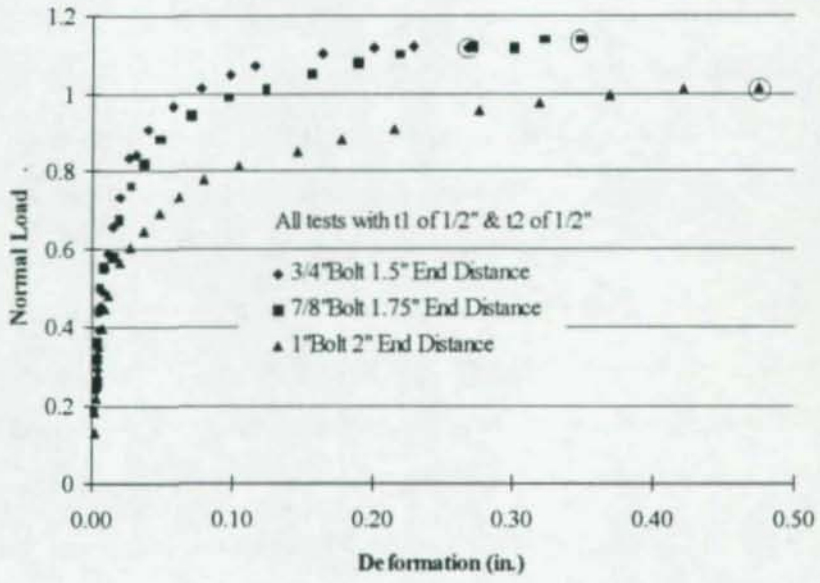


**Figure 21 Effect of $d_b$ and $L_e$ On Bolt Failure Behavior**

### *7.1.1.5 Effect Of Bolt Grade*

The effect of bolt grade (A325 or A490) is based on the test results of Gillet (1978). Two groups of tests that had plate failures and with identical parameters except for bolt grade are plotted in Figure 22. This was the only group of tests of this type. Consequently, observations from this single group are far from conclusive. However, it does appear that as bolt grade increased the transition load as well as the deformation at failure increased. Note that the plate test load for this group of tests only reached 80% of the expected load capacity.

Two groups of tests that had bolt failures and with identical parameters except for bolt grade are plotted in Figure 23. Again, this is the only group of tests of this type. There are two basic observations. First, the transition load appears to decrease with increasing bolt grade. Second, the deformation at failure appears to increase with increasing bolt grade.

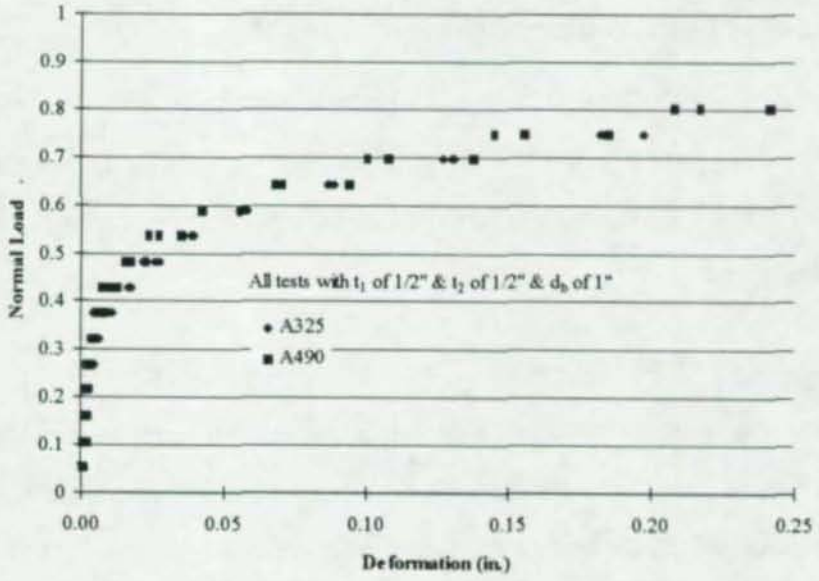


**Figure 22 Effect of Bolt Grade On Plate Failure Behavior**

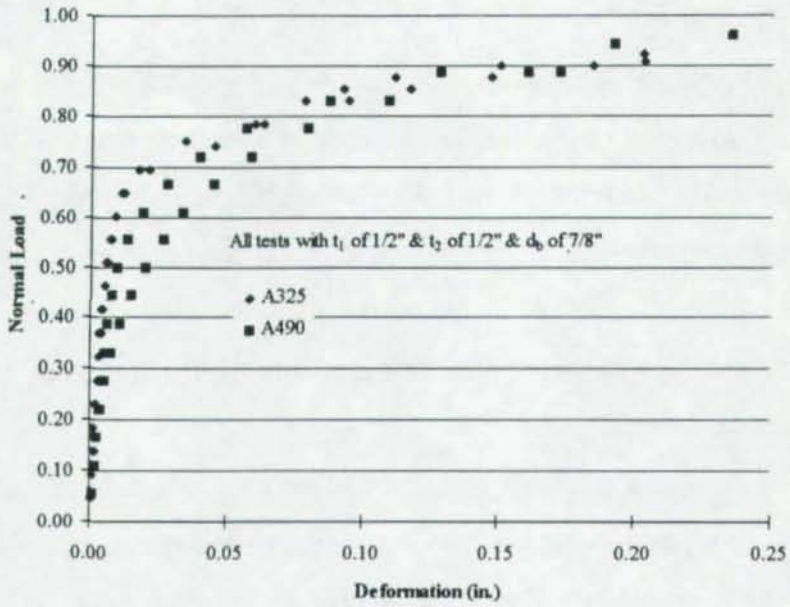


**Figure 23 Effect of Bolt Grade On Bolt Failure Behavior**

## 7.1.2 Connections With Snug Tight Bolts

Sarkar and Wallace (1992) was the only source of test data for tests with snug tight bolts. They investigated the effect of end distance, plate thickness, and bolt grade. Because all but a couple of the tests failed by bolt shear only tests with bolt shear failures will be considered.

### *7.1.2.1 Effect of Plate Thickness*

Three groups of tests with identical parameters except for plate thickness are plotted in Figure 24. There are three tentative observations. As plate thickness decreased the deformation at failure increased, the plastic stiffness decreased, and the overall load-deformation response softened. These observations are particularly evident going from 5/16-in. plate to the 1/4-in. plate. They are less noticeable going from the 3/8-in. plate to the 5/16-in. plate because in this case the plate strength was substantially higher than the bolt strength; whereas, the plate strength for the 1/4-in. plates was very close to the bolt strength.

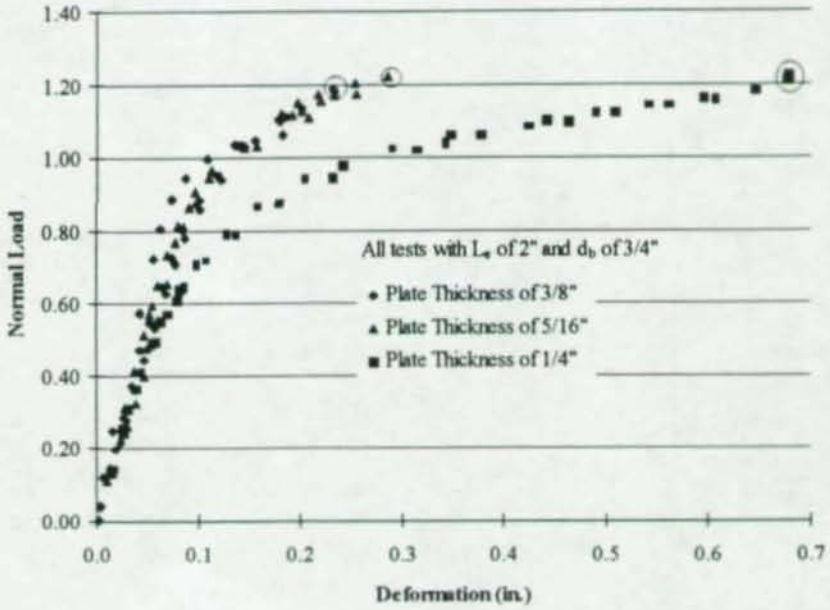


**Figure 24 Effect of Plate Thickness on Bolt Failure Behavior**

### *7.1.2.2 Effect Of End Distance*

Two groups of tests with identical parameters except for end distance are plotted in Figure 25. Based on this plot there appears to be little to no effect of changing end distance. However, it should be noted that for both groups of tests the plate strength was substantially higher than the bolt strength.

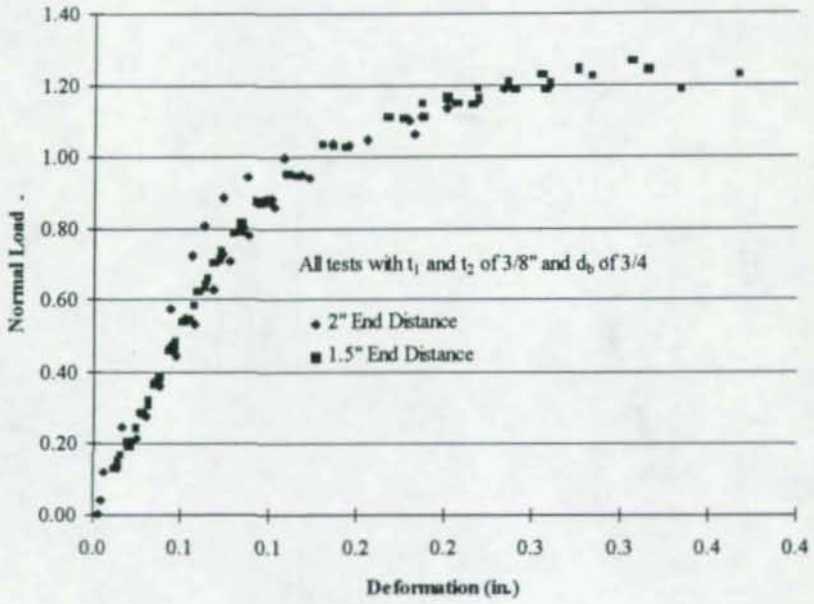


**Figure 25 Effect of End Distance On Bolt Failure Behavior**

### *7.1.2.3 Effect Of Bolt Grade*

Two groups of tests with identical parameters except for bolt grade are plotted in Figure 26. Review of Figure 26 indicates an apparent increase in the deformation at failure, decrease in the plastic stiffness, and decrease in the load-deformation behavior stiffness with increased bolt grade.

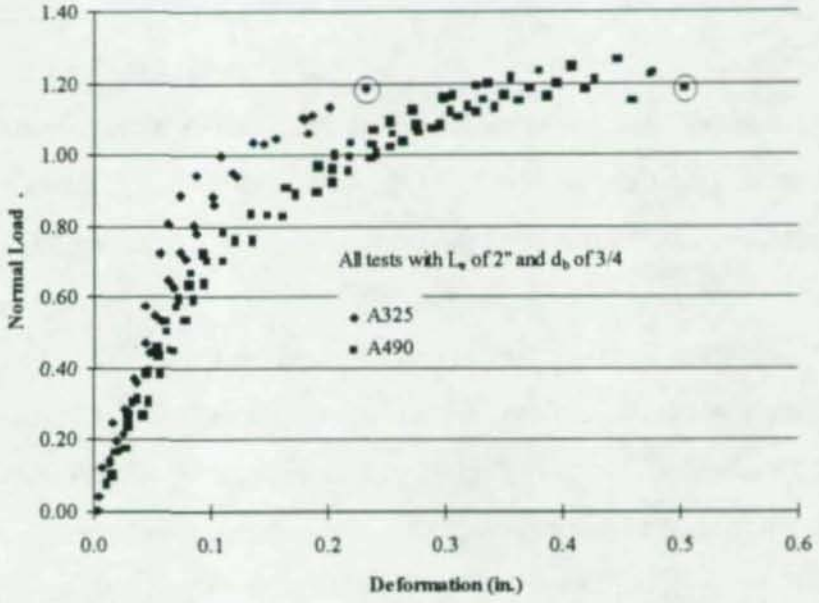


**Figure 26 Effect of Bolt Grade On Bolt Failure Behavior**

## 7.1.3 General Observations of Parameter Effects

The observations based on the individual parameters can be summarized in terms of two parameters: plate strength and bolt strength. First, consider plate strength and the effects seen for tests with plate failures.

### *7.1.3.1 Plate Strength And Effect On Plate Failures*

Plate strength increases with increasing $t_1$, $t_2$ or $L_e$. Consequently, these three parameters are lumped into the single parameter of plate strength. In general, as plate strength increased there was a decrease in the transition load, increase in the plastic stiffness, and the load-deformation behavior decreased in stiffness. Because $t_2$ does not have a direct influence on the actual plate failing load, like $t_1$ and $L_e$ have, this parameter had less influence than the other two. In fact, the only time there was a noticeable influence was when $t_2$ was equal to $t_1$. Explanations for these trends are discussed in the following paragraphs.

The transition load is not the same as the slip load; however, the transition load is related to the slip load. The slip load is the maximum load that can be carried by friction between the plates. The transition load is (in general) the combination of the slip load and the load transferred through bearing of the bolts and plates. Because the majority of the load is transferred by friction until slip occurs the bearing behavior has little influence until slip occurs. Thus the transition load is only slightly affected by the plate strength (which would influence the bearing behavior). The transition load is more dominated by the bolt size and grade which are typically related to the slipping load. Once slip occurs then the load transfer shifts from mainly friction to mainly bearing. Thus the later behavior (after the transition load) is dominated by bearing and consequently by plate strength.

The three tests plotted in Figure 14 represent three different ratios of transition load over plate strength. For these three tests the transition load before normalizing by the plate strength was approximately the same. This is a result of the fact that the bolt size and grade were constant. For the 1/8-in. plate the transition load actually exceeds the plate strength. This results in the negative plastic slope as the load transfer changes from friction to bearing. For the 1/4-in. plate the transition load is approximately the same as the plate strength and consequently the plastic slope is approximately zero. Finally, for the 3/8-in. plate the transition load is less than the plate strength which results in a positive plastic slope. The reason the transition load appears to decrease with increasing plate strength is because it is being normalized by the increased plate strength.

The reason for the reducing stiffness of the load-deformation behavior with increasing plate strength is as follows. As plate 1 (plate of thickness $t_1$) strength increases the deformation associated with a given load should, ideally, decrease (i.e. as plate strength increases there should be an increase in the stiffness of the load-deformation response). However, because the data is normalized by the plate strength this increasing stiffness is eliminated in the normalized plots. The reason for the reducing normalized load-deformation behavior is the fact that the bolt size and the strength of plate 2 (plate of thickness $t_2$) is constant. As plate 1 strength increases then deformations in the bolt and

plate 2 for a given normalized load level increase (i.e. at 50% of the 1/8-in. thick plate 1 strength the deformation in the bolt and plate 2 will be less than the deformation in the bolt and plate 2 associated with the load at 50% of the 1/4-in. plate 1 strength).

As previously mentioned, $t_2$ appeared to only affect the load-deformation behavior when it was the same as $t_1$. This is primarily because $t_2$ does not affect the strength of the connection and the fact that if $t_2$ is larger than $t_1$ then the deformations in plate 2 will be much less than the deformations in plate 1. Ideally, there is an increase in connection stiffness with increasing value of $t_2$; however, the change in connection deformation resulting from variations in $t_2$ when it is larger than $t_1$ are expected to be small compared to the overall connection deformations and are consequently very difficult to see. When $t_2$ is equal to $t_1$ the deformations associated with plate 2 are greatly increased and the influence of $t_2$ is much easier to see in the test data. It is uncertain at this time why the transition load appears to decrease when $t_2$ is equal to $t_1$.

#### *7.1.3.2 Plate Strength And Effect on Bolt Failures*

The general effects of increased plate strength on the tests that had bolt failures included a reduction in the deformation at failure, an increase in the plastic slope, and an increase in the stiffness of the load-deformation behavior. However, when considering the tests reported by Sarkar and Wallace (1992) there was no effect noticed for increased end distance.

First, consider the reduced deformation at failure. Because these tests were limited by bolt strength, increases in the plate strength correspond to reduced plate deformations at the failure load of the bolt and consequently reduced overall connection deformations.

Second, consider the increase in plastic slope. The reason for the increase in the plastic slope is not completely clear; however, there are a couple of theories that may explain it. First, as just discussed, increases in plate strength result in decreased plate deformations at the bolt failure load. When considering the individual plate load-deformation behavior, this means that the tangent stiffness associated with the deformation in the plate at bolt failure load will most likely increase with increasing plate strength.

This effect will be most noticeable when the plate strength is relatively close to the bolt strength because of the rapid reduction in tangent stiffness as the plate gets close to failure. A second possible explanation considers the uneven bearing stress distribution that the bolt imposes on the bolt hole. As the bolt increases in stiffness compared to the plate (i.e. as plate strength decreases compared to the bolt strength) the stress distribution throughout the thickness of the plate should become more uniform. As the stress distribution becomes more uniform it is believed that the plastic slope of the connection response will decrease; and (if the opposite holds true), as plate strength increases there should be an increase in the non-uniformity of the stress distribution through the plate thickness and thus an increase in the plastic stiffness.

Third, based on the same concept used in the argument for the reduced deformation at failure it is easy to explain the increased stiffness of the load-deformation response with increasing plate strength. As plate strength increases the deformation in the plate at a given load (i.e. the failure load of the bolt or some percentage of that load) decreases. This results in decreased deformations at any load level and consequently an overall stiffer response.

Finally, an explanation for lack of any noticeable change in behavior for increased end distance in two groups of tests by Sarkar and Wallace (1992) needs addressed. The reasoning for this is the same as the reasoning for why there was no noticeable effect of $t_2$ when it was larger than $t_1$. The plate strength for the tests reported by Sarkar and Wallace (1992) was simply much larger than the bolt strength. Consequently, the plates were in the early stages of their individual load deformation behaviors when the bolt failed. Because there is little change in deformation for a large change in load during this stage of plate behavior the change in the plate deformations between the two end distances was most likely too small to be noticed.

#### *7.1.3.3 Bolt Strength and Effect on Plate Failures*

Bolt strength is determined by bolt diameter, bolt grade, and location of shearing plane. The shearing plane location was not systematically varied; consequently, only the

bolt diameter and bolt grade are considered. Based on the analysis of increasing bolt diameter and increasing end distance it was observed that the effects of increased end distance were offset by the effects of increasing the bolt diameter. This means that increasing the bolt diameter should tend to increase the transition load, reduce the plastic slope, and stiffen the overall load-deformation response. The increase in transition load was also seen in the evaluation of increasing bolt grade. The arguments for these observations are just the opposite of those given for the effects of increasing plate strength on plate failure behavior.

#### *7.1.3.4 Bolt Strength and Effect of Bolt Failures*

In general, the effects associated with increasing bolt strength on the load-deformation behavior of connections failing by bolt shear were an increase in the deformation at failure, a decrease in the transition load, a decrease in the plastic slope, an overall softening of the load-deformation response. In addition to these somewhat expected effects there was one unexpected effect noticed. This was that the ratio of test failure load over the predicted failure load tended to decrease with increasing bolt diameter.

The arguments for the increased deformation at failure, the reduced plastic slope, and the overall softening of the load-deformation response are the opposite of those given for the effects of increasing plate strength on the bolt failure behavior. It should be noted that the observation of increasing deformation at failure with increasing bolt grade is in contrast to the observations by Wallaert and Fisher (1965). They noticed that the total deformation at failure of single bolt test specimens in double shear was unaffected by bolt grade. They indicated that the increased plate deformations were offset by reduced bolt ductility at failure. However, all of their test specimens had plate strengths severely higher (4 to 5 times higher) than the bolt strength while most of the tests in the current report had plate strengths 1 to 2 times the bolt strength. Consequently, it is apparent that the effect of bolt grade is somewhat dependent on the test parameters; however, in general, it is

believed that the increase in plate deformation will typically be much larger than any reduction in bolt ductility.

The reasons for the decreased transition load and the decreased ratio of test to calculated strength are less clear; however, there are a couple of theories. First, the transition load decreases because the slip load does not increase as fast as the shearing capacity of the bolt. Ideally, these two quantities should increase at the same rate because they are typically considered to be functions of the bolt area and the ultimate strength of the bolt. However, the difficulty in properly tensioning the bolts increases as the bolt diameter increases. Consequently, it is likely that bolt tension after installation was not as high a percentage of the bolt ultimate tensile strength in the large bolts as compared to the smaller bolt diameters. Kulak et al (1987) also indicated that short grip large diameter bolts may be inadequately tensioned using the 1/3 turn-of-nut method and that the method should be calibrated in these situations.

Second, there is currently no good theory for why there would be a reduction in the ratio of test to calculated strength with increasing bolt diameter other than the possible size effects that are inherent with increasing quantity of steel in the large bolt diameters.

## 7.2 Relationships Between Connection and Equation Parameters

In this section relationships between the connection parameters and the Richard Equation and Fisher Equation parameters are developed. Once again, because of the significant difference in behavior between connections with fully tensioned bolts and connections with snug tight bolts these two bolt conditions need considered separately.

### 7.2.1 Connections With Fully Tensioned Bolts

The typical load-deformation behavior for single bolt lap plate connections with fully tensioned bolts is characterized by two distinct stages of behavior: before the transition load and after the transition load. Before the transition load has been reached the load-deformation behavior is almost linear at a slope consistent with the initial stiffness and is highly dominated by frictional resistance. Once the transition load has been

exceeded then behavior depends more on the connection parameters that affect bearing behavior such as the plate and bolt material and geometry.

Based on the general observation above as well as the specific observations discussed previously it is concluded that there are primarily two relationships that determine the basic shape of the load-deformation behavior as it goes from the initial (initial stiffness) to final (plate or bolt failure) behavior.

1. Transition load capacity compared to bearing load capacity
2. Plate load capacity compared to bolt load capacity

The bolt and plate load capacity have already been considered however the transition load still needs development. After discussion of the transition load, methods for relating the connection parameters to the connection parameters will be developed.

#### *7.2.1.1 Transition Load*

The transition load can normally be determined from test data because of a sudden jump in the data; however, each of the test programs that used fully tightened bolts ensured that the bolts were already in bearing before the tests began for the very purpose of eliminating this jump in the measurements. Consequently, determining the transition load from the test data becomes somewhat subjective. For purposes of this study the transition load was defined as the load at 0.01-in. of connection deformation. Visual observations of this load compared to the load-deformation data showed that this definition of transition load corresponded with a load that was typically just above the point where the load-deformation data started to noticeably deviate from the slope of the initial stiffness.

The transition loads were evaluated against the geometric and material parameters. Based on this evaluation approximately twelve different combinations of parameters were considered for parametric relationships. Non-linear regression was used to determine parameter coefficients for each relationship. The precision of each parametric expression was then evaluated to determine the best expression. The final parametric relationship chosen is given by

$$R_{transition} = 0.14\ F_{ub}\ d_b^2 + 12\ t_1/d_b \qquad \text{(Eq 28)}$$

This expression had a coefficient of variation of 16% and an $L_2$ Norm of 34.3 kips when comparing test over predicted values.

The relationship between transition load and bolt strength is expected considering the transition load should be highly dominated by the slipping load which is typically related to the bolt strength; however, the transition load actually had a stronger correlation to the second term, $t_1/d_b$.

There are a couple of possible theories for why there is such a strong correlation to $t_1/d_b$. The first of these was mentioned earlier and is that when the bolt grip becomes short compared to the bolt diameter it is difficult to obtain proper tension loads in the bolt (Kulak et al 1987). If this theory was true then the transition load would tend to increase with increasing grip; however, comparisons between tests with the same $t_1$ but different $t_2$ values showed that the total grip had little influence on the transition load. A second theory was found in Frank and Yura (1981). The authors indicated that previous investigators had noticed a difference in the slipping load for test specimens in compression compared to those in tension. One source of this difference was believed to be the lateral contraction of the plates vs. the lateral expansion of the plates resulting from Poisson's effect for the tests in tension vs. those in compression respectively. The lateral contraction of the plate would tend to reduce the bolt elongation and consequently the bolt tension load which results in a reduced slipping load. It is possible that as the plates become thinner the effect of any lateral contraction may become more significant.

#### *7.2.1.2 Parameter Relationships*

In the following paragraphs relationships between the connection parameters and the equation parameters of the Richard Equation and the Fisher Equation are discussed and presented. A total of three different sets of relationships are presented. The first two of these are relationships are for determining Richard Equation parameters. A detailed and a slightly simplified relationship are included. The last relationship is for determining Fisher Equation parameters.

7.2.1.2.1 Parameter Relationships For The Richard Equation

Based on the observations of how the basic shape was affected by plate strength, bolt strength, transition load, and $t_2$ two relationships between connection parameters and the Richard Equation parameters were developed. The constants in these two sets of relationships were determined by non-linear regression.

The first relationship is the more detailed of the two relationships and will be shown later to provide slightly better accuracy. The first relationship makes use of all four of the coefficients in the Richard Equation. For clarity the method is given below as a series of rules. All units are in kips and inches.

$$R_n = R_{np} \le R_{nb} \quad \text{(Eq 29)}$$

$$K = K_i = 5751\, t_1 d_b + 1213 \quad \text{(Eq 30)}$$

$$K_p = 9 \{ R_{np} / R_{nb} \}^{2.9} \quad \text{(Eq 31)}$$

$$R_{transition} = 0.14\, F_{ub}\, d_b^2 + 12 t_1 / d_b \le R_n \quad \text{(Eq 32)}$$

$$R_o = R_n - 0.25\, K_p \ge R_{transition} \quad \text{(Eq 33)}$$

$$R_1 = R_{transition} (t_2/t_1)^{0.1} \le 0.98\, R_o \quad \text{(Eq 34)}$$

$$n = \frac{-\ln(2)}{\ln\left(\frac{R_1}{R_o} - \frac{K_p}{K - K_p}\right)} \le 3 \quad \text{(Eq 35)}$$

In the above equations, upper and lower bounds have been placed on some of the load constants to avoid having predicted loads above the nominal strength of the connection (i.e. the increased strength over the plate strength resulting from friction, which was seen for thin plate combinations, is ignored). In addition, only positive plastic slopes are assumed.

The second relationship is less detailed than the first and assumes that $K_p$ is zero. This results in $R_o$ being equal to $R_n$ and all of the difference in load-deformation shape being accounted for by the curvature parameter n. K and $R_{transition}$ are the same as above except $R_{transition}$ is limited to 0.9 $R_n$. The curvature parameter only considers the ratio of $R_{transition}$ to $R_o$.

$$n = \frac{0.5}{\left(0.95 - \frac{R_{transition}}{R_o}\right)^{0.8}} \qquad \text{(Eq 36)}$$

7.2.1.2.2 Parameter Relationships For The Fisher Equation

Unlike the Richard Equation where all the equation parameters are easily related to the curve characteristics the Fisher Equation only has one such parameter: $R_{ult}$. Fisher (1965) showed that $R_{ult}$ could be taken as the maximum load capacity of the connection. Regression analysis of the data in this report showed this relationship to be true. Consequently, only relationships for predicting the coefficients $\mu$ and $\lambda$ are needed. The first step in developing these relationships was to normalize the test data.

The test data was normalized by dividing the test loads by the predicted load capacity and the test deformations by the predicted failure deformation. Methods for predicting the load capacity and failure deformation were developed earlier in this report. The normalized data was then analyzed using non-linear regression to determine the best values of the coefficients $\mu$ and $\lambda$ for each group of tests with identical connection parameters. The resulting coefficient values were then evaluated with respect to the connection parameters to identify relationships.

Because two fairly complex relationships for determining the coefficients of the Richard Equation were already developed, a simple method of relating the connection parameters to the coefficients of the Fisher Equation was sought. It was determined that the strength ratio, SR, (plate strength over bolt strength) had the most significant influence on the these coefficients. Subsequent regression analysis resulted in the following relationships.

$$\mu = 10.9\ SR^{-2.33} \qquad \text{(Eq 37)}$$

$$\lambda = 0.468\ SR^{-0.456} \qquad \text{(Eq 38)}$$

Note that these relationships are for normalized load and deformation; consequently the connection strength and failure deformation have to be determined prior to using the Fisher Equation with these coefficients.

### 7.2.2 Connections With Snug Tight Bolts

The primary difference in the behavior of connections with fully tightened bolts compared to those with snug tight bolts is that connections with snug tight bolts have little to no frictional resistance. Consequently, the connection parameters that would be expected to affect bearing behavior will influence the shape of the load-deformation behavior from beginning to end.

There were only 16 connections reported with bolts in the snug tight condition. Out of these 16 tests there were only five different combinations of connection parameters, all but two failed in bolt shear, and all the connections had both plates made of the same material and thickness. Because of these limitations it was decided to supplement the test data with some analytical data.

The component modeling method presented in Section 4 of this report was used to generate analytical data to help supplement the limited number of experimental tests. Twenty-four different bolt and plate combinations were analyzed to determine load-deformation data for each combination.

Because of the limited number of observations of parameter effects on the shape of the load-deformation behavior (resulting from the few number of experimental tests) it was decided to seek only one set of relationships between connection and test parameters. It was decided to use the Fisher Equation. The procedure used to determine relationships between the connection and equation parameters was the same as that used for the connections with fully tightened bolts except the results of the analytical study were also included. Once again, it was determined that the strength ratio, SR, (plate strength over bolt strength) had the most significant influence on the these coefficients. However, unlike the relations seen for fully tensioned bolts, the relations for the snug tight bolts were piecewise continuous with discontinuities when the SR was close to a value of one. Subsequent regression analysis resulted in the following relationships.

$$\text{For } SR \le 0.8 \qquad \mu = 4.5 \qquad \text{(Eq 39)}$$

$$\text{For } 0.8 < SR \le 1.0 \qquad \mu = 8.5 - 5\,SR$$

$$\text{For } 1.0 < SR \qquad \mu = 3.5 + \ln(SR)$$

$$\text{For } SR \leq 1.0 \qquad \lambda = 0.5 + 0.15\,SR \qquad \text{(Eq 40)}$$

$$\text{For } SR > 1.0 \qquad \lambda = 0.14 + [1 - e^{-0.7\,SR}]^{0.2}$$

Note that these relationships are for normalized load and deformation; consequently the connection strength and failure deformation have to be determined prior to using the Fisher Equation with these coefficients.

# 8. Evaluation of Methods to Approximate Load-Deformation Behavior

At this point in the report there are a number of methods that can be used to approximate the load-deformation behavior of single bolt lap plate connections with both fully tensioned and snug tight bolts. Two existing methods were discussed in Section 1. These were found in Karsu (1995) and the AISC Manual Vol. II (*Load and*, 1993). Next there is the component method which was discussed in Section 4. And finally, there are a number of parametric methods that were developed in Sections 5, 6, and 7. All of these methods fit into one of three broad categories:

- Component Method
- Methods for determining the coefficients for the Richard Equation.
- Methods for determining the coefficients for the Fisher Equation.

Each of these methods is evaluated against the experimental load-deformation data to determine the relative accuracy and precision of the methods. However, before this evaluation can be conducted, benchmarks against which accuracy and precision can be compared are needed.

## 8.1 Benchmarks For Evaluation of Methods

In the following section each of the methods for approximating the load-deformation behavior of single bolt lap plate connections will be evaluated against the test data. In doing so values for the coefficient of variation and the $L_2$ Norm will be

determined for each method. Without having something to compare these numbers to it is difficult to determine if the method is good or bad. Two different benchmark evaluations were conducted to determine variations and norms by which the results of the subsequent evaluations could be compared.

It is assumed that the best any method could come to approximating the load-deformation behavior is if that method were able to predict the coefficients for either the Richard Equation or Fisher Equation that would minimize the $L_2$ Norm for each group of identical tests. The first benchmark is based on this assumption. Non-linear regression was used to determine the best (minimize the $L_2$ Norm) equation coefficients for the Richard and Fisher Equations for each group of identical tests. Next, using these coefficients, the load at each test deformation was calculated. These loads were then compared to the test loads to determine values of the coefficient of variation (of test over predict) and the $L_2$ Norm. The first benchmark will be referred to as Benchmark Level 1.

The second benchmark considers the current inability to predict connection strength. The assumption is that if the basic shape of the load-deformation curve is correct but the calculated connection strength is wrong then the variation and norm values may be large despite the fact that the basic shape is being predicted very well. To determine what part of the variation and norm values is attributable to poor predictions of the connection strength a second set of benchmark values were determined. These values were determined comparing revised test load estimates to the test loads. The revised estimates were the load estimates used for the first benchmark but were scaled by the ratio of predicted over test strength. The second benchmark will be referred to as Benchmark Level 2.

These two sets of benchmark values were determined for connection tests with both snug tight and fully tensioned bolts. However, because no method was developed for determining the Richard Equation coefficients for connections with snug tight bolts no benchmark values using the Richard Equation and the test data for snug tight bolts were determined.

## 8.2 Evaluation of Methods

Each of the methods discussed so far was evaluated against the load-deformation behavior of the experimental connections. Only test data with deformations less than or equal to 0.25-in. was included. In addition, the tests reported by Caccavale (1975), five of the tests reported by Karsu (1995), and three of the tests reported by Sarkar and Wallace (1992) were excluded from the evaluation. The reasons for these tests being excluded was discussed in Section 2. Also note that the analytical test data used to increase the range of parameters for tests with snug tight bolts has not been included.

For each experimental load-deformation point the load was calculated using each of the different methods. The ratio of test load over predicted load was then determined. The average and coefficient of variation for this ratio are given in Table 11. Next the $L_2$ Norm based on the difference of the test and predicted loads was determined. This value is also presented in Table 11.

**Table 11 Evaluation Of Load-Deformation Models**

| Method | Fully Tensioned Bolts | | | Snug Tight Bolts | | |
|---|---|---|---|---|---|---|
| | Average | COV | $L_2$ Norm (kips) | Average | COV | $L_2$ Norm (kips) |
| Component Method | 1.02 | 20% | 140 | 0.92 | 25% | 43 |
| Richard Equation Methods | | | | | | |
| Parametric Detailed | 1.09 | 21% | 167 | - | - | - |
| Parametric Simplified | 1.13 | 20% | 171 | - | - | - |
| Karsu Unified Curves | 1.20 | 30% | 231 | - | - | - |
| Benchmark Level 1 | 0.99 | 11% | 52 | - | - | - |
| Benchmark Level 2 | 1.04 | 16% | 160 | - | - | - |
| Fisher Equation Methods | | | | | | |
| Parametric Normalized | 0.99 | 26% | 207 | 1.19 | 20% | 57 |
| AISC Vol II | 1.67 | 41% | 339 | 0.88 | 31% | 63 |
| Benchmark Level 1 | 0.96 | 23% | 85 | 1.00 | 14% | 13 |
| Benchmark Level 2 | 0.99 | 31% | 189 | 1.13 | 17% | 40 |

With regard to connections with fully tensioned bolts based on a review of the benchmark variations and norms it is clear that the Richard Equation is able to better approximate the load-deformation behavior than the Fisher Equation. This is somewhat expected because of the Richard Equation having four coefficients while the Fisher

equation only has three. It is also clear by comparing the Level 1 and Level 2 benchmarks that a majority of the variation associated with some methods is attributable to poor estimates of the load capacity. Comparison of the component method to the level 2 benchmark for the Richard Equation indicates a slight increase in variation but a reduced $L_2$ Norm. Both the parametric methods for the Richard Equation coefficients have slightly higher variation than the Level 2 benchmark but approximately the same $L_2$ norm as the benchmark. The parametric method for the Fisher Equation compares well with Level 2 benchmark for the Fisher Equation. Neither of the current methods (Karsu Unified Curves and AISC Vol. II) compare very well to the benchmarks.

With regard to connections with snug tight bolts the component method has a comparable $L_2$ norm to the Level 2 benchmark but has 8% increase in variation. The parametric method has a better variation and a better average compared to the Level 2 benchmark but a $L_2$ norm which does not compare as well. The AISC Vol. II method does not variation or an L2 norm comparing well to the benchmark.

Overall the component method does the best job of predicting the load-deformation behavior. The parametric relationships for the Richard equation provide good estimates with less complexity than the component method. Finally, the parametric relationship for the Fisher equation provides reasonable estimates with very simple relationships and is applicable to both fully tensioned and snug tight bolted connections.

# 9. Summary, Conclusions, and Recommendations

## 9.1 Summary and Conclusions

The load-deformation behavior of high strength bolts in single shear is needed for the development of methods to approximate beam-girder moment-rotation behavior. It has been assumed that bolt load-deformation behavior in the beam-girder connection can be approximated by the load-deformation behavior of single bolt lap plate connections. Consequently, methods for approximating the lap plate connection behavior are needed. There are currently two such methods available neither of which properly account for the

effect many connection parameters have on the load-deformation behavior. As a result, new methods for approximating the lap plate connection behavior were sought.

The first step in the development of new methods was to collect all available experimental data on single bolt lap plate connections. The data from four experimental programs was collected, compiled, and analyzed. Next, the strength of the connection was evaluated. Based on an evaluation of strength predictions vs. experimental strength it was concluded that:

- The method given in the current AISC Specification (*Load and*, 1993) for determining the plate bearing / tearout strength provided good predictions of connection strength when compared to tests that failed by bearing / tearout or by plate splitting.
- The method given in the AISC Specification (*Load and*, 1986) for determining the bolt shear strength predicted bolt strengths that were on average 9% conservative compared to the strengths of tests that failed by bolt shear. Possible reasons for this were discussed.

Next, the component method was developed. Here it was assumed that the lap plate connection behavior was composed of three component behaviors: plate, bolt, and friction. By using a previously developed method for approximating plate behavior (Rex and Easterling, 1996) and the experimental data, methods for approximating the load-deformation behavior of the bolt component and the friction component were developed. Based on this development it was seen that the frictional resistance typically degraded from a maximum resistance at the onset of slipping down to almost zero resistance.

The initial stiffness of the lap plate connection load-deformation behavior was then considered. Existing methods for predicting the initial stiffness were discussed and parametric methods were developed. These methods along with the component method were then evaluated against the test data. With regard to connections with fully tensioned bolts, existing methods were shown to provide poor predictions, the component method provided much better predictions and the parametric methods provided the best predictions of all. With regard to connections with snug tight bolts similar results were

observed with the exception that the method derived from EC 3 Annex J (1994) provided predictions on par with those of the component method. However, a high degree of caution is recommended when using the parametric methods developed for the connections with snug tight bolts because of the lack of test data.

The deformation at failure was also studied. There was no existing literature that dealt with this topic directly. The component method was shown to give reasonably accurate estimates for failure deformations when plate failure occurred. A simplified method based on the component method was developed and provided even better correlation to the test data. The component method was shown to give accurate but not very precise estimates of the failure deformation when bolt failure occurred. A strictly parametric expression was developed and provided better precision but still had a coefficient of variation of approximately three times the expected variation.

As part of the development of parametric methods for approximating the load-deformation behavior a complete analysis of parameter effects was conducted. From this analysis it was concluded that the primary factors influencing the load-deformation behavior were the plate strength, bolt strength, bolt tension, and transition load (related to friction). It was seen that the initial behavior of connections with fully tensioned bolts was dominated by frictional behavior and that the parameters affecting bearing resistance had little influence. However, in the later stages of the load deformation behavior for connections with fully tightened bolts and for the entire load-deformation behavior of connections with snug tight bolts the parameters affecting bearing resistance dominated the behavior. Based on the observed influence of the connection parameters relationships between the parameters and equation coefficients for the Richard Equation and the Fisher Equation were developed.

Finally, both existing methods, the component method, and the parametric methods were evaluated against the test data. In general, it was observed that the component method provided the best results; however, it was also the most complicated. Based on a comparison of the Richard Equation and the Fisher Equation it was shown that

the Richard Equation was better able to represent the load-deformation behavior. Comparisons of parametric methods showed that as the complexity of the method decreased so did the agreement between predicted and test behavior. However, generally good agreement was still obtained using the simplest of these methods. The existing load-deformation relationship currently used in the AISC Manual Vol. II (*Load and*, 1993) did not provide very good agreement with the test data.

## 9.2 Recommendations

The frictional component behavior was based on the assumption that the bearing behavior of the bolts and plates could be satisfactorily approximated with the component method. A much better understanding of this behavior could be obtained based on the load-displacement histories of actual friction tests such as those conducted by Frank and Yura (1981). The data from the Frank and Yura (1981) tests should be collected and compiled. In addition, new tests considering thinner plates and possibly specially designed lap plate connection tests that avoid initial bearing should be conducted. Also, literature from the area of tribology should also be consulted. A brief literature review in this area produced at least one paper (Simkins, 1967) that may provide some insight into the pre and post-slip frictional behaviors.

There were only 16 lap plate connection tests with bolts in the snug tight condition. Additional tests should be conducted. These tests would provide a better basis for evaluation of method to predict the load-deformation behavior. In addition, they could be used to gain a better understanding of the bolt component load-deformation behavior. Finally, when combined with the database of connection tests that had fully tightened bolts a much better understanding of the frictional component behavior could be obtained.

It has been shown that the shape of the load-deformation behavior and the deformation at failure are not constant values; however, this is the assumption made when using the current ultimate strength method for analysis of eccentrically loaded bolt groups. An analytical study of the effect of varying shape and failure deformation on the load

capacity of eccentric bolt groups should be conducted to determine if using constant shape and failure deformation values provides sufficient accuracy and safe results.

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# Appendix A

## Material Properties For Tests Reported by Karsu (1995)

## Table A-1 Steel Properties

| Coupon | Width (in.) | Thickness (in.) | Elongation | Fy (ksi) | Average | Fu (ksi) | Average |
|---|---|---|---|---|---|---|---|
| 1-1 | 1.510 | 0.251 | 31% | 45.0 | 45.5 | 65.0 | 65.0 |
| 1-2 | 1.500 | 0.251 | 31% | 46.0 | | 65.0 | |
| 2-1 | 1.510 | 0.250 | 30% | 46.0 | 45.8 | 65.5 | 65.5 |
| 2-2 | 1.510 | 0.250 | 31% | 45.5 | | 65.5 | |
| 3-1 | 1.500 | 0.625 | 29% | 44.0 | 44.5 | 67.0 | 67.5 |
| 3-2 | 1.500 | 0.625 | 30% | 45.0 | | 68.0 | |
| 5-1 | 1.500 | 0.995 | 30% | 43.9 | 43.5 | 70.0 | 70.0 |
| 5-2 | 1.500 | 0.996 | 29% | 43.0 | | 70.0 | |
| 6-1 | 1.490 | 0.998 | 30% | 43.0 | 43.5 | 67.0 | 67.0 |
| 6-2 | 1.490 | 0.999 | 31% | 44.0 | | 67.0 | |
| 7-1 | 1.500 | 0.750 | 29% | 45.0 | 45.0 | 67.0 | 67.0 |
| 7-2 | 1.500 | 0.750 | 30% | 45.0 | | 67.0 | |
| 8-1 | 1.500 | 0.750 | 31% | 45.0 | 45.0 | 68.0 | 68.0 |
| 8-2 | 1.500 | 0.750 | 30% | 45.0 | | 68.0 | |
| 9-1 | 1.500 | 0.750 | 29% | 45.5 | 45.8 | 69.0 | 69.0 |
| 9-2 | 1.500 | 0.750 | 30% | 46.0 | | 69.0 | |
| 10-1 | 1.500 | 0.375 | 32% | 51.0 | 51.0 | 74.0 | 74.0 |
| 10-2 | 1.500 | 0.375 | 31% | 51.0 | | 74.0 | |
| 11-1 | 1.500 | 0.500 | 29% | 52.5 | 53.3 | 74.5 | 74.8 |
| 11-2 | 1.500 | 0.500 | 30% | 54.0 | | 75.0 | |
| 12-1 | 1.500 | 0.500 | 31% | 51.0 | 51.5 | 74.5 | 74.5 |
| 12-2 | 1.500 | 0.500 | 30% | 52.0 | | 74.5 | |
| 13-1 | 1.500 | 0.625 | 29% | 47.0 | 46.8 | 70.0 | 70.0 |
| 13-2 | 1.500 | 0.625 | 31% | 46.5 | | 70.0 | |
| 15-1 | 1.490 | 0.121 | 32% | 42.8 | 43.3 | 60.9 | 61.4 |
| 15-2 | 1.490 | 0.120 | 31% | 43.8 | | 61.8 | |
| 16-1 | 1.498 | 0.121 | 29% | 42.6 | 42.9 | 60.7 | 61.1 |
| 16-2 | 1.497 | 0.119 | 29% | 43.1 | | 61.5 | |
| 17-1 | 1.497 | 0.120 | 29% | 44.5 | 44.2 | 62.0 | 62.0 |
| 17-2 | 1.500 | 0.120 | 32% | 43.8 | | 62.0 | |
| 18-1 | 1.500 | 0.249 | 29% | 47.8 | 47.5 | 66.9 | 66.7 |
| 18-2 | 1.490 | 0.248 | 29% | 47.2 | | 66.5 | |
| 19-1 | 1.500 | 0.246 | 29% | 47.1 | 46.9 | 66.8 | 66.6 |
| 19-2 | 1.500 | 0.249 | 29% | 46.7 | | 66.4 | |
| 20-1 | 1.497 | 0.248 | 28% | 45.9 | 46.1 | 66.4 | 66.2 |
| 20-2 | 1.498 | 0.250 | 31% | 46.3 | | 65.9 | |
| 21-1 | 1.490 | 0.367 | 29% | 43.7 | 43.4 | 63.7 | 63.7 |
| 21-2 | 1.499 | 0.370 | 29% | 43.1 | | 63.6 | |
| 22-1 | 1.490 | 0.367 | 30% | 44.3 | 43.4 | 63.8 | 63.9 |
| 22-2 | 1.490 | 0.370 | 29% | 42.5 | | 63.9 | |
| 23-1 | 1.500 | 0.367 | 29% | 44.1 | 43.9 | 63.8 | 63.8 |
| 23-2 | 1.490 | 0.370 | 29% | 43.6 | | 63.8 | |
| 24-1 | 1.500 | 0.369 | 29% | 42.9 | 43.3 | 63.7 | 63.7 |
| 24-2 | 1.500 | 0.367 | 29% | 43.7 | | 63.6 | |
| 25-1 | 1.500 | 0.371 | 30% | 43.3 | 43.7 | 63.7 | 63.7 |
| 25-2 | 1.500 | 0.368 | 30% | 44.1 | | 63.7 | |

## Table A-1 Steel Properties (Cont.)

| Coupon | Width (in.) | Thickness (in.) | Elongation | Fy (ksi) | Average | Fu (ksi) | Average |
|---|---|---|---|---|---|---|---|
| 26-1 | 1.490 | 0.500 | 31% | 43.3 | 43.9 | 64.3 | 64.4 |
| 26-2 | 1.490 | 0.500 | 30% | 44.5 | | 64.4 | |
| 27-1 | 1.500 | 0.624 | 30% | 45.0 | 44.9 | 68.4 | 68.1 |
| 27-2 | 1.500 | 0.622 | 29% | 44.7 | | 67.8 | |
| 27a-1 | 1.500 | 0.627 | 30% | 45.1 | 45.4 | 68.5 | 68.4 |
| 27a-2 | 1.500 | 0.623 | 29% | 45.7 | | 68.3 | |
| 28-1 | 1.500 | 0.749 | 29% | 44.7 | 44.8 | 68.9 | 69.0 |
| 28-2 | 1.500 | 0.750 | 31% | 44.9 | | 69.1 | |
| 29-1 | 1.500 | 0.750 | 29% | 44.8 | 44.7 | 71.9 | 70.4 |
| 29-2 | 1.500 | 0.749 | 30% | 44.5 | | 68.9 | |
| 30-1 | 1.500 | 0.997 | 30% | 40.1 | 40.4 | 66.3 | 66.4 |
| 30-2 | 1.500 | 0.998 | 32% | 40.6 | | 66.4 | |
| 31-1 | 1.500 | 1.000 | 32% | 41.8 | 42.2 | 67.9 | 67.8 |
| 31-2 | 1.500 | 1.000 | 31% | 42.5 | | 67.7 | |
| 32-1 | 1.500 | 1.000 | 30% | 41.1 | 41.5 | 67.4 | 67.6 |
| 32-2 | 1.500 | 1.000 | 31% | 41.8 | | 67.7 | |
| 33-1 | 1.500 | 0.491 | 28% | 52.9 | 53.3 | 73.8 | 74.0 |
| 33-2 | 1.500 | 0.491 | 28% | 53.7 | | 74.1 | |
| 34-1 | 1.500 | 0.493 | 29% | 51.4 | 51.8 | 73.3 | 73.9 |
| 34-2 | 1.500 | 0.493 | 28% | 52.2 | | 74.4 | |
| 35-1 | 1.500 | 0.486 | 27% | 52.9 | 52.7 | 73.8 | 73.6 |
| 35-2 | 1.500 | 0.486 | 28% | 52.4 | | 73.4 | |
| 40-1 | 1.500 | 0.246 | 31% | 47.9 | 47.9 | 66.6 | 67.0 |
| 40-2 | 1.500 | 0.246 | 30% | 47.9 | | 67.3 | |
| 41-1 | 1.500 | 0.247 | 31% | 47.6 | 47.8 | 65.9 | 68.3 |
| 41-2 | 1.500 | 0.248 | 31% | 47.9 | | 70.6 | |
| 42-1 | 1.500 | 0.496 | 30% | 47.1 | 46.8 | 71.1 | 70.8 |
| 42-2 | 1.500 | 0.495 | 29% | 46.5 | | 70.5 | |
| 43-1 | 1.500 | 0.627 | 31% | 44.2 | 43.7 | 64.0 | 63.3 |
| 43-2 | 1.500 | 0.625 | 31% | 43.2 | | 62.6 | |
| 44-1 | 1.500 | 0.748 | 30% | 44.2 | 44.5 | 67.7 | 67.8 |
| 44-2 | 1.500 | 0.742 | 31% | 44.7 | | 67.8 | |
| 45-1 | 1.490 | 0.248 | 18% | 60.0 | 60.0 | 100.0 | 100.0 |
| 45-2 | 1.493 | 0.248 | 18% | 60.0 | | 100.0 | |
| 46-1 | 1.504 | 0.249 | 19% | 60.0 | 56.5 | 97.0 | 95.0 |
| 46-2 | 1.500 | 0.250 | 20% | 53.0 | | 93.0 | |
| 47-1 | 1.496 | 0.248 | 19% | 58.0 | 59.0 | 98.0 | 96.5 |
| 47-2 | 1.497 | 0.248 | 11% | 60.0 | | 95.0 | |
| 48-1 | 1.475 | 0.249 | 10% | 74.0 | 73.5 | 111.0 | 109.0 |
| 48-2 | 1.491 | 0.249 | 15% | 73.0 | | 107.0 | |
| 50a | 1.501 | 0.493 | 30% | 44.8 | 45.1 | 67.1 | 67.5 |
| 50b | 1.501 | 0.498 | 30% | 45.5 | | 67.8 | |
| 51a | 1.499 | 0.246 | 28% | 44.9 | 44.5 | 65.4 | 65.5 |
| 51b | 1.500 | 0.246 | 29% | 44.1 | | 65.5 | |

# Appendix B

## Single Bolt Lap Plate Connection Tests Reported By Karsu (1995)

## Table B - 1
## Connection Geometry And Material Parameters

| Report Test Number | Bolt $d_b$ (in.) | Bolt Grade | Was Bolt Pre-tensioned | Plate 1 $t_1$ (in.) | Width (in.) | $L_e$ (in.) | Edge Condition | $f_y$ (ksi) | $f_u$ (ksi) | Plate 2 $t_2$ (in.) | Width (in.) | $L_e$ (in.) | Edge Condition | $f_y$ (ksi) | $f_u$ (ksi) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.75 | A325-X | Yes | 0.2500 | 5.00 | 1.500 | Sawed | 45.8 | 65.5 | 0.2500 | 5.00 | 1.500 | Sawed | 45.8 | 65.5 |
| 3 | 0.75 | A325-X | Yes | 0.2500 | 5.00 | 1.500 | Sawed | 45.8 | 65.5 | 0.5000 | 5.00 | 1.500 | Sawed | 51.5 | 74.5 |
| 4 | 0.75 | A325-X | Yes | 0.2500 | 5.00 | 1.500 | Sawed | 45.8 | 65.5 | 0.6250 | 5.00 | 1.500 | Sawed | 46.8 | 70.0 |
| 7 | 0.75 | A325-X | Yes | 0.3750 | 4.00 | 1.500 | Sawed | 51.0 | 74.0 | 0.3750 | 4.00 | 1.500 | Sawed | 51.0 | 74.0 |
| 8 | 0.75 | A325-X | Yes | 0.3750 | 4.00 | 1.500 | Sawed | 51.0 | 74.0 | 0.5000 | 5.00 | 1.500 | Sawed | 51.8 | 74.3 |
| 9 | 0.75 | A325-X | Yes | 0.3750 | 4.00 | 1.500 | Sawed | 51.0 | 74.0 | 0.6250 | 5.00 | 1.500 | Sawed | 44.5 | 67.5 |
| 10 | 0.75 | A325-X | Yes | 0.3750 | 4.00 | 1.500 | Sawed | 51.0 | 74.0 | 0.7500 | 5.00 | 1.500 | Sheared | 45.0 | 67.0 |
| 12 | 0.75 | A325-X | Yes | 0.1250 | 6.00 | 1.500 | Sawed | 44.2 | 62.0 | 0.1250 | 6.00 | 1.500 | Sawed | 44.2 | 62.0 |
| 13 | 0.75 | A325-X | Yes | 0.1250 | 5.00 | 1.500 | Sheared | 43.3 | 61.4 | 0.2500 | 4.00 | 1.500 | Sheared | 47.5 | 66.7 |
| 14 | 0.75 | A325-X | Yes | 0.1250 | 5.00 | 1.500 | Sawed | 44.2 | 62.0 | 0.3750 | 4.00 | 1.500 | ? | 43.4 | 63.7 |
| 15 | 0.75 | A325-X | Yes | 0.1250 | 5.00 | 1.500 | Sheared | 43.3 | 61.4 | 0.5000 | 4.00 | 1.500 | Sawed | 51.5 | 74.5 |
| 16 | 0.75 | A325-X | Yes | 0.1250 | 5.00 | 1.500 | Sawed | 44.2 | 62.0 | 0.6250 | 4.00 | 1.500 | Sawed | 44.9 | 68.1 |
| 17 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.500 | Sheared | 47.5 | 66.7 | 1.0000 | 4.00 | 1.500 | Sawed | 43.5 | 70.0 |
| 18 | 0.75 | A325-X | Yes | 0.3750 | 4.00 | 1.500 | ? | 43.4 | 63.7 | 0.3750 | 4.00 | 1.500 | ? | 43.4 | 63.7 |
| 19 | 0.75 | A325-X | Yes | 0.3750 | 4.00 | 1.500 | ? | 43.4 | 63.7 | 1.0000 | 4.00 | 1.500 | Sawed | 43.5 | 70.0 |
| 20 | 0.75 | A325-X | Yes | 0.5000 | 4.00 | 1.500 | Sheared | 43.9 | 64.4 | 0.5000 | 4.00 | 1.500 | Sheared | 43.9 | 64.4 |
| 21 | 0.75 | A325-X | Yes | 0.5000 | 4.00 | 1.500 | Sheared | 43.9 | 64.4 | 0.6250 | 4.00 | 1.500 | Sawed | 44.9 | 68.1 |
| 22 | 0.75 | A325-X | Yes | 0.5000 | 4.00 | 1.500 | Sheared | 43.9 | 64.4 | 1.0000 | 4.00 | 1.500 | Sheared | 43.5 | 67.0 |
| 23 | 0.75 | A325-X | Yes | 0.6250 | 4.00 | 1.500 | Sawed | 46.8 | 70.0 | 0.6250 | 4.00 | 1.500 | Sawed | 46.8 | 70.0 |
| 26 | 0.875 | A325-X | Yes | 0.1250 | 5.00 | 1.500 | Sheared | 42.9 | 61.1 | 0.1250 | 5.00 | 1.500 | Sheared | 42.9 | 61.1 |
| 27 | 0.875 | A325-X | Yes | 0.1250 | 5.00 | 1.500 | Sheared | 42.9 | 61.1 | 0.2500 | 4.00 | 1.500 | Sheared | 46.9 | 66.6 |
| 28 | 0.875 | A325-X | Yes | 0.1250 | 5.00 | 1.563 | Sheared | 42.9 | 61.1 | 0.3750 | 4.00 | 1.563 | ? | 43.9 | 63.8 |
| 29 | 0.875 | A325-X | Yes | 0.1250 | 5.00 | 1.625 | Sheared | 42.9 | 61.1 | 0.5000 | 4.00 | 1.625 | Sawed | 51.8 | 73.9 |
| 30 | 0.875 | A325-X | Yes | 0.1250 | 5.00 | 1.625 | Sheared | 43.3 | 61.4 | 0.7500 | 4.00 | 1.625 | Sawed | 44.8 | 69.0 |
| 31 | 0.875 | A325-X | Yes | 0.2500 | 4.00 | 1.750 | Sheared | 46.1 | 66.2 | 0.2500 | 4.00 | 1.750 | Sheared | 46.1 | 66.2 |
| 32 | 0.875 | A325-X | Yes | 0.2500 | 4.00 | 1.750 | Sheared | 46.1 | 66.2 | 0.3750 | 4.00 | 1.750 | Sheared | 43.4 | 63.9 |
| 33 | 0.875 | A325-X | Yes | 0.2500 | 4.00 | 1.750 | Sheared | 46.1 | 66.2 | 0.5000 | 4.00 | 1.750 | Sawed | 51.8 | 73.9 |
| 34 | 0.875 | A325-X | Yes | 0.2500 | 4.00 | 1.750 | Sheared | 46.1 | 66.2 | 0.7500 | 4.00 | 1.750 | Sawed | 44.7 | 70.4 |
| 35 | 0.875 | A325-X | Yes | 0.2500 | 4.00 | 1.625 | Sheared | 46.1 | 66.2 | 1.0000 | 4.00 | 1.625 | Sawed | 41.5 | 67.6 |
| 36 | 0.875 | A325-X | Yes | 0.3750 | 4.00 | 1.625 | Sheared | 43.4 | 63.9 | 0.3750 | 4.00 | 1.625 | Sheared | 43.4 | 63.9 |
| 37 | 0.875 | A325-X | Yes | 0.3750 | 4.00 | 1.626 | Sheared | 43.4 | 63.9 | 0.5000 | 4.00 | 1.625 | Sawed | 52.7 | 73.6 |
| 38 | 0.875 | A325-X | Yes | 0.3750 | 4.00 | 1.625 | Sheared | 43.4 | 63.9 | 0.7500 | 4.00 | 1.625 | Sawed | 44.7 | 70.4 |
| 40 | 0.875 | A325-X | Yes | 0.5000 | 4.00 | 1.750 | Sawed | 51.8 | 73.9 | 0.5000 | 4.00 | 1.750 | Sawed | 51.8 | 73.9 |

## Table B - 1
## Connection Geometry And Material Parameters

| Report Test Number | Bolt | | | Plate 1 | | | | | | Plate 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $d_b$ (in.) | Bolt Grade | Was Bolt Pre-tensioned | $t_1$ (in.) | Width (in.) | $L_e$ (in.) | Edge Condition | $f_y$ (ksi) | $f_u$ (ksi) | $t_2$ (in.) | Width (in.) | $L_e$ (in.) | Edge Condition | $f_y$ (ksi) | $f_u$ (ksi) |
| 41 | 0.875 | A325-X | Yes | 0.5000 | 4.00 | 1.750 | Sawed | 51.8 | 73.9 | 0.7500 | 4.00 | 1.750 | Sawed | 44.7 | 70.4 |
| 42 | 0.875 | A325-X | Yes | 0.5000 | 4.00 | 1.750 | Sawed | 53.3 | 74.0 | 1.0000 | 4.00 | 1.750 | Sawed | 42.2 | 67.8 |
| 43 | 0.875 | A325-X | Yes | 0.7500 | 4.00 | 1.750 | Sawed | 44.7 | 70.4 | 0.7500 | 4.00 | 1.750 | Sawed | 44.7 | 70.4 |
| 44 | 0.875 | A325-X | Yes | 0.7500 | 4.00 | 1.750 | Sawed | 44.7 | 70.4 | 1.0000 | 4.00 | 1.750 | Sawed | 40.4 | 66.4 |
| 45 | 0.875 | A325-X | Yes | 1.0000 | 4.00 | 1.750 | Sawed | 41.5 | 67.6 | 1.0000 | 4.00 | 1.750 | Sawed | 41.5 | 67.6 |
| 46 | 1 | A325-X | Yes | 0.2500 | 4.00 | 2.000 | Sheared | 46.1 | 66.2 | 0.2500 | 4.00 | 2.000 | Sheared | 46.1 | 66.2 |
| 47 | 1 | A325-X | Yes | 0.2500 | 4.00 | 2.000 | Sheared | 46.1 | 66.2 | 0.3750 | 4.00 | 2.000 | Sheared | 43.7 | 63.7 |
| 48 | 1 | A325-X | Yes | 0.2500 | 4.00 | 2.000 | Sawed | 47.9 | 67.0 | 0.5000 | 4.00 | 2.000 | Sawed | 51.5 | 74.5 |
| 49 | 1 | A325-X | Yes | 0.2500 | 4.00 | 2.000 | Sawed | 47.8 | 68.3 | 0.6250 | 4.00 | 2.000 | Sawed | 45.5 | 68.4 |
| 50 | 1 | A325-X | Yes | 0.2500 | 4.00 | 2.000 | Sawed | 47.8 | 68.3 | 1.0000 | 4.00 | 2.000 | Sawed | 40.4 | 66.4 |
| 51 | 1 | A325-X | Yes | 0.2500 | 4.00 | 2.000 | Sawed | 47.8 | 68.3 | 0.7500 | 4.00 | 2.000 | Sawed | 44.8 | 69.0 |
| 52 | 1 | A325-X | Yes | 0.3750 | 4.00 | 2.000 | Sheared | 43.3 | 63.7 | 0.3750 | 4.00 | 2.000 | Sheared | 43.3 | 63.7 |
| 53 | 1 | A325-X | Yes | 0.3750 | 4.00 | 2.000 | Sheared | 43.3 | 63.7 | 0.5000 | 4.00 | 2.000 | Sawed | 51.5 | 74.5 |
| 54 | 1 | A325-X | Yes | 0.3750 | 4.00 | 2.000 | Sheared | 43.3 | 63.7 | 0.6250 | 4.00 | 2.000 | Sawed | 45.5 | 68.4 |
| 55 | 1 | A325-X | Yes | 0.3750 | 4.00 | 2.000 | Sheared | 43.3 | 63.7 | 0.7500 | 4.00 | 2.000 | Sawed | 44.8 | 69.0 |
| 56 | 1 | A325-X | Yes | 0.3750 | 4.00 | 2.000 | Sheared | 43.3 | 63.7 | 1.0000 | 4.00 | 2.000 | Sawed | 42.2 | 67.8 |
| 57 | 1 | A325-X | Yes | 0.5000 | 4.00 | 2.000 | Sawed | 51.8 | 73.9 | 0.5000 | 4.00 | 2.000 | Sawed | 51.8 | 73.9 |
| 58 | 1 | A325-X | Yes | 0.5000 | 4.00 | 2.000 | Sawed | 51.8 | 73.9 | 0.6250 | 4.00 | 2.000 | Sawed | 45.4 | 68.4 |
| 59 | 1 | A325-X | Yes | 0.5000 | 4.00 | 2.000 | Sawed | 51.8 | 73.9 | 0.7500 | 4.00 | 2.000 | Sawed | 44.7 | 70.4 |
| 60 | 1 | A325-X | Yes | 0.5000 | 4.00 | 2.000 | Sawed | 52.7 | 73.6 | 1.0000 | 4.00 | 2.000 | Sawed | 42.2 | 67.8 |
| 62 | 1 | A325-X | Yes | 0.6250 | 4.00 | 2.000 | Sawed | 43.7 | 63.3 | 0.7500 | 4.00 | 2.000 | Sawed | 44.9 | 67.8 |
| 64 | 1 | A325-X | Yes | 0.7500 | 5.00 | 2.000 | Sawed | 44.5 | 67.8 | 0.7500 | 5.00 | 2.000 | Sawed | 44.5 | 67.8 |
| 65 | 0.75 | A325-X | Yes | 0.1250 | 5.00 | 1.125 | Sawed | 44.2 | 62.0 | 0.1250 | 5.00 | 1.125 | Sawed | 44.2 | 62.0 |
| 66 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.125 | Sawed | 47.9 | 67.0 | 0.2500 | 4.00 | 1.125 | Sawed | 47.9 | 67.0 |
| 67 | 0.75 | A325-X | Yes | 0.3750 | 5.00 | 1.125 | Sheared | 43.7 | 63.7 | 0.3750 | 5.00 | 1.125 | Sheared | 43.7 | 63.7 |
| 68 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.125 | Sawed | 47.9 | 67.0 | 0.5000 | 5.00 | 1.125 | Sawed | 46.8 | 70.8 |
| 69 | 0.75 | A325-X | Yes | 0.5000 | 5.00 | 1.125 | Sawed | 46.8 | 70.8 | 0.5000 | 5.00 | 1.125 | Sawed | 46.8 | 70.8 |
| 70 | 0.75 | A325-X | Yes | 0.2500 | 5.00 | 1.125 | Sawed | 47.8 | 68.3 | 0.6250 | 5.00 | 1.125 | Sawed | 43.7 | 63.3 |

## Table B - 2
## Test Results And Equation Coefficients

| Report Test Number | General: Failure Mode | $R_{ult}$ (kips) | $\Delta_{max}$ (in.) | $R_f$ (kips) | $\Delta_f$ (in.) | $K_i$ (k/in.) | Loads @ Various Test Deformations: @ 0.16 in. (kips) | @ 0.25 in. (kips) | @ 0.34 in. (kips) | @ 0.50 in (kips) | Fisher Equation Coefficients: $R_{ult}$ (kips) | $\mu$ (1/in.) | $\lambda$ | Richard Equation Coefficients: K (k/in.) | $K_p$ (k/in.) | $R_o$ (kips) | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Bearing | 28.9 | 1.080 | 28.9 | 1.080 | 2889 | 23.3 | 24.7 | 25.4 | 26.1 | 24.9 | 19.3 | 0.401 | 3675 | 23.9 | 19.5 | 1.402 |
| 3 | Bearing | 27.6 | 0.613 | 27.6 | 0.613 | 1230 | 22.3 | 23.9 | 25.1 | 27.2 | 27.5 | 4.7 | 0.325 | 4337 | -21.8 | 62.3 | 0.382 |
| 4 | Bearing | 30.0 | 0.705 | 30.0 | 0.705 | 1835 | 27.9 | 28.4 | 28.7 | 29.2 | 28.7 | 17.7 | 0.497 | 2817 | 12.2 | 30.5 | 0.752 |
| 7 | Bolt Shear | 36.3 | 0.529 | 36.3 | 0.529 | 3732 | 29.5 | 32.5 | 34.4 | 36.1 | 75.0 | 0.2 | 0.272 | 3788 | 101.9 | 12.9 | 20.869 |
| 8 | Bolt Shear | 33.5 | 0.442 | 33.5 | 0.442 | 3096 | 18.7 | 29.0 | 31.9 | 0.0 | 103.6 | 0.5 | 0.655 | 3025 | 93.2 | 3.9 | 130.804 |
| 9 | Bolt Shear | 37.1 | 0.235 | 37.1 | 0.235 | 2224 | 35.4 | 0.0 | 0.0 | 0.0 | 39.1 | 10.8 | 0.480 | 16871 | -37.1 | 160.3 | 0.278 |
| 10 | Bolt Shear | 37.5 | 0.218 | 37.5 | 0.218 | 1782 | 36.3 | 0.0 | 0.0 | 0.0 | 35.7 | 37.2 | 0.651 | 2063 | 20.3 | 33.9 | 1.441 |
| 12 | Splitting | 13.3 | 0.927 | 12.7 | 1.053 | 1260 | 12.4 | 12.1 | 12.3 | 12.2 | 12.5 | 174.1 | 0.968 | 1330 | -5.6 | 13.4 | 2.530 |
| 13 | Splitting | 16.0 | 0.066 | 13.6 | 0.555 | 1754 | 15.4 | 14.7 | 14.3 | 14.0 | 15.0 | 241.9 | 2.202 | 1960 | -5.5 | 16.2 | 2.063 |
| 14 | Bearing | 16.4 | 0.070 | 11.8 | 0.638 | 1512 | 15.6 | 14.5 | 14.2 | 13.2 | 14.9 | 204.5 | 1.905 | 1736 | -8.8 | 16.9 | 1.843 |
| 15 | Bearing | 17.2 | 0.037 | 12.4 | 0.453 | 1537 | 14.8 | 13.7 | 12.9 | 0.0 | 15.5 | 191.8 | 0.665 | 1630 | -17.5 | 17.8 | 2.859 |
| 16 | Splitting | 15.2 | 0.064 | 11.2 | 0.569 | 1531 | 14.0 | 12.9 | 12.5 | 11.5 | 13.8 | 214.1 | 1.366 | 1718 | -12.1 | 16.0 | 1.865 |
| 17 | Bearing | 27.0 | 0.123 | 22.8 | 0.464 | 1773 | 26.6 | 24.7 | 24.3 | 0.0 | 25.4 | 81.5 | 0.762 | 2135 | -14.8 | 29.2 | 1.407 |
| 18 | Splitting | 35.0 | 1.057 | 35.0 | 1.057 | 2831 | 29.0 | 31.2 | 32.6 | 33.6 | 32.1 | 13.4 | 0.399 | 5159 | 17.9 | 29.1 | 0.757 |
| 19 | Bolt Shear | 38.5 | 0.467 | 38.5 | 0.467 | 2313 | 34.7 | 36.7 | 38.3 | 0.0 | 36.2 | 24.2 | 0.479 | 3019 | 24.2 | 32.1 | 1.169 |
| 20 | Bolt Shear | 35.7 | 0.230 | 35.5 | 0.268 | 2262 | 34.9 | 35.6 | 0.0 | 0.0 | 35.0 | 28.2 | 0.427 | 3040 | 8.7 | 35.0 | 1.106 |
| 21 | Bolt Shear | 40.0 | 0.248 | 40.0 | 0.248 | 3376 | 37.9 | 0.0 | 0.0 | 0.0 | 38.1 | 23.5 | 0.464 | 5678 | 13.6 | 40.4 | 0.752 |
| 22 | Bolt Shear | 37.4 | 0.203 | 37.4 | 0.203 | 1714 | 36.1 | 0.0 | 0.0 | 0.0 | 37.5 | 14.9 | 0.451 | 2263 | 15.1 | 38.4 | 0.898 |
| 23 | Bolt Shear | 35.4 | 0.241 | 35.4 | 0.241 | 3995 | 33.2 | 0.0 | 0.0 | 0.0 | 35.9 | 12.1 | 0.429 | 36143 | -34.2 | 142.7 | 0.254 |
| 26 | Buckling | 12.0 | 0.062 | 11.8 | 0.123 | 2196 | 0.0 | 0.0 | 0.0 | 0.0 | 11.5 | 367.2 | 2.213 | 2733 | -1.1 | 12.0 | 1.634 |
| 27 | Buckling | 16.6 | 0.104 | 14.3 | 0.366 | 1404 | 16.1 | 15.3 | 14.5 | 0.0 | 15.6 | 134.1 | 1.218 | 1700 | -6.3 | 17.2 | 1.550 |
| 28 | Bearing | 18.6 | 0.097 | 14.7 | 0.638 | 1506 | 17.9 | 16.5 | 15.9 | 15.3 | 17.0 | 125.0 | 0.668 | 1767 | -8.5 | 19.0 | 1.808 |
| 29 | Buckling | 19.6 | 0.079 | 13.5 | 0.658 | 1206 | 18.1 | 15.9 | 15.2 | 14.3 | 17.4 | 117.8 | 0.699 | 1419 | -19.4 | 21.2 | 1.782 |
| 30 | Bearing | 17.0 | 0.155 | 12.4 | 0.731 | 1179 | 17.0 | 16.3 | 15.6 | 15.0 | 16.4 | 69.2 | 0.796 | 1497 | -7.8 | 18.8 | 1.232 |
| 31 | Bearing | 30.2 | 1.180 | 30.2 | 1.180 | 2391 | 24.5 | 25.0 | 25.3 | 26.0 | 25.0 | 24.4 | 0.407 | 3237 | 16.8 | 21.8 | 1.168 |
| 32 | Splitting | 27.3 | 0.687 | 27.3 | 0.785 | 2772 | 26.5 | 26.7 | 26.7 | 26.7 | 26.3 | 40.8 | 0.560 | 4716 | 4.8 | 27.6 | 0.839 |
| 33 | Bearing | 30.1 | 0.098 | 28.7 | 0.567 | 2361 | 29.1 | 28.8 | 28.3 | 28.5 | 29.1 | 71.9 | 0.847 | 2986 | -25.6 | 35.8 | 1.066 |
| 34 | Bearing | 28.4 | 0.674 | 28.4 | 0.674 | 1655 | 27.2 | 27.4 | 27.5 | 28.1 | 27.1 | 69.9 | 0.915 | 1783 | 5.6 | 26.5 | 1.862 |
| 35 | Splitting | 28.9 | 0.717 | 28.9 | 0.717 | 1801 | 28.1 | 27.5 | 27.4 | 27.6 | 28.0 | 37.5 | 0.649 | 3401 | -85.3 | 72.4 | 0.540 |
| 36 | Bearing | 42.4 | 1.301 | 41.0 | 1.450 | 3759 | 29.6 | 31.9 | 33.3 | 35.2 | 33.6 | 10.9 | 0.381 | 6004 | 24.3 | 27.4 | 0.818 |
| 37 | Bearing | 42.9 | 0.850 | 42.1 | 0.919 | 3032 | 37.7 | 39.1 | 39.7 | 40.5 | 39.5 | 18.6 | 0.433 | 4899 | 18.4 | 38.0 | 0.838 |
| 38 | Bearing | 41.1 | 0.884 | 39.0 | 1.014 | 2172 | 34.5 | 35.9 | 36.8 | 38.2 | 36.2 | 23.0 | 0.534 | 3033 | 4.8 | 37.0 | 0.943 |
| 40 | Bolt Shear | 49.2 | 0.326 | 49.1 | 0.362 | 3796.3 | 45.2 | 48.0 | 49.1 | 0.0 | 48.1 | 15.8 | 0.371 | 7300 | 23.4 | 45.8 | 0.797 |
| 41 | Bolt Shear | 52.3 | 0.424 | 52.3 | 0.424 | 3079 | 45.6 | 49.7 | 50.9 | 0.0 | 50.6 | 11.6 | 0.398 | 4897 | 26.9 | 46.3 | 0.835 |
| 42 | Bolt Shear | 52.4 | 0.321 | 52.4 | 0.321 | 3268 | 48.0 | 50.9 | 0.0 | 0.0 | 51.5 | 14.2 | 0.463 | 6688 | 5.0 | 61.6 | 0.610 |
| 43 | Bolt Shear | 49.1 | 0.285 | 49.1 | 0.285 | 5161 | 41.3 | 47.0 | 0.0 | 0.0 | 72.9 | 0.9 | 0.278 | 173415 | 4.4 | 130.2 | 0.226 |
| 44 | Bolt Shear | 52.8 | 0.270 | 52.8 | 0.270 | 4043 | 48.2 | 51.5 | 0.0 | 0.0 | 53.5 | 9.4 | 0.369 | 45597 | -11.4 | 108.3 | 0.310 |
| 45 | Bolt Shear | 53.9 | 0.201 | 53.9 | 0.201 | 5189 | 51.7 | 0.0 | 0.0 | 0.0 | 53.5 | 16.3 | 0.400 | 18496 | -17.8 | 86.0 | 0.434 |
| 46 | Splitting | 38.1 | 1.262 | 38.1 | 1.262 | 1662 | 27.4 | 27.4 | 29.1 | 30.0 | 29.2 | 12.4 | 0.268 | 2118 | 10.4 | 25.9 | 1.350 |

## Table B - 2
## Test Results And Equation Coefficients

| Report Test Number | General: Failure Mode | $R_{ult}$ (kips) | $\Delta_{max}$ (in.) | $R_f$ (kips) | $\Delta_f$ (in.) | $K_i$ (k/in.) | Loads @ Various Test Deformations: @ 0.16 in. (kips) | @ 0.25 in. (kips) | @ 0.34 in. (kips) | @ 0.50 in (kips) | Fisher Equation Coefficients: $R_{ult}$ (kips) | $\mu$ (1/in.) | $\lambda$ | Richard Equation Coefficients: K (k/in.) | $K_p$ (k/in.) | $R_o$ (kips) | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 47 | Bearing | 33.5 | 0.440 | 32.9 | 0.544 | 2478 | 32.9 | 33.2 | 33.3 | 33.2 | 33.1 | 29.2 | 0.391 | 3222 | 5.4 | 32.9 | 1.174 |
| 48 | Splitting | 38.2 | 0.895 | 38.2 | 0.895 | 2364 | 35.4 | 34.9 | 34.7 | 34.8 | 34.6 | 61.1 | 0.800 | 2865 | 7.2 | 34.8 | 1.394 |
| 49 | Splitting | 35.4 | 0.180 | 33.3 | 0.744 | 2505 | 35.3 | 35.0 | 34.5 | 34.7 | 34.9 | 76.0 | 1.006 | 2500 | -9.6 | 37.4 | 1.570 |
| 50 | Splitting | 37.1 | 0.133 | 35.2 | 0.708 | 1812 | 36.9 | 36.0 | 35.3 | 34.9 | 36.0 | 75.9 | 1.186 | 1913 | -6.9 | 38.2 | 1.993 |
| 51 | Splitting | 36.1 | 0.811 | 36.1 | 0.811 | 2219 | 33.9 | 33.6 | 32.9 | 33.9 | 33.3 | 79.6 | 0.980 | 2565 | 6.9 | 33.5 | 1.676 |
| 52 | Bearing | 52.1 | 1.480 | 52.1 | 1.480 | 2963 | 38.3 | 39.9 | 41.7 | 43.7 | 40.9 | 26.6 | 0.373 | 3412 | 28.9 | 34.1 | 1.785 |
| 53 | Bearing | 54.1 | 1.104 | 54.1 | 1.104 | 3586 | 43.3 | 44.7 | 45.5 | 47.0 | 45.1 | 21.7 | 0.498 | 6259 | -2.0 | 51.8 | 0.698 |
| 54 | Splitting | 51.7 | 0.868 | 51.7 | 0.868 | 3216 | 44.3 | 45.4 | 46.1 | 46.4 | 45.3 | 33.1 | 0.562 | 4825 | -4.6 | 49.3 | 0.911 |
| 55 | Splitting | 51.7 | 0.870 | 51.7 | 0.870 | 2494 | 43.8 | 45.1 | 46.1 | 47.6 | 44.7 | 48.6 | 0.760 | 2802 | 29.9 | 39.0 | 1.941 |
| 56 | Splitting | 50.5 | 0.806 | 50.0 | 0.826 | 2097 | 43.8 | 45.5 | 46.2 | 47.1 | 44.4 | 53.5 | 1.014 | 2234 | 40.0 | 37.4 | 2.279 |
| 57 | Bolt Shear | 57.3 | 0.481 | 57.3 | 0.481 | 4056 | 48.5 | 52.6 | 55.4 | 0.0 | 55.8 | 9.7 | 0.361 | 5895 | 55.1 | 41.3 | 1.057 |
| 58 | Bolt Shear | 63.2 | 0.519 | 63.2 | 0.519 | 4116 | 50.3 | 54.6 | 58.5 | 62.8 | 59.6 | 8.8 | 0.348 | 6101 | 29.1 | 49.6 | 0.914 |
| 59 | Bolt Shear | 63.1 | 0.383 | 62.9 | 0.433 | 4384 | 53.1 | 57.3 | 61.2 | 0.0 | 61.8 | 9.0 | 0.403 | 6602 | 67.5 | 44.1 | 0.952 |
| 60 | Bolt Shear | 58.8 | 0.196 | 58.8 | 0.196 | 5076 | 56.8 | 0.0 | 0.0 | 0.0 | 56.9 | 28.6 | 0.510 | 8461 | 3.5 | 65.6 | 0.733 |
| 62 | Bolt Shear | 66.2 | 0.432 | 66.2 | 0.432 | 4784 | 54.4 | 58.5 | 62.9 | 0.0 | 63.0 | 10.8 | 0.441 | 8426 | 17.4 | 63.3 | 0.649 |
| 64 | Bolt Shear | 60.5 | 0.258 | 60.5 | 0.258 | 4692 | 55.8 | 60.2 | 0.0 | 0.0 | 61.3 | 12.9 | 0.547 | 42143 | -75.8 | 418.4 | 0.233 |
| 65 | Bearing | 13.3 | 0.085 | 10.3 | 0.743 | 1200 | 12.7 | 12.0 | 11.4 | 11.2 | 12.0 | 217.6 | 1.379 | 1235 | -3.1 | 13.0 | 3.510 |
| 66 | Bearing | 20.8 | 0.541 | 20.5 | 0.657 | 2274 | 18.9 | 19.2 | 19.9 | 20.7 | 18.9 | 179.1 | 1.266 | 2437 | 12.0 | 17.0 | 2.515 |
| 67 | Bearing | 32.2 | 0.876 | 32.2 | 0.876 | 2790 | 24.8 | 25.4 | 28.3 | 30.3 | 27.9 | 12.5 | 0.355 | 5607 | 4.4 | 27.0 | 0.720 |
| 68 | Bearing | 23.8 | 0.118 | 22.9 | 0.565 | 1545 | 23.7 | 23.7 | 23.0 | 22.4 | 23.0 | 67.0 | 0.977 | 1711 | 1.8 | 23.7 | 1.419 |
| 69 | Bolt Shear | 35.8 | 0.406 | 35.8 | 0.406 | 2967 | 32.2 | 34.4 | 35.4 | 0.0 | 34.1 | 23.9 | 0.472 | 3920 | 28.8 | 28.3 | 1.140 |
| 70 | Bearing | 23.7 | 0.144 | 20.8 | 0.461 | 1098 | 23.7 | 22.7 | 22.2 | 0.0 | 22.7 | 74.9 | 1.323 | 1179 | 2.2 | 23.3 | 1.970 |

**Test No: 1** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X1/4X3/4 Date: 2/17/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.25 | 1.5 | SAW | 2 |
| Bottom: | 5 | 0.25 | 1.5 | SAW | 2 |

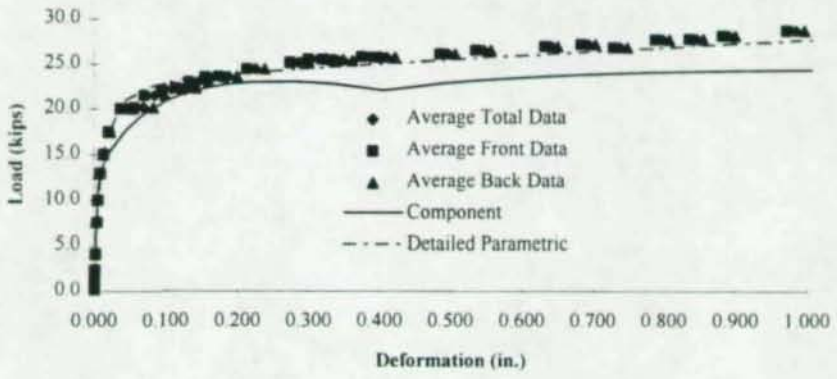
## TEST RESULTS

| | | | Deformation (in.) | Load (kips) |
|---|---|---|---|---|
| Limit State: | Bearing/Tearout | Maximum: | 1.08 | 28.9 |
| | | Failure: | 1.08 | 28.9 |
| | | Other: | 0.16 | 23.3 |
| | | | 0.25 | 24.7 |
| | | | 0.34 | 25.4 |

## COMMENTS

* At a load of 7500 lbs. straightening of plates was observed.
* First yielding started in front of the bolt on the 1/4-in. rear side plate at 20000 lbs.
* Plate curling and bulging on the tips of the plates were observed at 22000 lbs.
* At 23000 lbs. yielding started on the sides of the plates in line with the bolts.
* Corners started peeling back at 23500 lbs.
* Bulging got significant, excessive deformations occurred in front of the bolts at 26000 lbs.
* Signs of tear out appeared at 27000 lbs.

## CHART



**Test No: 1** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Load per | F1 | F2 | F3 | F4 | R1 | R2 | R3 | R4 | Total |
| Data Point | Plate (kips) | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | Avg |
| 1 | 0.2 | -0.001 | -0.001 | -0.001 | 0.000 | 0.000 | -0.001 | -0.001 | -0.001 | 0.001 |
| 2 | 1.2 | -0.001 | -0.002 | 0.000 | -0.001 | 0.000 | -0.001 | 0.000 | -0.001 | 0.001 |
| 3 | 2.3 | -0.002 | -0.003 | 0.000 | -0.001 | -0.001 | -0.001 | 0.000 | -0.001 | 0.001 |
| 4 | 4.1 | -0.003 | -0.004 | -0.001 | -0.001 | -0.002 | -0.001 | -0.001 | -0.001 | 0.002 |
| 5 | 7.5 | -0.005 | -0.007 | -0.002 | -0.004 | -0.004 | -0.001 | -0.005 | -0.001 | 0.004 |
| 6 | 10.0 | -0.005 | -0.011 | -0.002 | -0.006 | -0.007 | -0.002 | -0.008 | -0.001 | 0.005 |
| 7 | 13.0 | -0.005 | -0.017 | -0.002 | -0.012 | -0.011 | -0.002 | -0.012 | -0.001 | 0.008 |
| 8 | 15.0 | -0.007 | -0.024 | -0.004 | -0.019 | -0.018 | -0.007 | -0.019 | -0.006 | 0.013 |
| 9 | 17.5 | -0.013 | -0.032 | -0.009 | -0.028 | -0.026 | -0.018 | -0.027 | -0.018 | 0.021 |
| 10 | 20.0 | -0.031 | -0.048 | -0.026 | -0.043 | -0.056 | -0.053 | -0.057 | -0.053 | 0.046 |
| 11 | 20.2 | -0.050 | -0.065 | -0.046 | -0.061 | -0.083 | -0.080 | -0.085 | -0.082 | 0.069 |
| 12 | 21.5 | -0.064 | -0.080 | -0.061 | -0.075 | -0.098 | -0.097 | -0.101 | -0.099 | 0.084 |
| 13 | 22.1 | -0.088 | -0.104 | -0.085 | -0.099 | -0.121 | -0.122 | -0.125 | -0.124 | 0.108 |
| 14 | 22.3 | -0.108 | -0.124 | -0.105 | -0.118 | -0.140 | -0.141 | -0.144 | -0.144 | 0.128 |
| 15 | 22.9 | -0.127 | -0.143 | -0.123 | -0.136 | -0.157 | -0.158 | -0.162 | -0.161 | 0.146 |
| 16 | 23.5 | -0.150 | -0.166 | -0.145 | -0.158 | -0.178 | -0.180 | -0.183 | -0.183 | 0.168 |
| 17 | 23.6 | -0.170 | -0.185 | -0.164 | -0.178 | -0.196 | -0.199 | -0.202 | -0.203 | 0.187 |
| 18 | 24.4 | -0.210 | -0.224 | -0.202 | -0.216 | -0.234 | -0.237 | -0.241 | -0.242 | 0.226 |
| 19 | 25.1 | -0.272 | -0.283 | -0.263 | -0.277 | -0.295 | -0.299 | -0.303 | -0.305 | 0.287 |
| 20 | 25.5 | -0.298 | -0.310 | -0.289 | -0.303 | -0.322 | -0.325 | -0.329 | -0.331 | 0.313 |
| 21 | 25.5 | -0.319 | -0.330 | -0.310 | -0.323 | -0.344 | -0.347 | -0.351 | -0.353 | 0.335 |
| 22 | 25.4 | -0.333 | -0.346 | -0.324 | -0.338 | -0.357 | -0.360 | -0.364 | -0.366 | 0.348 |
| 23 | 25.8 | -0.371 | -0.384 | -0.364 | -0.377 | -0.394 | -0.397 | -0.401 | -0.403 | 0.386 |
| 24 | 25.7 | -0.394 | -0.407 | -0.387 | -0.400 | -0.417 | -0.421 | -0.423 | -0.426 | 0.409 |
| 25 | 26.1 | -0.481 | -0.494 | -0.476 | -0.488 | -0.502 | -0.506 | -0.508 | -0.510 | 0.496 |
| 26 | 26.5 | -0.531 | -0.544 | -0.527 | -0.540 | -0.552 | -0.556 | -0.558 | -0.560 | 0.546 |
| 27 | 27.0 | -0.630 | -0.642 | -0.623 | -0.636 | -0.647 | -0.650 | -0.652 | -0.654 | 0.642 |
| 28 | 27.2 | -0.681 | -0.692 | -0.675 | -0.688 | -0.699 | -0.703 | -0.705 | -0.707 | 0.694 |
| 29 | 26.8 | -0.727 | -0.738 | -0.720 | -0.732 | -0.743 | -0.747 | -0.751 | -0.753 | 0.739 |
| 30 | 27.7 | -0.789 | -0.798 | -0.777 | -0.788 | -0.801 | -0.806 | -0.810 | -0.813 | 0.798 |
| 31 | 27.8 | -0.835 | -0.845 | -0.824 | -0.839 | -0.850 | -0.855 | -0.857 | -0.859 | 0.845 |
| 32 | 28.1 | -0.881 | -0.891 | -0.872 | -0.886 | -0.895 | -0.900 | -0.902 | -0.904 | 0.891 |
| 33 | 28.7 | -0.969 | -0.981 | -0.962 | -0.977 | -0.989 | -0.995 | -0.999 | -1.003 | 0.985 |
| 34 | 28.9 | -1.057 | -1.068 | -1.051 | -1.068 | -1.088 | -1.096 | -1.102 | -1.107 | 1.080 |
| 35 | 24.3 | -1.062 | -1.073 | -1.056 | -1.072 | -1.154 | -1.160 | -1.172 | -1.177 | 1.116 |
| 36 | 16.5 | -1.061 | -1.072 | -1.053 | -1.070 | -1.206 | -1.214 | -1.235 | -1.238 | 1.144 |
| 37 | 16.4 | -1.060 | -1.072 | -1.053 | -1.070 | -1.206 | -1.214 | -1.234 | -1.238 | 1.144 |
| 38 | 0.1 | -1.023 | -1.046 | -1.025 | -1.055 | -1.179 | -1.195 | -1.221 | -1.228 | 1.122 |

**Test No: 3** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X1/2X3/4 Date: 2/27/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.25 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.25 | 1.5 | SAW | 2 |
| Bottom: | 5 | 0.5 | 1.5 | SAW | 12 |

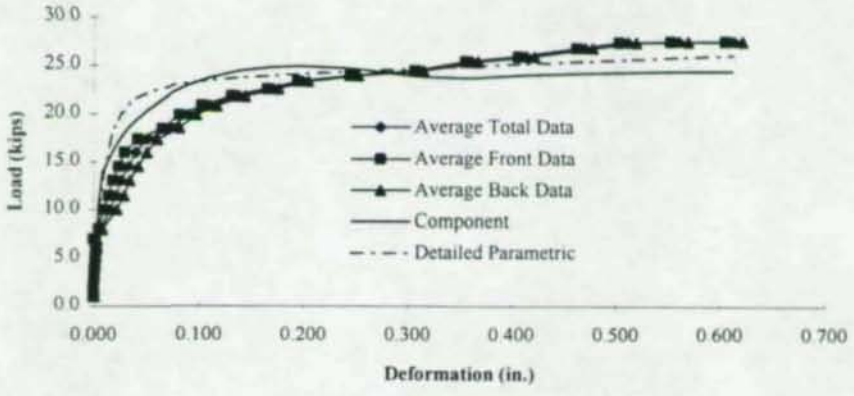
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: Bearing/Tearout | Maximum: | 0.613 | 27.6 |
| | Failure: | 0.613 | 27.6 |
| | Other: | 0.16 | 22.3 |
| | | 0.25 | 23.9 |
| | | 0.34 | 25.1 |

## COMMENTS

* Yielding started in front of the bolt on PL-2 at 13000 lbs.
* Yielding on the sides of PL-2 started at 19500 lbs.
* Bulging was observed on PL-2 at a load of 21200 lbs.
* Yielding on PL-12 at load 23500 lbs.
* Excessive bolt hole elongation at a load of 24500 lbs on PL-2.
* PL-2 teared out at a load of ?29100? lbs.

## CHART



Test No: 3
Recorder: BK

**Summary of One Bolt Lap Connection Tests**

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.000 |
| 2 | 2.0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.001 | 0 | 0.000 |
| 3 | 3.0 | -0.001 | -0.001 | 0 | 0 | 0 | 0 | -0.001 | -0.001 | 0.001 |
| 4 | 4.0 | -0.002 | -0.002 | 0 | 0 | 0 | 0 | -0.001 | -0.001 | 0.001 |
| 5 | 5.0 | -0.003 | -0.003 | 0 | -0.003 | 0 | 0 | -0.003 | -0.003 | 0.002 |
| 6 | 6.0 | -0.004 | -0.004 | 0 | 0 | 0 | -0.001 | -0.004 | -0.004 | 0.002 |
| 7 | 7.0 | 0 | 0 | 0 | 0 | 0 | -0.002 | -0.006 | -0.006 | 0.002 |
| 8 | 1.0 | -0.001 | 0 | 0 | 0 | 0 | -0.002 | 0 | 0 | 0.000 |
| 9 | 4.0 | -0.003 | -0.003 | 0 | 0 | 0 | 0 | -0.001 | -0.003 | 0.001 |
| 10 | 5.0 | -0.004 | -0.003 | 0 | 0 | 0 | 0 | -0.003 | -0.004 | 0.002 |
| 11 | 6.0 | -0.006 | -0.005 | 0 | 0 | 0 | 0 | -0.005 | -0.008 | 0.003 |
| 12 | 8.0 | -0.013 | -0.007 | 0 | 0 | 0 | 0 | -0.008 | -0.026 | 0.007 |
| 13 | 10.0 | -0.015 | -0.012 | -0.006 | -0.004 | -0.011 | -0.024 | -0.019 | -0.034 | 0.016 |
| 14 | 11.5 | -0.02 | -0.019 | -0.007 | -0.01 | -0.017 | -0.031 | -0.026 | -0.042 | 0.022 |
| 15 | 13.1 | -0.024 | -0.025 | -0.01 | -0.014 | -0.02 | -0.037 | -0.031 | -0.049 | 0.026 |
| 16 | 14.5 | -0.029 | -0.034 | -0.012 | -0.02 | -0.026 | -0.045 | -0.039 | -0.06 | 0.033 |
| 17 | 16.0 | -0.034 | -0.041 | -0.015 | -0.027 | -0.033 | -0.053 | -0.047 | -0.069 | 0.040 |
| 18 | 17.4 | -0.047 | -0.056 | -0.025 | -0.039 | -0.04 | -0.063 | -0.058 | -0.081 | 0.051 |
| 19 | 18.5 | -0.07 | -0.083 | -0.045 | -0.063 | -0.058 | -0.083 | -0.079 | -0.105 | 0.073 |
| 20 | 19.9 | -0.087 | -0.101 | -0.059 | -0.079 | -0.073 | -0.099 | -0.096 | -0.123 | 0.090 |
| 21 | 20.8 | -0.108 | -0.123 | -0.079 | -0.1 | -0.09 | -0.118 | -0.116 | -0.144 | 0.110 |
| 22 | 21.8 | -0.137 | -0.154 | -0.105 | -0.129 | -0.115 | -0.144 | -0.143 | -0.174 | 0.138 |
| 23 | 22.5 | -0.171 | -0.189 | -0.138 | -0.163 | -0.145 | -0.175 | -0.177 | -0.207 | 0.171 |
| 24 | 23.3 | -0.2 | -0.22 | -0.166 | -0.19 | -0.172 | -0.203 | -0.206 | -0.237 | 0.199 |
| 25 | 23.9 | -0.252 | -0.272 | -0.214 | -0.24 | -0.218 | -0.25 | -0.256 | -0.286 | 0.249 |
| 26 | 24.5 | -0.314 | -0.337 | -0.274 | -0.301 | -0.279 | -0.312 | -0.32 | -0.35 | 0.311 |
| 27 | 25.4 | -0.364 | -0.386 | -0.321 | -0.35 | -0.33 | -0.364 | -0.372 | -0.403 | 0.361 |
| 28 | 25.9 | -0.416 | -0.438 | -0.37 | -0.4 | -0.383 | -0.418 | -0.426 | -0.46 | 0.414 |
| 29 | 26.8 | -0.472 | -0.496 | -0.425 | -0.456 | -0.437 | -0.474 | -0.483 | -0.517 | 0.470 |
| 30 | 27.4 | -0.513 | -0.537 | -0.466 | -0.497 | -0.478 | -0.516 | -0.526 | -0.558 | 0.511 |
| 31 | 27.5 | -0.562 | -0.586 | -0.515 | -0.546 | -0.527 | -0.564 | -0.576 | -0.609 | 0.561 |
| 32 | 27.6 | -0.615 | -0.639 | -0.567 | -0.598 | -0.578 | -0.617 | -0.628 | -0.661 | 0.613 |
| 33 | | -0.055 | -0.02755 | -0.615 | -0.639 | -0.567 | -0.598 | -0.578 | -0.617 | 0.462 |

**Test No: 4** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X5/8X3/4 Date: 3/6/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.75 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.25 | 1.5 | SAW | 2 |
| Bottom: | 5 | 0.625 | 1.5 | SAW | 13 |

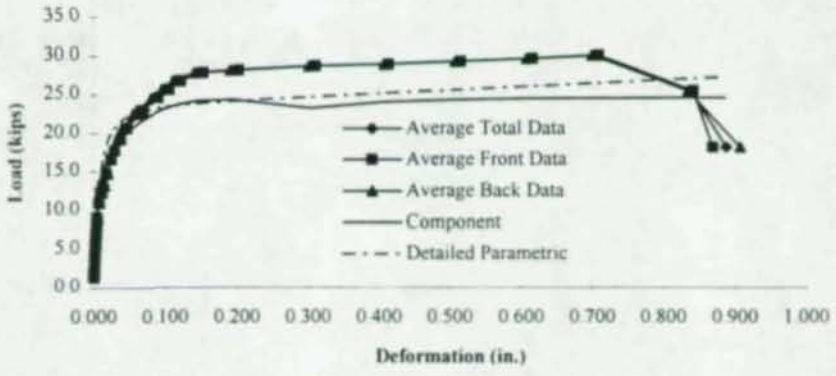
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bearing/Tearout | | |
| | Maximum: | 0.705 | 30 |
| | Failure: | 0.705 | 30 |
| | Other: | 0.16 | 27.9 |
| | | 0.25 | 28.4 |
| | | 0.34 | 28.7 |

## COMMENTS

* Yielding on PL-2 started at 19000 lbs.
* PL-2 tended to bend out of plane at 24000 lbs.
* Bulging on the tip of PL-2 started at 26000 lbs.
* Yielding on the sides of PL-2 occurred at 28000 lbs.
* Bolt holes stretched excessively at 29000 lbs.
* Yielding on PL-13 at 29500 lbs.
* Rupture on PL-2 at 30000 lbs.

## CHART



Test No: 4
Recorder: BK

## Summary of One Bolt Lap Connection Tests

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.4 | 0.000 | 0.000 | -0.001 | -0.001 | 0.000 | -0.001 | 0.000 | -0.001 | 0.000 |
| 2 | 1.8 | 0.000 | 0.000 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | -0.001 | 0.001 |
| 3 | 1.9 | -0.001 | 0.000 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | -0.001 | 0.001 |
| 4 | 2.1 | -0.001 | 0.000 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | -0.001 | 0.001 |
| 5 | 2.6 | -0.001 | 0.001 | -0.002 | -0.002 | -0.001 | -0.002 | 0.000 | -0.001 | 0.001 |
| 6 | 2.8 | -0.001 | 0.001 | -0.002 | -0.002 | -0.002 | -0.002 | 0.000 | -0.001 | 0.001 |
| 7 | 3.1 | -0.001 | 0.001 | -0.002 | -0.002 | -0.002 | -0.003 | 0.000 | -0.001 | 0.001 |
| 8 | 3.6 | -0.001 | 0.001 | -0.004 | -0.002 | -0.002 | -0.004 | 0.000 | -0.001 | 0.002 |
| 9 | 4.1 | -0.001 | 0.001 | -0.004 | -0.002 | -0.003 | -0.005 | 0.000 | -0.001 | 0.002 |
| 10 | 4.6 | -0.001 | 0.001 | -0.004 | -0.003 | -0.004 | -0.006 | 0.000 | -0.001 | 0.002 |
| 11 | 5.5 | -0.002 | 0.000 | -0.006 | -0.004 | -0.004 | -0.007 | 0.000 | -0.001 | 0.003 |
| 12 | 6.1 | -0.002 | 0.000 | -0.007 | -0.004 | -0.004 | -0.008 | 0.000 | -0.001 | 0.003 |
| 13 | 7.1 | -0.002 | 0.000 | -0.008 | -0.005 | -0.005 | -0.010 | 0.001 | -0.002 | 0.004 |
| 14 | 8.2 | -0.002 | -0.001 | -0.009 | -0.006 | -0.006 | -0.012 | 0.000 | -0.002 | 0.005 |
| 15 | 9.1 | -0.003 | 0.000 | -0.011 | -0.006 | -0.007 | -0.013 | 0.000 | -0.003 | 0.005 |
| 16 | 11.0 | -0.006 | 0.001 | -0.017 | -0.007 | -0.007 | -0.020 | 0.000 | -0.007 | 0.008 |
| 17 | 12.4 | -0.010 | 0.000 | -0.023 | -0.009 | -0.010 | -0.028 | 0.000 | -0.013 | 0.011 |
| 18 | 13.2 | -0.013 | -0.001 | -0.027 | -0.012 | -0.012 | -0.032 | -0.001 | -0.017 | 0.014 |
| 19 | 14.8 | -0.018 | -0.003 | -0.034 | -0.016 | -0.015 | -0.040 | -0.002 | -0.021 | 0.019 |
| 20 | 16.6 | -0.026 | -0.007 | -0.044 | -0.023 | -0.020 | -0.048 | -0.003 | -0.027 | 0.025 |
| 21 | 17.8 | -0.030 | -0.010 | -0.051 | -0.028 | -0.023 | -0.054 | -0.005 | -0.031 | 0.029 |
| 22 | 19.3 | -0.039 | -0.017 | -0.061 | -0.037 | -0.028 | -0.062 | -0.008 | -0.036 | 0.036 |
| 23 | 20.7 | -0.046 | -0.023 | -0.072 | -0.046 | -0.034 | -0.072 | -0.012 | -0.043 | 0.043 |
| 24 | 22.6 | -0.064 | -0.036 | -0.094 | -0.064 | -0.051 | -0.092 | -0.025 | -0.058 | 0.060 |
| 25 | 23.0 | -0.070 | -0.040 | -0.100 | -0.069 | -0.056 | -0.097 | -0.029 | -0.063 | 0.066 |
| 26 | 24.6 | -0.091 | -0.057 | -0.124 | -0.090 | -0.076 | -0.121 | -0.045 | -0.083 | 0.086 |
| 27 | 25.6 | -0.106 | -0.069 | -0.142 | -0.106 | -0.092 | -0.137 | -0.057 | -0.097 | 0.101 |
| 28 | 26.7 | -0.122 | -0.083 | -0.161 | -0.122 | -0.108 | -0.154 | -0.072 | -0.112 | 0.117 |
| 29 | 27.8 | -0.153 | -0.111 | -0.194 | -0.155 | -0.139 | -0.186 | -0.099 | -0.141 | 0.147 |
| 30 | 28.1 | -0.202 | -0.158 | -0.246 | -0.205 | -0.189 | -0.239 | -0.147 | -0.190 | 0.197 |
| 31 | 28.6 | -0.308 | -0.264 | -0.356 | -0.315 | -0.300 | -0.353 | -0.255 | -0.300 | 0.306 |
| 32 | 28.9 | -0.410 | -0.365 | -0.459 | -0.418 | -0.406 | -0.460 | -0.359 | -0.405 | 0.410 |
| 33 | 29.2 | -0.511 | -0.468 | -0.560 | -0.522 | -0.507 | -0.562 | -0.458 | -0.504 | 0.511 |
| 34 | 29.6 | -0.610 | -0.568 | -0.662 | -0.625 | -0.607 | -0.664 | -0.558 | -0.604 | 0.612 |
| 35 | 30.0 | -0.702 | -0.660 | -0.755 | -0.718 | -0.700 | -0.758 | -0.648 | -0.695 | 0.705 |
| 36 | 25.5 | -0.834 | -0.797 | -0.886 | -0.852 | -0.835 | -0.890 | -0.784 | -0.829 | 0.838 |
| 37 | 18.2 | -0.863 | -0.824 | -0.915 | -0.876 | -0.906 | -0.950 | -0.870 | -0.905 | 0.888 |

**Test No: 7** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 3/8X3/8X3/4 Date: 3/8/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.25 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.375 | 1.5 | SAW | 10 |
| Bottom: | 4 | 0.375 | 1.5 | SAW | 10 |

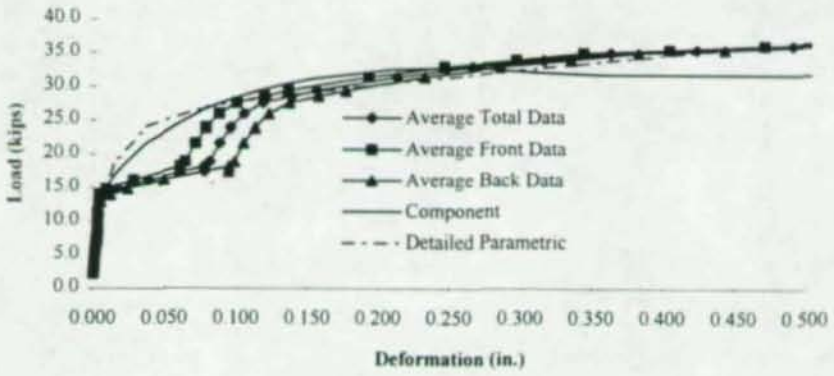
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.529 | 36.3 |
| | Failure: | 0.529 | 36.3 |
| | Other: | 0.16 | 29.5 |
| | | 0.25 | 32.5 |
| | | 0.34 | 34.4 |

## COMMENTS

* Bolts tended to decline at 16000 lbs.
* Slip of the connection occured at 17000 lbs. because of non-pretensioning with a banging sound.
* Yielding on PL-10 was seen at a load of 28500 lbs.
* PL-10 bended out of plane at 29000 lbs.
* Tips of the plates curlled back at 31000 lbs.
* Bolt hole stretched at 35000 lbs.
* Bolt failed in shear at a load of 36300 lbs.

## CHART



**Test No: 7**
**Recorder: BK**

## Summary of One Bolt Lap Connection Tests

**DATA**

| | | *Potentiometer Readings (in.)* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 2.2 | -0.001 | 0.000 | -0.001 | 0.000 | 0.000 | -0.001 | -0.001 | 0.000 | 0.000 |
| 2 | 3.3 | -0.001 | -0.001 | -0.002 | -0.001 | 0.000 | -0.001 | -0.001 | -0.001 | 0.001 |
| 3 | 3.9 | -0.001 | -0.001 | -0.002 | -0.001 | 0.000 | -0.001 | -0.002 | -0.001 | 0.001 |
| 4 | 5.1 | -0.001 | -0.001 | -0.003 | -0.001 | 0.000 | -0.001 | -0.003 | -0.001 | 0.001 |
| 5 | 6.1 | -0.001 | -0.001 | -0.003 | -0.002 | 0.000 | -0.001 | -0.004 | -0.001 | 0.002 |
| 6 | 6.5 | -0.002 | -0.001 | -0.004 | -0.002 | -0.001 | -0.001 | -0.004 | -0.001 | 0.002 |
| 7 | 6.9 | -0.002 | -0.001 | -0.004 | -0.003 | -0.001 | -0.001 | -0.004 | -0.001 | 0.002 |
| 8 | 7.4 | -0.002 | -0.002 | -0.004 | -0.004 | -0.001 | -0.002 | -0.004 | -0.001 | 0.003 |
| 9 | 8.0 | -0.002 | -0.002 | -0.004 | -0.004 | -0.001 | -0.002 | -0.004 | -0.002 | 0.003 |
| 10 | 8.5 | -0.003 | -0.002 | -0.005 | -0.004 | -0.001 | -0.002 | -0.004 | -0.002 | 0.003 |
| 11 | 8.5 | -0.003 | -0.002 | -0.004 | -0.004 | -0.001 | -0.002 | -0.004 | -0.002 | 0.003 |
| 12 | 9.1 | -0.003 | -0.002 | -0.004 | -0.004 | -0.002 | -0.002 | -0.006 | -0.002 | 0.003 |
| 13 | 10.2 | -0.003 | -0.003 | -0.003 | -0.004 | -0.002 | -0.003 | -0.006 | -0.002 | 0.003 |
| 14 | 11.4 | -0.003 | -0.003 | -0.003 | -0.004 | -0.002 | -0.004 | -0.007 | -0.003 | 0.004 |
| 15 | 12.9 | -0.004 | -0.004 | -0.004 | -0.005 | -0.004 | -0.005 | -0.009 | -0.004 | 0.005 |
| 16 | 14.0 | -0.006 | -0.003 | -0.006 | -0.005 | -0.010 | -0.011 | -0.016 | -0.012 | 0.008 |
| 17 | 14.8 | -0.012 | -0.006 | -0.012 | -0.008 | -0.024 | -0.020 | -0.031 | -0.021 | 0.017 |
| 18 | 16.2 | -0.029 | -0.025 | -0.031 | -0.028 | -0.054 | -0.043 | -0.059 | -0.042 | 0.039 |
| 19 | 18.1 | -0.061 | -0.056 | -0.065 | -0.061 | -0.104 | -0.087 | -0.105 | -0.085 | 0.078 |
| 20 | 17.5 | -0.061 | -0.056 | -0.065 | -0.061 | -0.104 | -0.087 | -0.104 | -0.085 | 0.078 |
| 21 | 18.9 | -0.065 | -0.059 | -0.069 | -0.065 | -0.108 | -0.090 | -0.108 | -0.089 | 0.082 |
| 22 | 21.7 | -0.072 | -0.066 | -0.076 | -0.072 | -0.114 | -0.095 | -0.116 | -0.095 | 0.088 |
| 23 | 23.9 | -0.079 | -0.072 | -0.085 | -0.080 | -0.122 | -0.103 | -0.125 | -0.102 | 0.096 |
| 24 | 26.0 | -0.087 | -0.081 | -0.094 | -0.090 | -0.133 | -0.111 | -0.136 | -0.111 | 0.105 |
| 25 | 27.6 | -0.098 | -0.093 | -0.108 | -0.103 | -0.146 | -0.125 | -0.152 | -0.126 | 0.119 |
| 26 | 28.6 | -0.117 | -0.111 | -0.128 | -0.123 | -0.167 | -0.144 | -0.174 | -0.146 | 0.139 |
| 27 | 29.4 | -0.133 | -0.128 | -0.145 | -0.140 | -0.186 | -0.163 | -0.194 | -0.164 | 0.157 |
| 28 | 31.4 | -0.189 | -0.185 | -0.201 | -0.197 | -0.241 | -0.217 | -0.253 | -0.220 | 0.213 |
| 29 | 32.9 | -0.242 | -0.238 | -0.253 | -0.253 | -0.297 | -0.269 | -0.307 | -0.271 | 0.266 |
| 30 | 33.9 | -0.292 | -0.289 | -0.304 | -0.303 | -0.347 | -0.319 | -0.357 | -0.319 | 0.316 |
| 31 | 34.9 | -0.338 | -0.336 | -0.352 | -0.350 | -0.393 | -0.366 | -0.405 | -0.366 | 0.363 |
| 32 | 35.4 | -0.399 | -0.395 | -0.412 | -0.412 | -0.454 | -0.426 | -0.465 | -0.427 | 0.424 |
| 33 | 36.1 | -0.465 | -0.462 | -0.480 | -0.478 | -0.524 | -0.494 | -0.533 | -0.492 | 0.491 |
| 34 | 36.3 | -0.504 | -0.500 | -0.518 | -0.518 | -0.562 | -0.532 | -0.572 | -0.530 | 0.529 |
| 35 | 1.6 | -0.569 | -0.566 | -0.584 | -0.584 | -0.628 | -0.598 | -0.640 | -0.596 | 0.596 |

**Test No: 8** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 3/8X1/2X3/4 Date: 3/8/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.75 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.375 | 1.5 | SAW | 10 |
| Bottom: | 5 | 0.5 | 1.5 | SAW | 11 |

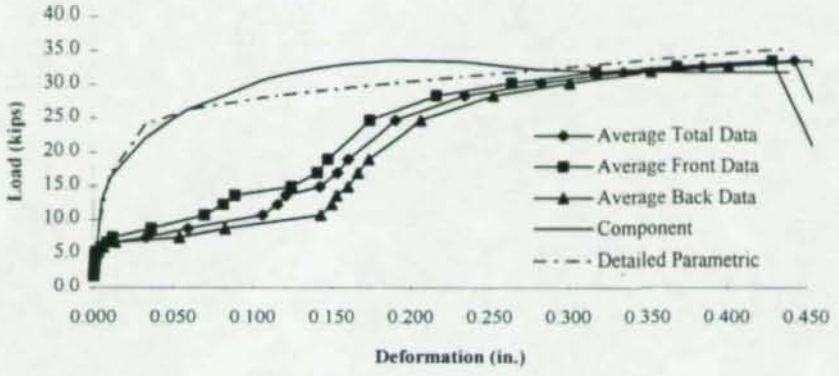
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: Bolt Shear | Maximum: | 0.442 | 33.5 |
| | Failure: | 0.442 | 33.5 |
| | Other: | 0.16 | 18.7 |
| | | 0.25 | 29 |
| | | 0.34 | 31.9 |

## COMMENTS

* Connection slipped at a load of 9000 lbs.with a banging sound, excessive deformations occurred at that poi
* PL-10 yielded at 19000 lbs.
* Bolts declined and PL-11 yielded at 24500 lbs.
* Yielding on the sides of PL-10 at 28000 lbs.
* Bolt hole on PL-10 stretched and tips curled back at 30000 lbs.
* Bulging on PL-10 at 31000 lbs.
* Bolt failure at 33500 lbs.

## CHART



**Test No: 8**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.8 | 0.000 | 0.000 | -0.001 | 0.000 | 0.000 | -0.001 | 0.000 | 0.000 | 0.000 |
| 2 | 2.7 | 0.000 | -0.001 | -0.001 | -0.001 | -0.001 | -0.002 | 0.000 | 0.000 | 0.001 |
| 3 | 3.2 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.002 | 0.000 | -0.001 | 0.001 |
| 4 | 4.2 | -0.001 | -0.001 | -0.002 | -0.001 | -0.001 | -0.004 | 0.000 | -0.001 | 0.001 |
| 5 | 4.7 | -0.001 | -0.001 | -0.002 | -0.001 | -0.002 | -0.004 | 0.000 | -0.001 | 0.002 |
| 6 | 5.2 | -0.001 | -0.001 | -0.003 | -0.001 | -0.003 | -0.006 | -0.002 | -0.002 | 0.002 |
| 7 | 5.9 | -0.004 | -0.004 | -0.006 | -0.005 | -0.006 | -0.010 | -0.004 | -0.006 | 0.006 |
| 8 | 6.6 | -0.006 | -0.008 | -0.010 | -0.010 | -0.015 | -0.017 | -0.012 | -0.012 | 0.011 |
| *9* | *7.4* | *-0.010* | *-0.012* | *-0.013* | *-0.015* | *-0.056* | *-0.055* | *-0.054* | *-0.051* | *0.033* |
| 10 | 8.6 | -0.030 | -0.039 | -0.034 | -0.042 | -0.086 | -0.084 | -0.081 | -0.080 | 0.060 |
| 11 | 10.7 | -0.060 | -0.075 | -0.065 | -0.079 | -0.147 | -0.144 | -0.141 | -0.139 | 0.106 |
| 12 | 12.3 | -0.070 | -0.089 | -0.075 | -0.093 | -0.155 | -0.152 | -0.148 | -0.145 | 0.116 |
| 13 | 13.6 | -0.076 | -0.099 | -0.081 | -0.101 | -0.159 | -0.155 | -0.151 | -0.148 | 0.121 |
| 14 | 14.9 | -0.109 | -0.138 | -0.114 | -0.138 | -0.168 | -0.163 | -0.158 | -0.153 | 0.143 |
| 15 | 17.0 | -0.125 | -0.153 | -0.130 | -0.155 | -0.175 | -0.171 | -0.163 | -0.158 | 0.154 |
| 16 | 19.0 | -0.128 | -0.163 | -0.135 | -0.166 | -0.180 | -0.180 | -0.169 | -0.166 | 0.161 |
| 17 | 24.7 | -0.142 | -0.196 | -0.155 | -0.204 | -0.212 | -0.222 | -0.193 | -0.200 | 0.190 |
| 18 | 28.4 | -0.177 | -0.237 | -0.196 | -0.255 | -0.257 | -0.271 | -0.235 | -0.246 | 0.234 |
| 19 | 30.2 | -0.221 | -0.286 | -0.246 | -0.304 | -0.306 | -0.323 | -0.281 | -0.293 | 0.283 |
| 20 | 31.8 | -0.272 | -0.340 | -0.300 | -0.359 | -0.358 | -0.376 | -0.330 | -0.344 | 0.335 |
| 21 | 32.6 | -0.323 | -0.390 | -0.351 | -0.410 | -0.408 | -0.427 | -0.378 | -0.392 | 0.385 |
| 22 | 33.5 | -0.383 | -0.450 | -0.410 | -0.470 | -0.464 | -0.483 | -0.431 | -0.447 | 0.442 |
| 23 | 1.7 | -0.446 | -0.515 | -0.475 | -0.535 | -0.520 | -0.542 | -0.487 | -0.505 | 0.503 |

**Test No: 9** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 3/8X5/8X3/4 Date: 3/9/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | |
|---|---|---|---|
| Type: | A325 | Diameter (in.): 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): 2.75 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: X | |
| | | Bolt Head Washer: X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.375 | 1.5 | SAW | 10 |
| Bottom: | 5 | 0.625 | 1.5 | SAW | 3 |

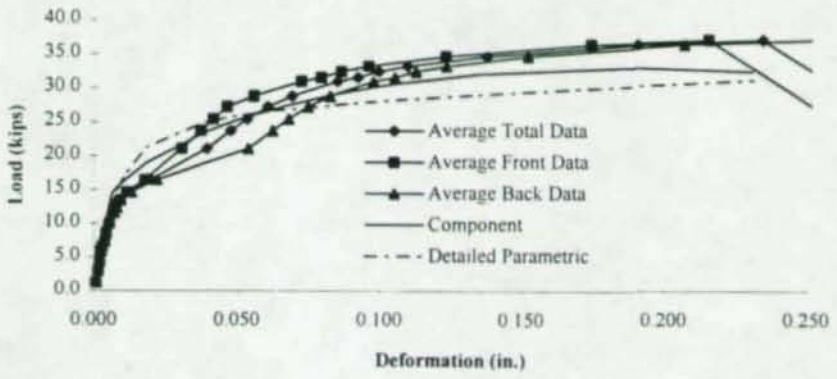
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.235 | 37.1 |
| | Failure: | 0.235 | 37.1 |
| | Other: | 0.16 | 35.4 |
| | | 0.25 | NA |
| | | 0.34 | NA |

## COMMENTS

* Yielding occurred on PL-10 at 31000 lbs.
* PL-10 bended out of plane at 32500 lbs.
* PL-3 yielded at 35000 lbs.
* Yielding on sides of both PL-10 and PL-3 at 36500 lbs.
* Bolt sheared at 37000 lbs.

## CHART



Test No: 9
Recorder: BK

**Summary of One Bolt Lap Connection Tests**

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.2 | -0.001 | 0.000 | -0.002 | -0.001 | -0.002 | -0.001 | 0.000 | -0.001 | 0.001 |
| 2 | 3.0 | -0.001 | -0.001 | -0.003 | -0.002 | -0.003 | -0.002 | 0.000 | -0.001 | 0.002 |
| 3 | 4.3 | -0.001 | -0.001 | -0.004 | -0.003 | -0.004 | -0.003 | 0.000 | 0.000 | 0.002 |
| 4 | 5.9 | -0.001 | 0.000 | -0.006 | -0.004 | -0.006 | -0.005 | 0.000 | -0.001 | 0.003 |
| 5 | 6.6 | -0.001 | 0.000 | -0.007 | -0.004 | -0.006 | -0.006 | 0.000 | -0.001 | 0.003 |
| 6 | 7.3 | -0.001 | -0.001 | -0.008 | -0.006 | -0.007 | -0.007 | -0.001 | -0.001 | 0.004 |
| 7 | 8.6 | -0.001 | 0.000 | -0.010 | -0.006 | -0.007 | -0.007 | -0.001 | -0.001 | 0.004 |
| 8 | 10.0 | -0.002 | 0.000 | -0.012 | -0.007 | -0.008 | -0.009 | -0.001 | -0.002 | 0.005 |
| 9 | 11.6 | -0.006 | -0.001 | -0.015 | -0.006 | -0.010 | -0.013 | -0.002 | -0.004 | 0.007 |
| 10 | 12.3 | -0.007 | 0.000 | -0.018 | -0.006 | -0.011 | -0.015 | -0.002 | -0.004 | 0.008 |
| 11 | 13.4 | -0.010 | -0.001 | -0.021 | -0.005 | -0.012 | -0.018 | -0.002 | -0.006 | 0.009 |
| 12 | 14.6 | -0.015 | -0.001 | -0.027 | -0.003 | -0.015 | -0.023 | -0.004 | -0.010 | 0.012 |
| 13 | 16.5 | -0.023 | -0.007 | -0.036 | -0.006 | -0.026 | -0.032 | -0.013 | -0.018 | 0.020 |
| 14 | 21.1 | -0.042 | 0.011 | -0.061 | -0.009 | -0.062 | -0.064 | -0.044 | -0.045 | 0.040 |
| 15 | 23.7 | -0.053 | 0.008 | -0.073 | -0.015 | -0.073 | -0.074 | -0.051 | -0.051 | 0.048 |
| 16 | 23.7 | -0.053 | 0.009 | -0.073 | -0.015 | -0.073 | -0.074 | -0.051 | -0.051 | 0.048 |
| 17 | 25.4 | -0.059 | 0.006 | -0.083 | -0.020 | -0.079 | -0.081 | -0.056 | -0.056 | 0.054 |
| 18 | 27.3 | -0.067 | 0.000 | -0.092 | -0.028 | -0.087 | -0.089 | -0.061 | -0.062 | 0.061 |
| 19 | 28.8 | -0.076 | -0.006 | -0.105 | -0.037 | -0.095 | -0.099 | -0.067 | -0.069 | 0.069 |
| 20 | 30.9 | -0.091 | -0.019 | -0.126 | -0.054 | -0.112 | -0.116 | -0.081 | -0.082 | 0.085 |
| 21 | 31.5 | -0.098 | -0.024 | -0.134 | -0.062 | -0.120 | -0.124 | -0.087 | -0.089 | 0.092 |
| 22 | 32.4 | -0.105 | -0.031 | -0.142 | -0.069 | -0.128 | -0.133 | -0.094 | -0.096 | 0.100 |
| 23 | 33.2 | -0.113 | -0.038 | -0.154 | -0.080 | -0.140 | -0.144 | -0.105 | -0.106 | 0.110 |
| 24 | 34.7 | -0.139 | -0.062 | -0.185 | -0.107 | -0.169 | -0.174 | -0.132 | -0.134 | 0.138 |
| 25 | 36.4 | -0.190 | -0.110 | -0.239 | -0.160 | -0.226 | -0.231 | -0.185 | -0.188 | 0.191 |
| 26 | 37.1 | -0.230 | -0.150 | -0.282 | -0.201 | -0.273 | -0.279 | -0.231 | -0.233 | 0.235 |
| 27 | 2.3 | -0.359 | -0.275 | -0.416 | -0.334 | -0.407 | -0.415 | -0.363 | -0.364 | 0.367 |
| 28 | 2.4 | -0.413 | -0.327 | -0.471 | -0.388 | -0.465 | -0.474 | -0.421 | -0.423 | 0.423 |

**Test No: 10** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 3/8X3/4X3/4 Date: 3/10/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.75 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.375 | 1.5 | SAW | 10 |
| Bottom: | 5 | 0.75 | 1.5 | SHEAR | 7 |

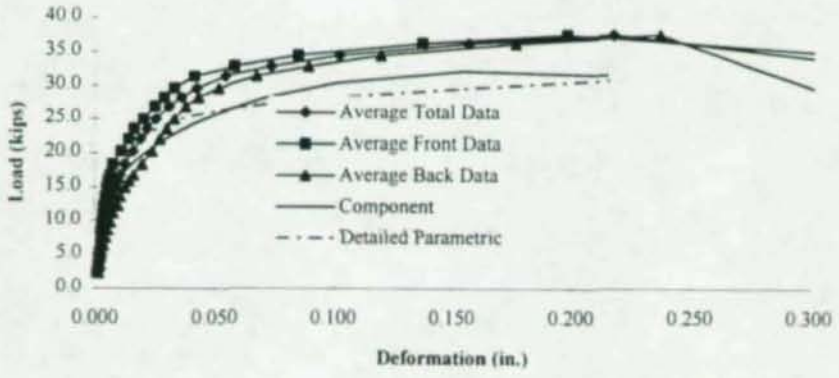
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.218 | 37.5 |
| | Failure: | 0.218 | 37.5 |
| | Other: | 0.16 | 36.3 |
| | | 0.25 | NA |
| | | 0.34 | NA |

## COMMENTS

* Yielding started on PL-10 at 25000 lbs.
* Yielding on the sides of PL-10 at 36000 lbs.
* Bulging on PL-10 at 37000 lbs.
* Bolt sheared at 37500 lbs.

## CHART



**Test No: 10**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 2.3 | -0.001 | 0.000 | -0.001 | -0.001 | -0.002 | -0.002 | -0.001 | 0.000 | 0.001 |
| 2 | 3.4 | -0.002 | 0.000 | -0.002 | -0.001 | -0.004 | -0.004 | -0.001 | 0.000 | 0.002 |
| 3 | 4.6 | -0.002 | 0.000 | -0.002 | -0.002 | -0.005 | -0.004 | 0.000 | 0.000 | 0.002 |
| 4 | 5.3 | -0.002 | 0.000 | -0.003 | -0.002 | -0.005 | -0.005 | 0.000 | 0.000 | 0.002 |
| 5 | 6.3 | -0.002 | -0.001 | -0.004 | -0.003 | -0.006 | -0.006 | -0.002 | 0.000 | 0.003 |
| 6 | 7.5 | -0.002 | -0.001 | -0.004 | -0.004 | -0.007 | -0.008 | -0.002 | 0.000 | 0.003 |
| 7 | 8.6 | -0.004 | 0.000 | -0.005 | -0.003 | -0.007 | -0.012 | 0.000 | -0.002 | 0.004 |
| 8 | 9.7 | -0.004 | -0.001 | -0.005 | -0.003 | -0.008 | -0.015 | -0.001 | -0.004 | 0.005 |
| 9 | 11.1 | -0.005 | -0.001 | -0.006 | -0.003 | -0.009 | -0.018 | 0.000 | -0.005 | 0.006 |
| 10 | 12.2 | -0.005 | -0.001 | -0.007 | -0.004 | -0.009 | -0.021 | -0.001 | -0.008 | 0.007 |
| 11 | 13.6 | -0.006 | -0.001 | -0.008 | -0.004 | -0.008 | -0.025 | 0.000 | -0.010 | 0.008 |
| 12 | 14.9 | -0.006 | -0.001 | -0.009 | -0.005 | -0.007 | -0.029 | -0.001 | -0.014 | 0.009 |
| 13 | 15.9 | -0.006 | -0.001 | -0.011 | -0.006 | -0.006 | -0.034 | 0.001 | -0.017 | 0.010 |
| 14 | 16.8 | -0.007 | -0.001 | -0.012 | -0.006 | -0.005 | -0.037 | 0.002 | -0.020 | 0.011 |
| 15 | 18.3 | -0.009 | -0.001 | -0.014 | -0.006 | -0.004 | -0.045 | 0.005 | -0.026 | 0.013 |
| 16 | 20.2 | -0.015 | -0.002 | -0.020 | -0.007 | -0.004 | -0.053 | 0.006 | -0.033 | 0.016 |
| 17 | 22.0 | -0.020 | -0.003 | -0.026 | -0.009 | -0.005 | -0.059 | 0.007 | -0.038 | 0.019 |
| 18 | 23.5 | -0.023 | -0.004 | -0.030 | -0.010 | -0.007 | -0.064 | 0.006 | -0.043 | 0.022 |
| 19 | 25.0 | -0.027 | -0.006 | -0.035 | -0.013 | -0.009 | -0.071 | 0.005 | -0.048 | 0.026 |
| 20 | 26.8 | -0.032 | -0.009 | -0.042 | -0.018 | -0.013 | -0.081 | 0.002 | -0.056 | 0.031 |
| 21 | 28.2 | -0.037 | -0.012 | -0.046 | -0.021 | -0.020 | -0.090 | -0.001 | -0.064 | 0.036 |
| 22 | 29.5 | -0.041 | -0.015 | -0.051 | -0.026 | -0.027 | -0.101 | -0.007 | -0.073 | 0.043 |
| 23 | 31.4 | -0.049 | -0.023 | -0.061 | -0.034 | -0.043 | -0.121 | -0.018 | -0.089 | 0.055 |
| 24 | 32.8 | -0.065 | -0.040 | -0.078 | -0.051 | -0.065 | -0.146 | -0.037 | -0.111 | 0.074 |
| 25 | 34.5 | -0.091 | -0.066 | -0.105 | -0.080 | -0.095 | -0.179 | -0.064 | -0.141 | 0.103 |
| 26 | 36.2 | -0.142 | -0.117 | -0.159 | -0.133 | -0.153 | -0.238 | -0.118 | -0.198 | 0.157 |
| 27 | 37.5 | -0.202 | -0.177 | -0.221 | -0.194 | -0.214 | -0.300 | -0.177 | -0.260 | 0.218 |
| 28 | 8.4 | -0.253 | -4.907 | -0.271 | -0.227 | -0.405 | -0.462 | -0.496 | -0.543 | 0.946 |

**Test No: 12** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/8X1/8X3/4 Date: 3/12/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 1.75 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 6 | 0.125 | 1.5 | SAW | 17 |
| Bottom: | 6 | 0.125 | 1.5 | SAW | 17 |

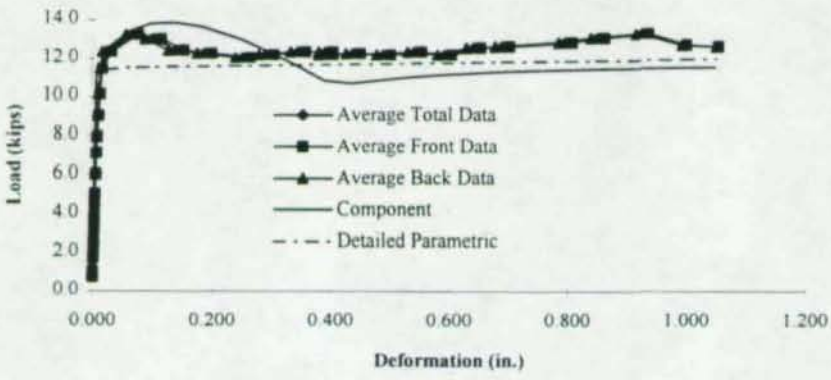
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Splitting | Maximum: | 0.927 | 13.3 |
| | | Failure: | 1.053 | 12.7 |
| | | Other: | 0.16 | 12.4 |
| | | | 0.25 | 12.1 |
| | | | 0.34 | 12.3 |

## COMMENTS

* Bolts declined at 5000 lbs.
*Bolt holes elongated at 6000 lbs.
*Tips of the plate curled back at 7000 lbs.
*Tension tearing at 12500 lbs.

## CHART



**Test No: 12**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 0.8 | -0.001 | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | 0.000 | 0.000 |
| 2 | 1.1 | -0.002 | -0.001 | -0.001 | 0.000 | -0.001 | -0.001 | 0.000 | 0.000 | 0.001 |
| 3 | 1.7 | -0.002 | -0.003 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | 0.000 | 0.001 |
| 4 | 2.2 | -0.003 | -0.003 | -0.001 | -0.001 | -0.002 | -0.001 | -0.001 | -0.001 | 0.001 |
| 5 | 2.7 | -0.004 | -0.004 | -0.002 | -0.001 | -0.003 | -0.001 | -0.001 | -0.001 | 0.002 |
| 6 | 3.2 | -0.006 | -0.004 | -0.002 | -0.001 | -0.004 | -0.002 | -0.002 | -0.001 | 0.003 |
| 7 | 3.6 | -0.006 | -0.005 | -0.003 | -0.001 | -0.004 | -0.002 | -0.002 | -0.001 | 0.003 |
| 8 | 4.0 | -0.006 | -0.006 | -0.004 | -0.001 | -0.005 | -0.002 | -0.002 | -0.001 | 0.003 |
| 9 | 4.6 | -0.006 | -0.007 | -0.004 | -0.001 | -0.006 | -0.002 | -0.003 | -0.001 | 0.004 |
| 10 | 5.0 | -0.007 | -0.007 | -0.004 | -0.002 | -0.007 | -0.002 | -0.005 | -0.001 | 0.004 |
| 11 | 6.1 | -0.007 | -0.009 | -0.006 | -0.004 | -0.009 | -0.003 | -0.006 | -0.001 | 0.006 |
| 12 | 7.2 | -0.009 | -0.010 | -0.007 | -0.005 | -0.010 | -0.004 | -0.007 | -0.002 | 0.007 |
| 13 | 8.0 | -0.010 | -0.012 | -0.007 | -0.006 | -0.011 | -0.005 | -0.008 | -0.004 | 0.008 |
| 14 | 9.1 | -0.012 | -0.014 | -0.009 | -0.009 | -0.013 | -0.007 | -0.010 | -0.005 | 0.010 |
| 15 | 10.2 | -0.015 | -0.017 | -0.012 | -0.012 | -0.015 | -0.010 | -0.012 | -0.008 | 0.012 |
| 16 | 11.5 | -0.018 | -0.020 | -0.015 | -0.017 | -0.016 | -0.013 | -0.014 | -0.010 | 0.015 |
| 17 | 12.4 | -0.029 | -0.038 | -0.029 | -0.032 | -0.018 | -0.017 | -0.017 | -0.015 | 0.024 |
| 18 | 13.2 | -0.073 | -0.084 | -0.074 | -0.080 | -0.059 | -0.054 | -0.059 | -0.052 | 0.067 |
| 19 | 13.0 | -0.109 | -0.121 | -0.113 | -0.118 | -0.091 | -0.086 | -0.091 | -0.084 | 0.102 |
| 20 | 12.4 | -0.147 | -0.160 | -0.150 | -0.155 | -0.130 | -0.125 | -0.131 | -0.122 | 0.140 |
| 21 | 12.3 | -0.194 | -0.208 | -0.196 | -0.203 | -0.177 | -0.174 | -0.179 | -0.171 | 0.188 |
| 22 | 12.1 | -0.259 | -0.274 | -0.259 | -0.268 | -0.241 | -0.239 | -0.243 | -0.236 | 0.252 |
| 23 | 12.2 | -0.298 | -0.314 | -0.298 | -0.307 | -0.280 | -0.279 | -0.281 | -0.276 | 0.292 |
| 24 | 12.4 | -0.353 | -0.368 | -0.350 | -0.361 | -0.334 | -0.333 | -0.336 | -0.328 | 0.345 |
| 25 | 12.4 | -0.398 | -0.414 | -0.397 | -0.408 | -0.381 | -0.379 | -0.381 | -0.376 | 0.392 |
| 26 | 12.2 | -0.398 | -0.414 | -0.397 | -0.408 | -0.381 | -0.379 | -0.381 | -0.376 | 0.392 |
| 27 | 12.3 | -0.443 | -0.461 | -0.443 | -0.454 | -0.427 | -0.426 | -0.429 | -0.423 | 0.438 |
| 28 | 12.2 | -0.495 | -0.512 | -0.494 | -0.505 | -0.479 | -0.478 | -0.481 | -0.473 | 0.489 |
| 29 | 12.4 | -0.547 | -0.565 | -0.546 | -0.557 | -0.531 | -0.531 | -0.534 | -0.525 | 0.542 |
| 30 | 12.2 | -0.597 | -0.615 | -0.596 | -0.610 | -0.580 | -0.582 | -0.584 | -0.576 | 0.593 |
| 31 | 12.6 | -0.647 | -0.664 | -0.646 | -0.659 | -0.629 | -0.630 | -0.633 | -0.626 | 0.642 |
| 32 | 12.7 | -0.695 | -0.712 | -0.694 | -0.707 | -0.679 | -0.678 | -0.682 | -0.674 | 0.690 |
| 33 | 12.9 | -0.801 | -0.818 | -0.800 | -0.814 | -0.784 | -0.786 | -0.790 | -0.782 | 0.797 |
| 34 | 13.1 | -0.857 | -0.872 | -0.854 | -0.869 | -0.837 | -0.841 | -0.844 | -0.836 | 0.851 |
| 35 | 13.3 | -0.928 | -0.948 | -0.928 | -0.944 | -0.914 | -0.916 | -0.921 | -0.911 | 0.927 |
| 36 | 12.7 | -0.993 | -1.012 | -0.991 | -1.008 | -0.991 | -0.993 | -1.000 | -0.989 | 0.997 |
| 37 | 12.7 | -1.045 | -1.066 | -1.045 | -1.062 | -1.048 | -1.051 | -1.058 | -1.047 | 1.053 |

**Test No: 13** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/8X1/4X3/4 Date: 3/12/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 0 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.125 | 1.5 | SHEAR | 15 |
| Bottom: | 4 | 0.25 | 1.5 | SHEAR | 18 |

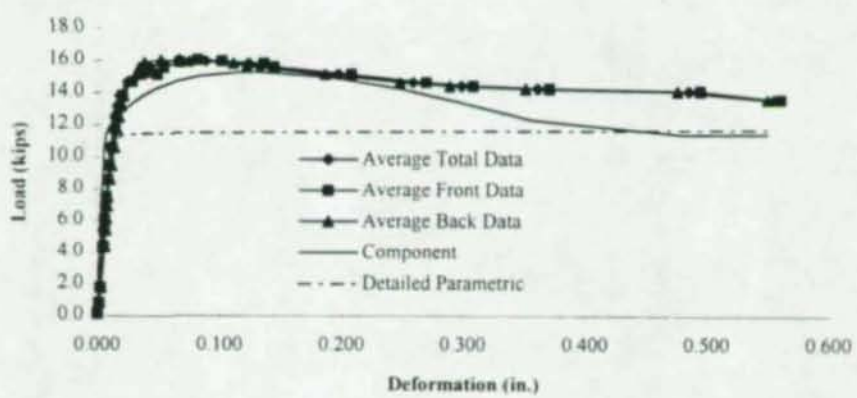
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Splitting | | |
| | Maximum: | 0.066 | 16 |
| | Failure: | 0.555 | 13.6 |
| | Other: | 0.16 | 15.4 |
| | | 0.25 | 14.7 |
| | | 0.34 | 14.3 |

## COMMENTS

* Yielding on PL-15 started at 14000 lbs.
* After 16000 lbs, load decreases.
* PL-18 yields at 15000 lbs.

## CHART



**Test No: 13**
**Recorder: BK**

## Summary of One Bolt Lap Connection Tests

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 0.2 | -0.001 | 0.000 | 0.000 | -0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 0.8 | -0.001 | -0.001 | -0.002 | -0.002 | -0.003 | -0.002 | -0.001 | -0.001 | 0.002 |
| 3 | 1.8 | 0.000 | 0.001 | -0.006 | -0.004 | -0.007 | -0.006 | 0.000 | 0.000 | 0.003 |
| 4 | 4.4 | 0.000 | 0.002 | -0.010 | -0.009 | -0.013 | -0.010 | 0.001 | 0.001 | 0.005 |
| 5 | 5.4 | 0.000 | 0.002 | -0.012 | -0.010 | -0.014 | -0.012 | 0.001 | 0.001 | 0.006 |
| 6 | 6.1 | 0.000 | 0.002 | -0.013 | -0.010 | -0.015 | -0.013 | 0.001 | 0.001 | 0.006 |
| 7 | 6.9 | -0.001 | 0.002 | -0.015 | -0.011 | -0.016 | -0.016 | 0.001 | 0.001 | 0.007 |
| 8 | 7.5 | -0.001 | 0.002 | -0.015 | -0.012 | -0.016 | -0.017 | 0.002 | 0.000 | 0.007 |
| 9 | 8.6 | -0.003 | 0.003 | -0.018 | -0.012 | -0.018 | -0.020 | 0.002 | -0.002 | 0.008 |
| 10 | 9.5 | -0.004 | 0.003 | -0.020 | -0.013 | -0.018 | -0.023 | 0.004 | -0.004 | 0.009 |
| 11 | 10.6 | -0.007 | 0.004 | -0.024 | -0.013 | -0.018 | -0.027 | 0.004 | -0.006 | 0.011 |
| 12 | 11.8 | -0.010 | 0.004 | -0.029 | -0.015 | -0.018 | -0.031 | 0.006 | -0.009 | 0.013 |
| 13 | 12.5 | -0.012 | 0.004 | -0.032 | -0.015 | -0.019 | -0.034 | 0.006 | -0.012 | 0.014 |
| 14 | 13.2 | -0.015 | 0.004 | -0.037 | -0.017 | -0.020 | -0.037 | 0.007 | -0.014 | 0.016 |
| 15 | 13.8 | -0.019 | 0.003 | -0.041 | -0.018 | -0.020 | -0.040 | 0.007 | -0.018 | 0.018 |
| 16 | 14.7 | -0.028 | -0.006 | -0.051 | -0.029 | -0.020 | -0.047 | 0.007 | -0.025 | 0.025 |
| 17 | 15.1 | -0.047 | -0.026 | -0.070 | -0.050 | -0.021 | -0.059 | 0.007 | -0.037 | 0.038 |
| 18 | 15.6 | -0.052 | -0.031 | -0.076 | -0.055 | -0.023 | -0.065 | 0.005 | -0.043 | 0.043 |
| 19 | 15.9 | -0.065 | -0.045 | -0.089 | -0.069 | -0.028 | -0.073 | 0.001 | -0.050 | 0.052 |
| 20 | 16.0 | -0.080 | -0.059 | -0.104 | -0.083 | -0.041 | -0.086 | -0.013 | -0.064 | 0.066 |
| 21 | 15.9 | -0.100 | -0.078 | -0.125 | -0.103 | -0.065 | -0.110 | -0.037 | -0.086 | 0.088 |
| 22 | 15.8 | -0.133 | -0.112 | -0.160 | -0.138 | -0.101 | -0.146 | -0.073 | -0.123 | 0.123 |
| 23 | 15.6 | -0.142 | -0.120 | -0.168 | -0.146 | -0.112 | -0.157 | -0.084 | -0.132 | 0.133 |
| 24 | 15.1 | -0.206 | -0.182 | -0.233 | -0.209 | -0.178 | -0.221 | -0.149 | -0.196 | 0.197 |
| 25 | 14.6 | -0.268 | -0.244 | -0.295 | -0.271 | -0.238 | -0.284 | -0.210 | -0.258 | 0.259 |
| 26 | 14.4 | -0.306 | -0.282 | -0.335 | -0.309 | -0.277 | -0.333 | -0.249 | -0.296 | 0.299 |
| 27 | 14.3 | -0.368 | -0.343 | -0.399 | -0.371 | -0.340 | -0.393 | -0.311 | -0.357 | 0.360 |
| 28 | 14.1 | -0.490 | -0.466 | -0.525 | -0.497 | -0.467 | -0.513 | -0.437 | -0.484 | 0.485 |
| 29 | 13.6 | -0.557 | -0.530 | -0.592 | -0.563 | -0.543 | -0.587 | -0.511 | -0.557 | 0.555 |

**Test No: 14** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/8X3/8X3/4 Date: 3/13/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 1.75 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.125 | 1.5 | SAW | 17 |
| Bottom: | 4 | 0.375 | 1.5 | Unknown | 21 |

## TEST RESULTS

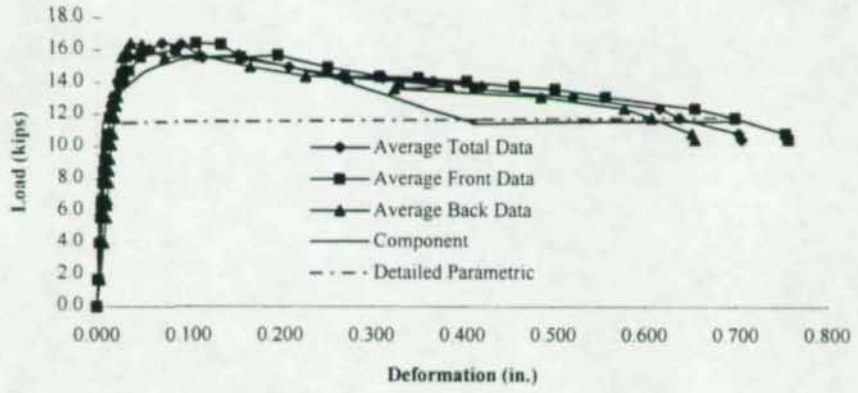
Limit State: Bearing/Tearout

| | Deformation (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.07 | 16.4 |
| Failure: | 0.638 | 11.8 |
| Other: | 0.16 | 15.6 |
| | 0.25 | 14.5 |
| | 0.34 | 14.2 |

## COMMENTS

* Yielding on PL-17 started at 13500 lbs and .02 in.
* Bulging on PL-17 started at 16000 lbs and .04 in.
* Load decreases at 16500 lbs at .08 in.
* Cracks formed at the tip of the plate at 0.2 in.

## CHART



**Test No: 14** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Load per | F1 | F2 | F3 | F4 | R1 | R2 | R3 | R4 | Total |
| Data Point | Plate (kips) | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | Avg |
| 1 | 0.0 | -0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 |
| 2 | 1.7 | 0.000 | -0.001 | -0.003 | -0.002 | -0.007 | -0.006 | 0.000 | 0.000 | 0.002 |
| 3 | 4.0 | -0.001 | 0.000 | -0.006 | -0.006 | -0.014 | -0.012 | 0.001 | 0.002 | 0.004 |
| 4 | 5.6 | -0.001 | -0.001 | -0.008 | -0.007 | -0.019 | -0.017 | 0.002 | 0.004 | 0.006 |
| 5 | 6.4 | -0.001 | -0.001 | -0.010 | -0.009 | -0.020 | -0.017 | 0.001 | 0.004 | 0.006 |
| 6 | 6.7 | 0.000 | -0.001 | -0.010 | -0.011 | -0.021 | -0.017 | 0.001 | 0.006 | 0.007 |
| 7 | 7.8 | 0.000 | -0.002 | -0.012 | -0.013 | -0.026 | -0.018 | 0.000 | 0.007 | 0.008 |
| 8 | 8.5 | 0.000 | -0.002 | -0.013 | -0.015 | -0.028 | -0.018 | 0.000 | 0.008 | 0.009 |
| 9 | 9.2 | -0.001 | -0.003 | -0.015 | -0.017 | -0.030 | -0.018 | -0.001 | 0.009 | 0.009 |
| 10 | 10.1 | -0.001 | -0.004 | -0.016 | -0.020 | -0.033 | -0.019 | -0.002 | 0.010 | 0.011 |
| 11 | 10.8 | -0.001 | -0.005 | -0.018 | -0.022 | -0.036 | -0.019 | -0.002 | 0.011 | 0.012 |
| 12 | 11.8 | -0.002 | -0.007 | -0.021 | -0.025 | -0.040 | -0.021 | -0.004 | 0.012 | 0.013 |
| 13 | 12.5 | -0.006 | -0.009 | -0.024 | -0.029 | -0.043 | -0.021 | -0.006 | 0.013 | 0.015 |
| 14 | 13.1 | -0.008 | -0.012 | -0.028 | -0.033 | -0.046 | -0.021 | -0.007 | 0.014 | 0.018 |
| 15 | 14.1 | -0.015 | -0.020 | -0.036 | -0.043 | -0.050 | -0.022 | -0.009 | 0.015 | 0.023 |
| 16 | 14.7 | -0.021 | -0.026 | -0.043 | -0.050 | -0.054 | -0.023 | -0.011 | 0.015 | 0.027 |
| 17 | 15.6 | -0.032 | -0.039 | -0.054 | -0.063 | -0.060 | -0.025 | -0.015 | 0.008 | 0.035 |
| 18 | 16.0 | -0.070 | -0.079 | -0.092 | -0.101 | -0.070 | -0.029 | -0.021 | 0.007 | 0.057 |
| 19 | 16.4 | -0.092 | -0.101 | -0.114 | -0.122 | -0.078 | -0.033 | -0.028 | 0.006 | 0.070 |
| 20 | 16.3 | -0.120 | -0.128 | -0.142 | -0.149 | -0.095 | -0.048 | -0.043 | -0.007 | 0.091 |
| 21 | 15.5 | -0.142 | -0.149 | -0.164 | -0.171 | -0.120 | -0.072 | -0.069 | -0.032 | 0.115 |
| 22 | 15.7 | -0.183 | -0.189 | -0.205 | -0.211 | -0.158 | -0.111 | -0.107 | -0.069 | 0.154 |
| 23 | 14.9 | -0.237 | -0.243 | -0.260 | -0.266 | -0.214 | -0.167 | -0.162 | -0.124 | 0.209 |
| 24 | 14.4 | -0.292 | -0.301 | -0.317 | -0.323 | -0.275 | -0.228 | -0.222 | -0.184 | 0.268 |
| 25 | 14.3 | -0.336 | -0.344 | -0.361 | -0.365 | -0.321 | -0.275 | -0.268 | -0.231 | 0.313 |
| 26 | 14.1 | -0.388 | -0.396 | -0.416 | -0.418 | -0.376 | -0.331 | -0.325 | -0.289 | 0.367 |
| 27 | 13.8 | -0.439 | -0.447 | -0.468 | -0.472 | -0.430 | -0.386 | -0.381 | -0.345 | 0.421 |
| 28 | 13.6 | -0.482 | -0.492 | -0.514 | -0.517 | -0.475 | -0.432 | 0.000 | -0.392 | 0.413 |
| 29 | 13.1 | -0.537 | -0.548 | -0.570 | -0.572 | -0.528 | -0.486 | -0.483 | -0.447 | 0.521 |
| 30 | 12.4 | -0.638 | -0.647 | -0.667 | -0.668 | -0.619 | -0.577 | -0.575 | -0.538 | 0.616 |
| | 11.8 | | -0.699 | | | | | -0.624 | -0.590 | 0.638 |
| 32 | 10.8 | -0.739 | -0.746 | -0.768 | -0.761 | -0.692 | -0.652 | -0.647 | -0.615 | 0.703 |
| 33 | 10.5 | -0.743 | -0.749 | -0.771 | -0.764 | -0.695 | -0.655 | -0.651 | -0.619 | 0.706 |

Test No: 15 **Summary of One Bolt Lap Connection Tests**
Recorder: BK

## TEST DESIGNATION

Test Designation: 1/8X1/2X3/4 Date: 3/13/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.125 | 1.5 | SHEAR | 15 |
| Bottom: | 4 | 0.5 | 1.5 | SAW | 12 |

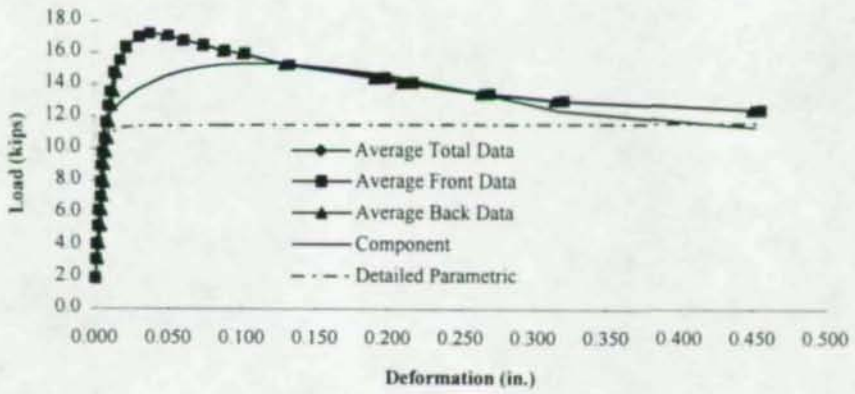
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bearing/Tearout | | |
| | Maximum: | 0.037 | 17.2 |
| | Failure: | 0.453 | 12.4 |
| | Other: | 0.16 | 14.8 |
| | | 0.25 | 13.7 |
| | | 0.34 | 12.9 |

## COMMENTS

* Yielding started at 13500 lbs and .013 in.
* Bulging on PL-17 started at .03 in. and 17000 lbs.
* Load decreased after 17250 lbs.
* Splitting observed at 0.13 in.

## CHART



**Test No: 15** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

**DATA**

| | | *Potentiometer Readings (in.)* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Load per | F1 | F2 | F3 | F4 | R1 | R2 | R3 | R4 | Total |
| Data Point | Plate (kips) | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | Avg |
| 1 | 2.0 | -0.001 | 0.000 | -0.001 | 0.000 | -0.002 | -0.001 | 0.000 | 0.000 | 0.001 |
| 2 | 3.1 | -0.001 | 0.000 | -0.002 | -0.001 | -0.004 | -0.003 | 0.001 | 0.002 | 0.001 |
| 3 | 4.1 | -0.002 | 0.000 | -0.002 | -0.001 | -0.005 | -0.004 | 0.001 | 0.002 | 0.001 |
| 4 | 5.2 | -0.002 | 0.000 | -0.004 | -0.002 | -0.008 | -0.006 | 0.001 | 0.003 | 0.002 |
| 5 | 6.1 | -0.002 | 0.000 | -0.006 | -0.002 | -0.009 | -0.007 | 0.001 | 0.003 | 0.003 |
| 6 | 7.0 | -0.004 | -0.001 | -0.007 | -0.004 | -0.010 | -0.008 | 0.000 | 0.003 | 0.004 |
| 7 | 7.9 | -0.004 | -0.001 | -0.008 | -0.004 | -0.012 | -0.009 | 0.000 | 0.004 | 0.004 |
| 8 | 9.0 | -0.006 | 0.000 | -0.010 | -0.005 | -0.015 | -0.010 | -0.001 | 0.004 | 0.005 |
| 9 | 9.8 | -0.006 | 0.000 | -0.011 | -0.006 | -0.017 | -0.012 | -0.001 | 0.004 | 0.006 |
| 10 | 10.6 | -0.007 | 0.001 | -0.013 | -0.007 | -0.018 | -0.013 | -0.002 | 0.004 | 0.007 |
| 11 | 11.6 | -0.008 | 0.001 | -0.015 | -0.009 | -0.020 | -0.014 | -0.003 | 0.004 | 0.008 |
| 12 | 12.7 | -0.010 | 0.000 | -0.018 | -0.010 | -0.023 | -0.016 | -0.004 | 0.004 | 0.010 |
| 13 | 13.5 | -0.012 | 0.000 | -0.020 | -0.011 | -0.026 | -0.018 | -0.006 | 0.004 | 0.011 |
| 14 | 14.7 | -0.015 | -0.002 | -0.024 | -0.013 | -0.029 | -0.020 | -0.009 | 0.002 | 0.014 |
| 15 | 15.5 | -0.019 | -0.005 | -0.029 | -0.017 | -0.034 | -0.023 | -0.012 | 0.000 | 0.017 |
| 16 | 16.3 | -0.023 | -0.008 | -0.034 | -0.020 | -0.040 | -0.028 | -0.017 | -0.003 | 0.021 |
| 17 | 17.0 | -0.032 | -0.015 | -0.043 | -0.029 | -0.050 | -0.035 | -0.026 | -0.010 | 0.030 |
| 18 | 17.2 | -0.040 | -0.023 | -0.051 | -0.036 | -0.056 | -0.042 | -0.032 | -0.017 | 0.037 |
| 19 | 17.0 | -0.053 | -0.035 | -0.064 | -0.050 | -0.068 | -0.053 | -0.044 | -0.028 | 0.049 |
| *20* | *16.8* | *-0.063* | *-0.046* | *-0.075* | *-0.060* | *-0.079* | *-0.065* | *-0.055* | *-0.039* | *0.060* |
| 21 | 16.5 | -0.076 | -0.059 | -0.087 | -0.073 | -0.092 | -0.078 | -0.069 | -0.053 | 0.074 |
| 22 | 16.1 | -0.091 | -0.074 | -0.101 | -0.088 | -0.106 | -0.092 | -0.083 | -0.067 | 0.088 |
| 23 | 15.9 | -0.104 | -0.088 | -0.115 | -0.102 | -0.119 | -0.106 | -0.097 | -0.080 | 0.101 |
| 24 | 15.2 | -0.135 | -0.119 | -0.146 | -0.133 | -0.147 | -0.135 | -0.126 | -0.107 | 0.131 |
| 25 | 14.4 | -0.200 | -0.185 | -0.210 | -0.200 | -0.208 | -0.196 | -0.188 | -0.169 | 0.195 |
| 26 | 14.1 | -0.220 | -0.204 | -0.229 | -0.219 | -0.227 | -0.215 | -0.207 | -0.188 | 0.214 |
| 27 | 13.5 | -0.271 | -0.257 | -0.282 | -0.272 | -0.283 | -0.269 | -0.261 | -0.243 | 0.267 |
| 28 | 13.0 | -0.322 | -0.308 | -0.333 | -0.324 | -0.334 | -0.321 | -0.311 | -0.293 | 0.318 |
| 29 | 12.4 | -0.455 | -0.443 | -0.468 | -0.459 | -0.470 | -0.456 | -0.447 | -0.427 | 0.453 |

**Test No: 16** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/8X5/8X3/4 Date: 3/14/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 0 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.125 | 1.5 | SAW | 17 |
| Bottom: | 4 | 0.625 | 1.5 | SAW | 27 |

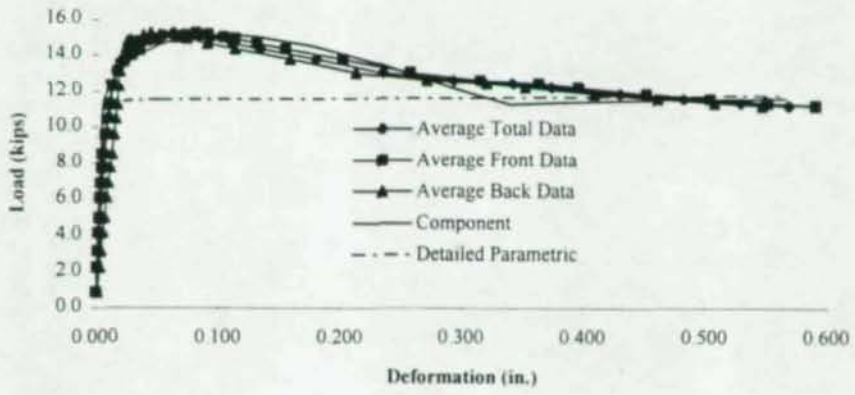
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Splitting | Maximum: | 0.064 | 15.2 |
| | | Failure: | 0.569 | 11.2 |
| | | Other: | 0.16 | 14 |
| | | | 0.25 | 12.9 |
| | | | 0.34 | 12.5 |

## COMMENTS

* Yielding on PL-17 started at 13500 lbs and 0.02 in.
* At 14500 lbs, bulging on PL-17 was observed.
* After 15500 lbs, load decreased.
* Splitting seen at 0.11 in.

## CHART



Test No: 16
Recorder: BK

**Summary of One Bolt Lap Connection Tests**

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.9 | 0.000 | 0.000 | -0.002 | -0.001 | -0.002 | -0.002 | 0.000 | 0.001 | 0.001 |
| 2 | 2.3 | -0.001 | 0.000 | -0.003 | -0.002 | -0.006 | -0.006 | 0.001 | 0.001 | 0.002 |
| 3 | 3.1 | -0.001 | 0.000 | -0.004 | -0.002 | -0.009 | -0.007 | 0.001 | 0.002 | 0.003 |
| 4 | 4.2 | -0.001 | 0.000 | -0.005 | -0.004 | -0.010 | -0.010 | 0.001 | 0.002 | 0.003 |
| 5 | 5.0 | -0.001 | 0.000 | -0.006 | -0.006 | -0.013 | -0.011 | 0.002 | 0.003 | 0.004 |
| 6 | 6.1 | -0.001 | 0.000 | -0.008 | -0.006 | -0.016 | -0.014 | 0.002 | 0.004 | 0.005 |
| 7 | 6.9 | -0.001 | 0.000 | -0.009 | -0.007 | -0.018 | -0.017 | 0.002 | 0.004 | 0.006 |
| 8 | 7.8 | -0.002 | 0.000 | -0.010 | -0.009 | -0.021 | -0.018 | 0.002 | 0.005 | 0.007 |
| 9 | 8.5 | -0.004 | 0.000 | -0.011 | -0.007 | -0.023 | -0.023 | 0.004 | 0.004 | 0.007 |
| 10 | 9.6 | -0.006 | 0.001 | -0.015 | -0.009 | -0.025 | -0.026 | 0.006 | 0.003 | 0.009 |
| 11 | 10.5 | -0.008 | 0.001 | -0.018 | -0.011 | -0.027 | -0.029 | 0.007 | 0.002 | 0.010 |
| 12 | 11.3 | -0.009 | 0.000 | -0.020 | -0.013 | -0.029 | -0.031 | 0.007 | 0.002 | 0.012 |
| 13 | 12.3 | -0.012 | -0.001 | -0.024 | -0.016 | -0.032 | -0.035 | 0.007 | 0.001 | 0.014 |
| 14 | 13.1 | -0.018 | -0.006 | -0.029 | -0.021 | -0.034 | -0.039 | 0.007 | -0.001 | 0.018 |
| 15 | 13.6 | -0.024 | -0.010 | -0.034 | -0.026 | -0.035 | -0.041 | 0.007 | -0.002 | 0.021 |
| 16 | 14.0 | -0.029 | -0.017 | -0.041 | -0.032 | -0.038 | -0.045 | 0.007 | -0.004 | 0.025 |
| 17 | 14.4 | -0.035 | -0.023 | -0.047 | -0.039 | -0.041 | -0.048 | 0.006 | -0.006 | 0.029 |
| 18 | 14.3 | -0.036 | -0.023 | -0.047 | -0.039 | -0.041 | -0.048 | 0.006 | -0.006 | 0.029 |
| 19 | 14.8 | -0.042 | -0.029 | -0.053 | -0.044 | -0.043 | -0.051 | 0.004 | -0.008 | 0.033 |
| 20 | 14.9 | -0.051 | -0.039 | -0.062 | -0.053 | -0.047 | -0.056 | 0.002 | -0.012 | 0.040 |
| 21 | 15.1 | -0.073 | -0.061 | -0.083 | -0.075 | -0.058 | -0.068 | -0.008 | -0.023 | 0.056 |
| 22 | 15.2 | -0.083 | -0.070 | -0.092 | -0.083 | -0.064 | -0.075 | -0.013 | -0.029 | 0.064 |
| 23 | 15.2 | -0.093 | -0.080 | -0.103 | -0.094 | -0.071 | -0.082 | -0.021 | -0.037 | 0.072 |
| 24 | 15.0 | -0.106 | -0.092 | -0.116 | -0.106 | -0.084 | -0.095 | -0.034 | -0.050 | 0.085 |
| 25 | 14.9 | -0.114 | -0.102 | -0.124 | -0.116 | -0.093 | -0.104 | -0.043 | -0.059 | 0.094 |
| 26 | 14.6 | -0.133 | -0.120 | -0.143 | -0.133 | -0.109 | -0.120 | -0.061 | -0.076 | 0.112 |
| 27 | 14.4 | -0.157 | -0.144 | -0.165 | -0.157 | -0.132 | -0.144 | -0.083 | -0.099 | 0.135 |
| 28 | 13.8 | -0.204 | -0.191 | -0.213 | -0.203 | -0.177 | -0.188 | -0.128 | -0.144 | 0.181 |
| 29 | 13.0 | -0.258 | -0.248 | -0.268 | -0.259 | -0.232 | -0.242 | -0.183 | -0.197 | 0.236 |
| 30 | 12.6 | -0.316 | -0.307 | -0.325 | -0.317 | -0.288 | -0.300 | -0.242 | -0.256 | 0.294 |
| 31 | 12.5 | -0.364 | -0.354 | -0.373 | -0.364 | -0.338 | -0.349 | -0.290 | -0.304 | 0.342 |
| 32 | 12.2 | -0.397 | -0.387 | -0.404 | -0.397 | -0.370 | -0.381 | -0.323 | -0.335 | 0.374 |
| 33 | 11.9 | -0.451 | -0.443 | -0.460 | -0.453 | -0.425 | -0.438 | -0.380 | -0.393 | 0.430 |
| 34 | 11.6 | -0.505 | -0.496 | -0.511 | -0.505 | -0.477 | -0.490 | -0.432 | -0.445 | 0.483 |
| 35 | 11.4 | -0.552 | -0.544 | -0.558 | -0.552 | -0.523 | -0.536 | -0.479 | -0.493 | 0.530 |
| 36 | 11.2 | -0.591 | -0.584 | -0.596 | -0.591 | -0.562 | -0.576 | -0.518 | -0.531 | 0.569 |

**Test No: 17** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X1X3/4 Date: 3/14/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.5 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.25 | 1.5 | SHEAR | 18 |
| Bottom: | 4 | 1 | 1.5 | SAW | 5 |

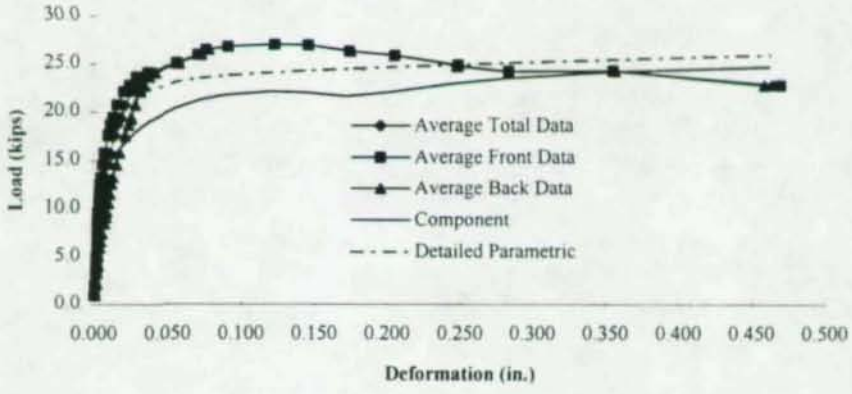
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bearing/Tearout | | |
| | Maximum: | 0.146 | 27 |
| | Failure: | 0.464 | 22.8 |
| | Other: | 0.16 | 26.6 |
| | | 0.25 | 24.7 |
| | | 0.34 | 24.3 |

## COMMENTS

* Yielding on PL-18 started at 22000 lbs and 0.025 in.
* At 25000 lbs splitting occurred.
* After 27000 lbs at 0.15 in. load decreased.

## CHART



**Test No: 17**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 1.0 | 0.000 | 0.000 | -0.001 | -0.001 | -0.002 | 0.000 | -0.001 | 0.001 | 0.000 |
| 2 | 2.1 | -0.001 | 0.000 | -0.001 | -0.001 | -0.003 | -0.002 | -0.001 | 0.001 | 0.001 |
| 3 | 3.4 | -0.001 | 0.000 | -0.002 | -0.002 | -0.004 | -0.004 | -0.001 | 0.001 | 0.002 |
| 4 | 4.1 | -0.001 | 0.000 | -0.002 | -0.003 | -0.005 | -0.005 | 0.000 | 0.001 | 0.002 |
| 5 | 5.1 | -0.001 | 0.000 | -0.003 | -0.004 | -0.005 | -0.006 | 0.000 | 0.001 | 0.002 |
| 6 | 5.9 | -0.001 | 0.000 | -0.004 | -0.004 | -0.007 | -0.007 | 0.000 | 0.001 | 0.003 |
| 7 | 6.6 | -0.001 | 0.000 | -0.004 | -0.004 | -0.009 | -0.009 | 0.000 | 0.001 | 0.003 |
| 8 | 7.4 | -0.001 | 0.000 | -0.004 | -0.004 | -0.010 | -0.010 | 0.001 | 0.001 | 0.004 |
| 9 | 8.4 | -0.001 | 0.000 | -0.004 | -0.004 | -0.013 | -0.013 | 0.001 | 0.001 | 0.004 |
| 10 | 9.1 | -0.002 | 0.000 | -0.004 | -0.004 | -0.015 | -0.016 | 0.001 | 0.001 | 0.005 |
| 11 | 9.7 | -0.002 | 0.000 | -0.005 | -0.004 | -0.015 | -0.017 | 0.002 | 0.001 | 0.005 |
| 12 | 10.6 | -0.002 | 0.000 | -0.006 | -0.006 | -0.016 | -0.020 | 0.002 | -0.001 | 0.006 |
| 13 | 11.5 | -0.002 | 0.000 | -0.007 | -0.006 | -0.017 | -0.022 | 0.002 | -0.001 | 0.007 |
| 14 | 12.5 | -0.002 | -0.001 | -0.007 | -0.007 | -0.018 | -0.025 | 0.004 | -0.002 | 0.007 |
| 15 | 13.3 | -0.002 | -0.001 | -0.009 | -0.009 | -0.018 | -0.027 | 0.004 | -0.003 | 0.008 |
| 16 | 14.6 | -0.002 | -0.001 | -0.010 | -0.011 | -0.020 | -0.031 | 0.005 | -0.006 | 0.009 |
| 17 | 15.8 | -0.002 | -0.002 | -0.011 | -0.014 | -0.020 | -0.036 | 0.006 | -0.008 | 0.011 |
| 18 | 17.7 | -0.002 | -0.005 | -0.013 | -0.019 | -0.024 | -0.043 | 0.006 | -0.012 | 0.014 |
| 19 | 18.7 | -0.003 | -0.007 | -0.014 | -0.022 | -0.026 | -0.048 | 0.006 | -0.015 | 0.016 |
| 20 | 19.4 | -0.003 | -0.009 | -0.015 | -0.026 | -0.028 | -0.051 | 0.004 | -0.018 | 0.018 |
| 21 | 19.3 | -0.003 | -0.009 | -0.015 | -0.026 | -0.027 | -0.051 | 0.005 | -0.018 | 0.018 |
| 22 | 20.7 | -0.004 | -0.012 | -0.018 | -0.031 | -0.031 | -0.057 | 0.004 | -0.021 | 0.021 |
| 23 | 22.1 | -0.006 | -0.017 | -0.021 | -0.039 | -0.035 | -0.065 | 0.002 | -0.026 | 0.026 |
| 24 | 22.8 | -0.007 | -0.022 | -0.023 | -0.045 | -0.038 | -0.070 | 0.001 | -0.030 | 0.029 |
| 25 | 23.7 | -0.010 | -0.027 | -0.028 | -0.052 | -0.041 | -0.076 | -0.001 | -0.034 | 0.033 |
| 26 | 24.1 | -0.015 | -0.035 | -0.034 | -0.063 | -0.045 | -0.081 | -0.004 | -0.038 | 0.039 |
| 27 | 25.1 | -0.031 | -0.057 | -0.052 | -0.086 | -0.060 | -0.100 | -0.017 | -0.054 | 0.057 |
| 28 | 25.9 | -0.043 | -0.072 | -0.065 | -0.103 | -0.076 | -0.118 | -0.030 | -0.069 | 0.072 |
| 29 | 26.4 | -0.048 | -0.077 | -0.071 | -0.109 | -0.081 | -0.124 | -0.034 | -0.074 | 0.077 |
| 30 | 26.8 | -0.062 | -0.092 | -0.085 | -0.125 | -0.094 | -0.138 | -0.047 | -0.087 | 0.091 |
| 31 | 27.0 | -0.092 | -0.125 | -0.117 | -0.158 | -0.125 | -0.169 | -0.076 | -0.119 | 0.123 |
| 32 | 27.0 | -0.114 | -0.148 | -0.140 | -0.182 | -0.149 | -0.193 | -0.100 | -0.143 | 0.146 |
| 33 | 26.3 | -0.142 | -0.176 | -0.168 | -0.212 | -0.178 | -0.223 | -0.128 | -0.173 | 0.175 |
| 34 | 25.9 | -0.172 | -0.209 | -0.199 | -0.243 | -0.208 | -0.252 | -0.158 | -0.202 | 0.205 |
| 35 | 24.8 | -0.215 | -0.253 | -0.242 | -0.286 | -0.250 | -0.295 | -0.202 | -0.244 | 0.248 |
| 36 | 24.8 | -0.215 | -0.253 | -0.242 | -0.286 | -0.250 | -0.295 | -0.202 | -0.244 | 0.248 |
| 37 | 24.3 | -0.250 | -0.288 | -0.276 | -0.322 | -0.285 | -0.330 | -0.239 | -0.280 | 0.284 |
| 38 | 24.3 | -0.322 | -0.357 | -0.347 | -0.395 | -0.357 | -0.402 | -0.312 | -0.354 | 0.356 |
| 39 | 22.8 | -0.436 | -0.472 | -0.462 | -0.508 | -0.460 | -0.507 | -0.413 | -0.454 | 0.464 |

**Test No: 18** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 3/8X3/8X3/4 Date: 3/15/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.375 | 1.5 | Unknown | 21 |
| Bottom: | 4 | 0.375 | 1.5 | Unknown | 21 |

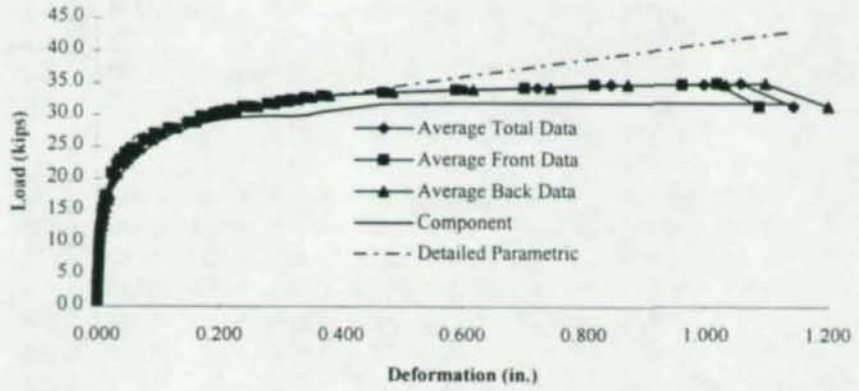
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Splitting | | |
| | Maximum: | 1.057 | 35 |
| | Failure: | 1.057 | 35 |
| | Other: | 0.16 | 29 |
| | | 0.25 | 31.2 |
| | | 0.34 | 32.6 |

## COMMENTS

* Yielding occurred on PL-21 at 24000 lbs and 0.05 in.
* Bulging on PL-21 started at 0.1 in.
* Tips of the plates curled back at 30500 lbs and 0.21 in.

## CHART



Test No: 18
Recorder: BK

## Summary of One Bolt Lap Connection Tests

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.9 | -0.001 | -0.001 | -0.001 | 0.000 | -0.001 | 0.000 | -0.001 | -0.001 | 0.001 |
| 2 | 2.1 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.002 | -0.001 | 0.001 |
| 3 | 3.3 | -0.001 | -0.001 | -0.002 | -0.001 | -0.002 | -0.002 | -0.002 | -0.001 | 0.001 |
| 4 | 4.3 | -0.002 | -0.002 | -0.002 | -0.001 | -0.002 | -0.002 | -0.002 | -0.001 | 0.002 |
| 5 | 4.9 | -0.002 | -0.002 | -0.002 | -0.001 | -0.002 | -0.002 | -0.002 | -0.001 | 0.002 |
| 6 | 5.9 | -0.003 | -0.002 | -0.004 | -0.001 | -0.003 | -0.002 | -0.003 | -0.001 | 0.002 |
| 7 | 6.9 | -0.004 | -0.002 | -0.004 | -0.001 | -0.005 | -0.002 | -0.004 | -0.001 | 0.003 |
| 8 | 7.9 | -0.005 | -0.002 | -0.005 | -0.001 | -0.005 | -0.003 | -0.005 | -0.001 | 0.003 |
| 9 | 8.6 | -0.006 | -0.002 | -0.006 | -0.001 | -0.006 | -0.003 | -0.006 | -0.001 | 0.004 |
| 10 | 9.7 | -0.006 | -0.003 | -0.007 | -0.001 | -0.007 | -0.004 | -0.006 | -0.001 | 0.004 |
| 11 | 10.5 | -0.007 | -0.003 | -0.007 | -0.001 | -0.008 | -0.004 | -0.007 | -0.002 | 0.005 |
| 12 | 11.5 | -0.009 | -0.003 | -0.009 | -0.001 | -0.009 | -0.004 | -0.007 | -0.002 | 0.006 |
| 13 | 12.5 | -0.012 | -0.003 | -0.010 | -0.001 | -0.012 | -0.007 | -0.011 | -0.004 | 0.007 |
| 14 | 13.5 | -0.015 | -0.004 | -0.013 | -0.002 | -0.014 | -0.009 | -0.014 | -0.006 | 0.009 |
| 15 | 14.5 | -0.016 | -0.004 | -0.015 | -0.002 | -0.017 | -0.010 | -0.016 | -0.007 | 0.011 |
| 16 | 15.5 | -0.017 | -0.005 | -0.017 | -0.003 | -0.020 | -0.012 | -0.019 | -0.009 | 0.013 |
| 17 | 16.6 | -0.020 | -0.006 | -0.020 | -0.004 | -0.024 | -0.015 | -0.024 | -0.010 | 0.015 |
| 18 | 17.4 | -0.021 | -0.007 | -0.022 | -0.006 | -0.028 | -0.017 | -0.026 | -0.012 | 0.018 |
| 19 | 20.8 | -0.032 | -0.016 | -0.033 | -0.015 | -0.042 | -0.028 | -0.040 | -0.021 | 0.028 |
| 20 | 22.3 | -0.041 | -0.024 | -0.042 | -0.024 | -0.054 | -0.039 | -0.051 | -0.031 | 0.038 |
| 21 | 22.9 | -0.045 | -0.029 | -0.046 | -0.029 | -0.060 | -0.044 | -0.057 | -0.037 | 0.043 |
| 22 | 22.9 | -0.045 | -0.030 | -0.046 | -0.029 | -0.060 | -0.043 | -0.057 | -0.037 | 0.043 |
| 23 | 24.0 | -0.053 | -0.039 | -0.054 | -0.038 | -0.071 | -0.053 | -0.067 | -0.046 | 0.053 |
| 24 | 24.7 | -0.062 | -0.050 | -0.064 | -0.049 | -0.083 | -0.065 | -0.078 | -0.058 | 0.064 |
| 25 | 26.0 | -0.081 | -0.070 | -0.084 | -0.069 | -0.101 | -0.085 | -0.097 | -0.077 | 0.083 |
| 26 | 27.0 | -0.098 | -0.087 | -0.101 | -0.086 | -0.116 | -0.101 | -0.113 | -0.093 | 0.099 |
| 27 | 27.8 | -0.122 | -0.111 | -0.124 | -0.111 | -0.141 | -0.125 | -0.138 | -0.118 | 0.124 |
| 28 | 28.8 | -0.154 | -0.144 | -0.155 | -0.143 | -0.171 | -0.155 | -0.169 | -0.149 | 0.155 |
| 29 | 29.7 | -0.172 | -0.164 | -0.175 | -0.163 | -0.191 | -0.175 | -0.189 | -0.170 | 0.175 |
| 30 | 30.1 | -0.194 | -0.186 | -0.196 | -0.185 | -0.213 | -0.196 | -0.210 | -0.191 | 0.196 |
| 31 | 30.4 | -0.204 | -0.196 | -0.205 | -0.195 | -0.223 | -0.206 | -0.221 | -0.200 | 0.206 |
| 32 | 30.7 | -0.218 | -0.211 | -0.220 | -0.210 | -0.237 | -0.221 | -0.235 | -0.215 | 0.221 |
| 33 | 31.2 | -0.239 | -0.234 | -0.242 | -0.232 | -0.260 | -0.244 | -0.258 | -0.238 | 0.243 |
| 34 | 31.2 | -0.251 | -0.248 | -0.255 | -0.246 | -0.273 | -0.256 | -0.272 | -0.251 | 0.256 |
| 35 | 31.7 | -0.279 | -0.277 | -0.283 | -0.275 | -0.301 | -0.284 | -0.300 | -0.279 | 0.285 |
| 36 | 32.1 | -0.300 | -0.297 | -0.303 | -0.295 | -0.321 | -0.304 | -0.322 | -0.300 | 0.305 |
| 37 | 32.3 | -0.316 | -0.315 | -0.320 | -0.313 | -0.338 | -0.321 | -0.339 | -0.317 | 0.322 |
| 38 | 32.7 | -0.338 | -0.338 | -0.342 | -0.335 | -0.360 | -0.344 | -0.361 | -0.340 | 0.345 |
| 39 | 33.0 | -0.365 | -0.366 | -0.371 | -0.364 | -0.389 | -0.373 | -0.390 | -0.369 | 0.373 |
| 40 | 33.6 | -0.465 | -0.469 | -0.470 | -0.467 | -0.495 | -0.479 | -0.495 | -0.469 | 0.476 |
| 41 | 34.0 | -0.584 | -0.590 | -0.591 | -0.588 | -0.629 | -0.613 | -0.625 | -0.599 | 0.602 |
| 42 | 34.3 | -0.697 | -0.704 | -0.704 | -0.702 | -0.755 | -0.740 | -0.756 | -0.725 | 0.723 |
| 43 | 34.8 | -0.812 | -0.821 | -0.818 | -0.815 | -0.881 | -0.864 | -0.887 | -0.855 | 0.844 |
| 44 | 34.8 | -0.956 | -0.966 | -0.959 | -0.960 | -1.037 | -1.018 | -1.052 | -1.019 | 0.996 |
| 45 | 35.0 | -1.015 | -1.025 | -1.013 | -1.015 | -1.099 | -1.082 | -1.119 | -1.087 | 1.057 |
| 46 | 31.4 | -1.087 | -1.098 | -1.081 | -1.081 | -1.197 | -1.183 | -1.224 | -1.195 | 1.143 |

**Test No: 19** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 3/8X1X3/4 Date: 3/15/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.75 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.375 | 1.5 | Unknown | 21 |
| Bottom: | 4 | 1 | 1.5 | SAW | 5 |

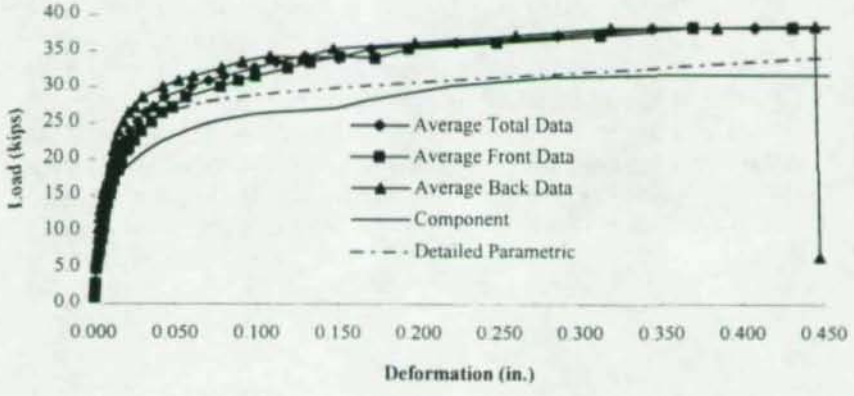
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.467 | 38.5 |
| | Failure: | 0.467 | 38.5 |
| | Other: | 0.16 | 34.7 |
| | | 0.25 | 36.7 |
| | | 0.34 | 38.3 |

## COMMENTS

*Yielding on PL-21 observed at 25000 lbs.
* Bulging on PL-21 observed at 37000 lbs.

## CHART



**Test No: 19**
**Recorder: BK**

## Summary of One Bolt Lap Connection Tests

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 0.000 | 0.000 | -0.001 | -0.001 | -0.001 | 0.000 | -0.001 | 0.000 | 0.001 |
| 2 | 2.0 | -0.001 | 0.000 | -0.002 | -0.001 | -0.002 | 0.000 | -0.001 | 0.000 | 0.001 |
| 3 | 2.9 | 0.000 | 0.000 | -0.002 | -0.002 | -0.004 | 0.000 | -0.001 | 0.001 | 0.001 |
| 4 | 4.9 | 0.000 | 0.000 | -0.004 | -0.003 | -0.004 | 0.000 | -0.001 | 0.001 | 0.001 |
| 5 | 5.4 | 0.000 | 0.001 | -0.004 | -0.004 | -0.005 | 0.000 | -0.001 | 0.001 | 0.002 |
| 6 | 6.4 | -0.001 | 0.001 | -0.006 | -0.004 | -0.006 | 0.000 | -0.002 | 0.001 | 0.002 |
| 7 | 7.0 | -0.001 | 0.001 | -0.006 | -0.006 | -0.006 | 0.000 | -0.002 | 0.001 | 0.002 |
| 8 | 7.6 | -0.001 | 0.001 | -0.007 | -0.007 | -0.007 | 0.000 | -0.002 | 0.001 | 0.003 |
| 9 | 9.1 | -0.001 | 0.001 | -0.010 | -0.009 | -0.007 | 0.000 | -0.004 | 0.001 | 0.003 |
| 10 | 10.4 | -0.001 | 0.001 | -0.012 | -0.011 | -0.007 | 0.000 | -0.004 | 0.001 | 0.004 |
| 11 | 11.9 | -0.001 | 0.001 | -0.013 | -0.013 | -0.009 | 0.000 | -0.005 | 0.001 | 0.005 |
| 12 | 13.0 | -0.001 | 0.000 | -0.014 | -0.015 | -0.010 | 0.000 | -0.005 | 0.001 | 0.005 |
| 13 | 13.9 | -0.001 | -0.001 | -0.015 | -0.016 | -0.012 | 0.000 | -0.006 | 0.001 | 0.006 |
| 14 | 15.2 | -0.002 | -0.002 | -0.017 | -0.018 | -0.014 | 0.000 | -0.007 | 0.002 | 0.007 |
| 15 | 16.0 | -0.002 | -0.003 | -0.018 | -0.020 | -0.016 | 0.000 | -0.008 | 0.002 | 0.008 |
| 16 | 17.1 | -0.004 | -0.004 | -0.020 | -0.022 | -0.020 | 0.000 | -0.010 | 0.002 | 0.010 |
| 17 | 18.5 | -0.006 | -0.006 | -0.023 | -0.026 | -0.024 | 0.000 | -0.013 | 0.002 | 0.012 |
| 18 | 19.6 | -0.007 | -0.009 | -0.026 | -0.029 | -0.028 | 0.000 | -0.014 | 0.002 | 0.014 |
| 19 | 21.2 | -0.008 | -0.011 | -0.029 | -0.034 | -0.032 | 0.000 | -0.017 | 0.002 | 0.016 |
| 20 | 21.6 | -0.009 | -0.012 | -0.031 | -0.036 | -0.033 | 0.000 | -0.018 | 0.002 | 0.017 |
| 21 | 22.6 | -0.010 | -0.015 | -0.035 | -0.042 | -0.036 | 0.000 | -0.020 | 0.001 | 0.020 |
| 22 | 23.9 | -0.013 | -0.019 | -0.039 | -0.048 | -0.040 | 0.000 | -0.022 | -0.001 | 0.023 |
| 23 | 25.2 | -0.017 | -0.024 | -0.046 | -0.056 | -0.045 | 0.000 | -0.026 | -0.004 | 0.027 |
| 24 | 26.4 | -0.022 | -0.030 | -0.053 | -0.064 | -0.051 | 0.000 | -0.029 | -0.008 | 0.032 |
| 25 | 27.2 | -0.026 | -0.036 | -0.060 | -0.072 | -0.057 | -0.001 | -0.033 | -0.012 | 0.037 |
| 26 | 28.6 | -0.033 | -0.044 | -0.069 | -0.082 | -0.065 | -0.001 | -0.039 | -0.017 | 0.044 |
| 27 | 30.0 | -0.052 | -0.064 | -0.091 | -0.105 | -0.082 | -0.004 | -0.053 | -0.032 | 0.060 |
| 28 | 30.9 | -0.061 | -0.076 | -0.102 | -0.117 | -0.093 | -0.012 | -0.062 | -0.042 | 0.071 |
| 29 | 31.6 | -0.070 | -0.086 | -0.113 | -0.129 | -0.103 | -0.021 | -0.070 | -0.050 | 0.080 |
| 30 | 32.7 | -0.089 | -0.106 | -0.133 | -0.150 | -0.121 | -0.041 | -0.086 | -0.067 | 0.099 |
| 31 | 33.6 | -0.102 | -0.119 | -0.147 | -0.165 | -0.134 | -0.054 | -0.097 | -0.080 | 0.112 |
| 32 | 34.3 | -0.119 | -0.138 | -0.166 | -0.184 | -0.151 | -0.073 | -0.113 | -0.096 | 0.130 |
| 33 | 34.1 | -0.139 | -0.158 | -0.188 | -0.207 | -0.171 | -0.095 | -0.132 | -0.116 | 0.151 |
| 34 | 35.4 | -0.158 | -0.179 | -0.209 | -0.229 | -0.191 | -0.116 | -0.149 | -0.134 | 0.171 |
| 35 | 36.3 | -0.211 | -0.234 | -0.264 | -0.286 | -0.243 | -0.169 | -0.196 | -0.183 | 0.223 |
| 36 | 37.3 | -0.272 | -0.298 | -0.328 | -0.351 | -0.306 | -0.234 | -0.256 | -0.244 | 0.286 |
| 37 | 38.3 | -0.328 | -0.354 | -0.387 | -0.409 | -0.366 | -0.294 | -0.314 | -0.301 | 0.344 |
| 38 | 38.3 | -0.388 | -0.415 | -0.448 | -0.473 | -0.431 | -0.361 | -0.378 | -0.366 | 0.408 |
| 39 | 38.5 | -0.446 | -0.474 | -0.508 | -0.533 | -0.492 | -0.423 | -0.438 | -0.425 | 0.467 |
| 40 | 6.6 | -1.518 | -0.843 | -1.102 | -1.523 | -0.487 | -0.450 | -0.426 | -0.426 | 0.847 |

**Test No: 20** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/2X1/2X3/4 Date: 3/15/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.25 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.5 | 1.5 | SHEAR | 26 |
| Bottom: | 4 | 0.5 | 1.5 | SHEAR | 26 |

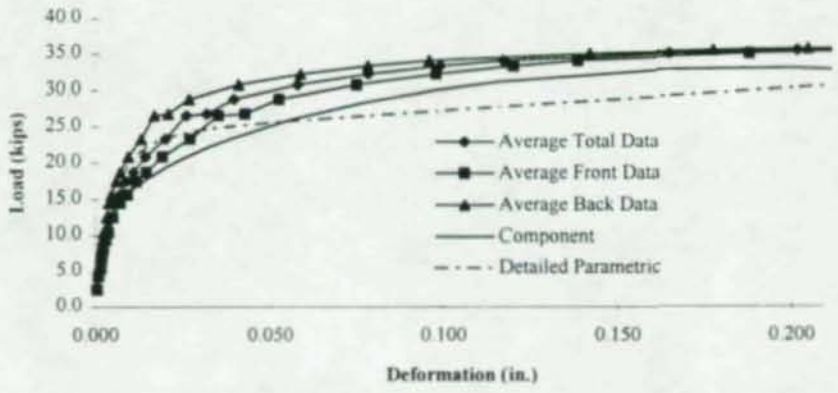
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.23 | 35.7 |
| | Failure: | 0.268 | 35.5 |
| | Other: | 0.16 | 34.9 |
| | | 0.25 | 35.6 |
| | | 0.34 | NA |

## COMMENTS

* Yielding on PL-26 started at 28000 lbs.

## CHART



**Test No: 20**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Load per | *F1* | *F2* | *F3* | *F4* | *R1* | *R2* | *R3* | *R4* | Total |
| Data Point | Plate (kips) | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | Avg |
| 1 | 2.4 | -0.001 | 0.000 | -0.001 | 0.000 | -0.001 | 0.000 | -0.001 | -0.001 | 0.000 |
| 2 | 4.2 | -0.002 | -0.001 | -0.001 | 0.000 | -0.001 | -0.001 | -0.001 | -0.001 | 0.001 |
| 3 | 5.3 | -0.003 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | 0.001 |
| 4 | 6.2 | -0.003 | -0.001 | -0.002 | -0.001 | -0.002 | -0.001 | -0.001 | -0.002 | 0.002 |
| 5 | 6.9 | -0.004 | -0.001 | -0.002 | -0.001 | -0.001 | -0.001 | -0.002 | -0.002 | 0.002 |
| 6 | 7.6 | -0.004 | -0.001 | -0.002 | -0.001 | -0.002 | -0.001 | -0.002 | -0.002 | 0.002 |
| 7 | 8.1 | -0.004 | -0.001 | -0.003 | -0.001 | -0.001 | -0.001 | -0.002 | -0.002 | 0.002 |
| 8 | 9.4 | -0.006 | -0.001 | -0.004 | -0.001 | -0.002 | -0.001 | -0.002 | -0.002 | 0.003 |
| 9 | 10.4 | -0.007 | -0.001 | -0.006 | -0.001 | -0.002 | -0.001 | -0.003 | -0.003 | 0.003 |
| 10 | 12.5 | -0.010 | -0.001 | -0.009 | -0.001 | -0.002 | -0.002 | -0.004 | -0.004 | 0.004 |
| 11 | 14.4 | -0.015 | -0.001 | -0.013 | -0.001 | -0.003 | -0.003 | -0.005 | -0.004 | 0.006 |
| 12 | 15.6 | -0.018 | -0.001 | -0.016 | -0.001 | -0.004 | -0.004 | -0.006 | -0.006 | 0.007 |
| 13 | 17.4 | -0.023 | -0.002 | -0.020 | -0.002 | -0.005 | -0.006 | -0.006 | -0.007 | 0.009 |
| 14 | 18.7 | -0.026 | -0.004 | -0.024 | -0.004 | -0.007 | -0.007 | -0.007 | -0.008 | 0.011 |
| 15 | 20.8 | -0.032 | -0.009 | -0.029 | -0.007 | -0.010 | -0.009 | -0.010 | -0.010 | 0.014 |
| 16 | 23.3 | -0.042 | -0.016 | -0.038 | -0.013 | -0.014 | -0.012 | -0.013 | -0.013 | 0.020 |
| 17 | 26.5 | -0.050 | -0.024 | -0.046 | -0.021 | -0.018 | -0.015 | -0.018 | -0.017 | 0.026 |
| 18 | 26.7 | -0.057 | -0.031 | -0.055 | -0.028 | -0.023 | -0.019 | -0.021 | -0.020 | 0.032 |
| 19 | 28.8 | -0.067 | -0.042 | -0.065 | -0.037 | -0.030 | -0.025 | -0.028 | -0.025 | 0.040 |
| 20 | 30.8 | -0.091 | -0.064 | -0.087 | -0.059 | -0.046 | -0.039 | -0.042 | -0.038 | 0.058 |
| 21 | 32.2 | -0.114 | -0.087 | -0.109 | -0.081 | -0.064 | -0.057 | -0.059 | -0.055 | 0.078 |
| 22 | 33.3 | -0.136 | -0.110 | -0.131 | -0.104 | -0.084 | -0.076 | -0.079 | -0.074 | 0.099 |
| 23 | 34.1 | -0.154 | -0.128 | -0.150 | -0.123 | -0.101 | -0.093 | -0.098 | -0.092 | 0.117 |
| 24 | 35.0 | -0.204 | -0.177 | -0.199 | -0.172 | -0.148 | -0.139 | -0.144 | -0.138 | 0.165 |
| 25 | 35.5 | -0.242 | -0.215 | -0.237 | -0.210 | -0.184 | -0.176 | -0.179 | -0.173 | 0.202 |
| 26 | 35.7 | -0.270 | -0.245 | -0.266 | -0.237 | -0.211 | -0.203 | -0.205 | -0.200 | 0.230 |
| 27 | 35.5 | -0.312 | -0.284 | -0.306 | -0.276 | -0.248 | -0.240 | -0.242 | -0.236 | 0.268 |
| 28 | 9.2 | -0.919 | -0.633 | -0.517 | -0.479 | -0.239 | -0.240 | -0.231 | -0.225 | 0.435 |

**Test No: 21** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/2X5/8X3/4 Date: 3/16/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | |
|---|---|---|---|
| Type: | A325 | Diameter (in.): 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): 2.5 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: X | |
| | | Bolt Head Washer: X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.5 | 1.5 | SHEAR | 26 |
| Bottom: | 4 | 0.625 | 1.5 | SAW | 27 |

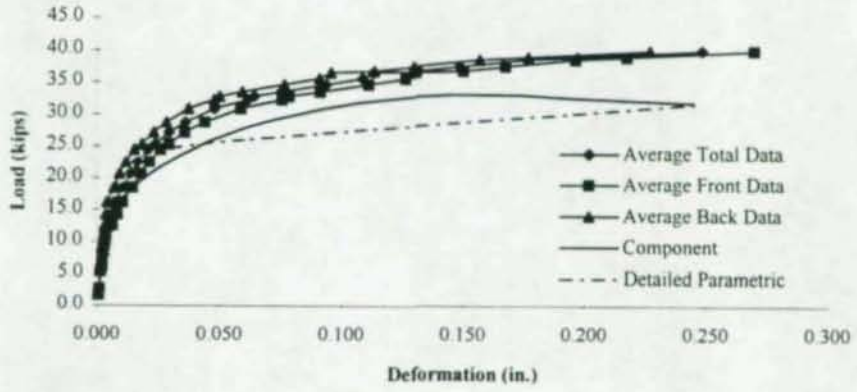
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.248 | 40 |
| | Failure: | 0.248 | 40 |
| | Other: | 0.16 | 37.9 |
| | | 0.25 | NA |
| | | 0.34 | NA |

## COMMENTS

* Yielding on PL-26 started at 29000 lbs and .025 in.
* PL-27 yielded at 34000 lbs.
* Bulging observed on PL-26 at 40000 lbs.

## CHART



*Test No: 21*
**Recorder: BK**

## *Summary of One Bolt Lap Connection Tests*

**DATA**

| | | *Potentiometer Readings (in.)* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 1.7 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | -0.001 | 0.001 |
| 2 | 2.7 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | -0.001 | 0.001 |
| 3 | 5.4 | -0.001 | -0.001 | -0.002 | -0.002 | -0.002 | -0.001 | -0.001 | -0.001 | 0.001 |
| 4 | 6.1 | -0.002 | -0.002 | -0.002 | -0.002 | -0.002 | -0.002 | -0.001 | -0.002 | 0.002 |
| 5 | 7.0 | -0.002 | -0.002 | -0.002 | -0.003 | -0.002 | -0.002 | -0.001 | -0.002 | 0.002 |
| 6 | 8.4 | -0.002 | -0.003 | -0.002 | -0.004 | -0.003 | -0.003 | -0.001 | -0.002 | 0.003 |
| 7 | 9.3 | -0.002 | -0.004 | -0.002 | -0.006 | -0.004 | -0.003 | -0.001 | -0.002 | 0.003 |
| 8 | 10.2 | -0.002 | -0.004 | -0.003 | -0.006 | -0.004 | -0.004 | -0.002 | -0.002 | 0.003 |
| 9 | 11.0 | -0.002 | -0.005 | -0.002 | -0.007 | -0.005 | -0.004 | -0.002 | -0.002 | 0.004 |
| 10 | 12.2 | -0.002 | -0.006 | -0.003 | -0.009 | -0.005 | -0.004 | -0.002 | -0.002 | 0.004 |
| 11 | 12.5 | -0.002 | -0.009 | -0.004 | -0.012 | -0.004 | -0.004 | -0.002 | -0.003 | 0.005 |
| 12 | 14.3 | -0.002 | -0.011 | -0.006 | -0.015 | -0.005 | -0.004 | -0.002 | -0.004 | 0.006 |
| 13 | 16.1 | -0.003 | -0.015 | -0.006 | -0.019 | -0.005 | -0.006 | -0.003 | -0.004 | 0.008 |
| *14* | *18.5* | *-0.005* | *-0.021* | *-0.008* | *-0.025* | *-0.010* | *-0.007* | *-0.007* | *-0.006* | *0.011* |
| 15 | 20.7 | -0.007 | -0.026 | -0.010 | -0.031 | -0.013 | -0.009 | -0.009 | -0.007 | 0.014 |
| 16 | 22.5 | -0.008 | -0.031 | -0.012 | -0.036 | -0.016 | -0.011 | -0.012 | -0.009 | 0.017 |
| 17 | 24.5 | -0.011 | -0.037 | -0.015 | -0.042 | -0.021 | -0.014 | -0.016 | -0.011 | 0.021 |
| 18 | 25.3 | -0.013 | -0.042 | -0.017 | -0.047 | -0.024 | -0.017 | -0.020 | -0.013 | 0.024 |
| 19 | 27.1 | -0.017 | -0.050 | -0.021 | -0.056 | -0.031 | -0.021 | -0.024 | -0.017 | 0.030 |
| 20 | 28.7 | -0.023 | -0.059 | -0.028 | -0.067 | -0.037 | -0.027 | -0.029 | -0.021 | 0.036 |
| 21 | 30.9 | -0.035 | -0.076 | -0.041 | -0.084 | -0.047 | -0.035 | -0.039 | -0.029 | 0.048 |
| 22 | 32.3 | -0.050 | -0.094 | -0.057 | -0.103 | -0.059 | -0.046 | -0.048 | -0.039 | 0.062 |
| 23 | 32.8 | -0.053 | -0.097 | -0.059 | -0.106 | -0.060 | -0.049 | -0.051 | -0.041 | 0.065 |
| 24 | 33.5 | -0.064 | -0.110 | -0.072 | -0.120 | -0.071 | -0.058 | -0.059 | -0.049 | 0.075 |
| 25 | 34.7 | -0.083 | -0.130 | -0.091 | -0.141 | -0.090 | -0.075 | -0.076 | -0.066 | 0.094 |
| 26 | 35.6 | -0.097 | -0.146 | -0.105 | -0.158 | -0.104 | -0.090 | -0.090 | -0.080 | 0.109 |
| 27 | 36.5 | -0.102 | -0.150 | -0.109 | -0.162 | -0.110 | -0.095 | -0.095 | -0.084 | 0.113 |
| 28 | 36.8 | -0.120 | -0.171 | -0.128 | -0.182 | -0.128 | -0.113 | -0.113 | -0.101 | 0.132 |
| 29 | 37.5 | -0.137 | -0.188 | -0.145 | -0.201 | -0.145 | -0.130 | -0.129 | -0.116 | 0.149 |
| *30* | *38.6* | *-0.165* | *-0.218* | *-0.172* | *-0.231* | *-0.173* | *-0.157* | *-0.156* | *-0.142* | *0.177* |
| 31 | 38.9 | -0.185 | -0.240 | -0.193 | -0.253 | -0.194 | -0.177 | -0.175 | -0.161 | 0.197 |
| 32 | 40.0 | -0.236 | -0.294 | -0.244 | -0.306 | -0.246 | -0.228 | -0.225 | -0.210 | 0.248 |

**Test No: 22** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/2X1X3/4 Date: 3/15/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.75 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.5 | 1.5 | SHEAR | 26 |
| Bottom: | 4 | 1 | 1.5 | SHEAR | 6 |

## TEST RESULTS

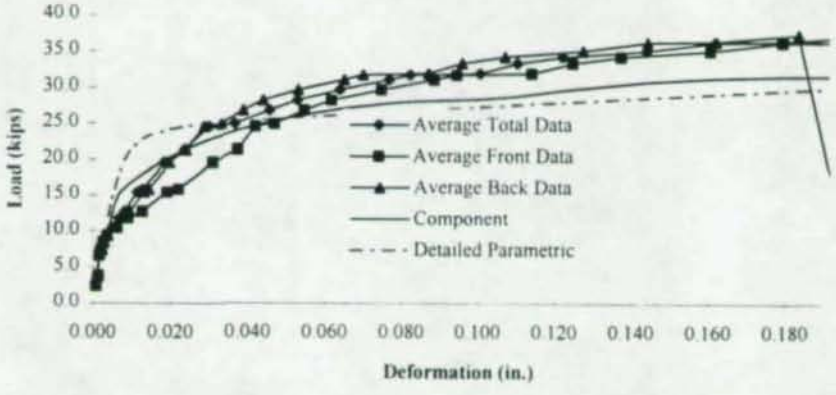
Limit State: Bolt Shear

| | Deformation (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.203 | 37.4 |
| Failure: | 0.203 | 37.4 |
| Other: | 0.16 | 36.1 |
| | 0.25 | NA |
| | 0.34 | NA |

## COMMENTS

* Yielding started on PL-26 at 25000 lbs.

## CHART



Test No: 22
Recorder: BK

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 2.5 | -0.001 | 0.000 | -0.001 | -0.001 | -0.002 | -0.001 | -0.001 | 0.000 | 0.001 |
| 2 | 3.8 | -0.001 | -0.001 | -0.002 | -0.002 | -0.002 | -0.001 | -0.001 | 0.000 | 0.001 |
| 3 | 6.7 | -0.001 | 0.000 | -0.004 | -0.002 | -0.004 | -0.002 | -0.001 | 0.000 | 0.002 |
| 4 | 7.4 | -0.001 | 0.000 | -0.005 | -0.002 | -0.004 | -0.004 | -0.001 | -0.001 | 0.002 |
| 5 | 8.4 | -0.003 | 0.000 | -0.006 | -0.002 | -0.005 | -0.006 | 0.000 | -0.001 | 0.003 |
| 6 | 9.4 | -0.005 | 0.001 | -0.008 | -0.001 | -0.005 | -0.007 | 0.000 | -0.002 | 0.003 |
| 7 | 10.5 | -0.010 | 0.002 | -0.013 | 0.001 | -0.004 | -0.011 | 0.002 | -0.006 | 0.005 |
| 8 | 11.8 | -0.013 | 0.003 | -0.018 | 0.002 | -0.004 | -0.015 | 0.002 | -0.009 | 0.007 |
| 9 | 12.7 | -0.018 | 0.005 | -0.024 | 0.004 | -0.003 | -0.019 | 0.003 | -0.013 | 0.008 |
| 10 | 15.4 | -0.028 | 0.009 | -0.034 | 0.006 | -0.002 | -0.026 | 0.005 | -0.020 | 0.011 |
| 11 | 15.8 | -0.032 | 0.010 | -0.040 | 0.007 | -0.002 | -0.028 | 0.006 | -0.022 | 0.013 |
| 12 | 19.6 | -0.046 | 0.013 | -0.057 | 0.007 | -0.002 | -0.039 | 0.007 | -0.032 | 0.019 |
| 13 | 21.3 | -0.059 | 0.015 | -0.070 | 0.007 | -0.002 | -0.048 | 0.007 | -0.040 | 0.024 |
| 14 | 24.5 | -0.070 | 0.012 | -0.084 | 0.003 | -0.005 | -0.057 | 0.006 | -0.047 | 0.030 |
| 15 | 24.9 | -0.081 | 0.009 | -0.096 | -0.002 | -0.008 | -0.065 | 0.005 | -0.055 | 0.037 |
| 16 | 26.8 | -0.094 | 0.002 | -0.111 | -0.012 | -0.013 | -0.076 | 0.002 | -0.065 | 0.046 |
| 17 | 28.2 | -0.103 | -0.004 | -0.122 | -0.019 | -0.018 | -0.085 | -0.002 | -0.072 | 0.053 |
| 18 | 29.7 | -0.117 | -0.013 | -0.138 | -0.031 | -0.026 | -0.097 | -0.008 | -0.082 | 0.064 |
| 19 | 31.1 | -0.131 | -0.024 | -0.155 | -0.044 | -0.036 | -0.113 | -0.018 | -0.095 | 0.077 |
| 20 | 31.7 | -0.138 | -0.029 | -0.162 | -0.049 | -0.041 | -0.118 | -0.021 | -0.100 | 0.082 |
| 21 | 31.9 | -0.158 | -0.047 | -0.184 | -0.068 | -0.057 | -0.138 | -0.035 | -0.118 | 0.101 |
| 22 | 33.4 | -0.169 | -0.056 | -0.196 | -0.079 | -0.066 | -0.148 | -0.043 | -0.127 | 0.110 |
| 23 | 34.3 | -0.181 | -0.067 | -0.210 | -0.091 | -0.078 | -0.160 | -0.052 | -0.139 | 0.122 |
| 24 | 35.1 | -0.205 | -0.089 | -0.235 | -0.114 | -0.098 | -0.183 | -0.070 | -0.160 | 0.144 |
| 25 | 36.3 | -0.224 | -0.107 | -0.254 | -0.132 | -0.115 | -0.201 | -0.085 | -0.177 | 0.162 |
| 26 | 36.4 | -0.243 | -0.125 | -0.274 | -0.149 | -0.133 | -0.219 | -0.102 | -0.195 | 0.180 |
| 27 | 37.4 | -0.267 | -0.148 | -0.299 | -0.172 | -0.155 | -0.242 | -0.122 | -0.216 | 0.203 |
| 28 | 3.7 | -1.654 | -0.715 | -0.668 | -1.952 | -0.193 | -0.249 | -0.130 | -0.219 | 0.723 |

**Test No: 23** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 5/8X5/8X3/4 Date: 3/15/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.5 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.625 | 1.5 | SAW | 13 |
| Bottom: | 4 | 0.625 | 1.5 | SAW | 13 |

## TEST RESULTS

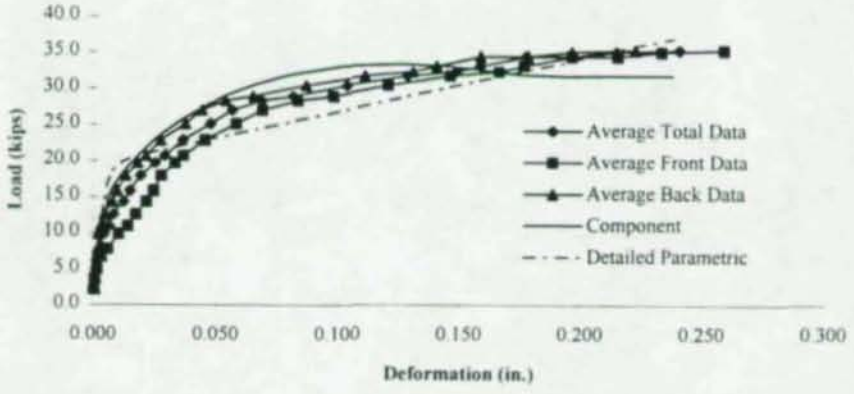
Limit State: Bolt Shear

| | Deformation (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.241 | 35.4 |
| Failure: | 0.241 | 35.4 |
| Other: | 0.16 | 33.2 |
| | 0.25 | NA |
| | 0.34 | NA |

## COMMENTS

* PL-13 yielded at 27000 lbs. at 0.07 in.
* Bolts declined at 32000 lbs.

## CHART



Test No: 23
Recorder: BK

## Summary of One Bolt Lap Connection Tests

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.2 | 0.000 | -0.001 | 0.000 | -0.001 | -0.002 | -0.001 | -0.001 | 0.000 | 0.001 |
| 2 | 3.7 | 0.000 | -0.001 | -0.001 | -0.001 | -0.002 | -0.001 | -0.001 | 0.000 | 0.001 |
| 3 | 5.0 | 0.001 | -0.002 | -0.001 | -0.002 | -0.002 | -0.001 | -0.001 | 0.000 | 0.001 |
| 4 | 6.7 | 0.002 | -0.006 | -0.001 | -0.006 | -0.002 | -0.001 | -0.001 | 0.000 | 0.002 |
| 5 | 7.8 | 0.003 | -0.010 | 0.001 | -0.010 | -0.002 | -0.002 | -0.001 | -0.001 | 0.003 |
| 6 | 9.9 | 0.005 | -0.018 | 0.002 | -0.017 | -0.002 | -0.003 | -0.001 | -0.001 | 0.005 |
| 7 | 11.0 | 0.006 | -0.024 | 0.002 | -0.024 | -0.002 | -0.005 | -0.001 | -0.004 | 0.006 |
| 8 | 12.6 | 0.007 | -0.029 | 0.003 | -0.030 | -0.002 | -0.009 | -0.001 | -0.007 | 0.008 |
| 9 | 14.3 | 0.007 | -0.039 | 0.002 | -0.039 | -0.002 | -0.015 | -0.001 | -0.013 | 0.012 |
| 10 | 15.8 | 0.007 | -0.045 | 0.001 | -0.045 | -0.003 | -0.018 | -0.001 | -0.017 | 0.015 |
| 11 | 17.8 | 0.005 | -0.053 | -0.001 | -0.053 | -0.005 | -0.024 | -0.002 | -0.021 | 0.019 |
| 12 | 19.7 | 0.002 | -0.063 | -0.005 | -0.064 | -0.008 | -0.031 | -0.004 | -0.029 | 0.025 |
| 13 | 20.7 | -0.001 | -0.069 | -0.008 | -0.070 | -0.010 | -0.035 | -0.006 | -0.034 | 0.029 |
| 14 | 22.8 | -0.007 | -0.080 | -0.015 | -0.081 | -0.015 | -0.044 | -0.010 | -0.042 | 0.037 |
| 15 | 25.1 | -0.016 | -0.095 | -0.026 | -0.096 | -0.023 | -0.057 | -0.017 | -0.053 | 0.048 |
| 16 | 27.0 | -0.025 | -0.108 | -0.035 | -0.108 | -0.029 | -0.065 | -0.021 | -0.062 | 0.057 |
| 17 | 28.3 | -0.039 | -0.123 | -0.050 | -0.123 | -0.038 | -0.077 | -0.028 | -0.073 | 0.069 |
| 18 | 28.9 | -0.053 | -0.138 | -0.064 | -0.138 | -0.048 | -0.090 | -0.039 | -0.085 | 0.082 |
| 19 | 30.4 | -0.076 | -0.162 | -0.086 | -0.161 | -0.070 | -0.112 | -0.060 | -0.108 | 0.104 |
| 20 | 31.8 | -0.102 | -0.187 | -0.111 | -0.186 | -0.093 | -0.137 | -0.083 | -0.134 | 0.129 |
| 21 | 32.3 | -0.122 | -0.207 | -0.131 | -0.207 | -0.113 | -0.157 | -0.101 | -0.153 | 0.149 |
| 22 | 33.2 | -0.132 | -0.218 | -0.141 | -0.217 | -0.123 | -0.167 | -0.111 | -0.163 | 0.159 |
| 23 | 34.5 | -0.151 | -0.238 | -0.161 | -0.237 | -0.140 | -0.186 | -0.130 | -0.181 | 0.178 |
| 24 | 34.5 | -0.170 | -0.258 | -0.179 | -0.256 | -0.160 | -0.206 | -0.149 | -0.200 | 0.197 |
| 25 | 35.1 | -0.188 | -0.275 | -0.198 | -0.275 | -0.178 | -0.224 | -0.167 | -0.218 | 0.215 |
| 26 | 35.4 | -0.213 | -0.300 | -0.223 | -0.301 | -0.204 | -0.251 | -0.193 | -0.244 | 0.241 |

**Test No: 26** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/8X1/8X7/8 Date: 3/17/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.125 | 1.5 | SHEAR | 16 |
| Bottom: | 5 | 0.125 | 1.5 | SHEAR | 16 |

## TEST RESULTS

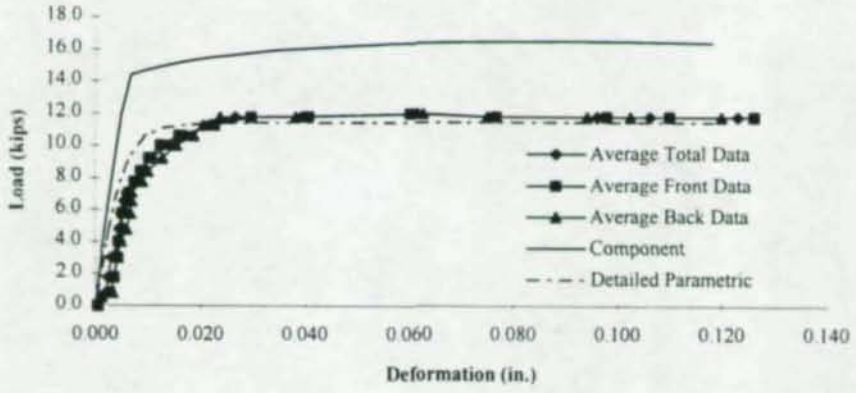
Limit State: Buckling

| | Deformation (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.062 | 12 |
| Failure: | 0.123 | 11.8 |
| Other: | 0.16 | NA |
| | 0.25 | NA |
| | 0.34 | NA |

## COMMENTS

* Bolts declined at 6000 lbs.
* Bulging started at 10000 lbs and 0.03 in.
* Bulged part curled excessively.

## CHART



**Test No: 26**
**Recorder: BK**

## Summary of One Bolt Lap Connection Tests

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 0.0 | -0.001 | 0 | 0 | -0.001 | -0.001 | -0.001 | 0 | 0 | 0.001 |
| 2 | 0.5 | -0.002 | -0.001 | 0 | -0.002 | -0.003 | -0.002 | 0 | 0 | 0.001 |
| 3 | 0.8 | -0.004 | -0.003 | 0.001 | 0.003 | -0.007 | -0.006 | 0 | 0 | 0.002 |
| 4 | 1.8 | -0.006 | -0.004 | 0.001 | 0.003 | -0.007 | -0.006 | 0 | 0 | 0.002 |
| 5 | 3.0 | -0.008 | -0.004 | 0.001 | 0.004 | -0.009 | -0.008 | 0 | 0 | 0.003 |
| 6 | 4.0 | -0.009 | -0.005 | 0 | -0.004 | -0.011 | -0.009 | 0 | 0 | 0.005 |
| 7 | 4.8 | -0.01 | -0.006 | -0.001 | 0.004 | -0.012 | -0.011 | 0 | -0.001 | 0.005 |
| 8 | 5.8 | -0.01 | -0.006 | -0.001 | 0.004 | -0.014 | -0.011 | -0.001 | -0.001 | 0.005 |
| 9 | 6.5 | -0.012 | -0.007 | -0.001 | 0.004 | -0.014 | -0.012 | -0.001 | -0.001 | 0.006 |
| 10 | 7.1 | -0.013 | -0.008 | -0.002 | 0.003 | -0.014 | -0.012 | -0.001 | -0.001 | 0.006 |
| 11 | 7.8 | -0.015 | -0.008 | -0.004 | 0.003 | -0.015 | -0.015 | -0.002 | -0.004 | 0.008 |
| 12 | 8.4 | -0.018 | -0.008 | -0.006 | 0.003 | -0.017 | -0.016 | -0.003 | -0.004 | 0.009 |
| 13 | 9.2 | -0.02 | -0.008 | -0.01 | 0.003 | -0.02 | -0.019 | -0.006 | -0.006 | 0.011 |
| 14 | 10.0 | -0.025 | -0.011 | -0.014 | 0 | -0.022 | -0.022 | -0.009 | -0.009 | 0.014 |
| 15 | 10.6 | -0.03 | -0.014 | -0.017 | -0.003 | -0.026 | -0.025 | -0.012 | -0.012 | 0.017 |
| 16 | 11.3 | -0.037 | -0.02 | -0.025 | -0.009 | -0.028 | -0.026 | -0.014 | -0.014 | 0.022 |
| 17 | 11.8 | -0.044 | -0.027 | -0.031 | -0.017 | -0.031 | -0.03 | -0.017 | -0.017 | 0.027 |
| 18 | 11.8 | -0.055 | -0.039 | -0.042 | -0.027 | -0.046 | -0.044 | -0.033 | -0.03 | 0.040 |
| 19 | 12.0 | -0.074 | -0.058 | -0.062 | -0.047 | -0.068 | -0.065 | -0.056 | -0.062 | 0.062 |
| 20 | 11.8 | -0.091 | -0.075 | -0.078 | -0.063 | -0.082 | -0.08 | -0.07 | -0.068 | 0.076 |
| 21 | 11.8 | -0.112 | -0.097 | -0.099 | -0.084 | -0.1 | -0.101 | -0.089 | -0.087 | 0.096 |
| 22 | 11.8 | -0.12 | -0.11 | -0.11 | -0.1 | -0.11 | -0.11 | -0.1 | -0.09 | 0.106 |
| 23 | 11.8 | -0.135 | -0.12 | -0.125 | -0.125 | -0.125 | -0.11 | -0.125 | -0.12 | 0.123 |
| 24 | 11.8 | | | | | | | | | |

**Test No: 27** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/8X1/4X7/8 Date: 3/23/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | |
|---|---|---|---|
| Type: | A325 | Diameter (in.): 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): 2 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: X | |
| | | Bolt Head Washer: X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.125 | 1.5 | SHEAR | 16 |
| Bottom: | 4 | 0.25 | 1.5 | SHEAR | 19 |

## TEST RESULTS

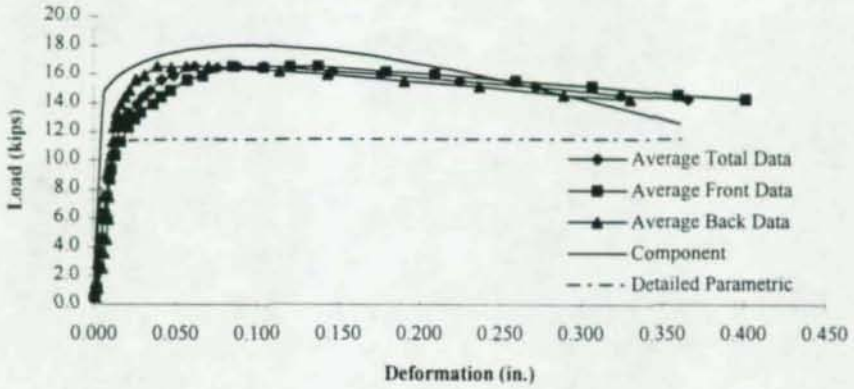
Limit State: Buckling

| | Deformation (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.104 | 16.6 |
| Failure: | 0.366 | 14.3 |
| Other: | 0.16 | 16.1 |
| | 0.25 | 15.3 |
| | 0.34 | 14.5 |

## COMMENTS

* Yielding on PL-16 started at 14000 Lbs.
* Bulging on PL-16 started at 16000 lbs (0.1 in. of deformation).
* Yielding on PL-19 started at 16200 lbs
* Load decreased after 0.2 in. of deformation.

## CHART



**Test No: 27**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 0.5 | 0.000 | 0.001 | -0.002 | -0.002 | -0.002 | -0.002 | 0.001 | 0.001 | 0.001 |
| 2 | 1.1 | 0.000 | 0.001 | -0.004 | -0.004 | -0.005 | -0.004 | 0.001 | 0.001 | 0.002 |
| 3 | 2.6 | 0.000 | 0.002 | -0.007 | -0.006 | -0.010 | -0.008 | 0.002 | 0.002 | 0.003 |
| 4 | 3.6 | 0.000 | 0.002 | -0.009 | -0.007 | -0.012 | -0.009 | 0.002 | 0.003 | 0.004 |
| 5 | 4.5 | -0.001 | 0.002 | -0.010 | -0.009 | -0.015 | -0.012 | 0.002 | 0.003 | 0.005 |
| 6 | 5.9 | 0.000 | 0.001 | -0.012 | -0.010 | -0.017 | -0.014 | 0.002 | 0.003 | 0.006 |
| 7 | 6.3 | -0.001 | 0.000 | -0.013 | -0.013 | -0.017 | -0.013 | 0.002 | 0.003 | 0.006 |
| 8 | 7.5 | -0.001 | -0.001 | -0.016 | -0.016 | -0.018 | -0.015 | 0.001 | 0.003 | 0.008 |
| 9 | 8.7 | -0.001 | -0.002 | -0.018 | -0.018 | -0.020 | -0.017 | 0.001 | 0.002 | 0.009 |
| 10 | 9.4 | -0.001 | -0.002 | -0.020 | -0.020 | -0.021 | -0.018 | 0.001 | 0.002 | 0.010 |
| 11 | 10.3 | -0.004 | -0.004 | -0.023 | -0.023 | -0.023 | -0.019 | 0.001 | 0.002 | 0.011 |
| 12 | 11.3 | -0.006 | -0.007 | -0.026 | -0.026 | -0.024 | -0.020 | 0.000 | 0.002 | 0.014 |
| 13 | 12.3 | -0.010 | -0.012 | -0.031 | -0.032 | -0.026 | -0.022 | -0.001 | 0.001 | 0.017 |
| 14 | 12.9 | -0.013 | -0.017 | -0.034 | -0.037 | -0.028 | -0.024 | -0.001 | 0.001 | 0.019 |
| 15 | 13.3 | -0.017 | -0.020 | -0.037 | -0.042 | -0.029 | -0.024 | -0.002 | 0.001 | 0.021 |
| 16 | 13.9 | -0.023 | -0.028 | -0.045 | -0.050 | -0.033 | -0.028 | -0.005 | -0.001 | 0.026 |
| 17 | 14.4 | -0.028 | -0.033 | -0.050 | -0.055 | -0.037 | -0.030 | -0.007 | -0.003 | 0.030 |
| 18 | 14.9 | -0.032 | -0.040 | -0.055 | -0.061 | -0.040 | -0.032 | -0.010 | -0.005 | 0.034 |
| 19 | 15.6 | -0.042 | -0.051 | -0.064 | -0.072 | -0.045 | -0.036 | -0.014 | -0.008 | 0.042 |
| 20 | 15.9 | -0.050 | -0.061 | -0.073 | -0.083 | -0.051 | -0.042 | -0.020 | -0.012 | 0.049 |
| 21 | 16.6 | -0.067 | -0.081 | -0.089 | -0.103 | -0.059 | -0.049 | -0.028 | -0.019 | 0.062 |
| 22 | 16.5 | -0.086 | -0.100 | -0.107 | -0.123 | -0.068 | -0.058 | -0.036 | -0.028 | 0.076 |
| 23 | 16.6 | -0.102 | -0.117 | -0.124 | -0.139 | -0.078 | -0.067 | -0.045 | -0.037 | 0.089 |
| 24 | 16.6 | -0.119 | -0.135 | -0.141 | -0.157 | -0.091 | -0.080 | -0.058 | -0.051 | 0.104 |
| 25 | 16.2 | -0.159 | -0.177 | -0.182 | -0.200 | -0.135 | -0.125 | -0.101 | -0.095 | 0.147 |
| 26 | 16.0 | -0.190 | -0.208 | -0.212 | -0.230 | -0.164 | -0.154 | -0.131 | -0.125 | 0.177 |
| 27 | 15.5 | -0.239 | -0.258 | -0.261 | -0.281 | -0.212 | -0.202 | -0.177 | -0.173 | 0.225 |
| 28 | 15.2 | -0.286 | -0.305 | -0.308 | -0.328 | -0.258 | -0.249 | -0.223 | -0.219 | 0.272 |
| 29 | 14.6 | -0.339 | -0.359 | -0.362 | -0.381 | -0.312 | -0.301 | -0.275 | -0.271 | 0.325 |
| 30 | 14.3 | -0.380 | -0.400 | -0.404 | -0.423 | -0.352 | -0.343 | -0.315 | -0.311 | 0.366 |

**Test No: 28** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/8X3/8X7/8 Date: 3/23/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.125 | 1.563 | SHEAR | 16 |
| Bottom: | 4 | 0.375 | 1.563 | Unknown | 23 |

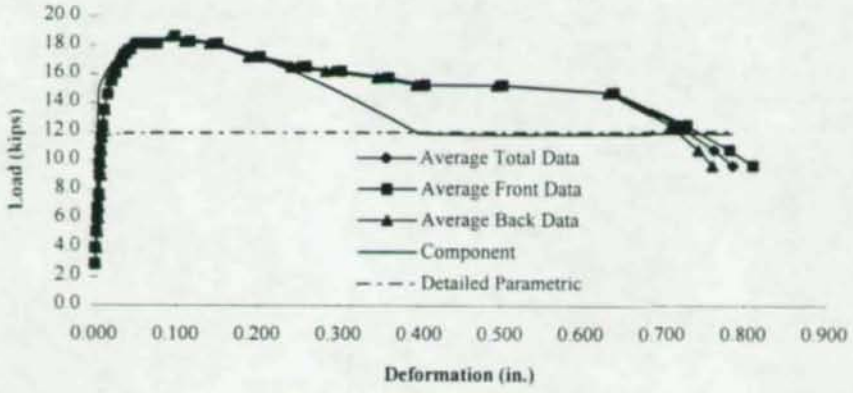
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bearing/Tearout | | |
| | Maximum: | 0.097 | 18.6 |
| | Failure: | 0.638 | 14.7 |
| | Other: | 0.16 | 17.9 |
| | | 0.25 | 16.5 |
| | | 0.34 | 15.9 |

## COMMENTS

* PL-16 yielded at 16000 lbs with 0.025 in. of deformation.
* PL-19 yielded at 18500 lbs.
* PL-16 started bulging at 18750 lbs with a deformation of 0.15 in.
* Connection lost strength after 18750 lbs.

## CHART



**Test No: 28**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 2.9 | -0.001 | 0.001 | -0.002 | -0.001 | -0.003 | -0.002 | 0.001 | 0.000 | 0.001 |
| 2 | 4.0 | 0.000 | 0.001 | -0.004 | -0.002 | -0.006 | -0.005 | 0.001 | 0.001 | 0.002 |
| 3 | 5.1 | 0.000 | 0.001 | -0.006 | -0.005 | -0.008 | -0.007 | 0.001 | 0.001 | 0.003 |
| 4 | 6.0 | 0.000 | 0.001 | -0.007 | -0.007 | -0.009 | -0.009 | 0.002 | 0.001 | 0.004 |
| 5 | 6.8 | 0.000 | 0.002 | -0.009 | -0.007 | -0.010 | -0.011 | 0.002 | 0.001 | 0.004 |
| 6 | 7.6 | -0.001 | 0.002 | -0.012 | -0.009 | -0.012 | -0.013 | 0.003 | 0.000 | 0.005 |
| 7 | 9.0 | -0.002 | 0.003 | -0.013 | -0.010 | -0.014 | -0.017 | 0.004 | -0.001 | 0.006 |
| 8 | 9.8 | -0.002 | 0.003 | -0.015 | -0.011 | -0.015 | -0.018 | 0.003 | -0.001 | 0.007 |
| 9 | 10.7 | -0.003 | 0.003 | -0.017 | -0.012 | -0.016 | -0.020 | 0.003 | -0.002 | 0.008 |
| 10 | 11.6 | -0.004 | 0.003 | -0.019 | -0.014 | -0.017 | -0.021 | 0.003 | -0.002 | 0.009 |
| 11 | 12.4 | -0.005 | 0.002 | -0.021 | -0.017 | -0.019 | -0.023 | 0.003 | -0.004 | 0.010 |
| 12 | 13.5 | -0.007 | 0.001 | -0.026 | -0.019 | -0.021 | -0.027 | 0.002 | -0.006 | 0.013 |
| 13 | 14.6 | -0.012 | -0.001 | -0.033 | -0.024 | -0.025 | -0.031 | -0.001 | -0.009 | 0.017 |
| 14 | 15.5 | -0.017 | -0.006 | -0.039 | -0.030 | -0.028 | -0.035 | -0.004 | -0.013 | 0.021 |
| 15 | 16.1 | -0.021 | -0.010 | -0.043 | -0.035 | -0.032 | -0.039 | -0.006 | -0.015 | 0.025 |
| 16 | 16.8 | -0.028 | -0.018 | -0.051 | -0.043 | -0.037 | -0.045 | -0.010 | -0.021 | 0.032 |
| 17 | 17.4 | -0.032 | -0.022 | -0.056 | -0.049 | -0.042 | -0.050 | -0.015 | -0.025 | 0.036 |
| 18 | 17.7 | -0.037 | -0.028 | -0.062 | -0.055 | -0.046 | -0.055 | -0.018 | -0.030 | 0.041 |
| 19 | 18.1 | -0.046 | -0.038 | -0.071 | -0.065 | -0.056 | -0.064 | -0.028 | -0.039 | 0.051 |
| 20 | 18.1 | -0.057 | -0.050 | -0.083 | -0.078 | -0.068 | -0.076 | -0.039 | -0.050 | 0.063 |
| 21 | 18.1 | -0.068 | -0.061 | -0.093 | -0.089 | -0.079 | -0.088 | -0.051 | -0.061 | 0.074 |
| 22 | 18.6 | -0.090 | -0.082 | -0.115 | -0.112 | -0.103 | -0.112 | -0.076 | -0.085 | 0.097 |
| 23 | 18.3 | -0.108 | -0.100 | -0.134 | -0.130 | -0.120 | -0.130 | -0.093 | -0.102 | 0.115 |
| 24 | 18.1 | -0.142 | -0.135 | -0.168 | -0.163 | -0.151 | -0.161 | -0.123 | -0.132 | 0.147 |
| 25 | 17.2 | -0.194 | -0.187 | -0.220 | -0.216 | -0.200 | -0.209 | -0.169 | -0.180 | 0.197 |
| 26 | 16.5 | -0.251 | -0.244 | -0.276 | -0.273 | -0.253 | -0.262 | -0.223 | -0.232 | 0.252 |
| 27 | 16.2 | -0.295 | -0.288 | -0.319 | -0.316 | -0.295 | -0.305 | -0.265 | -0.274 | 0.295 |
| 28 | 15.8 | -0.353 | -0.347 | -0.379 | -0.375 | -0.359 | -0.368 | -0.328 | -0.338 | 0.356 |
| 29 | 15.3 | -0.398 | -0.391 | -0.423 | -0.420 | -0.407 | -0.415 | -0.378 | -0.386 | 0.402 |
| 30 | 15.3 | -0.493 | -0.488 | -0.520 | -0.517 | -0.506 | -0.515 | -0.478 | -0.486 | 0.500 |
| 31 | 14.7 | -0.631 | -0.624 | -0.657 | -0.655 | -0.646 | -0.653 | -0.617 | -0.619 | 0.638 |
| 32 | 12.5 | -0.722 | -0.716 | -0.746 | -0.745 | -0.722 | -0.732 | -0.695 | -0.698 | 0.722 |
| 33 | 10.8 | -0.775 | -0.770 | -0.796 | -0.796 | -0.757 | -0.766 | -0.729 | -0.730 | 0.765 |
| 34 | 9.7 | -0.805 | -0.800 | -0.823 | -0.825 | -0.775 | -0.784 | -0.747 | -0.746 | 0.788 |

**Test No: 29** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/8X1/2X7/8 Date: 3/24/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.125 | 1.625 | SHEAR | 16 |
| Bottom: | 4 | 0.5 | 1.625 | SAW | 34 |

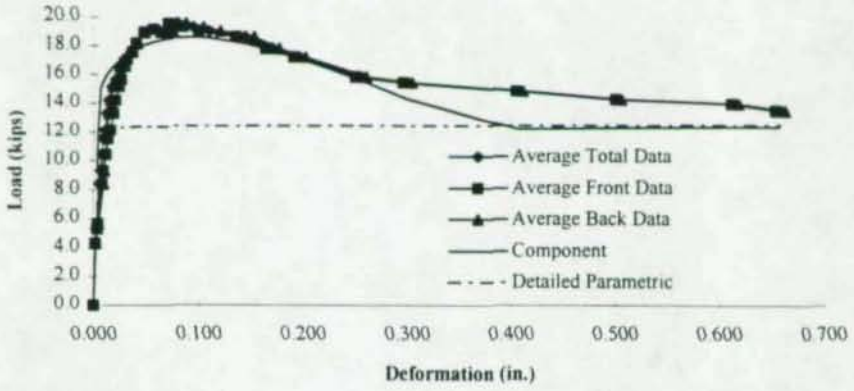
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Buckling | | |
| | Maximum: | 0.079 | 19.6 |
| | Failure: | 0.658 | 13.5 |
| | Other: | 0.16 | 18.1 |
| | | 0.25 | 15.9 |
| | | 0.34 | 15.2 |

## COMMENTS

* Yielding on PL-16 started at 17000 lbs with 0.03 in. of deformation.
* Load capacity decreased at 0.17 in. of deformation.
* Bulged part bent out of plane at 0.2 in.

## CHART



**Test No: 29** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 4.3 | 0.000 | 0.000 | -0.005 | -0.003 | -0.004 | -0.004 | 0.001 | 0.001 | 0.002 |
| 4 | 5.3 | 0.000 | 0.001 | -0.007 | -0.006 | -0.008 | -0.006 | 0.001 | 0.001 | 0.003 |
| 5 | 5.6 | -0.001 | 0.002 | -0.009 | -0.006 | -0.009 | -0.007 | 0.002 | 0.002 | 0.003 |
| 6 | 8.4 | -0.002 | 0.004 | -0.017 | -0.010 | -0.017 | -0.013 | 0.004 | 0.004 | 0.006 |
| 7 | 9.3 | -0.002 | 0.005 | -0.020 | -0.011 | -0.019 | -0.015 | 0.004 | 0.004 | 0.007 |
| 8 | 10.5 | -0.004 | 0.007 | -0.024 | -0.013 | -0.023 | -0.017 | 0.003 | 0.004 | 0.008 |
| 9 | 11.6 | -0.006 | 0.008 | -0.029 | -0.013 | -0.026 | -0.018 | 0.002 | 0.005 | 0.010 |
| 10 | 12.2 | -0.009 | 0.009 | -0.034 | -0.014 | -0.028 | -0.018 | 0.001 | 0.005 | 0.011 |
| 11 | 13.3 | -0.012 | 0.011 | -0.039 | -0.015 | -0.032 | -0.020 | -0.001 | 0.005 | 0.013 |
| 12 | 14.2 | -0.014 | 0.011 | -0.043 | -0.015 | -0.034 | -0.021 | -0.003 | 0.005 | 0.014 |
| 13 | 15.2 | -0.020 | 0.012 | -0.050 | -0.017 | -0.039 | -0.023 | -0.007 | 0.005 | 0.017 |
| 14 | 15.7 | -0.023 | 0.012 | -0.054 | -0.017 | -0.045 | -0.028 | -0.014 | 0.001 | 0.021 |
| 15 | 16.5 | -0.028 | 0.010 | -0.061 | -0.019 | -0.050 | -0.029 | -0.017 | 0.000 | 0.024 |
| 16 | 17.1 | -0.032 | 0.009 | -0.066 | -0.021 | -0.057 | -0.034 | -0.023 | -0.004 | 0.029 |
| 17 | 17.6 | -0.041 | 0.004 | -0.076 | -0.027 | -0.064 | -0.039 | -0.030 | -0.009 | 0.035 |
| 18 | 18.2 | -0.046 | 0.001 | -0.083 | -0.032 | -0.071 | -0.045 | -0.037 | -0.013 | 0.041 |
| 19 | 18.9 | -0.054 | -0.006 | -0.092 | -0.038 | -0.079 | -0.052 | -0.044 | -0.019 | 0.048 |
| 20 | 19.1 | -0.064 | -0.013 | -0.102 | -0.045 | -0.093 | -0.063 | -0.057 | -0.031 | 0.059 |
| 21 | 18.9 | -0.073 | -0.019 | -0.111 | -0.053 | -0.108 | -0.076 | -0.074 | -0.045 | 0.070 |
| 22 | 19.6 | -0.080 | -0.024 | -0.120 | -0.059 | -0.120 | -0.088 | -0.087 | -0.056 | 0.079 |
| 23 | 19.3 | -0.094 | -0.038 | -0.134 | -0.073 | -0.136 | -0.104 | -0.103 | -0.072 | 0.094 |
| 24 | 19.0 | -0.108 | -0.053 | -0.149 | -0.088 | -0.153 | -0.121 | -0.120 | -0.088 | 0.110 |
| 25 | 18.6 | -0.143 | -0.089 | -0.184 | -0.124 | -0.185 | -0.153 | -0.152 | -0.121 | 0.144 |
| 26 | 17.8 | -0.173 | -0.119 | -0.212 | -0.152 | -0.209 | -0.177 | -0.174 | -0.146 | 0.170 |
| 27 | 17.2 | -0.201 | -0.147 | -0.237 | -0.178 | -0.234 | -0.203 | -0.200 | -0.172 | 0.196 |
| 28 | 15.8 | -0.261 | -0.208 | -0.297 | -0.236 | -0.292 | -0.260 | -0.259 | -0.230 | 0.255 |
| 29 | 15.4 | -0.306 | -0.253 | -0.342 | -0.281 | -0.337 | -0.304 | -0.303 | -0.274 | 0.300 |
| 30 | 14.9 | -0.416 | -0.363 | -0.449 | -0.390 | -0.443 | -0.410 | -0.409 | -0.382 | 0.408 |
| 31 | 14.3 | -0.509 | -0.462 | -0.545 | -0.484 | -0.537 | -0.504 | -0.506 | -0.475 | 0.503 |
| 32 | 14.0 | -0.623 | -0.573 | -0.655 | -0.595 | -0.648 | -0.614 | -0.620 | -0.590 | 0.615 |
| 33 | 13.5 | -0.665 | -0.615 | -0.697 | -0.636 | -0.691 | -0.657 | -0.666 | -0.634 | 0.658 |

**Test No: 30** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/8X3/4X7/8 Date: 3/24/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.25 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.125 | 1.625 | SHEAR | 15 |
| Bottom: | 4 | 0.75 | 1.625 | SAW | 28 |

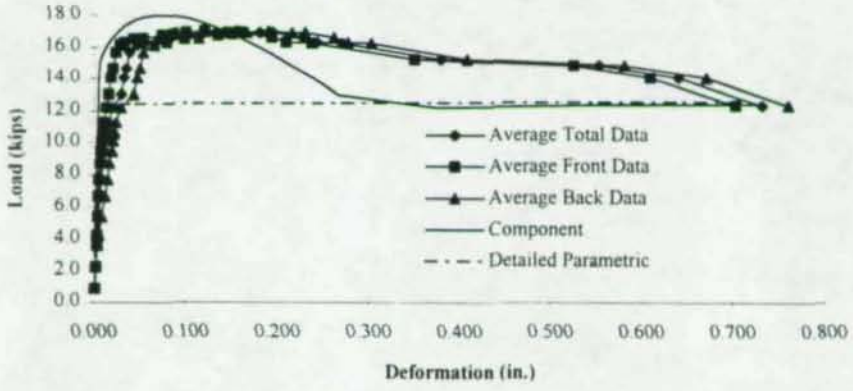
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: Bearing/Tearout | Maximum: | 0.155 | 17 |
| | Failure: | 0.731 | 12.4 |
| | Other: | 0.16 | 17 |
| | | 0.25 | 16.3 |
| | | 0.34 | 15.6 |

## COMMENTS

* PL-15 yielded at 15500 lbs with a deformation of 0.03 in.
* Strength loss observed after 0.25 in. of deformation.

## CHART



**Test No: 30**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 0.9 | -0.001 | 0.001 | -0.002 | -0.002 | -0.001 | -0.001 | 0.000 | 0.000 | 0.001 |
| 2 | 2.3 | 0.000 | 0.000 | -0.004 | -0.005 | -0.004 | -0.004 | 0.000 | 0.001 | 0.002 |
| 3 | 3.6 | 0.000 | -0.001 | -0.006 | -0.007 | -0.008 | -0.007 | 0.001 | 0.001 | 0.003 |
| 4 | 4.2 | 0.000 | -0.001 | -0.006 | -0.008 | -0.010 | -0.010 | 0.002 | 0.001 | 0.004 |
| 5 | 5.4 | 0.000 | -0.001 | -0.007 | -0.010 | -0.014 | -0.015 | 0.002 | 0.001 | 0.005 |
| 6 | 6.7 | 0.000 | -0.002 | -0.006 | -0.011 | -0.020 | -0.022 | 0.004 | 0.002 | 0.007 |
| 7 | 7.7 | 0.001 | -0.003 | -0.007 | -0.012 | -0.024 | -0.028 | 0.006 | 0.003 | 0.008 |
| 8 | 8.7 | 0.001 | -0.004 | -0.009 | -0.015 | -0.025 | -0.034 | 0.008 | 0.001 | 0.010 |
| 9 | 9.4 | 0.001 | -0.003 | -0.011 | -0.017 | -0.027 | -0.040 | 0.008 | -0.004 | 0.012 |
| 10 | 10.1 | 0.000 | -0.002 | -0.015 | -0.018 | -0.028 | -0.042 | 0.009 | -0.006 | 0.013 |
| 11 | 10.5 | 0.000 | -0.002 | -0.016 | -0.020 | -0.029 | -0.045 | 0.009 | -0.006 | 0.014 |
| 12 | 10.7 | -0.001 | -0.002 | -0.018 | -0.021 | -0.029 | -0.045 | 0.008 | -0.008 | 0.015 |
| 13 | 11.3 | -0.001 | -0.002 | -0.020 | -0.021 | -0.031 | -0.049 | 0.007 | -0.010 | 0.016 |
| 14 | 12.2 | -0.005 | -0.001 | -0.025 | -0.023 | -0.038 | -0.059 | 0.002 | -0.018 | 0.021 |
| 15 | 13.0 | -0.007 | 0.000 | -0.031 | -0.026 | -0.052 | -0.075 | -0.012 | -0.034 | 0.030 |
| 16 | 14.1 | -0.012 | 0.000 | -0.035 | -0.028 | -0.057 | -0.080 | -0.013 | -0.037 | 0.033 |
| 17 | 14.7 | -0.015 | -0.001 | -0.039 | -0.029 | -0.061 | -0.084 | -0.015 | -0.039 | 0.035 |
| 18 | 15.7 | -0.017 | -0.002 | -0.043 | -0.032 | -0.066 | -0.090 | -0.018 | -0.040 | 0.039 |
| 19 | 16.2 | -0.022 | -0.006 | -0.050 | -0.036 | -0.078 | -0.102 | -0.029 | -0.053 | 0.047 |
| 20 | 16.1 | -0.022 | -0.006 | -0.049 | -0.036 | -0.078 | -0.102 | -0.029 | -0.053 | 0.047 |
| 21 | 16.3 | -0.026 | -0.009 | -0.054 | -0.040 | -0.090 | -0.115 | -0.043 | -0.067 | 0.056 |
| 22 | 16.6 | -0.035 | -0.018 | -0.065 | -0.051 | -0.109 | -0.135 | -0.062 | -0.086 | 0.070 |
| 23 | 16.6 | -0.045 | -0.029 | -0.075 | -0.062 | -0.125 | -0.150 | -0.077 | -0.102 | 0.083 |
| 24 | 16.8 | -0.067 | -0.049 | -0.097 | -0.083 | -0.146 | -0.171 | -0.098 | -0.122 | 0.104 |
| 25 | 16.9 | -0.079 | -0.061 | -0.109 | -0.095 | -0.161 | -0.187 | -0.113 | -0.138 | 0.118 |
| 26 | 16.9 | -0.092 | -0.074 | -0.124 | -0.109 | -0.178 | -0.203 | -0.129 | -0.154 | 0.133 |
| 27 | 17.0 | -0.112 | -0.094 | -0.144 | -0.130 | -0.201 | -0.227 | -0.153 | -0.178 | 0.155 |
| 28 | 16.9 | -0.137 | -0.120 | -0.168 | -0.155 | -0.226 | -0.253 | -0.179 | -0.204 | 0.180 |
| 29 | 16.9 | -0.151 | -0.135 | -0.183 | -0.169 | -0.240 | -0.267 | -0.193 | -0.219 | 0.195 |
| 30 | 16.6 | -0.186 | -0.168 | -0.216 | -0.203 | -0.272 | -0.300 | -0.224 | -0.250 | 0.227 |
| 31 | 16.3 | -0.202 | -0.184 | -0.232 | -0.218 | -0.286 | -0.314 | -0.240 | -0.265 | 0.243 |
| 32 | 16.3 | -0.231 | -0.213 | -0.260 | -0.247 | -0.313 | -0.341 | -0.266 | -0.290 | 0.270 |
| 33 | 15.2 | -0.344 | -0.327 | -0.371 | -0.360 | -0.418 | -0.446 | -0.373 | -0.394 | 0.379 |
| 34 | 14.9 | -0.519 | -0.505 | -0.542 | -0.534 | -0.590 | -0.618 | -0.546 | -0.569 | 0.553 |
| 35 | 14.1 | -0.603 | -0.591 | -0.624 | -0.618 | -0.676 | -0.705 | -0.638 | -0.663 | 0.640 |
| 36 | 12.4 | -0.700 | -0.687 | -0.716 | -0.708 | -0.765 | -0.791 | -0.731 | -0.753 | 0.731 |

**Test No: 31** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X1/4X7/8 Date: 3/25/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.25 | 1.75 | SHEAR | 20 |
| Bottom: | 4 | 0.25 | 1.75 | SHEAR | 20 |

## TEST RESULTS

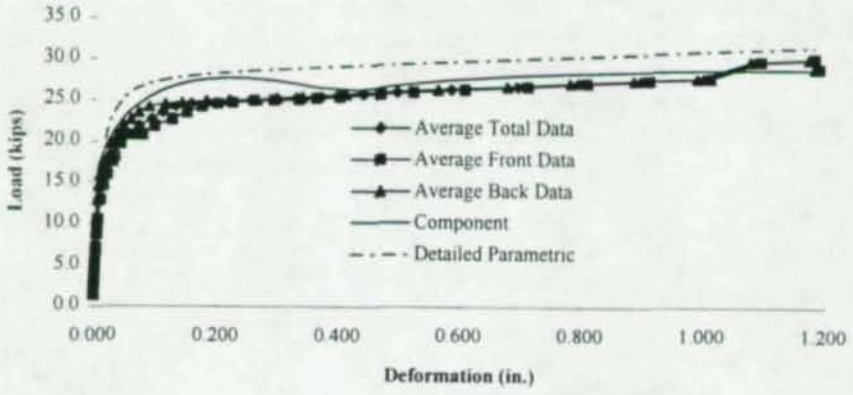
Limit State: Bearing/Tearout

| | Deformation (in.) | Load (kips) |
|---|---|---|
| Maximum: | 1.18 | 30.2 |
| Failure: | 1.18 | 30.2 |
| Other: | 0.16 | 24.5 |
| | 0.25 | 25 |
| | 0.34 | 25.3 |

## COMMENTS

* Yielding on PL-20 started at 19000 lbs with a deformation of 0.04 in.
* Bulging started at 24000 lbs (0.15 in.).
* Strength of the connection increased.

## CHART



Test No: 31
Recorder: BK

**Summary of One Bolt Lap Connection Tests**

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.5 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | 0.000 | -0.001 | 0.001 |
| 2 | 2.6 | -0.001 | -0.001 | -0.001 | -0.001 | -0.002 | -0.001 | -0.001 | -0.001 | 0.001 |
| 3 | 3.6 | -0.001 | -0.001 | -0.002 | -0.002 | -0.003 | -0.002 | -0.001 | -0.001 | 0.002 |
| 4 | 4.3 | -0.002 | -0.001 | -0.003 | -0.002 | -0.004 | -0.003 | -0.002 | -0.001 | 0.002 |
| 5 | 5.5 | -0.003 | -0.001 | -0.004 | -0.002 | -0.005 | -0.002 | -0.002 | -0.001 | 0.003 |
| 6 | 6.6 | -0.005 | -0.002 | -0.004 | -0.004 | -0.006 | -0.002 | -0.003 | -0.001 | 0.003 |
| 7 | 7.2 | -0.006 | -0.003 | -0.005 | -0.004 | -0.007 | -0.002 | -0.004 | -0.001 | 0.004 |
| 8 | 8.8 | -0.007 | -0.004 | -0.006 | -0.006 | -0.008 | -0.003 | -0.004 | -0.001 | 0.005 |
| 9 | 9.9 | -0.007 | -0.005 | -0.007 | -0.006 | -0.009 | -0.004 | -0.006 | -0.002 | 0.006 |
| 10 | 10.6 | -0.008 | -0.006 | -0.008 | -0.007 | -0.009 | -0.004 | -0.006 | -0.003 | 0.006 |
| 11 | 13.0 | -0.012 | -0.010 | -0.012 | -0.012 | -0.010 | -0.007 | -0.006 | -0.004 | 0.009 |
| 12 | 14.6 | -0.015 | -0.017 | -0.015 | -0.018 | -0.011 | -0.009 | -0.008 | -0.007 | 0.012 |
| 13 | 16.0 | -0.018 | -0.025 | -0.020 | -0.026 | -0.012 | -0.012 | -0.009 | -0.009 | 0.017 |
| 14 | 17.5 | -0.024 | -0.037 | -0.026 | -0.037 | -0.022 | -0.020 | -0.019 | -0.017 | 0.025 |
| 15 | 18.2 | -0.028 | -0.042 | -0.029 | -0.042 | -0.026 | -0.022 | -0.023 | -0.018 | 0.029 |
| 16 | 19.7 | -0.034 | -0.053 | -0.036 | -0.053 | -0.035 | -0.026 | -0.032 | -0.023 | 0.037 |
| 17 | 20.8 | -0.057 | -0.078 | -0.057 | -0.078 | -0.049 | -0.034 | -0.045 | -0.029 | 0.054 |
| 18 | 20.8 | -0.068 | -0.091 | -0.069 | -0.091 | -0.053 | -0.036 | -0.050 | -0.032 | 0.061 |
| 19 | 21.8 | -0.086 | -0.110 | -0.087 | -0.112 | -0.061 | -0.040 | -0.057 | -0.036 | 0.074 |
| 20 | 22.6 | -0.114 | -0.141 | -0.115 | -0.143 | -0.075 | -0.050 | -0.071 | -0.046 | 0.094 |
| 21 | 23.4 | -0.135 | -0.165 | -0.139 | -0.166 | -0.088 | -0.062 | -0.085 | -0.058 | 0.112 |
| 22 | 24.2 | -0.160 | -0.191 | -0.163 | -0.193 | -0.105 | -0.078 | -0.102 | -0.074 | 0.133 |
| 23 | 24.5 | -0.184 | -0.218 | -0.188 | -0.217 | -0.132 | -0.105 | -0.129 | -0.100 | 0.159 |
| 24 | 24.7 | -0.209 | -0.243 | -0.212 | -0.242 | -0.160 | -0.131 | -0.156 | -0.127 | 0.185 |
| 25 | 24.9 | -0.242 | -0.280 | -0.247 | -0.278 | -0.199 | -0.171 | -0.195 | -0.167 | 0.222 |
| 26 | 25.0 | -0.275 | -0.312 | -0.278 | -0.312 | -0.237 | -0.207 | -0.233 | -0.203 | 0.257 |
| 27 | 25.1 | -0.316 | -0.354 | -0.319 | -0.355 | -0.283 | -0.253 | -0.280 | -0.250 | 0.301 |
| 28 | 25.3 | -0.342 | -0.382 | -0.347 | -0.383 | -0.316 | -0.284 | -0.313 | -0.282 | 0.331 |
| 29 | 25.4 | -0.381 | -0.422 | -0.385 | -0.421 | -0.358 | -0.326 | -0.355 | -0.324 | 0.371 |
| 30 | 25.8 | -0.447 | -0.491 | -0.452 | -0.489 | -0.430 | -0.398 | -0.426 | -0.395 | 0.441 |
| 31 | 26.0 | -0.500 | -0.545 | -0.504 | -0.545 | -0.490 | -0.456 | -0.483 | -0.452 | 0.497 |
| 32 | 26.3 | -0.584 | -0.631 | -0.589 | -0.631 | -0.584 | -0.550 | -0.576 | -0.546 | 0.586 |
| 33 | 26.7 | -0.684 | -0.737 | -0.691 | -0.737 | -0.700 | -0.666 | -0.689 | -0.659 | 0.695 |
| 34 | 27.1 | -0.780 | -0.836 | -0.789 | -0.836 | -0.805 | -0.771 | -0.793 | -0.763 | 0.797 |
| 35 | 27.5 | -0.882 | -0.939 | -0.892 | -0.940 | -0.912 | -0.875 | -0.898 | -0.866 | 0.901 |
| 36 | 27.7 | -0.982 | -1.042 | -0.992 | -1.040 | -1.016 | -0.979 | -1.003 | -0.971 | 1.003 |
| 37 | 29.8 | -1.066 | -1.126 | -1.074 | -1.123 | -1.103 | -1.066 | -1.089 | -1.058 | 1.088 |
| 38 | 30.2 | -1.152 | -1.214 | -1.160 | -1.211 | -1.201 | -1.161 | -1.185 | -1.154 | 1.180 |
| 39 | 29.0 | -1.159 | -1.222 | -1.169 | -1.219 | -1.210 | -1.171 | -1.195 | -1.163 | 1.188 |

**Test No: 32** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X3/8X7/8 Date: 3/24/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.25 | 1.75 | SHEAR | 20 |
| Bottom: | 4 | 0.375 | 1.75 | SHEAR | 22 |

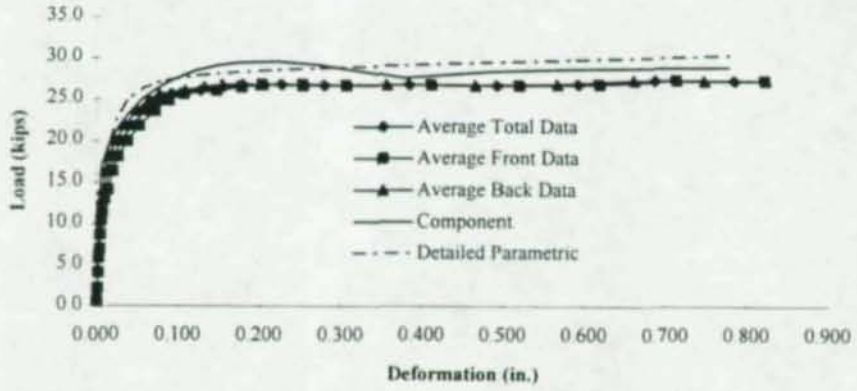
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Splitting | | |
| | Maximum: | 0.785 | 27.3 |
| | Failure: | 0.785 | 27.3 |
| | Other: | 0.16 | 26.5 |
| | | 0.25 | 26.7 |
| | | 0.34 | 26.7 |

## COMMENTS

* PL-20 yielded at 0.04 in of deformation with a load of 20800 lbs.
* Excessive deformations started at 23000 lbs.
* PL-20 bulged at 27000 lbs and 0.15 in. of deforamtion.
* PL-22 bulged at 27500 lbs and 0.3 in. of deformation.
* Splitting occured at 0.80 in. of deformation.

## CHART



**Test No: 32**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 0.7 | 0.000 | 0.001 | -0.002 | -0.002 | -0.001 | -0.001 | -0.001 | 0.000 | 0.001 |
| 2 | 2.2 | 0.000 | 0.001 | -0.004 | -0.003 | -0.003 | -0.002 | -0.001 | 0.000 | 0.001 |
| 3 | 4.2 | 0.000 | 0.000 | -0.007 | -0.005 | -0.005 | -0.003 | -0.001 | 0.000 | 0.003 |
| 4 | 5.9 | -0.001 | 0.000 | -0.008 | -0.006 | -0.006 | -0.004 | -0.001 | 0.000 | 0.003 |
| 5 | 7.0 | 0.000 | -0.001 | -0.010 | -0.008 | -0.006 | -0.005 | -0.002 | 0.000 | 0.004 |
| 6 | 8.8 | 0.000 | -0.001 | -0.012 | -0.010 | -0.008 | -0.006 | -0.002 | -0.001 | 0.005 |
| 7 | 10.4 | 0.000 | -0.002 | -0.013 | -0.012 | -0.009 | -0.007 | -0.002 | -0.001 | 0.006 |
| 8 | 11.4 | -0.001 | -0.002 | -0.015 | -0.014 | -0.010 | -0.007 | -0.004 | -0.001 | 0.007 |
| 9 | 12.9 | -0.002 | -0.005 | -0.018 | -0.018 | -0.010 | -0.010 | -0.004 | -0.002 | 0.009 |
| 10 | 14.1 | -0.004 | -0.009 | -0.022 | -0.023 | -0.010 | -0.012 | -0.003 | -0.004 | 0.011 |
| 11 | 16.3 | -0.008 | -0.015 | -0.027 | -0.031 | -0.014 | -0.018 | -0.004 | -0.009 | 0.016 |
| 12 | 18.0 | -0.013 | -0.021 | -0.032 | -0.039 | -0.018 | -0.023 | -0.007 | -0.013 | 0.021 |
| 13 | 19.9 | -0.021 | -0.035 | -0.042 | -0.053 | -0.028 | -0.032 | -0.013 | -0.020 | 0.031 |
| 14 | 21.8 | -0.032 | -0.051 | -0.056 | -0.069 | -0.040 | -0.045 | -0.023 | -0.028 | 0.043 |
| 15 | 23.6 | -0.050 | -0.071 | -0.074 | -0.091 | -0.057 | -0.060 | -0.036 | -0.042 | 0.060 |
| 16 | 24.8 | -0.067 | -0.088 | -0.090 | -0.109 | -0.072 | -0.075 | -0.051 | -0.056 | 0.076 |
| 17 | 25.6 | -0.085 | -0.106 | -0.108 | -0.127 | -0.085 | -0.088 | -0.063 | -0.069 | 0.091 |
| 18 | 26.0 | -0.124 | -0.147 | -0.149 | -0.167 | -0.117 | -0.120 | -0.094 | -0.100 | 0.127 |
| 19 | 26.4 | -0.155 | -0.177 | -0.181 | -0.198 | -0.141 | -0.146 | -0.117 | -0.124 | 0.155 |
| 20 | 26.7 | -0.181 | -0.203 | -0.206 | -0.225 | -0.163 | -0.168 | -0.140 | -0.147 | 0.179 |
| 21 | 26.7 | -0.230 | -0.253 | -0.256 | -0.275 | -0.210 | -0.214 | -0.186 | -0.192 | 0.227 |
| 22 | 26.7 | -0.282 | -0.306 | -0.310 | -0.329 | -0.261 | -0.266 | -0.237 | -0.244 | 0.280 |
| 23 | 26.7 | -0.385 | -0.410 | -0.416 | -0.436 | -0.365 | -0.373 | -0.343 | -0.348 | 0.385 |
| 24 | 26.7 | -0.490 | -0.517 | -0.525 | -0.546 | -0.476 | -0.483 | -0.450 | -0.455 | 0.493 |
| 25 | 26.8 | -0.589 | -0.615 | -0.625 | -0.645 | -0.576 | -0.584 | -0.550 | -0.554 | 0.592 |
| 26 | 27.3 | -0.684 | -0.709 | -0.718 | -0.741 | -0.672 | -0.680 | -0.643 | -0.648 | 0.687 |
| 27 | 27.3 | -0.792 | -0.820 | -0.826 | -0.851 | -0.758 | -0.768 | -0.730 | -0.734 | 0.785 |

**Test No: 33** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X1/2X7/8 Date: 3/25/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.25 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.25 | 1.75 | SHEAR | 20 |
| Bottom: | 4 | 0.5 | 1.75 | SAW | 34 |

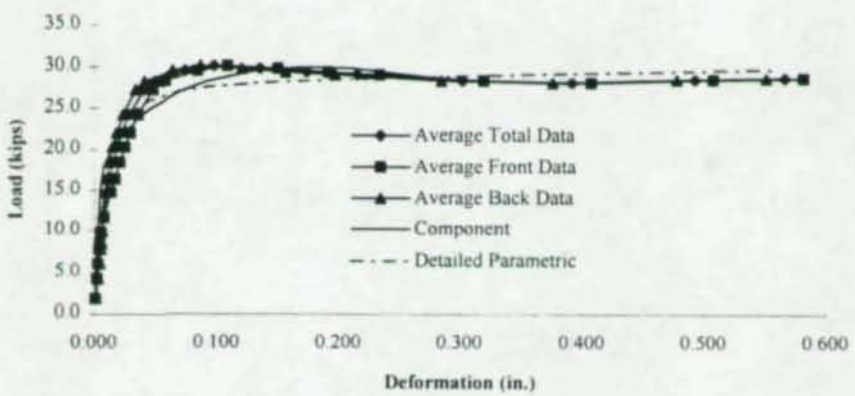
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bearing/Tearout | | |
| | Maximum: | 0.098 | 30.1 |
| | Failure: | 0.567 | 28.7 |
| | Other: | 0.16 | 29.1 |
| | | 0.25 | 30.9 |
| | | 0.34 | 31.4 |

## COMMENTS

* Yielding on PL-20 started at 20500 lbs and 0.02 in. of deformation.
* PL-34 yielded at 0.4 in.
* PL-20 torn out at 0.65 in.

## CHART



Test No: 33
Recorder: BK

## Summary of One Bolt Lap Connection Tests

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.8 | -0.001 | 0.000 | -0.002 | -0.002 | -0.003 | -0.002 | 0.000 | 0.001 | 0.001 |
| 2 | 4.2 | -0.001 | -0.001 | -0.004 | -0.005 | -0.007 | -0.006 | 0.000 | 0.001 | 0.003 |
| 3 | 6.1 | -0.001 | -0.001 | -0.006 | -0.007 | -0.010 | -0.007 | 0.001 | 0.001 | 0.004 |
| 4 | 7.8 | -0.001 | -0.001 | -0.007 | -0.009 | -0.012 | -0.009 | 0.001 | 0.001 | 0.005 |
| 5 | 8.6 | -0.001 | -0.001 | -0.009 | -0.010 | -0.013 | -0.010 | 0.001 | 0.001 | 0.005 |
| 6 | 9.9 | 0.000 | -0.001 | -0.010 | -0.012 | -0.013 | -0.012 | 0.001 | 0.000 | 0.006 |
| 7 | 11.7 | 0.002 | -0.002 | -0.012 | -0.017 | -0.015 | -0.015 | 0.001 | 0.000 | 0.007 |
| 8 | 14.8 | 0.003 | -0.007 | -0.016 | -0.028 | -0.018 | -0.018 | 0.001 | -0.002 | 0.011 |
| 9 | 16.4 | 0.004 | -0.012 | -0.018 | -0.035 | -0.019 | -0.018 | 0.001 | -0.002 | 0.012 |
| 10 | 18.5 | 0.004 | -0.017 | -0.021 | -0.043 | -0.023 | -0.022 | 0.001 | -0.003 | 0.016 |
| 11 | 20.3 | 0.005 | -0.023 | -0.023 | -0.051 | -0.028 | -0.026 | -0.002 | -0.004 | 0.019 |
| 12 | 22.0 | 0.005 | -0.029 | -0.024 | -0.059 | -0.034 | -0.029 | -0.006 | -0.006 | 0.023 |
| 13 | 24.3 | 0.004 | -0.039 | -0.029 | -0.072 | -0.042 | -0.034 | -0.011 | -0.008 | 0.029 |
| 14 | 27.3 | -0.004 | -0.055 | -0.041 | -0.093 | -0.058 | -0.043 | -0.021 | -0.013 | 0.041 |
| 15 | 28.3 | -0.010 | -0.067 | -0.050 | -0.105 | -0.068 | -0.050 | -0.029 | -0.018 | 0.050 |
| 16 | 29.5 | -0.034 | -0.094 | -0.076 | -0.135 | -0.095 | -0.073 | -0.050 | -0.037 | 0.074 |
| 17 | 30.1 | -0.056 | -0.118 | -0.100 | -0.162 | -0.120 | -0.097 | -0.072 | -0.059 | 0.098 |
| 18 | 29.8 | -0.096 | -0.160 | -0.141 | -0.205 | -0.155 | -0.131 | -0.105 | -0.092 | 0.136 |
| 19 | 29.4 | -0.136 | -0.201 | -0.182 | -0.247 | -0.192 | -0.168 | -0.140 | -0.127 | 0.174 |
| 20 | 29.1 | -0.179 | -0.243 | -0.224 | -0.289 | -0.234 | -0.210 | -0.180 | -0.167 | 0.216 |
| 21 | 28.4 | -0.264 | -0.329 | -0.310 | -0.377 | -0.322 | -0.296 | -0.267 | -0.254 | 0.302 |
| 22 | 28.1 | -0.348 | -0.417 | -0.400 | -0.466 | -0.414 | -0.388 | -0.358 | -0.343 | 0.392 |
| 23 | 28.5 | -0.449 | -0.516 | -0.502 | -0.565 | -0.517 | -0.492 | -0.458 | -0.445 | 0.493 |
| 24 | 28.7 | -0.520 | -0.589 | -0.577 | -0.641 | -0.592 | -0.565 | -0.531 | -0.516 | 0.567 |

**Test No: 34** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X3/4X7/8 Date: 3/25/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.5 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.25 | 1.75 | SHEAR | 20 |
| Bottom: | 4 | 0.75 | 1.75 | SAW | 29 |

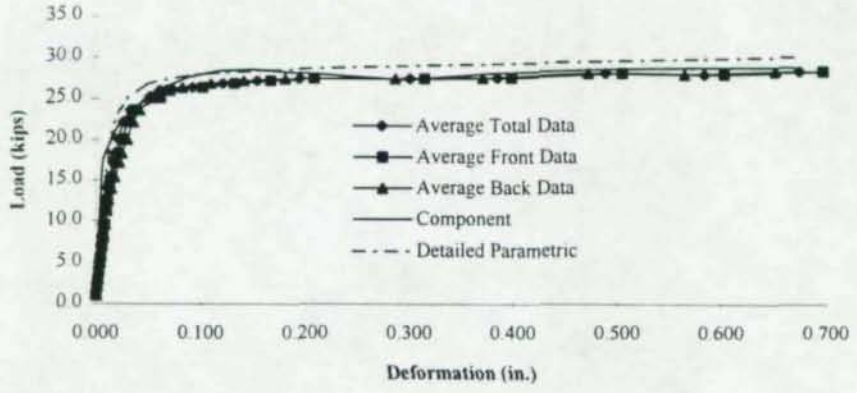
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bearing/Tearout | | |
| | Maximum: | 0.674 | 28.4 |
| | Failure: | 0.674 | 28.4 |
| | Other: | 0.16 | 27.2 |
| | | 0.25 | 27.4 |
| | | 0.34 | 27.5 |

## COMMENTS

* PL-20 yielded at 15500 lbs. and 0.014 in. of deformation.
* PL-20 started bulging at 0.044 in of deformation.
* The connection maintained its strength after yielding point.

## CHART



Test No: 34
Recorder: BK

**Summary of One Bolt Lap Connection Tests**

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 0.000 | 0.000 | -0.001 | -0.001 | -0.001 | -0.001 | 0.001 | 0.000 | 0.000 |
| 2 | 2.1 | 0.000 | 0.000 | -0.003 | -0.002 | -0.003 | -0.002 | 0.001 | 0.000 | 0.001 |
| 3 | 2.9 | 0.001 | 0.000 | -0.004 | -0.004 | -0.004 | -0.004 | 0.001 | -0.001 | 0.002 |
| 4 | 4.0 | 0.001 | 0.000 | -0.006 | -0.007 | -0.005 | -0.006 | 0.001 | -0.001 | 0.003 |
| 5 | 5.0 | 0.001 | 0.000 | -0.007 | -0.008 | -0.007 | -0.008 | 0.002 | -0.001 | 0.003 |
| 6 | 5.8 | 0.001 | -0.001 | -0.008 | -0.010 | -0.007 | -0.010 | 0.002 | -0.001 | 0.004 |
| 7 | 7.0 | 0.002 | -0.001 | -0.009 | -0.012 | -0.009 | -0.012 | 0.002 | -0.001 | 0.005 |
| 8 | 8.1 | 0.003 | -0.001 | -0.012 | -0.013 | -0.010 | -0.014 | 0.003 | -0.003 | 0.006 |
| 9 | 9.6 | 0.003 | -0.001 | -0.014 | -0.017 | -0.011 | -0.017 | 0.004 | -0.004 | 0.007 |
| 10 | 11.3 | 0.003 | -0.002 | -0.016 | -0.020 | -0.013 | -0.020 | 0.005 | -0.004 | 0.008 |
| 11 | 12.6 | 0.003 | -0.002 | -0.018 | -0.022 | -0.013 | -0.023 | 0.006 | -0.006 | 0.010 |
| 12 | 14.0 | 0.004 | -0.004 | -0.019 | -0.026 | -0.013 | -0.029 | 0.008 | -0.009 | 0.011 |
| 13 | 15.4 | 0.004 | -0.006 | -0.021 | -0.030 | -0.014 | -0.035 | 0.010 | -0.012 | 0.013 |
| 14 | 17.2 | 0.004 | -0.009 | -0.024 | -0.037 | -0.014 | -0.043 | 0.013 | -0.018 | 0.016 |
| 15 | 18.3 | 0.004 | -0.012 | -0.026 | -0.042 | -0.014 | -0.048 | 0.015 | -0.021 | 0.018 |
| 16 | 20.0 | 0.004 | -0.017 | -0.029 | -0.050 | -0.013 | -0.058 | 0.019 | -0.028 | 0.021 |
| 17 | 22.1 | 0.005 | -0.025 | -0.033 | -0.062 | -0.015 | -0.071 | 0.023 | -0.036 | 0.027 |
| 18 | 23.6 | 0.004 | -0.036 | -0.039 | -0.075 | -0.016 | -0.083 | 0.025 | -0.044 | 0.033 |
| 19 | 25.1 | -0.015 | -0.063 | -0.062 | -0.108 | -0.025 | -0.105 | 0.024 | -0.060 | 0.052 |
| 20 | 25.9 | -0.022 | -0.072 | -0.071 | -0.119 | -0.034 | -0.118 | 0.018 | -0.070 | 0.061 |
| 21 | 26.3 | -0.051 | -0.104 | -0.101 | -0.153 | -0.066 | -0.153 | -0.011 | -0.100 | 0.092 |
| 22 | 26.8 | -0.080 | -0.133 | -0.131 | -0.185 | -0.093 | -0.183 | -0.037 | -0.127 | 0.121 |
| 23 | 27.2 | -0.111 | -0.168 | -0.167 | -0.222 | -0.126 | -0.217 | -0.065 | -0.156 | 0.154 |
| 24 | 27.4 | -0.152 | -0.209 | -0.208 | -0.265 | -0.167 | -0.259 | -0.103 | -0.195 | 0.195 |
| 25 | 27.4 | -0.254 | -0.315 | -0.317 | -0.373 | -0.273 | -0.368 | -0.207 | -0.300 | 0.301 |
| 26 | 27.5 | -0.338 | -0.398 | -0.401 | -0.459 | -0.359 | -0.453 | -0.290 | -0.382 | 0.385 |
| 27 | 28.1 | -0.442 | -0.504 | -0.508 | -0.566 | -0.461 | -0.556 | -0.391 | -0.480 | 0.489 |
| 28 | 28.0 | -0.538 | -0.600 | -0.606 | -0.666 | -0.555 | -0.652 | -0.480 | -0.572 | 0.583 |
| 29 | 28.4 | -0.633 | -0.694 | -0.700 | -0.761 | -0.643 | -0.740 | -0.565 | -0.658 | 0.674 |

**Test No: 35** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X1X7/8 Date: 3/26/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | |
|---|---|---|---|
| Type: | A325 | Diameter (in.): 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): 2.75 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: X | |
| | | Bolt Head Washer: X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.25 | 1.625 | SHEAR | 20 |
| Bottom: | 4 | 1 | 1.625 | SAW | 32 |

## TEST RESULTS

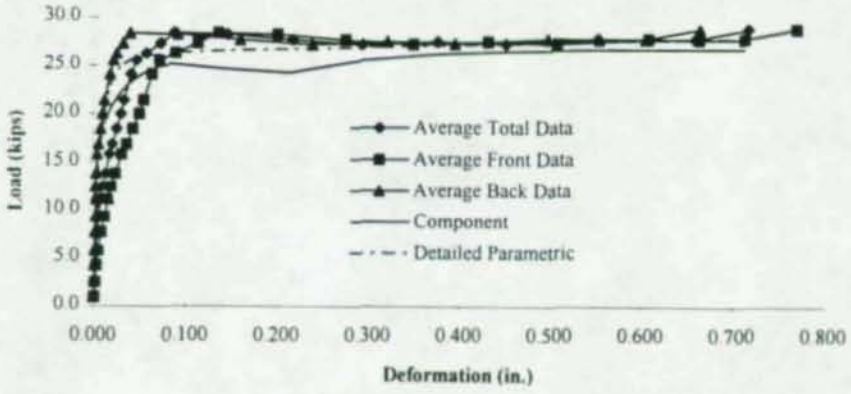
Limit State: Splitting

| | Deformation (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.717 | 28.9 |
| Failure: | 0.717 | 28.9 |
| Other: | 0.16 | 28.1 |
| | 0.25 | 27.5 |
| | 0.34 | 27.4 |

## COMMENTS

* PL-20 yielded at 21500 lbs.
* PL-20 bulged at 27500 lbs.
* Splitting occured at 0.75 in.

## CHART



Test No: 35
Recorder: BK

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 1.0 | 0.000 | 0.000 | -0.002 | -0.002 | 0.000 | 0.000 | -0.001 | 0.000 | 0.001 |
| 2 | 2.5 | 0.000 | 0.001 | -0.003 | -0.005 | 0.000 | -0.001 | -0.001 | -0.001 | 0.001 |
| 3 | 4.2 | 0.000 | 0.001 | -0.006 | -0.008 | 0.000 | -0.001 | -0.002 | -0.001 | 0.002 |
| 4 | 5.7 | 0.000 | 0.001 | -0.010 | -0.010 | 0.000 | -0.002 | -0.002 | -0.001 | 0.003 |
| 5 | 7.7 | 0.000 | 0.003 | -0.015 | -0.015 | 0.000 | -0.003 | -0.002 | -0.002 | 0.004 |
| 6 | 9.3 | -0.001 | 0.004 | -0.023 | -0.020 | 0.000 | -0.002 | -0.003 | -0.003 | 0.006 |
| 7 | 11.1 | -0.002 | 0.007 | -0.031 | -0.025 | 0.000 | -0.002 | -0.003 | -0.004 | 0.008 |
| 8 | 12.5 | -0.005 | 0.004 | -0.039 | -0.032 | 0.000 | -0.002 | -0.004 | -0.005 | 0.010 |
| 9 | 13.8 | -0.010 | -0.002 | -0.045 | -0.041 | 0.000 | -0.004 | -0.004 | -0.006 | 0.014 |
| 10 | 15.8 | -0.012 | -0.009 | -0.052 | -0.052 | 0.000 | -0.007 | -0.004 | -0.008 | 0.018 |
| 11 | 16.9 | -0.015 | -0.015 | -0.055 | -0.061 | 0.000 | -0.010 | -0.004 | -0.010 | 0.021 |
| 12 | 18.5 | -0.017 | -0.025 | -0.059 | -0.072 | 0.000 | -0.015 | -0.004 | -0.013 | 0.026 |
| 13 | 20.0 | -0.018 | -0.034 | -0.064 | -0.084 | 0.000 | -0.018 | -0.006 | -0.015 | 0.030 |
| 14 | 21.4 | -0.019 | -0.042 | -0.065 | -0.092 | 0.000 | -0.023 | -0.007 | -0.017 | 0.033 |
| 15 | 24.1 | -0.021 | -0.056 | -0.070 | -0.108 | 0.000 | -0.035 | -0.013 | -0.023 | 0.041 |
| 16 | 25.6 | -0.024 | -0.067 | -0.075 | -0.120 | 0.000 | -0.042 | -0.019 | -0.026 | 0.047 |
| 17 | 26.3 | -0.039 | -0.086 | -0.092 | -0.141 | 0.000 | -0.046 | -0.024 | -0.030 | 0.057 |
| 18 | 27.3 | -0.061 | -0.111 | -0.116 | -0.166 | 0.000 | -0.058 | -0.033 | -0.036 | 0.073 |
| 19 | 28.4 | -0.082 | -0.133 | -0.138 | -0.190 | 0.000 | -0.070 | -0.043 | -0.045 | 0.088 |
| 20 | 28.2 | -0.142 | -0.198 | -0.204 | -0.257 | 0.001 | -0.139 | -0.112 | -0.112 | 0.146 |
| 21 | 27.7 | -0.216 | -0.272 | -0.280 | -0.333 | -0.023 | -0.239 | -0.190 | -0.187 | 0.217 |
| 22 | 27.3 | -0.289 | -0.346 | -0.355 | -0.408 | -0.099 | -0.325 | -0.266 | -0.263 | 0.294 |
| 23 | 27.5 | -0.371 | -0.428 | -0.437 | -0.491 | -0.182 | -0.408 | -0.348 | -0.345 | 0.376 |
| 24 | 27.3 | -0.446 | -0.504 | -0.514 | -0.566 | -0.257 | -0.484 | -0.422 | -0.417 | 0.451 |
| 25 | 27.8 | -0.546 | -0.603 | -0.615 | -0.668 | -0.359 | -0.592 | -0.522 | -0.516 | 0.553 |
| 26 | 27.8 | -0.601 | -0.658 | -0.672 | -0.723 | -0.415 | -0.648 | -0.578 | -0.572 | 0.609 |
| 27 | 27.8 | -0.649 | -0.708 | -0.722 | -0.773 | -0.467 | -0.698 | -0.629 | -0.622 | 0.659 |
| 28 | 28.9 | -0.703 | -0.766 | -0.780 | -0.830 | -0.527 | -0.760 | -0.688 | -0.682 | 0.717 |

**Test No: 36** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 3/8X3/8X7/8 Date: 3/26/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.25 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.375 | 1.625 | SHEAR | 22 |
| Bottom: | 4 | 0.375 | 1.625 | SHEAR | 22 |

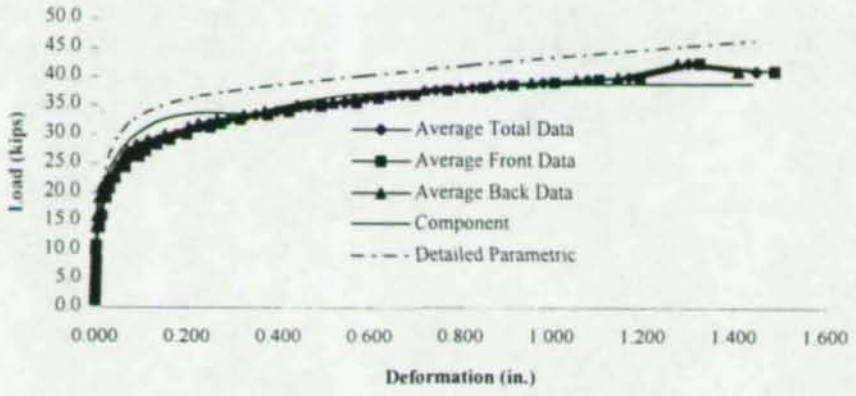
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: Bearing/Tearout | Maximum: | 1.301 | 42.4 |
| | Failure: | 1.45 | 41 |
| | Other: | 0.16 | 29.6 |
| | | 0.25 | 31.9 |
| | | 0.34 | 33.3 |

## COMMENTS

*PL-22 yielded at 23000 lbs and 0.04 in. of deformation.
*At 30000 lbs, bulging started on PL-22
*At 1.4 in. of deformation splitting was observed at the edge of the plate.

## CHART



*Test No: 36*
**Recorder: BK**

***Summary of One Bolt Lap Connection Tests***

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.3 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | -0.001 | 0.001 |
| 2 | 2.4 | -0.001 | -0.001 | -0.002 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | 0.001 |
| 3 | 3.7 | -0.002 | -0.001 | -0.002 | -0.001 | -0.002 | -0.002 | -0.001 | -0.001 | 0.002 |
| 4 | 4.9 | -0.002 | -0.001 | -0.004 | -0.001 | -0.003 | -0.003 | -0.001 | -0.002 | 0.002 |
| 5 | 6.4 | -0.004 | -0.001 | -0.006 | -0.001 | -0.004 | -0.003 | -0.002 | -0.002 | 0.003 |
| 6 | 8.2 | -0.005 | -0.001 | -0.007 | -0.002 | -0.004 | -0.004 | -0.002 | -0.002 | 0.003 |
| 7 | 9.5 | -0.006 | -0.001 | -0.008 | -0.002 | -0.006 | -0.005 | -0.002 | -0.003 | 0.004 |
| 8 | 10.8 | -0.009 | -0.001 | -0.012 | -0.001 | -0.006 | -0.006 | -0.002 | -0.004 | 0.005 |
| 9 | 13.9 | -0.021 | 0.000 | -0.024 | -0.001 | -0.006 | -0.009 | -0.002 | -0.007 | 0.009 |
| 10 | 15.9 | -0.030 | -0.001 | -0.033 | -0.002 | -0.006 | -0.012 | -0.002 | -0.009 | 0.012 |
| 11 | 19.1 | -0.043 | -0.007 | -0.046 | -0.009 | -0.006 | -0.020 | -0.001 | -0.017 | 0.019 |
| 12 | 20.8 | -0.053 | -0.013 | -0.056 | -0.013 | -0.009 | -0.026 | -0.004 | -0.024 | 0.025 |
| 13 | 22.4 | -0.067 | -0.021 | -0.071 | -0.022 | -0.025 | -0.041 | -0.020 | -0.039 | 0.038 |
| 14 | 24.4 | -0.093 | -0.040 | -0.096 | -0.040 | -0.043 | -0.059 | -0.039 | -0.056 | 0.058 |
| 15 | 26.2 | -0.125 | -0.070 | -0.128 | -0.068 | -0.057 | -0.074 | -0.052 | -0.070 | 0.081 |
| 16 | 27.2 | -0.139 | -0.083 | -0.142 | -0.081 | -0.065 | -0.084 | -0.061 | -0.079 | 0.092 |
| 17 | 28.3 | -0.166 | -0.108 | -0.167 | -0.105 | -0.084 | -0.105 | -0.079 | -0.098 | 0.114 |
| 18 | 29.1 | -0.194 | -0.134 | -0.196 | -0.132 | -0.108 | -0.130 | -0.102 | -0.124 | 0.140 |
| 19 | 30.0 | -0.231 | -0.171 | -0.234 | -0.168 | -0.144 | -0.168 | -0.138 | -0.161 | 0.177 |
| 20 | 31.3 | -0.284 | -0.222 | -0.284 | -0.218 | -0.196 | -0.220 | -0.188 | -0.213 | 0.228 |
| 21 | 31.9 | -0.308 | -0.244 | -0.308 | -0.240 | -0.217 | -0.242 | -0.209 | -0.236 | 0.251 |
| 22 | 32.6 | -0.349 | -0.285 | -0.351 | -0.283 | -0.256 | -0.285 | -0.249 | -0.276 | 0.292 |
| 23 | 33.4 | -0.410 | -0.345 | -0.413 | -0.342 | -0.315 | -0.345 | -0.307 | -0.334 | 0.351 |
| 24 | 34.0 | -0.457 | -0.391 | -0.459 | -0.388 | -0.361 | -0.391 | -0.352 | -0.379 | 0.397 |
| 25 | 34.9 | -0.528 | -0.461 | -0.531 | -0.458 | -0.432 | -0.463 | -0.423 | -0.450 | 0.468 |
| 26 | 35.5 | -0.607 | -0.539 | -0.609 | -0.536 | -0.509 | -0.542 | -0.500 | -0.528 | 0.546 |
| 27 | 36.3 | -0.656 | -0.585 | -0.657 | -0.584 | -0.557 | -0.589 | -0.547 | -0.576 | 0.594 |
| 28 | 36.8 | -0.733 | -0.664 | -0.737 | -0.663 | -0.638 | -0.669 | -0.629 | -0.654 | 0.673 |
| 29 | 37.6 | -0.806 | -0.736 | -0.811 | -0.735 | -0.711 | -0.745 | -0.701 | -0.727 | 0.746 |
| 30 | 38.0 | -0.885 | -0.813 | -0.890 | -0.815 | -0.790 | -0.824 | -0.781 | -0.809 | 0.826 |
| 31 | 38.5 | -0.949 | -0.878 | -0.957 | -0.881 | -0.855 | -0.890 | -0.845 | -0.872 | 0.891 |
| 32 | 39.0 | -1.040 | -0.969 | -1.049 | -0.973 | -0.944 | -0.980 | -0.937 | -0.963 | 0.982 |
| 33 | 39.6 | -1.139 | -1.065 | -1.147 | -1.070 | -1.043 | -1.078 | -1.035 | -1.062 | 1.080 |
| 34 | 39.9 | -1.228 | -1.156 | -1.237 | -1.161 | -1.134 | -1.169 | -1.126 | -1.153 | 1.170 |
| 35 | 42.4 | -1.359 | -1.285 | -1.368 | -1.290 | -1.264 | -1.302 | -1.258 | -1.282 | 1.301 |
| 36 | 41.0 | -1.522 | -1.452 | -1.531 | -1.455 | -1.404 | -1.444 | -1.371 | -1.421 | 1.450 |

Test No: 37 **Summary of One Bolt Lap Connection Tests**
Recorder: BK

## TEST DESIGNATION

Test Designation: 3/8X1/2X7/8 Date: 3/27/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.25 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.375 | 1.6258 | SHEAR | 22 |
| Bottom: | 4 | 0.5 | 1.625 | SAW | 35 |

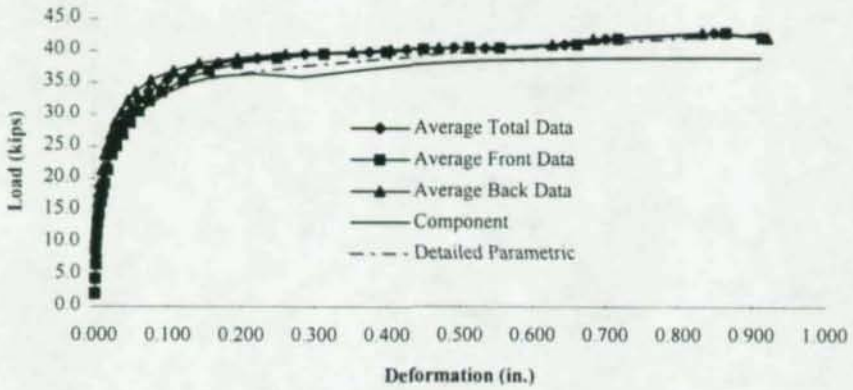
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bearing/Tearout | | |
| | Maximum: | 0.85 | 42.9 |
| | Failure: | 0.919 | 42.1 |
| | Other: | 0.16 | 37.7 |
| | | 0.25 | 39.1 |
| | | 0.34 | 39.7 |

## COMMENTS

* Yielding on PL-22 started at 27000 lbs with a deformation of 0.05 in.
* PL-35 yielded at 33500 lbs.
* The connection gained strength.

## CHART



**Test No: 37**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.1 | -0.001 | 0.000 | -0.001 | -0.001 | -0.001 | 0.000 | -0.001 | -0.001 | 0.001 |
| 2 | 4.4 | -0.002 | -0.001 | -0.002 | -0.002 | -0.002 | -0.001 | -0.001 | -0.001 | 0.001 |
| 3 | 6.6 | -0.002 | -0.002 | -0.003 | -0.002 | -0.004 | -0.002 | -0.002 | -0.001 | 0.002 |
| 4 | 8.5 | -0.003 | -0.002 | -0.004 | -0.004 | -0.005 | -0.003 | -0.002 | -0.002 | 0.003 |
| 5 | 9.8 | -0.004 | -0.002 | -0.005 | -0.004 | -0.005 | -0.004 | -0.002 | -0.002 | 0.004 |
| 6 | 11.2 | -0.004 | -0.004 | -0.006 | -0.006 | -0.007 | -0.004 | -0.004 | -0.002 | 0.005 |
| 7 | 13.0 | -0.003 | -0.006 | -0.006 | -0.009 | -0.007 | -0.005 | -0.004 | -0.002 | 0.005 |
| 8 | 14.4 | -0.003 | -0.010 | -0.007 | -0.012 | -0.009 | -0.005 | -0.005 | -0.002 | 0.007 |
| 9 | 16.3 | -0.003 | -0.015 | -0.007 | -0.018 | -0.011 | -0.006 | -0.006 | -0.002 | 0.008 |
| 10 | 17.7 | -0.004 | -0.018 | -0.008 | -0.021 | -0.013 | -0.006 | -0.008 | -0.002 | 0.010 |
| 11 | 19.3 | -0.004 | -0.022 | -0.010 | -0.026 | -0.016 | -0.006 | -0.010 | -0.002 | 0.012 |
| 12 | 21.3 | -0.006 | -0.028 | -0.012 | -0.032 | -0.021 | -0.007 | -0.015 | -0.002 | 0.015 |
| 13 | 23.7 | -0.008 | -0.035 | -0.017 | -0.042 | -0.029 | -0.009 | -0.020 | -0.003 | 0.020 |
| 14 | 25.1 | -0.012 | -0.041 | -0.023 | -0.050 | -0.035 | -0.011 | -0.025 | -0.004 | 0.025 |
| 15 | 26.8 | -0.018 | -0.049 | -0.032 | -0.061 | -0.043 | -0.014 | -0.031 | -0.005 | 0.032 |
| 16 | 28.6 | -0.026 | -0.058 | -0.043 | -0.073 | -0.053 | -0.019 | -0.038 | -0.008 | 0.040 |
| 17 | 30.4 | -0.036 | -0.070 | -0.055 | -0.087 | -0.065 | -0.027 | -0.046 | -0.012 | 0.050 |
| 18 | 32.2 | -0.048 | -0.083 | -0.070 | -0.102 | -0.077 | -0.035 | -0.055 | -0.018 | 0.061 |
| 19 | 33.6 | -0.064 | -0.098 | -0.087 | -0.120 | -0.091 | -0.045 | -0.066 | -0.026 | 0.075 |
| 20 | 35.3 | -0.091 | -0.127 | -0.117 | -0.152 | -0.116 | -0.065 | -0.087 | -0.043 | 0.100 |
| 21 | 36.9 | -0.124 | -0.161 | -0.155 | -0.190 | -0.150 | -0.095 | -0.118 | -0.070 | 0.133 |
| 22 | 38.0 | -0.160 | -0.198 | -0.195 | -0.231 | -0.188 | -0.130 | -0.153 | -0.102 | 0.169 |
| 23 | 38.9 | -0.213 | -0.251 | -0.251 | -0.286 | -0.244 | -0.182 | -0.205 | -0.151 | 0.223 |
| 24 | 39.5 | -0.275 | -0.314 | -0.316 | -0.352 | -0.312 | -0.248 | -0.270 | -0.216 | 0.288 |
| 25 | 39.9 | -0.358 | -0.398 | -0.403 | -0.439 | -0.407 | -0.341 | -0.361 | -0.305 | 0.377 |
| 26 | 40.2 | -0.407 | -0.451 | -0.453 | -0.491 | -0.461 | -0.392 | -0.415 | -0.353 | 0.428 |
| 27 | 40.5 | -0.469 | -0.513 | -0.518 | -0.555 | -0.529 | -0.458 | -0.481 | -0.419 | 0.493 |
| 28 | 40.4 | -0.509 | -0.556 | -0.561 | -0.597 | -0.572 | -0.501 | -0.524 | -0.461 | 0.535 |
| 29 | 41.0 | -0.615 | -0.659 | -0.669 | -0.705 | -0.686 | -0.613 | -0.636 | -0.575 | 0.645 |
| 30 | 41.9 | -0.670 | -0.716 | -0.725 | -0.761 | -0.745 | -0.670 | -0.692 | -0.628 | 0.701 |
| 31 | 42.9 | -0.815 | -0.864 | -0.874 | -0.911 | -0.897 | -0.818 | -0.840 | -0.778 | 0.850 |
| 32 | 42.1 | -0.865 | -0.912 | -0.925 | -0.959 | -0.985 | -0.906 | -0.932 | -0.866 | 0.919 |

**Test No: 38** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 3/8X3/4X7/8 Date: 3/27/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.5 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.375 | 1.625 | SHEAR | 22 |
| Bottom: | 4 | 0.75 | 1.625 | SAW | 29 |

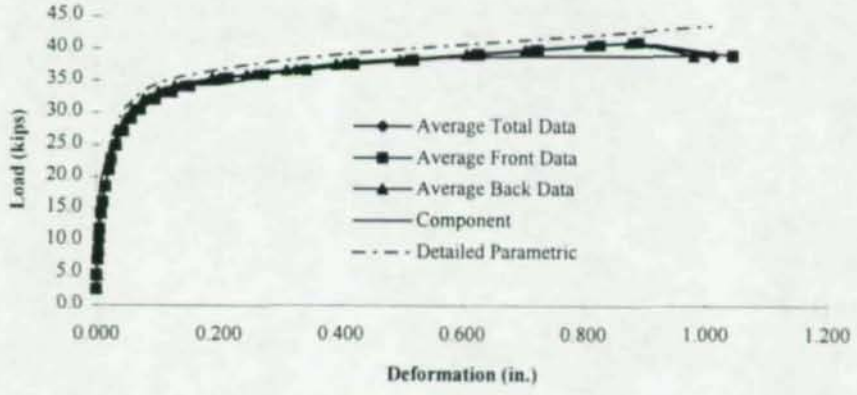
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bearing/Tearout | | |
| | Maximum: | 0.884 | 41.1 |
| | Failure: | 1.014 | 39 |
| | Other: | 0.16 | 34.5 |
| | | 0.25 | 35.9 |
| | | 0.34 | 36.8 |

## COMMENTS

* PL-22 yielded at 23000 lbs with a deformation of 0.025 in.
* PL-22 bulged at 33500 lbs, 0.12 in. of deformation.
* Splitting started at 0.95 in.
* Connection gained strength.

## CHART



**Test No: 38**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Load per | F1 | F2 | F3 | F4 | R1 | R2 | R3 | R4 | Total |
| Data Point | Plate (kips) | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | Avg |
| 1 | 2.6 | -0.001 | 0.000 | -0.002 | -0.002 | -0.003 | -0.002 | -0.001 | 0.001 | 0.001 |
| 2 | 4.7 | -0.001 | 0.000 | -0.003 | -0.004 | -0.006 | -0.004 | -0.001 | 0.001 | 0.002 |
| 3 | 7.1 | -0.001 | -0.001 | -0.006 | -0.006 | -0.009 | -0.007 | -0.001 | 0.001 | 0.004 |
| 4 | 8.5 | -0.001 | -0.002 | -0.007 | -0.008 | -0.010 | -0.009 | -0.001 | 0.001 | 0.005 |
| 5 | 10.5 | -0.001 | -0.002 | -0.007 | -0.010 | -0.012 | -0.011 | -0.001 | 0.001 | 0.006 |
| 6 | 11.9 | -0.001 | -0.004 | -0.009 | -0.012 | -0.013 | -0.013 | -0.001 | 0.000 | 0.006 |
| 7 | 14.3 | 0.000 | -0.007 | -0.010 | -0.017 | -0.016 | -0.017 | -0.001 | -0.001 | 0.009 |
| 8 | 16.0 | -0.001 | -0.010 | -0.013 | -0.023 | -0.018 | -0.020 | -0.002 | -0.002 | 0.011 |
| 9 | 18.5 | -0.002 | -0.014 | -0.017 | -0.030 | -0.024 | -0.024 | -0.005 | -0.005 | 0.015 |
| 10 | 21.1 | -0.004 | -0.020 | -0.022 | -0.039 | -0.031 | -0.029 | -0.009 | -0.007 | 0.020 |
| 11 | 22.7 | -0.006 | -0.024 | -0.024 | -0.045 | -0.037 | -0.034 | -0.013 | -0.009 | 0.024 |
| 12 | 24.9 | -0.008 | -0.034 | -0.031 | -0.057 | -0.045 | -0.039 | -0.019 | -0.012 | 0.031 |
| 13 | 27.1 | -0.014 | -0.046 | -0.041 | -0.075 | -0.059 | -0.048 | -0.028 | -0.016 | 0.041 |
| 14 | 29.0 | -0.022 | -0.060 | -0.054 | -0.093 | -0.074 | -0.059 | -0.039 | -0.022 | 0.053 |
| 15 | 30.5 | -0.032 | -0.077 | -0.066 | -0.113 | -0.090 | -0.069 | -0.050 | -0.029 | 0.066 |
| 16 | 32.1 | -0.053 | -0.103 | -0.089 | -0.141 | -0.111 | -0.087 | -0.068 | -0.042 | 0.087 |
| 17 | 33.2 | -0.078 | -0.131 | -0.115 | -0.171 | -0.139 | -0.109 | -0.092 | -0.063 | 0.112 |
| 18 | 34.1 | -0.105 | -0.161 | -0.143 | -0.202 | -0.168 | -0.135 | -0.120 | -0.087 | 0.140 |
| 19 | 35.4 | -0.163 | -0.224 | -0.206 | -0.269 | -0.233 | -0.198 | -0.181 | -0.144 | 0.202 |
| 20 | 36.0 | -0.218 | -0.282 | -0.264 | -0.330 | -0.291 | -0.255 | -0.237 | -0.197 | 0.259 |
| 21 | 36.6 | -0.286 | -0.351 | -0.335 | -0.402 | -0.359 | -0.322 | -0.302 | -0.260 | 0.327 |
| 22 | 37.6 | -0.362 | -0.429 | -0.413 | -0.484 | -0.442 | -0.405 | -0.382 | -0.340 | 0.407 |
| 23 | 38.3 | -0.457 | -0.527 | -0.511 | -0.585 | -0.548 | -0.511 | -0.486 | -0.442 | 0.508 |
| 24 | 39.1 | -0.563 | -0.634 | -0.620 | -0.699 | -0.660 | -0.623 | -0.596 | -0.549 | 0.618 |
| 25 | 39.9 | -0.657 | -0.730 | -0.716 | -0.797 | -0.759 | -0.722 | -0.692 | -0.643 | 0.715 |
| 26 | 40.7 | -0.756 | -0.833 | -0.818 | -0.903 | -0.865 | -0.829 | -0.796 | -0.749 | 0.819 |
| 27 | 41.1 | -0.820 | -0.896 | -0.881 | -0.967 | -0.932 | -0.896 | -0.863 | -0.812 | 0.884 |
| 28 | 39.0 | -0.975 | -1.057 | -1.031 | -1.121 | -1.038 | -1.005 | -0.965 | -0.918 | 1.014 |

**Test No: 40** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/2X1/2X7/8 Date: 3/28/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.5 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.5 | 1.75 | SAW | 34 |
| Bottom: | 4 | 0.5 | 1.75 | SAW | 34 |

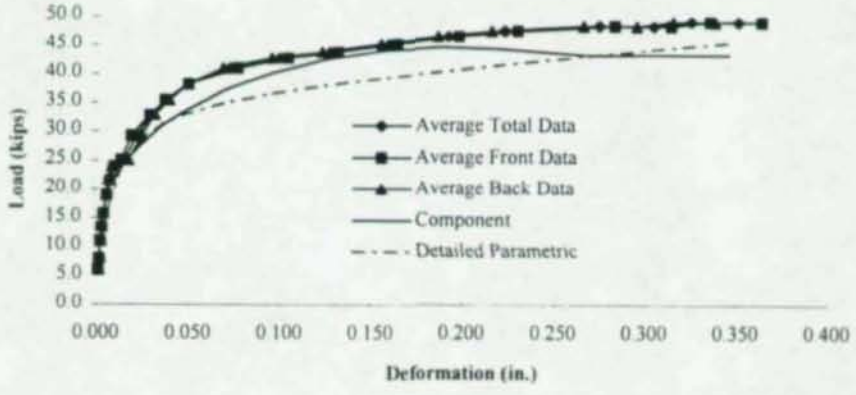
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.326 | 49.2 |
| | Failure: | 0.362 | 49.1 |
| | Other: | 0.16 | 45.2 |
| | | 0.25 | 48 |
| | | 0.34 | 49.1 |

## COMMENTS

* PL-34 yielded at 30500 lbs, 0.04 in of deformation.
* Bulging started on PL-34 at 49000 lbs.

## CHART



Test No: 40
Recorder: BK

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 6.1 | -0.001 | -0.001 | -0.001 | -0.002 | -0.002 | -0.002 | -0.002 | 0.000 | 0.001 |
| 2 | *8.0* | *-0.002* | *-0.001* | *-0.002* | *-0.002* | *-0.002* | *-0.003* | *-0.002* | *-0.001* | *0.002* |
| 3 | 11.1 | -0.004 | -0.001 | -0.004 | -0.003 | -0.003 | -0.004 | -0.004 | -0.002 | 0.003 |
| 4 | 13.5 | -0.005 | -0.001 | -0.006 | -0.004 | -0.003 | -0.005 | -0.004 | -0.003 | 0.004 |
| 5 | 15.7 | -0.007 | -0.001 | -0.008 | -0.004 | -0.004 | -0.006 | -0.004 | -0.004 | 0.005 |
| 6 | 19.0 | -0.010 | -0.001 | -0.012 | -0.003 | -0.005 | -0.008 | -0.004 | -0.007 | 0.006 |
| 7 | 21.6 | -0.014 | 0.000 | -0.017 | -0.002 | -0.005 | -0.011 | -0.004 | -0.009 | 0.008 |
| 8 | 24.0 | -0.019 | 0.000 | -0.021 | -0.002 | -0.005 | -0.015 | -0.004 | -0.013 | 0.010 |
| 9 | 25.1 | -0.025 | 0.001 | -0.029 | -0.002 | -0.011 | -0.027 | -0.010 | -0.025 | 0.016 |
| 10 | 29.2 | -0.033 | -0.002 | -0.039 | -0.006 | -0.017 | -0.035 | -0.015 | -0.034 | 0.023 |
| 11 | 32.8 | -0.046 | -0.009 | -0.052 | -0.012 | -0.024 | -0.044 | -0.021 | -0.041 | 0.031 |
| 12 | 35.5 | -0.056 | -0.015 | -0.062 | -0.018 | -0.031 | -0.053 | -0.028 | -0.050 | 0.039 |
| 13 | 38.2 | -0.070 | -0.026 | -0.078 | -0.029 | -0.041 | -0.064 | -0.038 | -0.060 | 0.051 |
| 14 | 41.0 | -0.099 | -0.051 | -0.107 | -0.053 | -0.059 | -0.084 | -0.056 | -0.080 | 0.074 |
| 15 | 42.7 | -0.128 | -0.078 | -0.136 | -0.080 | -0.085 | -0.110 | -0.083 | -0.107 | 0.101 |
| 16 | 43.7 | -0.157 | -0.105 | -0.164 | -0.105 | -0.112 | -0.137 | -0.111 | -0.134 | 0.128 |
| 17 | 45.3 | -0.191 | -0.136 | -0.197 | -0.137 | -0.144 | -0.170 | -0.144 | -0.167 | 0.161 |
| 18 | 46.6 | -0.226 | -0.169 | -0.231 | -0.171 | -0.175 | -0.201 | -0.175 | -0.198 | 0.193 |
| 19 | 47.6 | -0.258 | -0.200 | -0.263 | -0.202 | -0.205 | -0.230 | -0.204 | -0.228 | 0.224 |
| 20 | 48.4 | -0.312 | -0.253 | -0.317 | -0.254 | -0.255 | -0.280 | -0.255 | -0.279 | 0.276 |
| 21 | 48.4 | -0.343 | -0.285 | -0.348 | -0.284 | -0.283 | -0.309 | -0.284 | -0.308 | 0.306 |
| 22 | 49.2 | -0.364 | -0.305 | -0.370 | -0.305 | -0.304 | -0.328 | -0.304 | -0.328 | 0.326 |
| 23 | 49.1 | -0.393 | -0.334 | -0.398 | -0.334 | -0.327 | -0.352 | -0.327 | -0.351 | 0.352 |

**Test No: 41** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/2X3/4X7/8 Date: 4/3/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.75 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.5 | 1.75 | SAW | 34 |
| Bottom: | 4 | 0.75 | 1.75 | SAW | 29 |

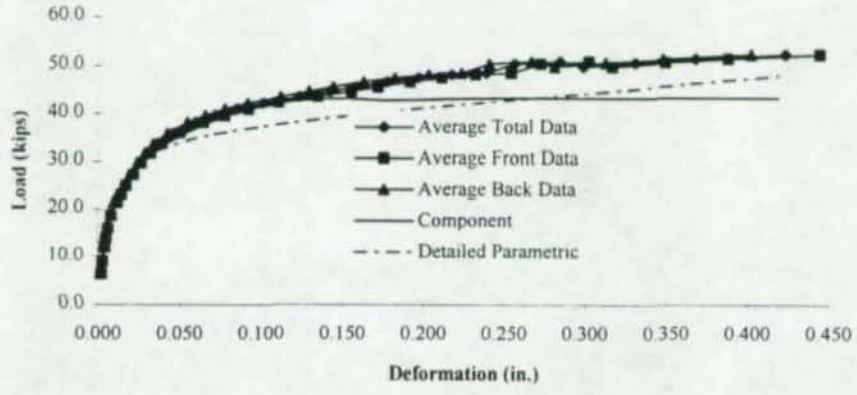
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.424 | 52.3 |
| | Failure: | 0.424 | 52.3 |
| | Other: | 0.16 | 50.9 |
| | | 0.25 | 49.7 |
| | | 0.34 | 45.6 |

## COMMENTS

* PL-34 yielded at 36000 lbs. 0.05 in. of deformation.
* PL-29 yielded at 41000 lbs. 0.1 in of deformation.
* PL-34 had a split at the edge of the plate at 0.45 in.

## CHART



**Test No: 41**
**Recorder: BK**

## Summary of One Bolt Lap Connection Tests

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 6.5 | -0.002 | -0.001 | -0.004 | -0.003 | -0.003 | -0.002 | -0.001 | -0.001 | 0.002 |
| 2 | 9.1 | -0.002 | -0.001 | -0.005 | -0.004 | -0.004 | -0.004 | -0.002 | -0.001 | 0.003 |
| 3 | 12.0 | -0.002 | -0.002 | -0.007 | -0.007 | -0.005 | -0.005 | -0.002 | -0.002 | 0.004 |
| 4 | 13.8 | -0.002 | -0.003 | -0.008 | -0.008 | -0.006 | -0.006 | -0.002 | -0.003 | 0.005 |
| 5 | 15.9 | -0.002 | -0.004 | -0.009 | -0.010 | -0.007 | -0.008 | -0.004 | -0.004 | 0.006 |
| 6 | 18.7 | -0.002 | -0.006 | -0.010 | -0.014 | -0.010 | -0.010 | -0.007 | -0.007 | 0.008 |
| 7 | 21.4 | -0.003 | -0.012 | -0.013 | -0.021 | -0.014 | -0.012 | -0.010 | -0.009 | 0.012 |
| 8 | 23.0 | -0.004 | -0.014 | -0.016 | -0.024 | -0.017 | -0.013 | -0.013 | -0.010 | 0.014 |
| 9 | 24.9 | -0.005 | -0.019 | -0.017 | -0.029 | -0.021 | -0.016 | -0.017 | -0.012 | 0.017 |
| 10 | 27.2 | -0.006 | -0.025 | -0.020 | -0.037 | -0.027 | -0.018 | -0.022 | -0.013 | 0.021 |
| 11 | 29.6 | -0.007 | -0.032 | -0.023 | -0.045 | -0.033 | -0.021 | -0.028 | -0.016 | 0.026 |
| 12 | 31.6 | -0.009 | -0.040 | -0.026 | -0.054 | -0.040 | -0.024 | -0.034 | -0.018 | 0.031 |
| 13 | 33.6 | -0.012 | -0.049 | -0.031 | -0.064 | -0.046 | -0.028 | -0.041 | -0.022 | 0.037 |
| 14 | 35.9 | -0.019 | -0.064 | -0.039 | -0.080 | -0.057 | -0.034 | -0.051 | -0.029 | 0.047 |
| 15 | 38.2 | -0.029 | -0.084 | -0.049 | -0.098 | -0.070 | -0.043 | -0.067 | -0.039 | 0.060 |
| 16 | 39.6 | -0.040 | -0.100 | -0.059 | -0.113 | -0.082 | -0.051 | -0.081 | -0.050 | 0.072 |
| 17 | 41.0 | -0.053 | -0.117 | -0.071 | -0.129 | -0.093 | -0.061 | -0.096 | -0.061 | 0.085 |
| 18 | 42.2 | -0.072 | -0.137 | -0.087 | -0.149 | -0.109 | -0.072 | -0.113 | -0.074 | 0.102 |
| 19 | 43.5 | -0.094 | -0.164 | -0.109 | -0.174 | -0.130 | -0.090 | -0.136 | -0.093 | 0.124 |
| 20 | 44.6 | -0.114 | -0.186 | -0.128 | -0.196 | -0.148 | -0.106 | -0.155 | -0.110 | 0.143 |
| 21 | 45.5 | -0.129 | -0.204 | -0.144 | -0.213 | -0.163 | -0.119 | -0.172 | -0.125 | 0.159 |
| 22 | 46.6 | -0.149 | -0.224 | -0.162 | -0.234 | -0.183 | -0.137 | -0.192 | -0.143 | 0.178 |
| 23 | 47.5 | -0.168 | -0.245 | -0.180 | -0.254 | -0.202 | -0.155 | -0.213 | -0.161 | 0.197 |
| 24 | 48.1 | -0.187 | -0.267 | -0.200 | -0.277 | -0.224 | -0.174 | -0.234 | -0.182 | 0.218 |
| 25 | 48.5 | -0.207 | -0.290 | -0.223 | -0.300 | -0.244 | -0.195 | -0.255 | -0.202 | 0.239 |
| 26 | 50.4 | -0.224 | -0.307 | -0.241 | -0.319 | -0.263 | -0.211 | -0.273 | -0.217 | 0.257 |
| 27 | 50.9 | -0.254 | -0.336 | -0.270 | -0.350 | -0.291 | -0.237 | -0.300 | -0.242 | 0.285 |
| 28 | 49.8 | -0.268 | -0.352 | -0.284 | -0.365 | -0.305 | -0.251 | -0.314 | -0.255 | 0.299 |
| 29 | 50.7 | -0.300 | -0.384 | -0.316 | -0.399 | -0.337 | -0.283 | -0.347 | -0.285 | 0.331 |
| 30 | 51.4 | -0.337 | -0.423 | -0.355 | -0.438 | -0.373 | -0.318 | -0.383 | -0.319 | 0.368 |
| 31 | 52.3 | -0.393 | -0.479 | -0.412 | -0.496 | -0.428 | -0.370 | -0.440 | -0.373 | 0.424 |

**Test No: 42** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/2X1X7/8 Date: 4/2/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | |
|---|---|---|---|
| Type: | A325 | Diameter (in.): 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): 3 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: X | |
| | | Bolt Head Washer: X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.5 | 1.75 | SAW | 33 |
| Bottom: | 4 | 1 | 1.75 | SAW | 31 |

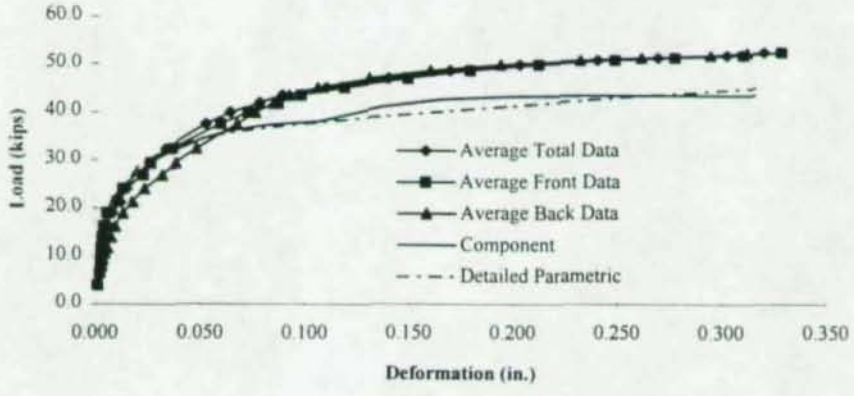
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.321 | 52.4 |
| | Failure: | 0.321 | 52.4 |
| | Other: | 0.16 | 48 |
| | | 0.25 | 50.9 |
| | | 0.34 | NA |

## COMMENTS

* PL-33 yielded at 37500 lbs. 0.055 in. of deformation.
* PL-31 yielded at 45000 lbs and 0.12 in. of deformation.
* PL-33 bulged at 48000 lbs. 0.25 in. of deformation.

## CHART



**Test No: 42**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.0 | -0.001 | 0.000 | -0.002 | -0.002 | -0.002 | -0.001 | -0.001 | 0.000 | 0.001 |
| 2 | 6.5 | -0.001 | -0.001 | -0.004 | -0.003 | -0.004 | -0.003 | -0.001 | 0.000 | 0.002 |
| 3 | 8.0 | -0.001 | -0.001 | -0.004 | -0.004 | -0.007 | -0.004 | -0.002 | 0.000 | 0.003 |
| 4 | 9.2 | -0.001 | -0.001 | -0.004 | -0.004 | -0.009 | -0.004 | -0.002 | 0.000 | 0.003 |
| 5 | 10.6 | -0.002 | -0.001 | -0.004 | -0.004 | -0.010 | -0.005 | -0.002 | 0.001 | 0.004 |
| 6 | 11.7 | -0.002 | -0.001 | -0.004 | -0.004 | -0.012 | -0.006 | -0.004 | 0.001 | 0.004 |
| 7 | 14.0 | -0.003 | -0.002 | -0.004 | -0.004 | -0.016 | -0.007 | -0.005 | 0.002 | 0.005 |
| 8 | 16.2 | -0.003 | -0.002 | -0.005 | -0.006 | -0.020 | -0.007 | -0.007 | 0.002 | 0.006 |
| 9 | 18.9 | -0.003 | -0.003 | -0.007 | -0.008 | -0.027 | -0.006 | -0.013 | 0.005 | 0.008 |
| 10 | 21.2 | -0.009 | -0.006 | -0.014 | -0.013 | -0.037 | -0.005 | -0.021 | 0.009 | 0.012 |
| 11 | 24.0 | -0.012 | -0.008 | -0.018 | -0.017 | -0.049 | -0.002 | -0.031 | 0.013 | 0.015 |
| 12 | 26.9 | -0.020 | -0.017 | -0.029 | -0.028 | -0.064 | 0.002 | -0.044 | 0.019 | 0.023 |
| 13 | 29.3 | -0.023 | -0.020 | -0.032 | -0.032 | -0.075 | 0.004 | -0.053 | 0.022 | 0.026 |
| 14 | 32.3 | -0.032 | -0.030 | -0.044 | -0.043 | -0.092 | 0.007 | -0.067 | 0.029 | 0.034 |
| 15 | 37.4 | -0.053 | -0.051 | -0.069 | -0.067 | -0.129 | 0.008 | -0.098 | 0.036 | 0.053 |
| 16 | 39.9 | -0.065 | -0.063 | -0.083 | -0.081 | -0.150 | 0.005 | -0.115 | 0.036 | 0.064 |
| 17 | 41.8 | -0.078 | -0.077 | -0.099 | -0.095 | -0.172 | -0.004 | -0.134 | 0.031 | 0.079 |
| 18 | 43.4 | -0.088 | -0.087 | -0.111 | -0.108 | -0.187 | -0.012 | -0.147 | 0.024 | 0.089 |
| 19 | 45.0 | -0.108 | -0.107 | -0.132 | -0.130 | -0.215 | -0.029 | -0.172 | 0.009 | 0.110 |
| 20 | 46.9 | -0.137 | -0.137 | -0.162 | -0.162 | -0.250 | -0.054 | -0.205 | -0.013 | 0.140 |
| 21 | 48.5 | -0.166 | -0.166 | -0.193 | -0.194 | -0.285 | -0.081 | -0.237 | -0.039 | 0.170 |
| 22 | 49.7 | -0.197 | -0.199 | -0.226 | -0.228 | -0.321 | -0.114 | -0.273 | -0.069 | 0.203 |
| 23 | 50.7 | -0.232 | -0.234 | -0.265 | -0.265 | -0.362 | -0.150 | -0.312 | -0.105 | 0.241 |
| 24 | 51.2 | -0.261 | -0.262 | -0.294 | -0.294 | -0.394 | -0.179 | -0.342 | -0.132 | 0.270 |
| 25 | 51.8 | -0.293 | -0.295 | -0.327 | -0.328 | -0.429 | -0.210 | -0.377 | -0.163 | 0.303 |
| 26 | 52.4 | -0.311 | -0.313 | -0.346 | -0.346 | -0.448 | -0.227 | -0.395 | -0.180 | 0.321 |

Test No: 43 **Summary of One Bolt Lap Connection Tests**
Recorder: BK

## TEST DESIGNATION

Test Designation: 3/4X3/4X7/8 Date: 4/3/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 3 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

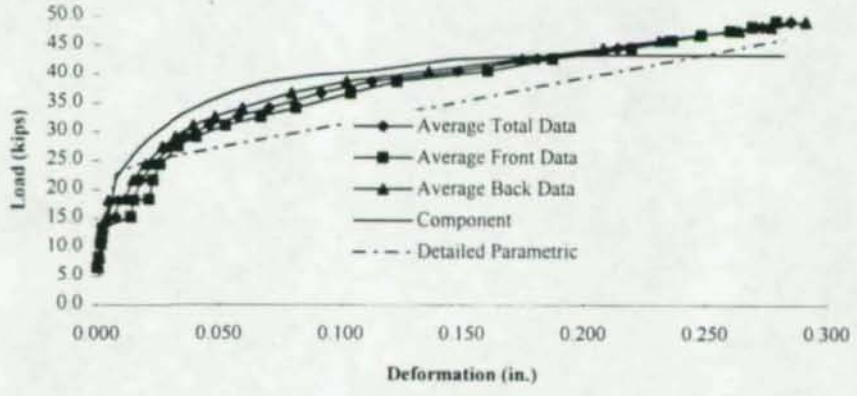
| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.75 | 1.75 | SAW | 29 |
| Bottom: | 4 | 0.75 | 1.75 | SAW | 29 |

## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.285 | 49.1 |
| | Failure: | 0.285 | 49.1 |
| | Other: | 0.16 | 41.3 |
| | | 0.25 | 47 |
| | | 0.34 | NA |

## COMMENTS

## CHART



**Test No: 43**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 6.6 | -0.001 | 0.000 | -0.001 | 0.000 | -0.001 | -0.001 | -0.001 | -0.001 | 0.001 |
| 2 | 8.2 | -0.001 | 0.000 | -0.002 | 0.001 | -0.001 | -0.002 | -0.001 | -0.001 | 0.001 |
| 3 | 10.6 | -0.002 | 0.000 | -0.004 | 0.001 | -0.002 | -0.003 | -0.001 | -0.002 | 0.002 |
| 4 | 11.6 | -0.004 | 0.000 | -0.004 | 0.001 | -0.002 | -0.003 | -0.002 | -0.002 | 0.002 |
| 5 | 13.3 | -0.004 | 0.000 | -0.006 | 0.001 | -0.003 | -0.003 | -0.002 | -0.002 | 0.002 |
| 6 | 15.3 | -0.017 | -0.015 | -0.019 | 0.005 | -0.004 | -0.005 | -0.005 | -0.002 | 0.008 |
| 7 | 18.1 | -0.019 | -0.015 | -0.022 | 0.005 | -0.006 | -0.005 | -0.006 | -0.002 | 0.009 |
| 8 | 18.3 | -0.027 | -0.024 | -0.030 | 0.004 | -0.013 | -0.010 | -0.015 | -0.007 | 0.015 |
| 9 | 21.6 | -0.031 | -0.024 | -0.035 | 0.003 | -0.017 | -0.013 | -0.019 | -0.010 | 0.018 |
| 10 | 24.4 | -0.037 | -0.024 | -0.042 | -0.001 | -0.024 | -0.017 | -0.025 | -0.014 | 0.023 |
| 11 | 27.4 | -0.045 | -0.027 | -0.052 | -0.010 | -0.032 | -0.023 | -0.034 | -0.020 | 0.030 |
| 12 | 29.0 | -0.051 | -0.035 | -0.059 | -0.018 | -0.038 | -0.028 | -0.039 | -0.024 | 0.036 |
| 13 | 31.0 | -0.063 | -0.047 | -0.072 | -0.029 | -0.046 | -0.035 | -0.046 | -0.030 | 0.046 |
| 14 | 32.6 | -0.077 | -0.062 | -0.085 | -0.044 | -0.055 | -0.045 | -0.055 | -0.039 | 0.058 |
| 15 | 34.1 | -0.095 | -0.068 | -0.102 | -0.061 | -0.066 | -0.057 | -0.065 | -0.050 | 0.071 |
| 16 | 36.7 | -0.119 | -0.084 | -0.127 | -0.086 | -0.085 | -0.079 | -0.085 | -0.070 | 0.092 |
| 17 | 38.7 | -0.145 | -0.084 | -0.152 | -0.111 | -0.108 | -0.105 | -0.107 | -0.089 | 0.113 |
| 18 | 40.5 | -0.163 | -0.151 | -0.184 | -0.144 | -0.139 | -0.139 | -0.136 | -0.131 | 0.148 |
| 19 | 42.7 | -0.163 | -0.180 | -0.223 | -0.182 | -0.176 | -0.181 | -0.173 | -0.168 | 0.181 |
| 20 | 44.5 | -0.164 | -0.243 | -0.256 | -0.216 | -0.206 | -0.214 | -0.206 | -0.206 | 0.214 |
| 21 | 45.8 | -0.165 | -0.243 | -0.289 | -0.250 | -0.235 | -0.245 | -0.236 | -0.207 | 0.234 |
| 22 | 46.9 | -0.165 | -0.243 | -0.312 | -0.273 | -0.257 | -0.269 | -0.258 | -0.207 | 0.248 |
| 23 | 47.6 | -0.165 | -0.243 | -0.336 | -0.297 | -0.278 | -0.291 | -0.280 | -0.207 | 0.262 |
| 24 | 48.3 | -0.165 | -0.243 | -0.355 | -0.315 | -0.295 | -0.310 | -0.297 | -0.207 | 0.273 |
| 25 | 49.1 | -0.165 | -0.243 | -0.374 | -0.335 | -0.314 | -0.329 | -0.316 | -0.207 | 0.285 |

**Test No: 44** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 3/4X1X7/8 Date: 4/3/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 3.25 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.75 | 1.75 | SAW | 29 |
| Bottom: | 4 | 1 | 1.75 | SAW | 30 |

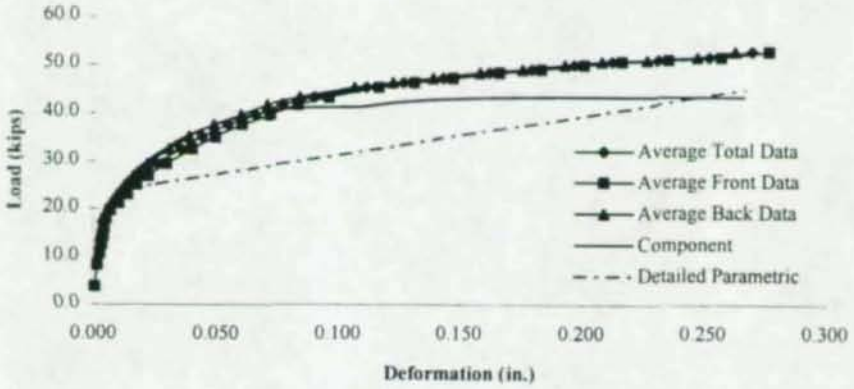
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.27 | 52.8 |
| | Failure: | 0.27 | 52.8 |
| | Other: | 0.16 | 48.2 |
| | | 0.25 | 51.5 |
| | | 0.34 | NA |

## COMMENTS

* PL-29 yielded at 30500 lbs, 0.03 in.
* PL-30 yielded at 42000 lbs, .085 in.

## CHART



**Test No: 44**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 3.9 | -0.002 | -0.001 | -0.001 | 0.000 | -0.001 | 0.000 | -0.002 | -0.001 | 0.001 |
| 2 | 8.4 | -0.005 | -0.002 | -0.001 | 0.000 | -0.002 | 0.000 | -0.004 | -0.001 | 0.002 |
| 3 | 10.8 | -0.006 | -0.004 | -0.002 | -0.001 | -0.002 | 0.000 | -0.006 | -0.002 | 0.003 |
| 4 | 12.7 | -0.007 | -0.006 | -0.002 | -0.001 | -0.002 | 0.000 | -0.007 | -0.002 | 0.003 |
| 5 | 14.4 | -0.008 | -0.006 | -0.002 | -0.002 | -0.002 | -0.001 | -0.007 | -0.002 | 0.004 |
| 6 | 16.0 | -0.009 | -0.007 | -0.002 | -0.002 | -0.003 | -0.001 | -0.009 | -0.002 | 0.004 |
| 7 | 18.0 | -0.009 | -0.009 | -0.002 | -0.002 | -0.003 | -0.001 | -0.010 | -0.003 | 0.005 |
| 8 | 19.7 | -0.012 | -0.013 | -0.002 | -0.003 | -0.004 | -0.002 | -0.012 | -0.006 | 0.007 |
| 9 | 21.2 | -0.015 | -0.018 | -0.003 | -0.007 | -0.006 | -0.003 | -0.014 | -0.007 | 0.009 |
| 10 | 22.9 | -0.018 | -0.024 | -0.005 | -0.010 | -0.009 | -0.004 | -0.018 | -0.009 | 0.012 |
| 11 | 25.1 | -0.021 | -0.029 | -0.007 | -0.015 | -0.013 | -0.006 | -0.024 | -0.010 | 0.016 |
| 12 | 26.9 | -0.026 | -0.037 | -0.009 | -0.020 | -0.019 | -0.006 | -0.030 | -0.012 | 0.020 |
| 13 | 29.5 | -0.033 | -0.048 | -0.012 | -0.028 | -0.027 | -0.009 | -0.039 | -0.014 | 0.026 |
| 14 | 29.5 | -0.034 | -0.048 | -0.012 | -0.028 | -0.027 | -0.009 | -0.039 | -0.014 | 0.026 |
| 15 | 32.6 | -0.044 | -0.064 | -0.016 | -0.039 | -0.040 | -0.013 | -0.053 | -0.019 | 0.036 |
| 16 | 35.0 | -0.054 | -0.080 | -0.020 | -0.047 | -0.050 | -0.017 | -0.066 | -0.024 | 0.045 |
| 17 | 37.6 | -0.065 | -0.097 | -0.024 | -0.057 | -0.063 | -0.022 | -0.081 | -0.032 | 0.055 |
| 18 | 39.6 | -0.076 | -0.114 | -0.031 | -0.069 | -0.076 | -0.028 | -0.097 | -0.041 | 0.066 |
| 19 | 41.7 | -0.087 | -0.130 | -0.037 | -0.081 | -0.087 | -0.035 | -0.112 | -0.051 | 0.078 |
| 20 | 43.2 | -0.100 | -0.147 | -0.046 | -0.094 | -0.103 | -0.043 | -0.130 | -0.062 | 0.091 |
| 21 | 45.3 | -0.118 | -0.173 | -0.062 | -0.116 | -0.126 | -0.062 | -0.157 | -0.083 | 0.112 |
| 22 | 46.2 | -0.132 | -0.190 | -0.074 | -0.131 | -0.143 | -0.075 | -0.175 | -0.098 | 0.127 |
| 23 | 47.2 | -0.146 | -0.208 | -0.087 | -0.149 | -0.161 | -0.091 | -0.193 | -0.114 | 0.144 |
| 24 | 48.4 | -0.164 | -0.229 | -0.106 | -0.169 | -0.181 | -0.108 | -0.213 | -0.132 | 0.163 |
| 25 | 49.0 | -0.180 | -0.247 | -0.122 | -0.187 | -0.199 | -0.123 | -0.232 | -0.149 | 0.180 |
| 26 | 50.0 | -0.198 | -0.266 | -0.138 | -0.204 | -0.217 | -0.139 | -0.250 | -0.167 | 0.197 |
| 27 | 50.7 | -0.212 | -0.281 | -0.153 | -0.221 | -0.233 | -0.154 | -0.266 | -0.181 | 0.213 |
| 28 | 51.1 | -0.230 | -0.302 | -0.172 | -0.240 | -0.252 | -0.172 | -0.285 | -0.200 | 0.231 |
| 29 | 51.6 | -0.252 | -0.324 | -0.193 | -0.262 | -0.273 | -0.192 | -0.306 | -0.219 | 0.253 |
| 30 | 52.8 | -0.271 | -0.344 | -0.212 | -0.281 | -0.290 | -0.207 | -0.323 | -0.233 | 0.270 |

**Test No: 45** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1X1X7/8 Date: 4/3/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.875 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 3.5 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 1 | 1.75 | SAW | 32 |
| Bottom: | 4 | 1 | 1.75 | SAW | 32 |

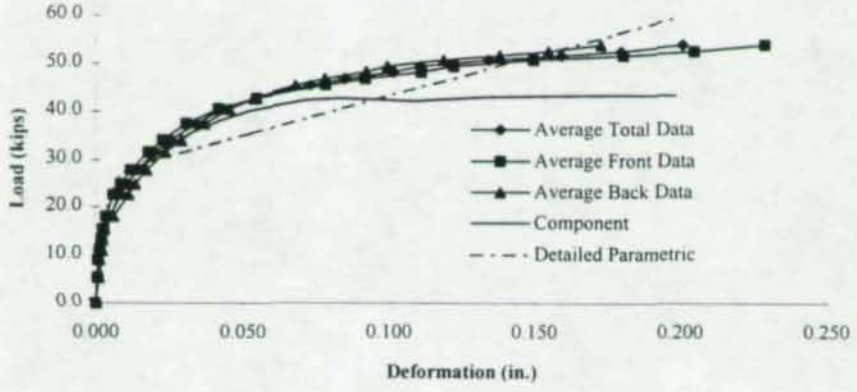
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.201 | 53.9 |
| | Failure: | 0.201 | 53.9 |
| | Other: | 0.16 | 51.7 |
| | | 0.25 | NA |
| | | 0.34 | NA |

## COMMENTS

* PL-32 yielded at 43000 lbs, 0.05 in.

## CHART



**Test No: 45**
**Recorder: BK**

## Summary of One Bolt Lap Connection Tests

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 0.0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | 0.000 |
| 2 | 5.3 | -0.001 | -0.001 | -0.001 | 0.000 | -0.001 | -0.001 | -0.002 | -0.001 | 0.001 |
| 3 | 8.9 | -0.001 | -0.001 | -0.002 | 0.000 | -0.002 | -0.001 | -0.002 | -0.001 | 0.001 |
| 4 | 11.1 | -0.002 | -0.002 | -0.002 | 0.000 | -0.003 | -0.002 | -0.002 | -0.001 | 0.002 |
| 5 | 10.9 | -0.002 | -0.002 | -0.001 | 0.000 | -0.003 | -0.002 | -0.003 | -0.001 | 0.002 |
| 6 | 13.1 | -0.002 | -0.003 | -0.002 | 0.000 | -0.004 | -0.002 | -0.003 | -0.001 | 0.002 |
| 7 | 15.3 | -0.004 | -0.003 | -0.002 | -0.001 | -0.003 | -0.004 | -0.003 | -0.002 | 0.003 |
| 8 | 18.0 | -0.005 | -0.003 | -0.004 | -0.002 | -0.002 | -0.011 | -0.003 | -0.009 | 0.005 |
| 9 | 22.6 | -0.011 | -0.002 | -0.010 | -0.002 | -0.001 | -0.022 | -0.002 | -0.020 | 0.009 |
| 10 | 24.8 | -0.017 | -0.001 | -0.015 | 0.000 | -0.001 | -0.026 | -0.002 | -0.024 | 0.011 |
| 11 | 27.8 | -0.024 | 0.000 | -0.022 | 0.001 | -0.001 | -0.034 | -0.003 | -0.031 | 0.014 |
| 12 | 31.5 | -0.037 | 0.000 | -0.032 | 0.003 | -0.005 | -0.043 | -0.007 | -0.040 | 0.020 |
| 13 | 33.9 | -0.046 | -0.002 | -0.042 | 0.001 | -0.010 | -0.050 | -0.011 | -0.047 | 0.026 |
| 14 | 37.4 | -0.060 | -0.007 | -0.054 | -0.002 | -0.017 | -0.059 | -0.018 | -0.055 | 0.034 |
| 15 | 40.4 | -0.074 | -0.015 | -0.069 | -0.010 | -0.025 | -0.069 | -0.025 | -0.064 | 0.044 |
| 16 | 42.6 | -0.091 | -0.026 | -0.083 | -0.020 | -0.033 | -0.078 | -0.034 | -0.072 | 0.054 |
| 17 | 45.4 | -0.118 | -0.050 | -0.108 | -0.038 | -0.048 | -0.092 | -0.046 | -0.085 | 0.073 |
| 18 | 46.8 | -0.133 | -0.063 | -0.122 | -0.050 | -0.059 | -0.103 | -0.057 | -0.094 | 0.085 |
| 19 | 48.2 | -0.157 | -0.081 | -0.141 | -0.066 | -0.073 | -0.117 | -0.070 | -0.108 | 0.102 |
| 20 | 49.4 | -0.169 | -0.092 | -0.152 | -0.076 | -0.081 | -0.125 | -0.078 | -0.115 | 0.111 |
| 21 | 50.7 | -0.198 | -0.120 | -0.180 | -0.101 | -0.100 | -0.146 | -0.097 | -0.133 | 0.134 |
| 22 | 51.7 | -0.232 | -0.151 | -0.209 | -0.129 | -0.120 | -0.167 | -0.114 | -0.151 | 0.159 |
| 23 | 52.5 | -0.258 | -0.176 | -0.233 | -0.152 | -0.138 | -0.185 | -0.130 | -0.167 | 0.180 |
| 24 | 53.9 | -0.283 | -0.202 | -0.257 | -0.175 | -0.158 | -0.203 | -0.147 | -0.184 | 0.201 |

**Test No: 46** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X1/4X1 Date: 4/4/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.25 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.25 | 2 | SHEAR | 20 |
| Bottom: | 4 | 0.25 | 2 | SHEAR | 20 |

## TEST RESULTS

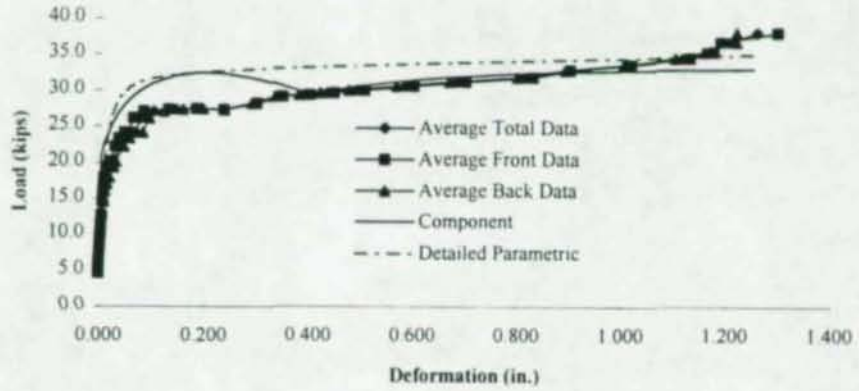
Limit State: Splitting

| | Deformation (in.) | Load (kips) |
|---|---|---|
| Maximum: | 1.262 | 38.1 |
| Failure: | 1.262 | 38.1 |
| Other: | 0.16 | 27.4 |
| | 0.25 | 27.4 |
| | 0.34 | 29.1 |

## COMMENTS

* PL-20 yielded at 18000 lbs

## CHART



Test No: 46
Recorder: BK

## Summary of One Bolt Lap Connection Tests

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.7 | -0.001 | 0.000 | -0.001 | -0.001 | 0.000 | -0.001 | 0.000 | -0.001 | 0.001 |
| 2 | 5.3 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.002 | -0.001 | -0.001 | 0.001 |
| 3 | 5.9 | -0.001 | -0.001 | -0.002 | -0.001 | -0.001 | -0.002 | -0.001 | -0.001 | 0.001 |
| 4 | 6.5 | -0.001 | -0.001 | -0.002 | -0.001 | -0.001 | -0.003 | -0.001 | -0.002 | 0.002 |
| 5 | 7.5 | -0.002 | -0.001 | -0.004 | -0.002 | -0.003 | -0.003 | -0.002 | -0.002 | 0.002 |
| 6 | 8.4 | -0.002 | -0.002 | -0.006 | -0.003 | -0.003 | -0.004 | -0.002 | -0.004 | 0.003 |
| 7 | 9.3 | -0.004 | -0.002 | -0.006 | -0.004 | -0.003 | -0.006 | -0.002 | -0.006 | 0.004 |
| 8 | 10.1 | -0.005 | -0.002 | -0.008 | -0.004 | -0.002 | -0.007 | -0.001 | -0.008 | 0.005 |
| 9 | 11.4 | -0.006 | -0.002 | -0.010 | -0.005 | -0.002 | -0.009 | -0.001 | -0.010 | 0.006 |
| 10 | 12.7 | -0.007 | -0.004 | -0.010 | -0.006 | -0.003 | -0.013 | -0.001 | -0.013 | 0.007 |
| 11 | 14.5 | -0.009 | -0.004 | -0.013 | -0.007 | -0.005 | -0.017 | -0.004 | -0.018 | 0.010 |
| 12 | 16.0 | -0.010 | -0.006 | -0.016 | -0.009 | -0.008 | -0.018 | -0.007 | -0.019 | 0.011 |
| 13 | 17.0 | -0.012 | -0.006 | -0.018 | -0.009 | -0.012 | -0.021 | -0.012 | -0.024 | 0.014 |
| 14 | 17.9 | -0.013 | -0.006 | -0.019 | -0.010 | -0.017 | -0.027 | -0.016 | -0.028 | 0.017 |
| 15 | 19.3 | -0.017 | -0.009 | -0.023 | -0.013 | -0.024 | -0.036 | -0.023 | -0.037 | 0.023 |
| 16 | 20.1 | -0.023 | -0.019 | -0.029 | -0.021 | -0.028 | -0.042 | -0.025 | -0.040 | 0.028 |
| 17 | 22.2 | -0.029 | -0.030 | -0.037 | -0.033 | -0.043 | -0.058 | -0.039 | -0.056 | 0.041 |
| 18 | 23.3 | -0.035 | -0.039 | -0.043 | -0.040 | -0.053 | -0.070 | -0.050 | -0.067 | 0.050 |
| 19 | 24.1 | -0.045 | -0.051 | -0.053 | -0.053 | -0.065 | -0.083 | -0.061 | -0.079 | 0.061 |
| 20 | 24.1 | -0.050 | -0.058 | -0.058 | -0.059 | -0.078 | -0.097 | -0.073 | -0.091 | 0.071 |
| 21 | 26.1 | -0.061 | -0.070 | -0.070 | -0.070 | -0.091 | -0.110 | -0.086 | -0.104 | 0.083 |
| 22 | 27.1 | -0.079 | -0.090 | -0.088 | -0.089 | -0.119 | -0.138 | -0.113 | -0.132 | 0.106 |
| 23 | 27.4 | -0.127 | -0.138 | -0.137 | -0.136 | -0.155 | -0.174 | -0.150 | -0.168 | 0.148 |
| 24 | 27.4 | -0.179 | -0.192 | -0.189 | -0.188 | -0.193 | -0.212 | -0.188 | -0.206 | 0.193 |
| 25 | 27.3 | -0.232 | -0.245 | -0.241 | -0.242 | -0.235 | -0.252 | -0.229 | -0.245 | 0.240 |
| 26 | 28.2 | -0.294 | -0.307 | -0.303 | -0.305 | -0.287 | -0.305 | -0.281 | -0.298 | 0.298 |
| 27 | 29.1 | -0.343 | -0.357 | -0.353 | -0.355 | -0.332 | -0.349 | -0.327 | -0.341 | 0.345 |
| 28 | 29.3 | -0.395 | -0.410 | -0.405 | -0.406 | -0.378 | -0.395 | -0.372 | -0.386 | 0.393 |
| 29 | 29.6 | -0.443 | -0.456 | -0.451 | -0.451 | -0.418 | -0.435 | -0.413 | -0.426 | 0.437 |
| 30 | 30.0 | -0.500 | -0.515 | -0.509 | -0.510 | -0.474 | -0.490 | -0.468 | -0.480 | 0.493 |
| 31 | 30.6 | -0.595 | -0.610 | -0.603 | -0.603 | -0.566 | -0.582 | -0.561 | -0.572 | 0.587 |
| 32 | 31.2 | -0.693 | -0.711 | -0.704 | -0.703 | -0.667 | -0.683 | -0.662 | -0.672 | 0.687 |
| 33 | 31.8 | -0.826 | -0.840 | -0.834 | -0.830 | -0.798 | -0.813 | -0.794 | -0.804 | 0.817 |
| 34 | 32.9 | -0.914 | -0.930 | -0.849 | -0.921 | -0.892 | -0.906 | -0.887 | -0.893 | 0.899 |
| 35 | 33.6 | -1.023 | -0.993 | -1.036 | -1.031 | -1.003 | -1.016 | -0.999 | -1.008 | 1.014 |
| 36 | 34.5 | -1.123 | -1.139 | -1.138 | -1.134 | -1.102 | -1.117 | -1.098 | -1.104 | 1.119 |
| 37 | 35.4 | -1.174 | -1.170 | -1.192 | -1.183 | -1.173 | -1.136 | -1.169 | -1.161 | 1.170 |
| 38 | 36.7 | -1.214 | -1.172 | -1.235 | -1.149 | -1.210 | -1.135 | -1.270 | -1.276 | 1.207 |
| 39 | 38.1 | -1.345 | -1.173 | -1.537 | -1.149 | -1.210 | -1.135 | -1.270 | -1.276 | 1.262 |

**Test No: 47** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X3/8X1 Date: 4/4/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | |
|---|---|---|---|
| Type: | A325 | Diameter (in.): 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): 2.25 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: X | |
| | | Bolt Head Washer: X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.25 | 2 | SHEAR | 20 |
| Bottom: | 4 | 0.37 | 2 | SHEAR | 25 |

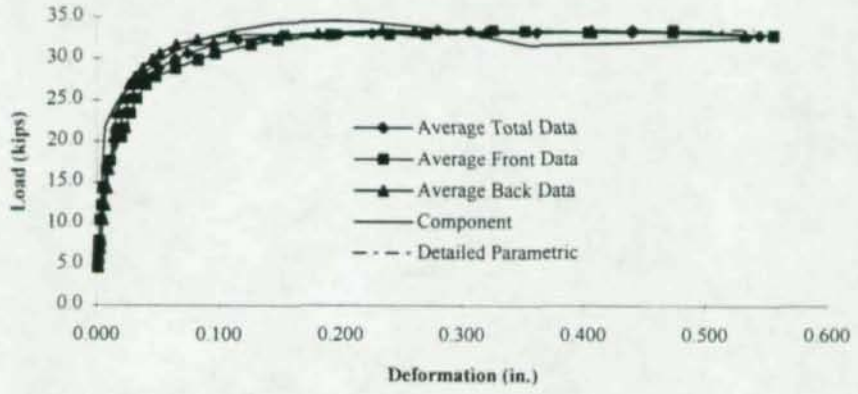
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: Bearing/Tearout | Maximum: | 0.44 | 33.5 |
| | Failure: | 0.544 | 32.9 |
| | Other: | 0.16 | 32.9 |
| | | 0.25 | 33.2 |
| | | 0.34 | 33.3 |

## COMMENTS

* PL-20 started yielding at 25700 lbs, 0.035 in.
* PL-25 started yielding at 29000 lbs with 0.065 in of deformation.
* Bulging on PL-20 started at 0.19 in. of deforamtion with 33000 lbs.

## CHART



Test No: 47
Recorder: BK

**Summary of One Bolt Lap Connection Tests**

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.7 | -0.001 | -0.001 | -0.002 | -0.001 | -0.002 | -0.002 | 0.000 | 0.001 | 0.001 |
| 2 | 5.8 | -0.001 | -0.001 | -0.002 | -0.002 | -0.004 | -0.004 | 0.000 | 0.001 | 0.002 |
| 3 | 6.9 | -0.001 | -0.001 | -0.004 | -0.002 | -0.006 | -0.006 | 0.000 | 0.001 | 0.002 |
| 4 | 7.9 | -0.001 | -0.002 | -0.004 | -0.003 | -0.007 | -0.007 | 0.000 | 0.001 | 0.003 |
| 5 | 10.5 | -0.002 | -0.002 | -0.005 | -0.004 | -0.010 | -0.011 | 0.000 | 0.000 | 0.004 |
| 6 | 12.2 | -0.004 | -0.003 | -0.007 | -0.004 | -0.012 | -0.013 | -0.001 | -0.001 | 0.006 |
| 7 | 14.3 | *-0.005* | *-0.003* | *-0.010* | *-0.006* | *-0.013* | *-0.017* | *-0.001* | *-0.003* | *0.007* |
| 8 | 16.5 | -0.009 | -0.004 | -0.015 | -0.006 | -0.015 | -0.019 | -0.001 | -0.004 | 0.009 |
| 9 | 17.6 | -0.012 | -0.006 | -0.018 | -0.009 | -0.016 | -0.021 | 0.000 | -0.006 | 0.011 |
| 10 | 20.5 | -0.018 | -0.015 | -0.027 | -0.020 | -0.018 | -0.026 | -0.002 | -0.008 | 0.017 |
| 11 | 21.6 | -0.020 | -0.018 | -0.030 | -0.023 | -0.018 | -0.028 | -0.002 | -0.010 | 0.019 |
| 12 | 23.4 | -0.023 | -0.024 | -0.034 | -0.030 | -0.020 | -0.034 | -0.002 | -0.014 | 0.023 |
| 13 | 25.2 | -0.026 | -0.031 | -0.038 | -0.037 | -0.021 | -0.040 | -0.003 | -0.020 | 0.027 |
| 14 | 26.9 | -0.031 | -0.041 | -0.044 | -0.046 | -0.027 | -0.048 | -0.006 | -0.026 | 0.034 |
| 15 | 27.8 | -0.037 | -0.051 | -0.050 | -0.056 | -0.030 | -0.054 | -0.011 | -0.031 | 0.040 |
| 16 | 28.8 | -0.052 | -0.068 | -0.064 | -0.074 | -0.035 | -0.061 | -0.015 | -0.037 | 0.051 |
| 17 | 29.9 | -0.068 | -0.089 | -0.081 | -0.094 | -0.042 | -0.071 | -0.023 | -0.047 | 0.064 |
| 18 | 29.9 | -0.068 | -0.089 | -0.081 | -0.094 | -0.042 | -0.071 | -0.023 | -0.047 | 0.064 |
| 19 | 30.6 | -0.081 | -0.105 | -0.094 | -0.108 | -0.048 | -0.078 | -0.028 | -0.053 | 0.074 |
| 20 | 31.7 | -0.108 | -0.136 | -0.121 | -0.139 | -0.060 | -0.092 | -0.040 | -0.067 | 0.095 |
| 21 | 32.3 | -0.130 | -0.159 | -0.143 | -0.161 | -0.077 | -0.110 | -0.057 | -0.083 | 0.115 |
| 22 | 32.9 | -0.172 | -0.203 | -0.185 | -0.206 | -0.103 | -0.143 | -0.084 | -0.116 | 0.151 |
| 23 | 32.9 | -0.220 | -0.253 | -0.232 | -0.256 | -0.145 | -0.188 | -0.127 | -0.162 | 0.198 |
| 24 | 33.0 | -0.249 | -0.281 | -0.263 | -0.289 | -0.168 | -0.215 | -0.154 | -0.187 | 0.226 |
| 25 | 33.5 | -0.302 | -0.336 | -0.319 | -0.344 | -0.220 | -0.268 | -0.207 | -0.239 | 0.280 |
| 26 | 33.4 | -0.329 | -0.361 | -0.345 | -0.371 | -0.248 | -0.295 | -0.232 | -0.266 | 0.306 |
| 27 | 33.2 | -0.380 | -0.415 | -0.396 | -0.424 | -0.307 | -0.355 | -0.290 | -0.324 | 0.361 |
| 28 | 33.2 | -0.447 | -0.486 | -0.465 | -0.496 | -0.393 | -0.444 | -0.377 | -0.412 | 0.440 |
| 29 | 33.5 | -0.448 | -0.486 | -0.465 | -0.496 | -0.393 | -0.444 | -0.377 | -0.412 | 0.440 |
| 30 | 32.9 | -0.527 | -0.569 | -0.547 | -0.581 | -0.523 | -0.572 | -0.502 | -0.535 | 0.544 |

**Test No: 48** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X1/2X1 Date: 4/4/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.25 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.25 | 2 | SAW | 40 |
| Bottom: | 4 | 0.5 | 2 | SAW | 12 |

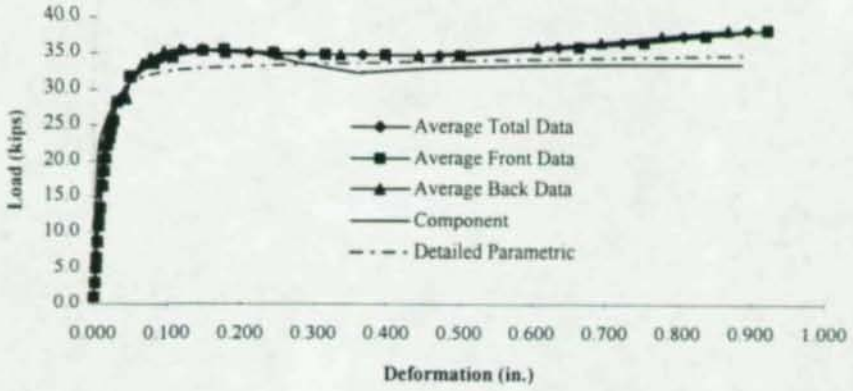
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Splitting | | |
| | Maximum: | 0.895 | 38.2 |
| | Failure: | 0.895 | 38.2 |
| | Other: | 0.16 | 35.4 |
| | | 0.25 | 34.9 |
| | | 0.34 | 34.7 |

## COMMENTS

* PL-40 started yielding at 0.04in. of deformation with 29000 lbs.
* At 35000 lbs, PL-40 started bulging in front of the bolt and PL-12 started yielding.
* Split occurred at 0.95 in. of deformation.
* Bearing / tear out also developed.

## CHART



Test No: 48
Recorder: BK

## Summary of One Bolt Lap Connection Tests

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0 | -0.001 | 0.001 | -0.002 | -0.001 | -0.001 | -0.001 | 0.000 | 0.001 | 0.001 |
| 2 | 3.0 | -0.001 | 0.001 | -0.005 | -0.004 | -0.004 | -0.004 | 0.000 | 0.001 | 0.002 |
| 3 | 5.1 | -0.001 | 0.001 | -0.007 | -0.007 | -0.006 | -0.007 | 0.000 | 0.001 | 0.003 |
| 4 | 6.5 | -0.001 | 0.001 | -0.009 | -0.007 | -0.007 | -0.009 | 0.000 | 0.001 | 0.004 |
| 5 | 8.7 | -0.001 | 0.001 | -0.012 | -0.010 | -0.010 | -0.012 | 0.000 | 0.001 | 0.005 |
| 6 | 10.9 | -0.002 | 0.001 | -0.013 | -0.012 | -0.013 | -0.015 | 0.000 | 0.001 | 0.007 |
| 7 | 11.7 | -0.002 | 0.001 | -0.015 | -0.012 | -0.014 | -0.016 | 0.000 | 0.001 | 0.007 |
| 8 | 13.4 | -0.004 | 0.002 | -0.018 | -0.013 | -0.015 | -0.018 | 0.000 | 0.000 | 0.008 |
| 9 | 16.5 | -0.007 | 0.003 | -0.024 | -0.017 | -0.017 | -0.023 | 0.000 | -0.002 | 0.011 |
| 10 | 18.5 | -0.010 | 0.004 | -0.029 | -0.018 | -0.018 | -0.025 | 0.000 | -0.003 | 0.012 |
| 11 | 20.4 | -0.012 | 0.004 | -0.032 | -0.019 | -0.020 | -0.028 | 0.000 | -0.004 | 0.014 |
| 12 | 22.2 | -0.016 | 0.004 | -0.038 | -0.020 | -0.021 | -0.033 | 0.001 | -0.007 | 0.016 |
| 13 | 23.1 | -0.021 | 0.002 | -0.043 | -0.023 | -0.023 | -0.039 | -0.004 | -0.012 | 0.020 |
| 14 | 24.4 | -0.022 | 0.003 | -0.047 | -0.024 | -0.023 | -0.042 | -0.003 | -0.013 | 0.021 |
| 15 | 25.6 | -0.028 | 0.001 | -0.053 | -0.028 | -0.026 | -0.047 | -0.007 | -0.018 | 0.026 |
| 16 | 28.2 | -0.034 | 0.000 | -0.062 | -0.033 | -0.030 | -0.057 | -0.010 | -0.025 | 0.031 |
| 17 | 28.6 | -0.043 | -0.005 | -0.075 | -0.041 | -0.042 | -0.073 | -0.022 | -0.039 | 0.042 |
| 18 | 31.7 | -0.053 | -0.010 | -0.086 | -0.048 | -0.047 | -0.084 | -0.025 | -0.048 | 0.050 |
| 19 | 33.6 | -0.088 | -0.039 | -0.122 | -0.079 | -0.058 | -0.106 | -0.037 | -0.066 | 0.074 |
| 20 | 34.3 | -0.115 | -0.062 | -0.150 | -0.103 | -0.066 | -0.120 | -0.043 | -0.078 | 0.092 |
| 21 | 35.2 | -0.157 | -0.102 | -0.193 | -0.143 | -0.081 | -0.144 | -0.057 | -0.099 | 0.122 |
| 22 | 35.5 | -0.185 | -0.130 | -0.221 | -0.173 | -0.102 | -0.169 | -0.077 | -0.122 | 0.147 |
| 23 | 35.0 | -0.251 | -0.196 | -0.289 | -0.242 | -0.166 | -0.231 | -0.136 | -0.183 | 0.212 |
| 24 | 34.8 | -0.323 | -0.267 | -0.359 | -0.315 | -0.238 | -0.306 | -0.207 | -0.255 | 0.284 |
| 25 | 34.7 | -0.404 | -0.348 | -0.443 | -0.399 | -0.323 | -0.392 | -0.291 | -0.341 | 0.367 |
| 26 | 34.7 | -0.506 | -0.450 | -0.547 | -0.503 | -0.431 | -0.500 | -0.399 | -0.446 | 0.473 |
| 27 | 35.8 | -0.668 | -0.611 | -0.711 | -0.669 | -0.596 | -0.665 | -0.560 | -0.607 | 0.636 |
| 28 | 36.5 | -0.757 | -0.701 | -0.799 | -0.757 | -0.682 | -0.754 | -0.647 | -0.694 | 0.724 |
| 29 | 37.4 | -0.843 | -0.784 | -0.884 | -0.841 | -0.766 | -0.840 | -0.728 | -0.777 | 0.808 |
| 30 | 38.2 | -0.927 | -0.867 | -0.970 | -0.926 | -0.856 | -0.929 | -0.819 | -0.870 | 0.895 |

**Test No: 49** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X5/8X1 Date: 4/5/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.5 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.25 | 2 | SAW | 41 |
| Bottom: | 4 | 0.625 | 2 | SAW | 27a |

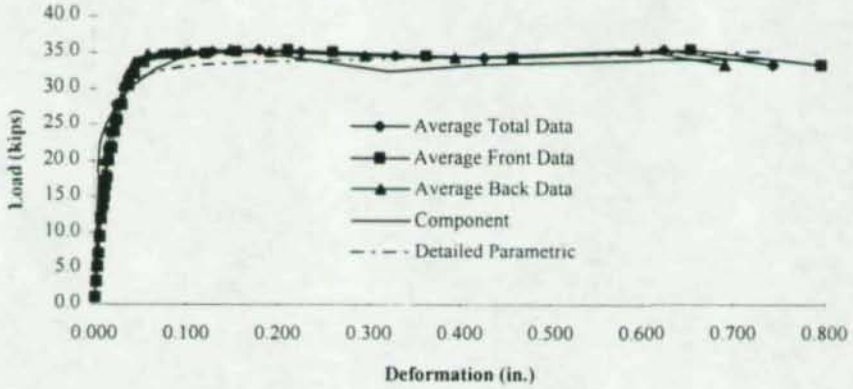
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Splitting | | |
| | Maximum: | 0.625 | 35.4 |
| | Failure: | 0.744 | 33.3 |
| | Other: | 0.16 | 35.3 |
| | | 0.25 | 35 |
| | | 0.34 | 34.5 |

## COMMENTS

* PL-41 yielded at a deformation of 0.042 in. with a load of 32000 lbs.
* Bulging on PL-41 occured at 35000 lbs. tips curled back.
* Splitting initiated at 0.73 in. of deformation.

## CHART



**Test No: 49**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 0.000 | -0.001 | -0.002 | -0.002 | -0.001 | -0.001 | -0.001 | 0.000 | 0.001 |
| 2 | 3.2 | 0.000 | 0.000 | -0.006 | -0.004 | -0.004 | -0.002 | -0.001 | 0.000 | 0.002 |
| 3 | 5.3 | 0.000 | 0.001 | -0.008 | -0.007 | -0.006 | -0.005 | -0.001 | 0.000 | 0.003 |
| 4 | 7.1 | 0.000 | 0.001 | -0.010 | -0.009 | -0.009 | -0.007 | -0.001 | 0.001 | 0.004 |
| 5 | 9.5 | 0.000 | 0.001 | -0.013 | -0.010 | -0.013 | -0.010 | -0.001 | 0.001 | 0.006 |
| 6 | 12.0 | -0.001 | 0.001 | -0.017 | -0.012 | -0.017 | -0.013 | 0.000 | 0.001 | 0.007 |
| 7 | 13.6 | -0.002 | -0.001 | -0.023 | -0.015 | -0.016 | -0.018 | -0.001 | -0.002 | 0.010 |
| 8 | 15.0 | -0.002 | 0.000 | -0.026 | -0.017 | -0.017 | -0.020 | -0.001 | -0.002 | 0.011 |
| 9 | 16.5 | -0.004 | 0.000 | -0.029 | -0.018 | -0.019 | -0.021 | -0.001 | -0.003 | 0.012 |
| 10 | 17.7 | -0.006 | 0.001 | -0.032 | -0.019 | -0.020 | -0.023 | -0.001 | -0.004 | 0.013 |
| 11 | 20.0 | -0.007 | 0.003 | -0.037 | -0.021 | -0.021 | -0.026 | 0.001 | -0.006 | 0.014 |
| 12 | 21.8 | -0.010 | 0.004 | -0.043 | -0.023 | -0.020 | -0.032 | 0.004 | -0.011 | 0.017 |
| 13 | 24.0 | -0.014 | 0.005 | -0.050 | -0.024 | -0.021 | -0.037 | 0.005 | -0.013 | 0.019 |
| 14 | 25.6 | -0.018 | 0.006 | -0.057 | -0.025 | -0.023 | -0.048 | 0.005 | -0.021 | 0.023 |
| 15 | 27.8 | -0.023 | 0.007 | -0.067 | -0.028 | -0.024 | -0.053 | 0.006 | -0.023 | 0.026 |
| 16 | 30.5 | -0.034 | 0.002 | -0.083 | -0.035 | -0.031 | -0.066 | 0.002 | -0.033 | 0.035 |
| 17 | 32.0 | -0.041 | -0.003 | -0.093 | -0.042 | -0.036 | -0.075 | -0.001 | -0.040 | 0.041 |
| 18 | 33.6 | -0.052 | -0.009 | -0.106 | -0.051 | -0.042 | -0.085 | -0.004 | -0.048 | 0.050 |
| 19 | 34.7 | -0.086 | -0.042 | -0.143 | -0.086 | -0.055 | -0.105 | -0.012 | -0.063 | 0.074 |
| 20 | 34.9 | -0.117 | -0.074 | -0.176 | -0.120 | -0.075 | -0.128 | -0.028 | -0.085 | 0.100 |
| 21 | 35.2 | -0.150 | -0.108 | -0.210 | -0.155 | -0.100 | -0.157 | -0.050 | -0.111 | 0.130 |
| 22 | 35.4 | -0.206 | -0.165 | -0.266 | -0.211 | -0.145 | -0.202 | -0.090 | -0.156 | 0.180 |
| 23 | 35.1 | -0.256 | -0.214 | -0.316 | -0.259 | -0.189 | -0.248 | -0.133 | -0.200 | 0.227 |
| 24 | 34.6 | -0.357 | -0.317 | -0.418 | -0.362 | -0.295 | -0.351 | -0.236 | -0.303 | 0.330 |
| 25 | 34.3 | -0.453 | -0.412 | -0.515 | -0.458 | -0.395 | -0.450 | -0.336 | -0.401 | 0.427 |
| 26 | 35.4 | -0.646 | -0.603 | -0.713 | -0.655 | -0.599 | -0.651 | -0.534 | -0.598 | 0.625 |
| 27 | 33.3 | -0.790 | -0.751 | -0.852 | -0.795 | -0.696 | -0.750 | -0.627 | -0.694 | 0.744 |

**Test No: 50** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X1X1 Date: 4/5/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.75 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.25 | 2 | SAW | 41 |
| Bottom: | 4 | 1 | 2 | SAW | 30 |

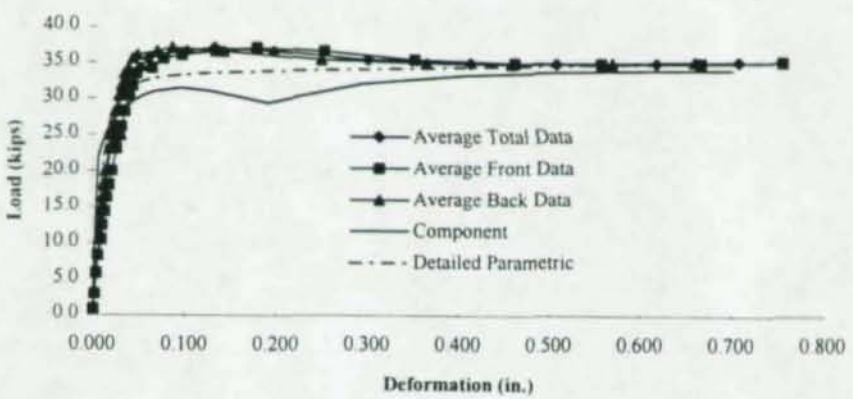
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Splitting | | |
| | Maximum: | 0.133 | 37.1 |
| | Failure: | 0.708 | 35.2 |
| | Other: | 0.16 | 36.9 |
| | | 0.25 | 36 |
| | | 0.34 | 35.3 |

## COMMENTS

* PL-41 yielded at 0.038 in. of deformation with 28500 lbs of load.
* Bulging started at 34000 lbs (0.11 in. of deformation).
* Bolt hole stretched excessively at 0.5 in. of deformation.
* At 0.9 in. splitting occurred.

## CHART



Test No: 50
Recorder: BK

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Load per* | *F1* | *F2* | *F3* | *F4* | *R1* | *R2* | *R3* | *R4* | *Total* |
| Data Point | Plate (kips) | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | Avg |
| 1 | 0.9 | 0.000 | 0.000 | -0.002 | -0.002 | -0.001 | -0.001 | -0.001 | 0.000 | 0.001 |
| 2 | 3.0 | 0.000 | 0.000 | -0.006 | -0.005 | -0.002 | -0.004 | -0.001 | 0.000 | 0.002 |
| 3 | 5.9 | 0.000 | 0.000 | -0.009 | -0.008 | -0.007 | -0.009 | -0.001 | 0.000 | 0.004 |
| 4 | 8.4 | -0.001 | 0.000 | -0.012 | -0.011 | -0.010 | -0.013 | -0.001 | 0.001 | 0.006 |
| 5 | 10.6 | -0.001 | 0.002 | -0.018 | -0.017 | -0.011 | -0.017 | -0.001 | 0.001 | 0.008 |
| 6 | *12.5* | *-0.001* | *0.002* | *-0.021* | *-0.018* | *-0.012* | *-0.021* | *-0.001* | *0.001* | *0.009* |
| 7 | 14.4 | -0.002 | 0.003 | -0.026 | -0.021 | -0.013 | -0.023 | -0.001 | -0.001 | 0.010 |
| 8 | 16.4 | -0.004 | 0.004 | -0.031 | -0.024 | -0.015 | -0.026 | 0.000 | -0.002 | 0.012 |
| 9 | 18.1 | -0.006 | 0.005 | -0.035 | -0.026 | -0.015 | -0.029 | 0.001 | -0.003 | 0.014 |
| 10 | 20.0 | -0.009 | 0.006 | -0.040 | -0.028 | -0.017 | -0.032 | 0.001 | -0.004 | 0.015 |
| 11 | 23.2 | -0.014 | 0.009 | -0.050 | -0.031 | -0.020 | -0.041 | 0.003 | -0.007 | 0.019 |
| 12 | 24.9 | -0.020 | 0.009 | -0.058 | -0.033 | -0.021 | -0.046 | 0.004 | -0.010 | 0.022 |
| 13 | 26.2 | -0.022 | 0.009 | -0.062 | -0.035 | -0.023 | -0.049 | 0.004 | -0.012 | 0.024 |
| 14 | 28.3 | -0.026 | 0.009 | -0.069 | -0.038 | -0.026 | -0.056 | 0.004 | -0.015 | 0.027 |
| 15 | 30.3 | -0.032 | 0.009 | -0.078 | -0.043 | -0.030 | -0.063 | 0.004 | -0.019 | 0.032 |
| 16 | 31.7 | -0.037 | 0.007 | -0.084 | -0.047 | -0.033 | -0.068 | 0.002 | -0.021 | 0.035 |
| 17 | 33.4 | -0.042 | 0.004 | -0.093 | -0.054 | -0.037 | -0.075 | 0.001 | -0.024 | 0.040 |
| 18 | 34.2 | -0.061 | -0.013 | -0.112 | -0.072 | -0.042 | -0.083 | -0.001 | -0.029 | 0.052 |
| 19 | 35.5 | -0.073 | -0.026 | -0.125 | -0.086 | -0.047 | -0.090 | -0.004 | -0.034 | 0.060 |
| 20 | 36.1 | -0.092 | -0.045 | -0.146 | -0.105 | -0.053 | -0.097 | -0.007 | -0.038 | 0.073 |
| 21 | 36.6 | -0.130 | -0.081 | -0.184 | -0.141 | -0.076 | -0.120 | -0.025 | -0.058 | 0.102 |
| 22 | 37.1 | -0.176 | -0.128 | -0.226 | -0.186 | -0.094 | -0.141 | -0.038 | -0.073 | 0.133 |
| 23 | 36.6 | -0.249 | -0.202 | -0.299 | -0.260 | -0.149 | -0.202 | -0.090 | -0.130 | 0.198 |
| 24 | 35.4 | -0.349 | -0.301 | -0.399 | -0.360 | -0.256 | -0.308 | -0.200 | -0.235 | 0.301 |
| 25 | 35.0 | -0.457 | -0.410 | -0.510 | -0.471 | -0.369 | -0.423 | -0.315 | -0.352 | 0.413 |
| 26 | 34.9 | -0.552 | -0.506 | -0.604 | -0.567 | -0.464 | -0.517 | -0.409 | -0.444 | 0.508 |
| 27 | 35.0 | -0.661 | -0.614 | -0.714 | -0.677 | -0.574 | -0.628 | -0.520 | -0.555 | 0.618 |
| 28 | 35.2 | -0.749 | -0.704 | -0.803 | -0.768 | -0.666 | -0.719 | -0.608 | -0.644 | 0.708 |

Test No: 51 **Summary of One Bolt Lap Connection Tests**
Recorder: BK

## TEST DESIGNATION

Test Designation: 1/4X3/4X1 Date: 4/5/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.5 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.25 | 2 | SAW | 41 |
| Bottom: | 4 | 0.75 | 2 | SAW | 28 |

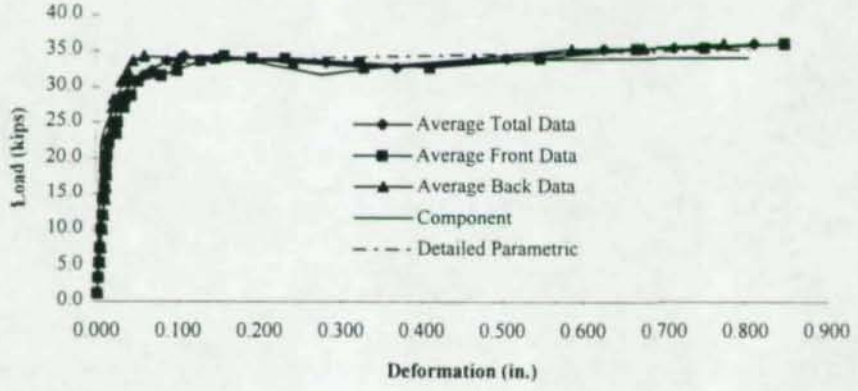
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: Splitting | Maximum: | 0.811 | 36.1 |
| | Failure: | 0.811 | 36.1 |
| | Other: | 0.16 | 33.9 |
| | | 0.25 | 33.6 |
| | | 0.34 | 32.9 |

## COMMENTS

* PL-41 yielded at 28300 lbs with a deformation of 0.035 in.
* Bulging started at 0.18 of deformation on PL-41.

## CHART



**Test No: 51** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Load per | F1 | F2 | F3 | F4 | R1 | R2 | R3 | R4 | Total |
| Data Point | Plate (kips) | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | Avg |
| 1 | 1.2 | -0.001 | 0.000 | -0.002 | -0.001 | -0.002 | -0.002 | 0.000 | 0.000 | 0.001 |
| 2 | 3.4 | -0.001 | 0.000 | -0.004 | -0.004 | -0.005 | -0.004 | 0.000 | 0.000 | 0.002 |
| 3 | 5.4 | -0.001 | 0.000 | -0.007 | -0.006 | -0.008 | -0.007 | -0.001 | 0.001 | 0.004 |
| 4 | 7.5 | -0.001 | 0.000 | -0.009 | -0.008 | -0.010 | -0.009 | -0.001 | 0.001 | 0.005 |
| 5 | 10.0 | -0.002 | 0.000 | -0.012 | -0.011 | -0.014 | -0.013 | -0.001 | 0.001 | 0.006 |
| 6 | 12.0 | -0.002 | 0.000 | -0.014 | -0.013 | -0.017 | -0.016 | 0.000 | 0.001 | 0.008 |
| 7 | 14.3 | -0.003 | 0.000 | -0.017 | -0.014 | -0.020 | -0.020 | 0.000 | 0.001 | 0.009 |
| 8 | 15.8 | -0.004 | -0.001 | -0.020 | -0.016 | -0.023 | -0.022 | 0.000 | 0.001 | 0.010 |
| 9 | *17.6* | *-0.004* | *0.000* | *-0.023* | *-0.019* | *-0.024* | *-0.024* | *0.000* | *0.001* | *0.012* |
| 10 | 18.9 | -0.004 | -0.001 | -0.026 | -0.020 | -0.025 | -0.026 | 0.001 | -0.001 | 0.013 |
| 11 | 20.4 | -0.006 | 0.000 | -0.029 | -0.023 | -0.027 | -0.028 | 0.001 | -0.001 | 0.014 |
| 12 | 22.1 | -0.007 | -0.001 | -0.032 | -0.025 | -0.029 | -0.031 | 0.001 | -0.001 | 0.016 |
| 13 | 23.4 | -0.015 | -0.008 | -0.045 | -0.032 | -0.032 | -0.032 | -0.001 | -0.002 | 0.021 |
| 14 | 25.0 | -0.016 | -0.008 | -0.047 | -0.034 | -0.033 | -0.035 | -0.001 | -0.002 | 0.022 |
| 15 | 27.0 | -0.023 | -0.015 | -0.057 | -0.043 | -0.036 | -0.040 | 0.000 | -0.004 | 0.027 |
| 16 | 28.3 | -0.023 | -0.015 | -0.059 | -0.046 | -0.037 | -0.043 | 0.000 | -0.005 | 0.029 |
| 17 | 28.8 | -0.028 | -0.022 | -0.069 | -0.053 | -0.045 | -0.052 | -0.006 | -0.013 | 0.036 |
| 18 | 30.8 | -0.035 | -0.029 | -0.078 | -0.063 | -0.048 | -0.056 | -0.006 | -0.014 | 0.041 |
| 19 | 31.6 | -0.063 | -0.058 | -0.105 | -0.092 | -0.056 | -0.065 | -0.009 | -0.019 | 0.058 |
| 20 | 32.2 | -0.082 | -0.078 | -0.126 | -0.111 | -0.058 | -0.067 | -0.009 | -0.020 | 0.069 |
| 21 | 33.6 | -0.111 | -0.106 | -0.155 | -0.140 | -0.067 | -0.076 | -0.012 | -0.025 | 0.086 |
| 22 | 34.3 | -0.139 | -0.135 | -0.183 | -0.169 | -0.084 | -0.092 | -0.023 | -0.036 | 0.108 |
| 23 | 34.2 | -0.139 | -0.135 | -0.183 | -0.169 | -0.084 | -0.092 | -0.024 | -0.036 | 0.108 |
| 24 | 33.9 | -0.172 | -0.169 | -0.219 | -0.204 | -0.128 | -0.135 | -0.066 | -0.077 | 0.146 |
| 25 | 33.9 | -0.212 | -0.210 | -0.260 | -0.245 | -0.173 | -0.179 | -0.111 | -0.123 | 0.189 |
| 26 | 33.4 | -0.304 | -0.301 | -0.352 | -0.337 | -0.269 | -0.274 | -0.206 | -0.217 | 0.282 |
| 27 | 32.7 | -0.389 | -0.387 | -0.441 | -0.425 | -0.356 | -0.362 | -0.293 | -0.305 | 0.370 |
| 28 | 34.0 | -0.526 | -0.524 | -0.579 | -0.559 | -0.495 | -0.499 | -0.428 | -0.439 | 0.506 |
| 29 | 35.3 | -0.645 | -0.640 | -0.699 | -0.680 | -0.618 | -0.619 | -0.549 | -0.558 | 0.626 |
| 30 | 35.5 | -0.727 | -0.725 | -0.785 | -0.763 | -0.708 | -0.709 | -0.637 | -0.646 | 0.712 |
| 31 | 36.1 | -0.824 | -0.823 | -0.883 | -0.863 | -0.807 | -0.808 | -0.736 | -0.743 | 0.811 |

**Test No: 52** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 3/8X3/8X1 Date: 4/5/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.5 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.375 | 2 | SHEAR | 24 |
| Bottom: | 4 | 0.375 | 2 | SHEAR | 24 |

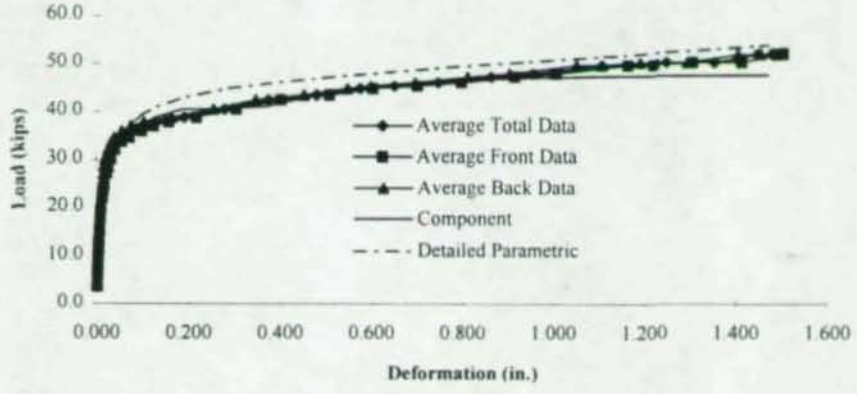
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: Bearing/Tearout | Maximum: | 1.48 | 52.1 |
| | Failure: | 1.48 | 52.1 |
| | Other: | 0.16 | 38.3 |
| | | 0.25 | 39.9 |
| | | 0.34 | 41.7 |

## COMMENTS

* At 35000 lbs. PL-24 yielded with a deforamtion of 0.05 in.
* At 36000 lbs, tips of the plates started curling back.
* Bulging started at 39000 lbs with a deformation of 0.2 in.
* Connection gained strength in the plastic region.

## CHART



Test No: 52
Recorder: BK

**Summary of One Bolt Lap Connection Tests**

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.7 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | 0.001 |
| 2 | 6.1 | -0.002 | -0.001 | -0.001 | -0.001 | -0.002 | -0.002 | -0.001 | -0.001 | 0.001 |
| 3 | 7.8 | -0.002 | -0.002 | -0.002 | -0.002 | -0.003 | -0.003 | -0.002 | -0.001 | 0.002 |
| 4 | 10.2 | -0.003 | -0.003 | -0.002 | -0.002 | -0.004 | -0.005 | -0.003 | -0.001 | 0.003 |
| 5 | 11.7 | -0.004 | -0.004 | -0.004 | -0.003 | -0.005 | -0.006 | -0.004 | -0.002 | 0.004 |
| 6 | 13.2 | -0.004 | -0.004 | -0.004 | -0.004 | -0.006 | -0.006 | -0.005 | -0.002 | 0.004 |
| 7 | 15.5 | -0.006 | -0.006 | -0.006 | -0.004 | -0.009 | -0.006 | -0.007 | -0.002 | 0.006 |
| 8 | 17.7 | -0.009 | -0.007 | -0.007 | -0.006 | -0.010 | -0.006 | -0.010 | -0.002 | 0.007 |
| 9 | 19.5 | -0.010 | -0.008 | -0.010 | -0.006 | -0.012 | -0.006 | -0.012 | -0.002 | 0.008 |
| 10 | 21.9 | -0.013 | -0.009 | -0.014 | -0.008 | -0.014 | -0.007 | -0.015 | -0.002 | 0.010 |
| 11 | 23.3 | -0.015 | -0.011 | -0.015 | -0.010 | -0.016 | -0.007 | -0.016 | -0.003 | 0.012 |
| 12 | 24.6 | -0.017 | -0.013 | -0.018 | -0.013 | -0.017 | -0.008 | -0.017 | -0.003 | 0.013 |
| 13 | 27.1 | -0.022 | -0.023 | -0.023 | -0.018 | -0.021 | -0.010 | -0.020 | -0.005 | 0.018 |
| 14 | 28.6 | -0.026 | -0.028 | -0.026 | -0.023 | -0.024 | -0.011 | -0.023 | -0.006 | 0.021 |
| 15 | 30.2 | -0.031 | -0.035 | -0.031 | -0.031 | -0.029 | -0.013 | -0.028 | -0.007 | 0.026 |
| 16 | 32.0 | -0.038 | -0.048 | -0.037 | -0.040 | -0.035 | -0.017 | -0.036 | -0.012 | 0.033 |
| 17 | 33.8 | -0.050 | -0.065 | -0.049 | -0.057 | -0.044 | -0.022 | -0.046 | -0.018 | 0.044 |
| 18 | 34.7 | -0.065 | -0.084 | -0.065 | -0.076 | -0.053 | -0.028 | -0.054 | -0.024 | 0.056 |
| 19 | 36.0 | -0.091 | -0.112 | -0.089 | -0.104 | -0.071 | -0.042 | -0.070 | -0.037 | 0.077 |
| 20 | 37.1 | -0.116 | -0.139 | -0.115 | -0.130 | -0.094 | -0.062 | -0.090 | -0.054 | 0.100 |
| 21 | 37.9 | -0.149 | -0.172 | -0.149 | -0.163 | -0.124 | -0.089 | -0.121 | -0.083 | 0.131 |
| 22 | 38.8 | -0.209 | -0.232 | -0.210 | -0.224 | -0.186 | -0.148 | -0.182 | -0.142 | 0.192 |
| 23 | 40.5 | -0.295 | -0.318 | -0.297 | -0.311 | -0.280 | -0.237 | -0.276 | -0.229 | 0.280 |
| 24 | 42.4 | -0.391 | -0.417 | -0.396 | -0.408 | -0.374 | -0.328 | -0.370 | -0.318 | 0.375 |
| 25 | 43.4 | -0.496 | -0.524 | -0.503 | -0.517 | -0.484 | -0.432 | -0.476 | -0.421 | 0.482 |
| 26 | 44.8 | -0.590 | -0.620 | -0.600 | -0.611 | -0.583 | -0.525 | -0.575 | -0.513 | 0.577 |
| 27 | 45.3 | -0.684 | -0.720 | -0.695 | -0.712 | -0.638 | -0.578 | -0.622 | -0.566 | 0.652 |
| 28 | 46.1 | -0.779 | -0.817 | -0.793 | -0.808 | -0.735 | -0.673 | -0.721 | -0.661 | 0.748 |
| 29 | 47.2 | -0.898 | -0.935 | -0.910 | -0.926 | -0.852 | -0.786 | -0.839 | -0.775 | 0.865 |
| 30 | 48.0 | -0.985 | -1.027 | -1.003 | -1.018 | -0.943 | -0.876 | -0.934 | -0.867 | 0.957 |
| 31 | 49.7 | -1.139 | -1.184 | -1.162 | -1.177 | -1.096 | -1.020 | -1.083 | -1.010 | 1.109 |
| 32 | 49.7 | -1.194 | -1.240 | -1.218 | -1.232 | -1.152 | -1.076 | -1.141 | -1.067 | 1.165 |
| 33 | 50.3 | -1.281 | -1.326 | -1.303 | -1.319 | -1.236 | -1.156 | -1.226 | -1.151 | 1.250 |
| 34 | 50.3 | -1.386 | -1.434 | -1.413 | -1.426 | -1.343 | -1.256 | -1.331 | -1.252 | 1.355 |
| 35 | 51.9 | -1.535 | -1.464 | -1.420 | -1.550 | -1.491 | -1.256 | -1.479 | -1.400 | 1.449 |
| 36 | 52.1 | -1.583 | -1.464 | -1.423 | -1.550 | -1.559 | -1.256 | -1.545 | -1.462 | 1.480 |

**Test No: 53** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 3/8X1/2X1 Date: 4/6/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.5 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.375 | 2 | SHEAR | 24 |
| Bottom: | 4 | 0.5 | 2 | SAW | 12 |

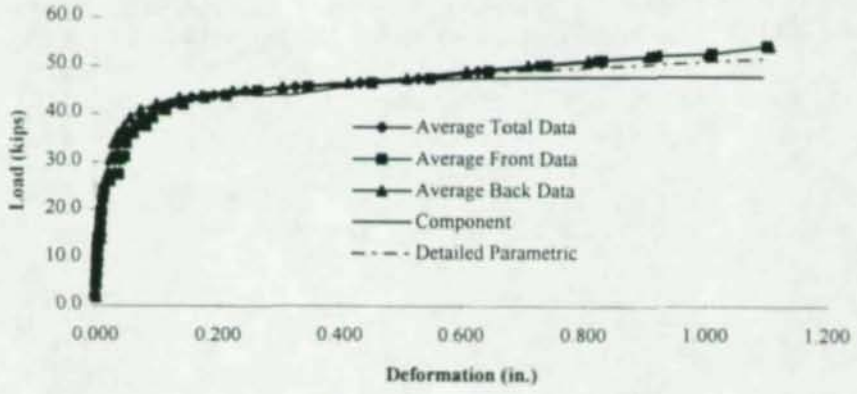
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: Bearing/Tearout | Maximum: | 1.104 | 54.1 |
| | Failure: | 1.104 | 54.1 |
| | Other: | 0.16 | 43.3 |
| | | 0.25 | 44.7 |
| | | 0.34 | 45.5 |

## COMMENTS

* PL-24 started yielding at 36000 lbs with a deformation of 0.06 in
* At 43500 lbs, PL-12 yielded with a deformation of 0.11 in.

## CHART



Test No: 53
Recorder: BK

**Summary of One Bolt Lap Connection Tests**

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.8 | -0.001 | 0.000 | -0.001 | -0.001 | -0.002 | -0.001 | -0.001 | 0.000 | 0.001 |
| 2 | 4.5 | -0.001 | -0.001 | -0.002 | -0.003 | -0.004 | -0.003 | -0.001 | -0.001 | 0.002 |
| 3 | 6.8 | -0.001 | -0.001 | -0.004 | -0.004 | -0.005 | -0.005 | -0.001 | -0.001 | 0.003 |
| 4 | 9.2 | -0.001 | -0.001 | -0.006 | -0.006 | -0.007 | -0.007 | -0.001 | -0.003 | 0.004 |
| 5 | 10.3 | -0.001 | -0.001 | -0.006 | -0.006 | -0.008 | -0.007 | -0.002 | -0.003 | 0.004 |
| 6 | 12.3 | -0.002 | -0.001 | -0.007 | -0.007 | -0.010 | -0.009 | -0.002 | -0.003 | 0.005 |
| 7 | 14.1 | -0.002 | -0.002 | -0.008 | -0.009 | -0.011 | -0.010 | -0.002 | -0.004 | 0.006 |
| 8 | 14.0 | -0.004 | -0.002 | -0.010 | -0.011 | -0.010 | -0.012 | -0.012 | -0.003 | 0.008 |
| 9 | 15.5 | -0.004 | -0.003 | -0.012 | -0.013 | -0.011 | -0.013 | -0.012 | -0.004 | 0.009 |
| 10 | 17.8 | -0.005 | -0.004 | -0.013 | -0.015 | -0.012 | -0.013 | -0.012 | -0.004 | 0.010 |
| 11 | 19.8 | -0.006 | -0.005 | -0.016 | -0.017 | -0.013 | -0.015 | -0.012 | -0.004 | 0.011 |
| 12 | 22.4 | -0.007 | -0.006 | -0.018 | -0.020 | -0.015 | -0.017 | -0.012 | -0.006 | 0.012 |
| 13 | 24.2 | -0.007 | -0.007 | -0.021 | -0.023 | -0.016 | -0.018 | -0.013 | -0.007 | 0.014 |
| 14 | 26.1 | -0.015 | -0.017 | -0.032 | -0.032 | -0.018 | -0.024 | -0.016 | -0.009 | 0.020 |
| 15 | 27.4 | -0.028 | -0.031 | -0.045 | -0.050 | -0.019 | -0.031 | -0.019 | -0.012 | 0.029 |
| 16 | 30.5 | -0.029 | -0.032 | -0.049 | -0.054 | -0.021 | -0.037 | -0.021 | -0.017 | 0.032 |
| 17 | 31.2 | -0.034 | -0.039 | -0.056 | -0.062 | -0.023 | -0.040 | -0.024 | -0.019 | 0.037 |
| 18 | 31.2 | -0.034 | -0.040 | -0.056 | -0.062 | -0.023 | -0.040 | -0.024 | -0.019 | 0.037 |
| 19 | 33.9 | -0.035 | -0.042 | -0.059 | -0.067 | -0.026 | -0.046 | -0.026 | -0.023 | 0.040 |
| 20 | 35.8 | -0.043 | -0.054 | -0.070 | -0.080 | -0.033 | -0.056 | -0.031 | -0.030 | 0.050 |
| 21 | 37.4 | -0.062 | -0.075 | -0.091 | -0.102 | -0.043 | -0.067 | -0.039 | -0.038 | 0.065 |
| 22 | 39.1 | -0.072 | -0.085 | -0.102 | -0.113 | -0.053 | -0.078 | -0.047 | -0.046 | 0.075 |
| 23 | 40.7 | -0.095 | -0.106 | -0.123 | -0.134 | -0.071 | -0.096 | -0.063 | -0.063 | 0.094 |
| 24 | 42.0 | -0.123 | -0.135 | -0.152 | -0.161 | -0.097 | -0.122 | -0.089 | -0.088 | 0.121 |
| 25 | 43.3 | -0.158 | -0.169 | -0.188 | -0.195 | -0.136 | -0.159 | -0.127 | -0.125 | 0.157 |
| 26 | 43.7 | -0.194 | -0.206 | -0.223 | -0.230 | -0.173 | -0.195 | -0.163 | -0.162 | 0.193 |
| 27 | 44.7 | -0.246 | -0.256 | -0.275 | -0.282 | -0.224 | -0.246 | -0.213 | -0.211 | 0.244 |
| 28 | 45.4 | -0.326 | -0.338 | -0.358 | -0.367 | -0.304 | -0.331 | -0.293 | -0.292 | 0.326 |
| 29 | 46.3 | -0.430 | -0.444 | -0.464 | -0.473 | -0.412 | -0.440 | -0.400 | -0.399 | 0.433 |
| 30 | 47.3 | -0.524 | -0.540 | -0.561 | -0.570 | -0.510 | -0.539 | -0.496 | -0.495 | 0.529 |
| 31 | 48.9 | -0.620 | -0.635 | -0.658 | -0.668 | -0.607 | -0.640 | -0.593 | -0.595 | 0.627 |
| 32 | 50.1 | -0.714 | -0.730 | -0.752 | -0.763 | -0.708 | -0.742 | -0.691 | -0.693 | 0.724 |
| 33 | 51.2 | -0.805 | -0.822 | -0.843 | -0.854 | -0.806 | -0.842 | -0.790 | -0.793 | 0.819 |
| 34 | 52.1 | -0.895 | -0.913 | -0.932 | -0.944 | -0.904 | -0.942 | -0.888 | -0.890 | 0.914 |
| 35 | 52.6 | -0.987 | -1.003 | -1.022 | -1.034 | -1.002 | -1.042 | -0.987 | -0.988 | 1.008 |
| 36 | 54.1 | -1.076 | -1.095 | -1.111 | -1.124 | -1.104 | -1.142 | -1.088 | -1.090 | 1.104 |

**Test No: 54** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 3/8X5/8X1 Date: 4/6/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.5 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.375 | 2 | SHEAR | 24 |
| Bottom: | 4 | 0.625 | 2 | SAW | 27a |

## TEST RESULTS

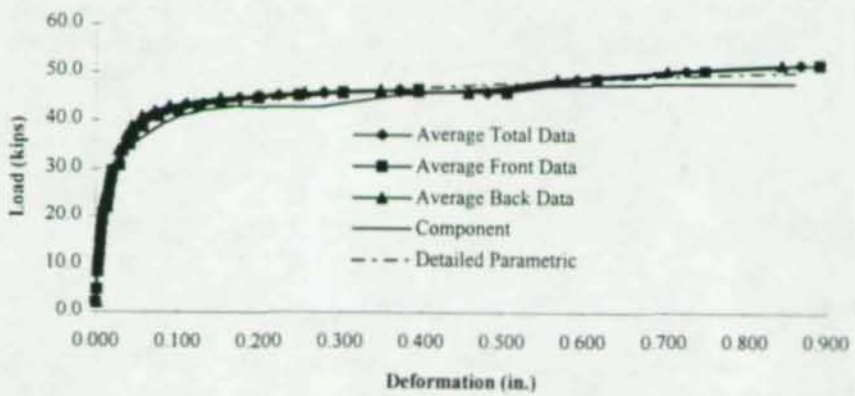
Limit State: Splitting

| | Deformation (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.868 | 51.7 |
| Failure: | 0.868 | 51.7 |
| Other: | 0.16 | 44.3 |
| | 0.25 | 45.4 |
| | 0.34 | 46.1 |

## COMMENTS

* At 35000 lbs, PL-24 yielded with a deformation of 0.04 in.
* Bulging on PL-24 started at 0.15 in of deformation.
* At 0.88 in. of deformation, splitting occurred on PL-24.
* The connection gained strength.

## CHART



**Test No: 54**
**Recorder: BK**

## Summary of One Bolt Lap Connection Tests

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.0 | 0.000 | 0.000 | -0.001 | -0.002 | -0.002 | -0.001 | 0.000 | 0.000 | 0.001 |
| 2 | 4.8 | -0.001 | 0.000 | -0.004 | -0.004 | -0.004 | -0.002 | 0.000 | 0.000 | 0.002 |
| 3 | 8.5 | -0.001 | 0.000 | -0.007 | -0.007 | -0.006 | -0.005 | -0.001 | 0.000 | 0.003 |
| 4 | 10.7 | -0.001 | 0.000 | -0.009 | -0.008 | -0.008 | -0.007 | -0.001 | -0.001 | 0.004 |
| 5 | 12.3 | -0.001 | -0.001 | -0.010 | -0.010 | -0.010 | -0.009 | -0.001 | -0.001 | 0.005 |
| 6 | 14.7 | -0.001 | -0.001 | -0.012 | -0.012 | -0.012 | -0.010 | -0.002 | -0.001 | 0.006 |
| 7 | 16.9 | -0.002 | -0.001 | -0.013 | -0.013 | -0.014 | -0.011 | -0.002 | -0.001 | 0.007 |
| 8 | 19.1 | -0.002 | -0.001 | -0.017 | -0.016 | -0.016 | -0.013 | -0.002 | -0.001 | 0.008 |
| 9 | 20.9 | -0.003 | -0.001 | -0.019 | -0.017 | -0.018 | -0.016 | -0.002 | -0.001 | 0.010 |
| 10 | 21.9 | -0.006 | -0.004 | -0.028 | -0.021 | -0.019 | -0.017 | -0.007 | -0.009 | 0.014 |
| 11 | 23.6 | -0.005 | -0.004 | -0.031 | -0.023 | -0.020 | -0.019 | -0.007 | -0.009 | 0.015 |
| 12 | 25.0 | -0.006 | -0.005 | -0.032 | -0.024 | -0.021 | -0.021 | -0.007 | -0.010 | 0.016 |
| 13 | 27.0 | -0.007 | -0.005 | -0.035 | -0.026 | -0.022 | -0.024 | -0.007 | -0.012 | 0.017 |
| 14 | 28.1 | -0.007 | -0.006 | -0.037 | -0.028 | -0.026 | -0.029 | -0.009 | -0.017 | 0.020 |
| 15 | 29.7 | -0.009 | -0.006 | -0.040 | -0.029 | -0.027 | -0.031 | -0.010 | -0.018 | 0.021 |
| 16 | 30.8 | -0.016 | -0.012 | -0.053 | -0.038 | -0.031 | -0.037 | -0.012 | -0.021 | 0.027 |
| 17 | 33.8 | -0.017 | -0.014 | -0.060 | -0.043 | -0.035 | -0.042 | -0.012 | -0.024 | 0.031 |
| 18 | 34.9 | -0.024 | -0.021 | -0.070 | -0.053 | -0.042 | -0.050 | -0.016 | -0.029 | 0.038 |
| 19 | 37.1 | -0.027 | -0.023 | -0.076 | -0.059 | -0.046 | -0.054 | -0.018 | -0.031 | 0.042 |
| 20 | 38.8 | -0.037 | -0.031 | -0.090 | -0.072 | -0.055 | -0.063 | -0.022 | -0.037 | 0.051 |
| 21 | 40.8 | -0.055 | -0.049 | -0.111 | -0.093 | -0.070 | -0.078 | -0.031 | -0.047 | 0.067 |
| 22 | 42.0 | -0.078 | -0.072 | -0.138 | -0.117 | -0.087 | -0.096 | -0.046 | -0.061 | 0.087 |
| 23 | 43.0 | -0.102 | -0.097 | -0.163 | -0.144 | -0.105 | -0.116 | -0.062 | -0.078 | 0.108 |
| 24 | 43.6 | -0.127 | -0.124 | -0.190 | -0.171 | -0.127 | -0.138 | -0.082 | -0.097 | 0.132 |
| 25 | 44.7 | -0.174 | -0.171 | -0.238 | -0.216 | -0.169 | -0.180 | -0.122 | -0.139 | 0.176 |
| 26 | 44.7 | -0.175 | -0.171 | -0.238 | -0.216 | -0.169 | -0.180 | -0.122 | -0.139 | 0.176 |
| 27 | 45.2 | -0.224 | -0.219 | -0.288 | -0.266 | -0.217 | -0.229 | -0.168 | -0.186 | 0.225 |
| 28 | 45.7 | -0.276 | -0.273 | -0.343 | -0.322 | -0.273 | -0.286 | -0.223 | -0.243 | 0.280 |
| 29 | 46.3 | -0.369 | -0.366 | -0.438 | -0.414 | -0.369 | -0.381 | -0.317 | -0.334 | 0.373 |
| 30 | 46.1 | -0.369 | -0.366 | -0.438 | -0.414 | -0.369 | -0.381 | -0.317 | -0.334 | 0.373 |
| 31 | 45.9 | -0.476 | -0.475 | -0.549 | -0.524 | -0.478 | -0.490 | -0.424 | -0.442 | 0.482 |
| 32 | 48.6 | -0.587 | -0.584 | -0.662 | -0.636 | -0.587 | -0.602 | -0.532 | -0.551 | 0.593 |
| 33 | 50.4 | -0.717 | -0.716 | -0.799 | -0.772 | -0.725 | -0.740 | -0.667 | -0.685 | 0.728 |
| 34 | 51.7 | -0.857 | -0.855 | -0.941 | -0.914 | -0.867 | -0.882 | -0.806 | -0.826 | 0.868 |

**Test No: 55** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 3/8X3/4X1 Date: 4/6/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.75 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.375 | 2 | SHEAR | 24 |
| Bottom: | 4 | 0.75 | 2 | SAW | 28 |

## TEST RESULTS

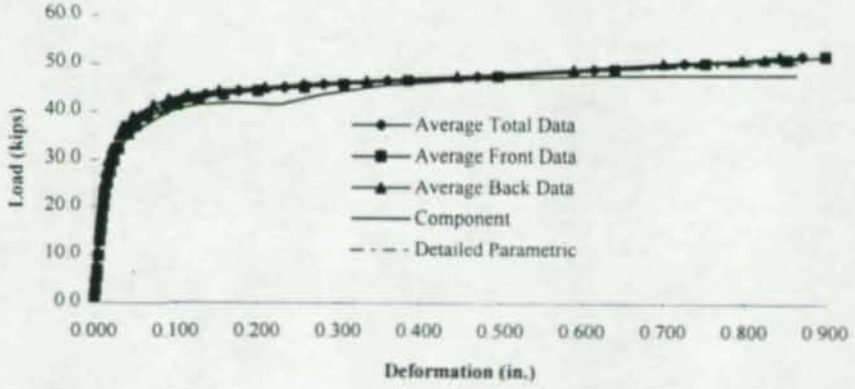
Limit State: Splitting

| | Deformation (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.87 | 51.7 |
| Failure: | 0.87 | 51.7 |
| Other: | 0.16 | 43.8 |
| | 0.25 | 45.1 |
| | 0.34 | 46.1 |

## COMMENTS

* PL-24 yielded at 35000 lbs with a deformation of 0.04 in.
* Bulging started at 0.15 in. on PL-24.
* At 0.8 in., splitting occurred.

## CHART



**Test No: 55**
**Recorder: BK**

## Summary of One Bolt Lap Connection Tests

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 1.3 | 0.000 | 0.000 | -0.002 | -0.002 | 0.000 | -0.001 | -0.001 | 0.000 | 0.001 |
| 2 | 2.7 | 0.000 | 0.000 | -0.004 | -0.004 | 0.001 | -0.001 | -0.001 | 0.000 | 0.001 |
| 3 | 5.3 | 0.000 | 0.000 | -0.007 | -0.007 | 0.000 | -0.001 | -0.001 | -0.001 | 0.002 |
| 4 | 6.9 | 0.000 | 0.000 | -0.008 | -0.009 | 0.000 | -0.002 | -0.012 | -0.001 | 0.004 |
| 5 | 9.8 | 0.000 | 0.000 | -0.011 | -0.012 | -0.001 | -0.004 | -0.013 | -0.001 | 0.005 |
| 6 | 12.9 | 0.000 | -0.001 | -0.013 | -0.014 | -0.004 | -0.006 | -0.013 | -0.001 | 0.007 |
| 7 | 15.2 | 0.000 | -0.001 | -0.015 | -0.017 | -0.006 | -0.009 | -0.013 | -0.001 | 0.008 |
| 8 | 17.6 | 0.000 | -0.002 | -0.017 | -0.020 | -0.007 | -0.011 | -0.013 | -0.002 | 0.009 |
| 9 | 20.1 | -0.001 | -0.002 | -0.020 | -0.023 | -0.009 | -0.013 | -0.013 | -0.002 | 0.010 |
| 10 | 22.6 | -0.001 | -0.003 | -0.023 | -0.026 | -0.011 | -0.015 | -0.013 | -0.003 | 0.012 |
| 11 | 25.0 | -0.001 | -0.006 | -0.025 | -0.032 | -0.013 | -0.018 | -0.014 | -0.004 | 0.014 |
| 12 | 27.3 | -0.002 | -0.009 | -0.028 | -0.038 | -0.016 | -0.021 | -0.015 | -0.004 | 0.017 |
| 13 | 29.7 | -0.004 | -0.013 | -0.032 | -0.045 | -0.020 | -0.024 | -0.017 | -0.006 | 0.020 |
| 14 | 32.1 | -0.006 | -0.018 | -0.039 | -0.055 | -0.026 | -0.031 | -0.020 | -0.009 | 0.025 |
| 15 | 35.2 | -0.012 | -0.029 | -0.051 | -0.074 | -0.037 | -0.040 | -0.028 | -0.015 | 0.036 |
| 16 | 36.9 | -0.017 | -0.038 | -0.061 | -0.086 | -0.044 | -0.047 | -0.031 | -0.018 | 0.043 |
| 17 | 38.9 | -0.028 | -0.052 | -0.076 | -0.105 | -0.059 | -0.061 | -0.040 | -0.026 | 0.056 |
| 18 | 41.2 | -0.059 | -0.088 | -0.113 | -0.147 | -0.088 | -0.091 | -0.061 | -0.047 | 0.087 |
| 19 | 42.5 | -0.083 | -0.114 | -0.138 | -0.174 | -0.109 | -0.112 | -0.077 | -0.063 | 0.109 |
| 20 | 43.3 | -0.113 | -0.144 | -0.168 | -0.207 | -0.133 | -0.137 | -0.098 | -0.085 | 0.136 |
| 21 | 44.1 | -0.153 | -0.186 | -0.211 | -0.251 | -0.174 | -0.178 | -0.135 | -0.121 | 0.176 |
| 22 | 44.9 | -0.209 | -0.242 | -0.268 | -0.311 | -0.232 | -0.238 | -0.188 | -0.175 | 0.233 |
| 23 | 45.5 | -0.255 | -0.291 | -0.317 | -0.361 | -0.281 | -0.287 | -0.236 | -0.222 | 0.281 |
| 24 | 46.3 | -0.333 | -0.370 | -0.396 | -0.442 | -0.359 | -0.367 | -0.311 | -0.298 | 0.360 |
| 25 | 47.3 | -0.441 | -0.481 | -0.508 | -0.555 | -0.473 | -0.479 | -0.424 | -0.408 | 0.471 |
| 26 | 48.8 | -0.582 | -0.624 | -0.652 | -0.701 | -0.617 | -0.625 | -0.565 | -0.549 | 0.614 |
| 27 | 50.2 | -0.691 | -0.735 | -0.764 | -0.815 | -0.728 | -0.738 | -0.674 | -0.657 | 0.725 |
| 28 | 50.9 | -0.790 | -0.836 | -0.865 | -0.917 | -0.826 | -0.836 | -0.770 | -0.752 | 0.824 |
| 29 | 51.7 | -0.836 | -0.883 | -0.912 | -0.964 | -0.873 | -0.882 | -0.816 | -0.798 | 0.870 |

**Test No: 56** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 3/8X1X1 Date: 4/7/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 3 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.375 | 2 | SHEAR | 24 |
| Bottom: | 4 | 1 | 2 | SAW | 31 |

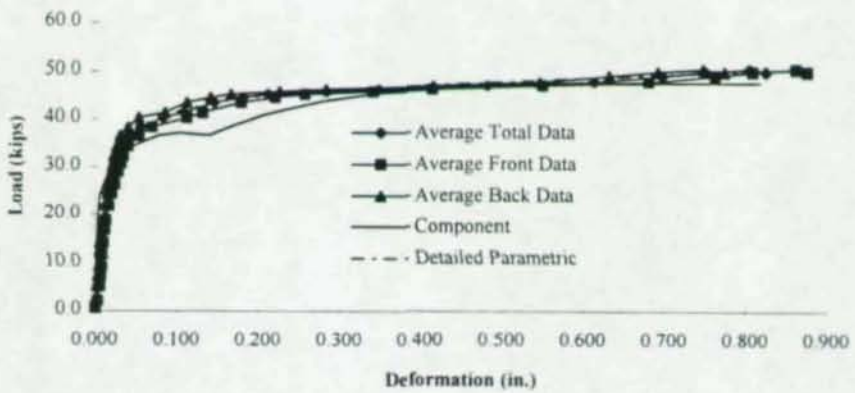
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Splitting | | |
| | Maximum: | 0.806 | 50.5 |
| | Failure: | 0.826 | 50 |
| | Other: | 0.16 | 43.8 |
| | | 0.25 | 45.5 |
| | | 0.34 | 46.2 |

## COMMENTS

* Yielding on PL-24 started at 0.033 in of deforamtion with a load of 36500 lbs.
* Cracks appeared on the bulged part at a deformation of 0.98 in.

## CHART



**Test No: 56**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 0.7 | 0.000 | 0.001 | -0.002 | -0.001 | -0.002 | -0.001 | 0.000 | -0.001 | 0.001 |
| 2 | 2.1 | 0.000 | 0.001 | -0.007 | -0.006 | -0.001 | 0.001 | -0.004 | -0.001 | 0.002 |
| 3 | 5.2 | 0.000 | 0.001 | -0.011 | -0.011 | -0.003 | -0.001 | -0.004 | -0.001 | 0.004 |
| 4 | 7.2 | 0.000 | 0.001 | -0.014 | -0.013 | -0.006 | -0.004 | -0.004 | -0.001 | 0.005 |
| 5 | 9.2 | -0.001 | 0.001 | -0.016 | -0.015 | -0.008 | -0.006 | -0.004 | -0.001 | 0.006 |
| 6 | 11.9 | -0.001 | 0.002 | -0.019 | -0.018 | -0.011 | -0.010 | -0.004 | -0.001 | 0.008 |
| 7 | 14.1 | -0.001 | 0.002 | -0.022 | -0.020 | -0.014 | -0.013 | -0.003 | -0.001 | 0.009 |
| 8 | 16.9 | -0.003 | 0.003 | -0.025 | -0.022 | -0.015 | -0.020 | -0.001 | -0.002 | 0.011 |
| 9 | 18.8 | -0.004 | 0.003 | -0.028 | -0.024 | -0.016 | -0.025 | 0.001 | -0.002 | 0.012 |
| 10 | 21.9 | -0.007 | 0.004 | -0.035 | -0.026 | -0.016 | -0.035 | 0.004 | -0.002 | 0.014 |
| 11 | 24.5 | -0.010 | 0.006 | -0.042 | -0.028 | -0.017 | -0.042 | 0.003 | -0.002 | 0.017 |
| 12 | 26.4 | -0.015 | 0.007 | -0.049 | -0.030 | -0.017 | -0.048 | 0.004 | -0.002 | 0.019 |
| 13 | 28.9 | -0.019 | 0.007 | -0.057 | -0.035 | -0.018 | -0.056 | 0.006 | -0.004 | 0.022 |
| 14 | 30.7 | -0.023 | 0.006 | -0.064 | -0.039 | -0.020 | -0.061 | 0.006 | -0.004 | 0.025 |
| 15 | 32.2 | -0.026 | 0.005 | -0.070 | -0.043 | -0.022 | -0.067 | 0.002 | -0.004 | 0.028 |
| 16 | 34.2 | -0.032 | 0.001 | -0.081 | -0.052 | -0.028 | -0.075 | 0.003 | -0.004 | 0.033 |
| 17 | 36.4 | -0.043 | -0.011 | -0.098 | -0.069 | -0.037 | -0.086 | -0.001 | -0.004 | 0.043 |
| 18 | 38.3 | -0.056 | -0.024 | -0.116 | -0.087 | -0.052 | -0.100 | -0.011 | -0.004 | 0.056 |
| 19 | 40.2 | -0.091 | -0.066 | -0.165 | -0.132 | -0.069 | -0.113 | -0.026 | -0.010 | 0.084 |
| 20 | 41.3 | -0.109 | -0.084 | -0.186 | -0.152 | -0.090 | -0.132 | -0.042 | -0.081 | 0.110 |
| 21 | 43.5 | -0.155 | -0.130 | -0.235 | -0.200 | -0.129 | -0.169 | -0.073 | -0.081 | 0.147 |
| 22 | 44.5 | -0.196 | -0.170 | -0.278 | -0.245 | -0.169 | -0.209 | -0.109 | -0.081 | 0.182 |
| 23 | 45.2 | -0.231 | -0.206 | -0.315 | -0.283 | -0.204 | -0.244 | -0.141 | -0.081 | 0.213 |
| 24 | 45.8 | -0.313 | -0.291 | -0.401 | -0.366 | -0.285 | -0.324 | -0.217 | -0.081 | 0.285 |
| 25 | 46.2 | -0.385 | -0.363 | -0.474 | -0.440 | -0.356 | -0.395 | -0.286 | -0.100 | 0.350 |
| 26 | 47.0 | -0.519 | -0.498 | -0.611 | -0.575 | -0.490 | -0.529 | -0.418 | -0.230 | 0.484 |
| 27 | 47.9 | -0.648 | -0.628 | -0.744 | -0.708 | -0.622 | -0.661 | -0.546 | -0.360 | 0.615 |
| 28 | 49.2 | -0.731 | -0.713 | -0.817 | -0.794 | -0.709 | -0.748 | -0.632 | -0.444 | 0.698 |
| 29 | 50.0 | -0.793 | -0.774 | -0.817 | -0.855 | -0.770 | -0.808 | -0.691 | -0.504 | 0.751 |
| 30 | 50.5 | -0.893 | -0.820 | -0.819 | -0.921 | -0.774 | -0.828 | -0.788 | -0.605 | 0.806 |
| 31 | 50.0 | -0.945 | -0.823 | -0.820 | -0.921 | -0.776 | -0.833 | -0.839 | -0.653 | 0.826 |

**Test No: 57** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/2X1/2X1 Date: 4/7/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.5 | by Turn of Nut Method |
| Shear Plane: | N | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.5 | 2 | SAW | 34 |
| Bottom: | 4 | 0.5 | 2 | SAW | 34 |

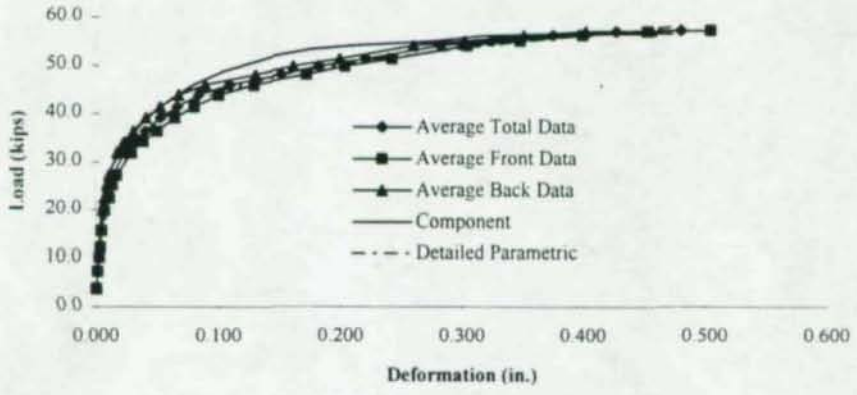
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.481 | 57.3 |
| | Failure: | 0.481 | 57.3 |
| | Other: | 0.16 | 48.5 |
| | | 0.25 | 52.6 |
| | | 0.34 | 55.4 |

## COMMENTS

* PL-34 yielded at 39000 lbs. with a deformation of 0.065 in.
* The connection went through the plastic portion.
* Bolt sheared in the threaded part.???

## CHART



Test No: 57
Recorder: BK

## Summary of One Bolt Lap Connection Tests

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.7 | -0.001 | -0.001 | -0.002 | -0.001 | -0.002 | -0.001 | -0.001 | -0.001 | 0.001 |
| 2 | 7.3 | -0.001 | -0.001 | -0.004 | -0.003 | -0.002 | -0.002 | -0.002 | -0.001 | 0.002 |
| 3 | 10.3 | -0.002 | -0.002 | -0.005 | -0.004 | -0.003 | -0.004 | -0.004 | -0.002 | 0.003 |
| 4 | 12.2 | -0.002 | -0.003 | -0.006 | -0.005 | -0.004 | -0.004 | -0.005 | -0.002 | 0.004 |
| 5 | 15.8 | -0.003 | -0.004 | -0.008 | -0.007 | -0.004 | -0.005 | -0.007 | -0.004 | 0.005 |
| 6 | 19.8 | -0.006 | -0.006 | -0.012 | -0.008 | -0.005 | -0.007 | -0.007 | -0.004 | 0.007 |
| 7 | 22.5 | -0.010 | -0.008 | -0.017 | -0.010 | -0.006 | -0.008 | -0.008 | -0.007 | 0.009 |
| 8 | 25.2 | -0.013 | -0.010 | -0.021 | -0.013 | -0.006 | -0.013 | -0.009 | -0.010 | 0.012 |
| 9 | 27.1 | -0.017 | -0.012 | -0.024 | -0.016 | -0.007 | -0.015 | -0.010 | -0.013 | 0.014 |
| 10 | 31.9 | -0.029 | -0.023 | -0.038 | -0.028 | -0.014 | -0.022 | -0.016 | -0.018 | 0.023 |
| 11 | 34.1 | -0.037 | -0.032 | -0.048 | -0.038 | -0.020 | -0.028 | -0.022 | -0.024 | 0.031 |
| 12 | 36.3 | -0.048 | -0.043 | -0.061 | -0.049 | -0.027 | -0.035 | -0.030 | -0.031 | 0.041 |
| 13 | 39.0 | -0.063 | -0.057 | -0.075 | -0.064 | -0.040 | -0.045 | -0.041 | -0.038 | 0.053 |
| 14 | 41.4 | -0.078 | -0.073 | -0.092 | -0.079 | -0.054 | -0.056 | -0.053 | -0.048 | 0.067 |
| 15 | 43.9 | -0.098 | -0.094 | -0.112 | -0.098 | -0.069 | -0.071 | -0.068 | -0.062 | 0.084 |
| 16 | 45.8 | -0.129 | -0.123 | -0.141 | -0.126 | -0.091 | -0.091 | -0.091 | -0.085 | 0.110 |
| 17 | 48.0 | -0.171 | -0.166 | -0.183 | -0.169 | -0.131 | -0.130 | -0.134 | -0.129 | 0.152 |
| 18 | 49.8 | -0.204 | -0.197 | -0.215 | -0.201 | -0.162 | -0.160 | -0.165 | -0.159 | 0.183 |
| 19 | 51.3 | -0.244 | -0.235 | -0.253 | -0.240 | -0.200 | -0.199 | -0.203 | -0.197 | 0.221 |
| 20 | 54.0 | -0.305 | -0.297 | -0.314 | -0.302 | -0.261 | -0.259 | -0.266 | -0.256 | 0.282 |
| 21 | 55.1 | -0.349 | -0.340 | -0.358 | -0.345 | -0.303 | -0.300 | -0.309 | -0.298 | 0.325 |
| 22 | 56.3 | -0.400 | -0.393 | -0.409 | -0.397 | -0.351 | -0.349 | -0.357 | -0.348 | 0.375 |
| 23 | 57.1 | -0.454 | -0.446 | -0.462 | -0.451 | -0.401 | -0.400 | -0.410 | -0.399 | 0.428 |
| 24 | 57.3 | -0.506 | -0.499 | -0.513 | -0.502 | -0.457 | -0.454 | -0.464 | -0.451 | 0.481 |

**Test No: 58** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/2X5/8X1 Date: 4/8/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.75 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.5 | 2 | SAW | 34 |
| Bottom: | 4 | 0.625 | 2 | SAW | 27a |

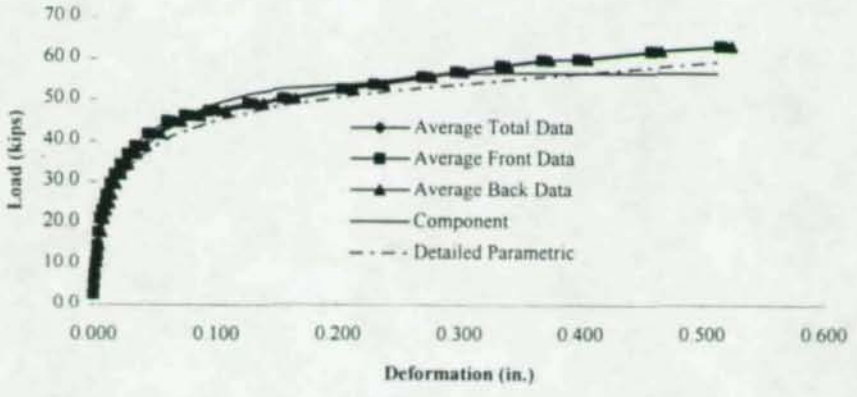
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: Bolt Shear | Maximum: | 0.519 | 63.2 |
| | Failure: | 0.519 | 63.2 |
| | Other: | 0.16 | 50.3 |
| | | 0.25 | 54.6 |
| | | 0.34 | 58.5 |

## COMMENTS

* PL-34 yielded at 39000 lbs with a deformation of 0.035 in.
* The connection went through the pastic portion an dgained strength.

## CHART



**Test No: 58**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.9 | -0.001 | 0.000 | 0.000 | -0.001 | -0.002 | -0.001 | 0.000 | 0.000 | 0.000 |
| 2 | 5.3 | -0.001 | 0.000 | -0.001 | -0.001 | -0.003 | -0.002 | -0.001 | 0.000 | 0.001 |
| 3 | 7.7 | -0.002 | -0.001 | -0.001 | -0.002 | -0.004 | -0.003 | -0.001 | -0.001 | 0.002 |
| 4 | 10.5 | -0.002 | -0.002 | -0.002 | -0.002 | -0.006 | -0.006 | -0.001 | -0.001 | 0.003 |
| 5 | 12.5 | -0.004 | -0.002 | -0.003 | -0.003 | -0.007 | -0.007 | -0.001 | -0.002 | 0.004 |
| 6 | 14.6 | -0.004 | -0.002 | -0.004 | -0.004 | -0.007 | -0.009 | -0.001 | -0.002 | 0.004 |
| 7 | 17.8 | -0.005 | -0.002 | -0.006 | -0.004 | -0.009 | -0.012 | -0.002 | -0.005 | 0.006 |
| 8 | 21.2 | -0.006 | -0.003 | -0.009 | -0.006 | -0.010 | -0.016 | -0.002 | -0.008 | 0.007 |
| 9 | 23.0 | -0.009 | -0.003 | -0.012 | -0.007 | -0.010 | -0.020 | -0.002 | -0.011 | 0.009 |
| 10 | 24.8 | -0.012 | -0.004 | -0.015 | -0.008 | -0.012 | -0.024 | -0.003 | -0.015 | 0.012 |
| 11 | 26.9 | -0.012 | -0.006 | -0.017 | -0.009 | -0.014 | -0.026 | -0.004 | -0.017 | 0.013 |
| 12 | 29.5 | -0.015 | -0.008 | -0.021 | -0.012 | -0.017 | -0.031 | -0.006 | -0.021 | 0.016 |
| 13 | 31.8 | -0.019 | -0.010 | -0.025 | -0.015 | -0.021 | -0.036 | -0.009 | -0.025 | 0.020 |
| 14 | 34.3 | -0.023 | -0.015 | -0.030 | -0.020 | -0.028 | -0.042 | -0.014 | -0.031 | 0.025 |
| 15 | 36.8 | -0.029 | -0.020 | -0.036 | -0.027 | -0.036 | -0.050 | -0.021 | -0.036 | 0.032 |
| 16 | 38.8 | -0.034 | -0.027 | -0.042 | -0.034 | -0.045 | -0.057 | -0.027 | -0.042 | 0.038 |
| 17 | 41.9 | -0.043 | -0.037 | -0.053 | -0.045 | -0.059 | -0.071 | -0.038 | -0.051 | 0.050 |
| 18 | 44.8 | -0.057 | -0.052 | -0.069 | -0.061 | -0.079 | -0.089 | -0.054 | -0.067 | 0.066 |
| 19 | 46.2 | -0.071 | -0.065 | -0.084 | -0.076 | -0.096 | -0.105 | -0.068 | -0.080 | 0.081 |
| 20 | 47.3 | -0.092 | -0.086 | -0.103 | -0.096 | -0.118 | -0.125 | -0.090 | -0.100 | 0.101 |
| 21 | 49.1 | -0.125 | -0.117 | -0.134 | -0.128 | -0.150 | -0.156 | -0.120 | -0.130 | 0.133 |
| 22 | 50.3 | -0.154 | -0.145 | -0.161 | -0.157 | -0.176 | -0.182 | -0.146 | -0.156 | 0.160 |
| 23 | 52.6 | -0.202 | -0.195 | -0.211 | -0.204 | -0.224 | -0.229 | -0.193 | -0.205 | 0.208 |
| 24 | 53.9 | -0.228 | -0.221 | -0.238 | -0.230 | -0.250 | -0.255 | -0.218 | -0.230 | 0.234 |
| 25 | 55.6 | -0.268 | -0.262 | -0.276 | -0.270 | -0.289 | -0.292 | -0.256 | -0.271 | 0.273 |
| 26 | 56.9 | -0.295 | -0.290 | -0.304 | -0.299 | -0.316 | -0.319 | -0.282 | -0.298 | 0.300 |
| 27 | 58.4 | -0.331 | -0.326 | -0.341 | -0.336 | -0.354 | -0.356 | -0.319 | -0.333 | 0.337 |
| 28 | 59.8 | -0.365 | -0.362 | -0.377 | -0.369 | -0.388 | -0.389 | -0.354 | -0.367 | 0.371 |
| 29 | 60.0 | -0.394 | -0.391 | -0.407 | -0.399 | -0.420 | -0.420 | -0.385 | -0.399 | 0.402 |
| 30 | 62.0 | -0.452 | -0.448 | -0.469 | -0.461 | -0.481 | -0.480 | -0.446 | -0.458 | 0.462 |
| 31 | 63.2 | -0.509 | -0.504 | -0.526 | -0.518 | -0.539 | -0.538 | -0.504 | -0.516 | 0.519 |

Test No: 59 **Summary of One Bolt Lap Connection Tests**
Recorder: BK

## TEST DESIGNATION

Test Designation: 1/2X3/4X1 Date: 4/8/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | |
|---|---|---|---|
| Type: | A325 | Diameter (in.): 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): 2.75 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: X | |
| | | Bolt Head Washer: X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.5 | 2 | SAW | 34 |
| Bottom: | 4 | 0.75 | 2 | SAW | 29 |

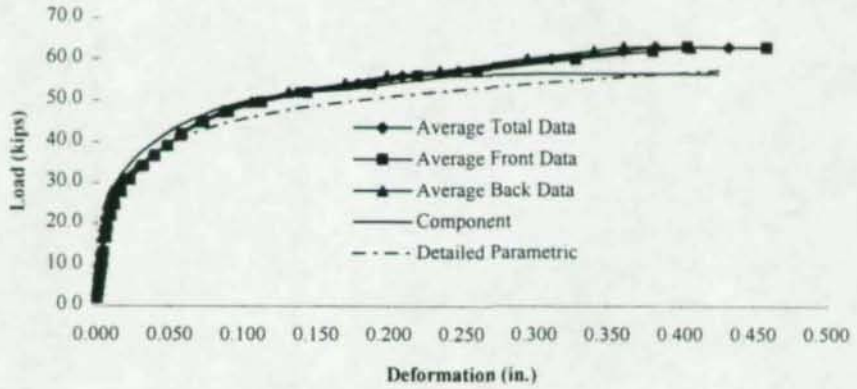
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | Maximum: | 0.383 | 63.1 |
| | | Failure: | 0.433 | 62.9 |
| | | Other: | 0.16 | 53.1 |
| | | | 0.25 | 57.3 |
| | | | 0.34 | 61.2 |

## COMMENTS

* PL-34 yielded at 42000 lbs with a deformation of 0.058 in.
* PL-29 yielded at 52000 lbs with a deformation of 0.14 in.
* The connection gained strength as it went through the plastic portion.

## CHART



**Test No: 59**
**Recorder: BK**

## Summary of One Bolt Lap Connection Tests

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.0 | -0.001 | 0.000 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | -0.001 | 0.001 |
| 2 | 3.5 | -0.001 | 0.000 | -0.003 | -0.002 | -0.001 | -0.001 | -0.001 | -0.001 | 0.001 |
| 3 | 5.3 | -0.001 | 0.000 | -0.004 | -0.004 | -0.001 | -0.001 | -0.001 | -0.001 | 0.002 |
| 4 | 7.3 | -0.001 | 0.000 | -0.005 | -0.006 | -0.002 | -0.002 | -0.001 | -0.001 | 0.002 |
| 5 | 8.8 | -0.001 | 0.000 | -0.007 | -0.007 | -0.002 | -0.002 | -0.001 | -0.001 | 0.003 |
| 6 | 10.6 | -0.001 | 0.000 | -0.008 | -0.008 | -0.003 | -0.003 | -0.001 | -0.001 | 0.003 |
| 7 | 13.1 | -0.001 | 0.000 | -0.009 | -0.010 | -0.004 | -0.004 | -0.001 | -0.002 | 0.004 |
| 8 | 16.8 | -0.003 | 0.000 | -0.013 | -0.011 | -0.005 | -0.007 | -0.001 | -0.003 | 0.005 |
| 9 | 19.1 | -0.004 | 0.000 | -0.015 | -0.012 | -0.007 | -0.009 | -0.002 | -0.004 | 0.006 |
| 10 | 21.9 | -0.007 | 0.001 | -0.020 | -0.013 | -0.008 | -0.011 | -0.002 | -0.005 | 0.008 |
| 11 | 24.7 | -0.011 | 0.001 | -0.024 | -0.015 | -0.009 | -0.014 | -0.002 | -0.007 | 0.010 |
| 12 | 27.8 | -0.016 | -0.002 | -0.032 | -0.018 | -0.010 | -0.020 | -0.002 | -0.011 | 0.014 |
| 13 | 30.8 | -0.021 | -0.006 | -0.040 | -0.024 | -0.015 | -0.028 | -0.006 | -0.018 | 0.020 |
| 14 | 34.1 | -0.030 | -0.012 | -0.052 | -0.035 | -0.031 | -0.038 | -0.019 | -0.027 | 0.031 |
| 15 | 36.6 | -0.036 | -0.018 | -0.062 | -0.043 | -0.043 | -0.046 | -0.030 | -0.033 | 0.039 |
| 16 | 39.1 | -0.043 | -0.024 | -0.073 | -0.053 | -0.056 | -0.055 | -0.041 | -0.039 | 0.048 |
| 17 | 41.7 | -0.052 | -0.031 | -0.085 | -0.064 | -0.068 | -0.064 | -0.050 | -0.045 | 0.057 |
| 18 | 41.7 | -0.052 | -0.031 | -0.085 | -0.064 | -0.068 | -0.064 | -0.050 | -0.045 | 0.057 |
| 19 | 44.7 | -0.065 | -0.043 | -0.103 | -0.081 | -0.085 | -0.076 | -0.064 | -0.054 | 0.071 |
| 20 | 47.2 | -0.080 | -0.057 | -0.123 | -0.100 | -0.105 | -0.094 | -0.078 | -0.066 | 0.088 |
| 21 | 49.5 | -0.103 | -0.076 | -0.149 | -0.124 | -0.130 | -0.116 | -0.097 | -0.081 | 0.109 |
| 22 | 51.9 | -0.134 | -0.106 | -0.182 | -0.153 | -0.159 | -0.143 | -0.120 | -0.103 | 0.137 |
| 23 | 54.2 | -0.179 | -0.150 | -0.228 | -0.196 | -0.201 | -0.180 | -0.159 | -0.138 | 0.179 |
| 24 | 56.0 | -0.211 | -0.182 | -0.260 | -0.226 | -0.230 | -0.210 | -0.188 | -0.165 | 0.209 |
| 25 | 57.2 | -0.252 | -0.223 | -0.302 | -0.266 | -0.268 | -0.246 | -0.225 | -0.200 | 0.248 |
| 26 | 60.1 | -0.321 | -0.289 | -0.371 | -0.333 | -0.329 | -0.308 | -0.285 | -0.257 | 0.312 |
| 27 | 62.1 | -0.373 | -0.341 | -0.424 | -0.385 | -0.375 | -0.355 | -0.331 | -0.301 | 0.361 |
| 28 | 63.1 | -0.396 | -0.365 | -0.449 | -0.409 | -0.396 | -0.376 | -0.352 | -0.320 | 0.383 |
| 29 | 62.9 | -0.451 | -0.419 | -0.503 | -0.463 | -0.444 | -0.421 | -0.396 | -0.366 | 0.433 |

**Test No: 60** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/2X1X1 Date: 4/7/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | |
|---|---|---|---|
| Type: | A325 | Diameter (in.): 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): 3 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: X | |
| | | Bolt Head Washer: X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.5 | 2 | SAW | 35 |
| Bottom: | 4 | 1 | 2 | SAW | 31 |

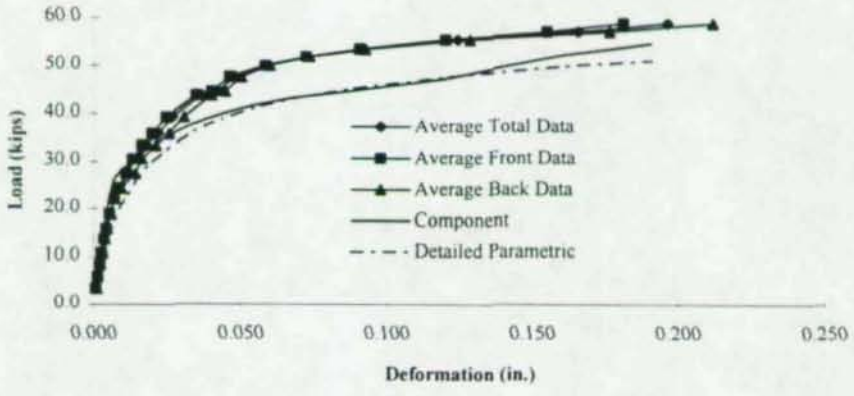
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.196 | 58.8 |
| | Failure: | 0.196 | 58.8 |
| | Other: | 0.16 | 56.8 |
| | | 0.25 | NA |
| | | 0.34 | NA |

## COMMENTS

* Yielding started on PL-35 at a deformation of 0.04 in.with a load of 45000 lbs.
* Bulging on PL-35 started at a deformation of 0.2 in.
* The connection had a short plastic period.

## CHART



Test No: 60
Recorder: BK

**Summary of One Bolt Lap Connection Tests**

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.5 | -0.001 | 0.000 | -0.001 | 0.001 | -0.002 | -0.001 | -0.001 | -0.001 | 0.001 |
| 2 | 5.9 | -0.001 | -0.001 | -0.004 | 0.000 | -0.002 | -0.001 | -0.001 | -0.001 | 0.001 |
| 3 | 8.4 | -0.001 | -0.001 | -0.006 | 0.001 | -0.004 | -0.002 | -0.002 | -0.001 | 0.002 |
| 4 | 10.8 | -0.002 | -0.001 | -0.007 | 0.000 | -0.005 | -0.003 | -0.002 | -0.002 | 0.003 |
| 5 | 13.7 | -0.002 | -0.001 | -0.010 | 0.001 | -0.007 | -0.004 | -0.002 | -0.002 | 0.004 |
| 6 | 15.9 | -0.002 | -0.001 | -0.013 | 0.001 | -0.008 | -0.006 | -0.002 | -0.003 | 0.004 |
| 7 | 18.9 | -0.004 | -0.001 | -0.016 | 0.001 | -0.009 | -0.008 | -0.002 | -0.004 | 0.005 |
| 8 | 22.1 | -0.007 | -0.001 | -0.020 | 0.000 | -0.011 | -0.010 | -0.002 | -0.005 | 0.007 |
| 9 | 24.3 | -0.008 | -0.002 | -0.023 | 0.000 | -0.010 | -0.017 | 0.001 | -0.010 | 0.009 |
| 10 | 27.3 | -0.010 | -0.006 | -0.028 | 0.001 | -0.010 | -0.024 | 0.002 | -0.020 | 0.012 |
| 11 | 30.5 | -0.013 | -0.007 | -0.032 | 0.001 | -0.011 | -0.029 | 0.003 | -0.023 | 0.014 |
| 12 | 33.4 | -0.017 | -0.010 | -0.038 | 0.001 | -0.013 | -0.038 | 0.003 | -0.031 | 0.018 |
| 13 | 35.8 | -0.020 | -0.015 | -0.045 | 0.000 | -0.015 | -0.046 | 0.003 | -0.038 | 0.022 |
| 14 | 39.2 | -0.024 | -0.020 | -0.054 | 0.001 | -0.017 | -0.057 | 0.003 | -0.045 | 0.027 |
| 15 | 43.7 | -0.035 | -0.033 | -0.070 | 0.001 | -0.023 | -0.075 | 0.002 | -0.059 | 0.037 |
| 16 | 44.5 | -0.041 | -0.040 | -0.078 | 0.001 | -0.026 | -0.084 | 0.001 | -0.067 | 0.042 |
| 17 | 47.6 | -0.048 | -0.049 | -0.087 | 0.001 | -0.032 | -0.094 | -0.001 | -0.073 | 0.048 |
| 18 | 49.9 | -0.061 | -0.066 | -0.105 | 0.001 | -0.040 | -0.109 | -0.006 | -0.085 | 0.059 |
| 19 | 51.8 | -0.078 | -0.087 | -0.123 | 0.001 | -0.053 | -0.127 | -0.014 | -0.100 | 0.073 |
| 20 | 53.4 | -0.100 | -0.114 | -0.147 | 0.001 | -0.070 | -0.150 | -0.029 | -0.121 | 0.091 |
| 21 | 55.4 | -0.138 | -0.156 | -0.187 | 0.000 | -0.101 | -0.191 | -0.061 | -0.160 | 0.124 |
| 22 | 57.0 | -0.182 | -0.204 | -0.233 | 0.000 | -0.146 | -0.243 | -0.105 | -0.211 | 0.166 |
| 23 | 58.8 | -0.215 | -0.240 | -0.269 | 0.001 | -0.179 | -0.283 | -0.136 | -0.249 | 0.196 |

**Test No: 62** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 5/8X3/4X1 Date: 4/8/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 3 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.625 | 2 | SAW | 43 |
| Bottom: | 4 | 0.75 | 2 | SAW | 44 |

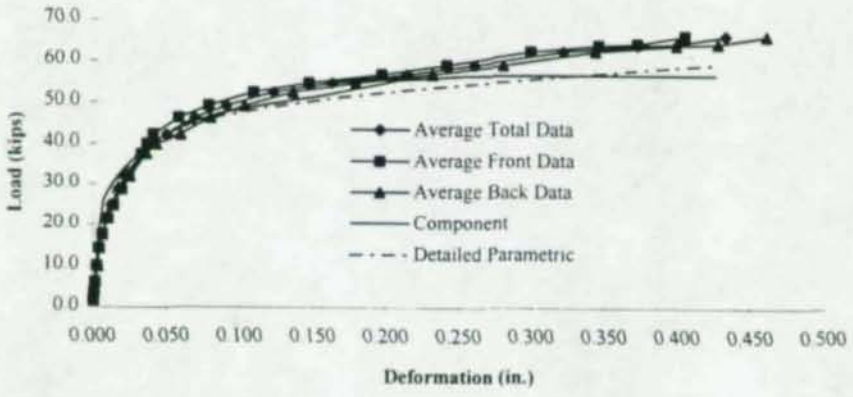
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.432 | 66.2 |
| | Failure: | 0.432 | 66.2 |
| | Other: | 0.16 | 54.4 |
| | | 0.25 | 58.5 |
| | | 0.34 | 62.9 |

## COMMENTS

* PL-37 yielded at 35000 lbs with a deformation of 0.025 in.
* The connection could not develope a well-defined a plastic region.

## CHART



**Test No: 62** **Summary of One Bolt Lap Connection Tests**

***Recorder:* BK**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 1.6 | -0.001 | 0.000 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | 0.000 | 0.001 |
| 2 | 3.8 | -0.001 | 0.000 | -0.002 | -0.002 | -0.003 | -0.002 | 0.000 | 0.000 | 0.001 |
| 3 | 6.2 | -0.001 | -0.001 | -0.002 | -0.002 | -0.004 | -0.003 | -0.001 | 0.000 | 0.002 |
| 4 | 10.0 | -0.002 | -0.001 | -0.004 | -0.004 | -0.007 | -0.004 | -0.001 | -0.001 | 0.003 |
| 5 | 14.4 | -0.003 | 0.000 | -0.008 | -0.006 | -0.009 | -0.006 | -0.002 | -0.002 | 0.004 |
| 6 | 17.7 | -0.007 | 0.001 | -0.012 | -0.006 | -0.013 | -0.006 | -0.005 | -0.001 | 0.006 |
| 7 | 21.5 | -0.013 | 0.003 | -0.019 | -0.006 | -0.021 | -0.006 | -0.012 | 0.000 | 0.009 |
| 8 | 24.8 | -0.020 | 0.006 | -0.026 | -0.005 | -0.029 | -0.007 | -0.018 | 0.001 | 0.012 |
| 9 | 28.7 | -0.029 | 0.008 | -0.037 | -0.004 | -0.040 | -0.009 | -0.027 | 0.001 | 0.017 |
| 10 | 31.9 | -0.037 | 0.010 | -0.047 | -0.003 | -0.052 | -0.010 | -0.037 | 0.001 | 0.022 |
| 11 | 37.4 | -0.050 | 0.007 | -0.064 | -0.009 | -0.073 | -0.016 | -0.054 | -0.002 | 0.033 |
| 12 | 39.9 | -0.056 | 0.003 | -0.072 | -0.015 | -0.084 | -0.021 | -0.062 | -0.004 | 0.039 |
| 13 | 42.1 | -0.062 | -0.002 | -0.080 | -0.018 | -0.109 | -0.035 | -0.081 | -0.011 | 0.050 |
| 14 | 46.1 | -0.075 | -0.017 | -0.099 | -0.040 | -0.137 | -0.056 | -0.102 | -0.024 | 0.069 |
| 15 | 49.0 | -0.093 | -0.034 | -0.123 | -0.064 | -0.166 | -0.078 | -0.124 | -0.042 | 0.090 |
| 16 | 52.2 | -0.132 | -0.058 | -0.154 | -0.092 | -0.203 | -0.109 | -0.160 | -0.071 | 0.122 |
| 17 | 54.6 | -0.165 | -0.095 | -0.194 | -0.132 | -0.249 | -0.152 | -0.205 | -0.109 | 0.163 |
| 18 | 56.7 | -0.208 | -0.144 | -0.247 | -0.187 | -0.304 | -0.204 | -0.259 | -0.158 | 0.214 |
| 19 | 59.0 | -0.250 | -0.188 | -0.294 | -0.234 | -0.354 | -0.253 | -0.308 | -0.205 | 0.261 |
| 20 | 62.4 | -0.308 | -0.239 | -0.355 | -0.295 | -0.420 | -0.316 | -0.372 | -0.264 | 0.321 |
| 21 | 63.9 | -0.360 | -0.264 | -0.409 | -0.349 | -0.477 | -0.373 | -0.427 | -0.317 | 0.372 |
| 22 | 64.3 | -0.386 | -0.287 | -0.437 | -0.377 | -0.506 | -0.401 | -0.457 | -0.344 | 0.399 |
| 23 | 66.2 | -0.420 | -0.314 | -0.473 | -0.411 | -0.539 | -0.434 | -0.490 | -0.377 | 0.432 |

**Test No: 64** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 3/4X3/4X1 Date: 4/8/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | |
|---|---|---|---|
| Type: | A325 | Diameter (in.): 1 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): 0 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: X | |
| | | Bolt Head Washer: X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.75 | 2 | SAW | 44 |
| Bottom: | 5 | 0.75 | 2 | SAW | 44 |

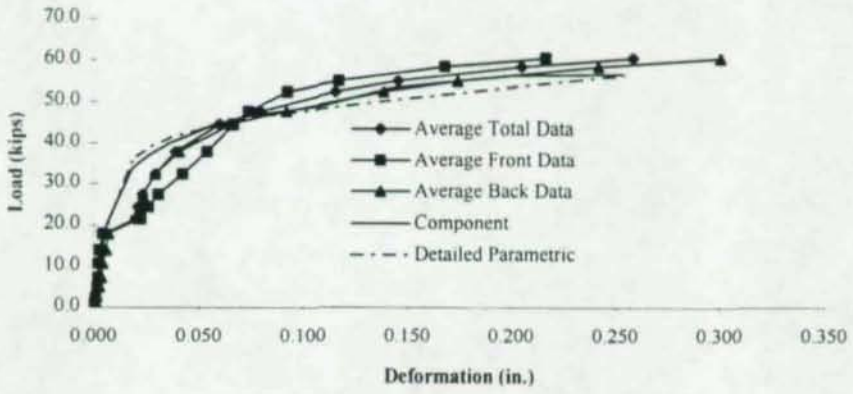
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.258 | 60.5 |
| | Failure: | 0.258 | 60.5 |
| | Other: | 0.16 | 55.8 |
| | | 0.25 | 60.2 |
| | | 0.34 | NA |

## COMMENTS

* PL-44 yielded on 32500 lbs with a deformation of 0.03 in.
* The connection could not develop a plastic region.

## CHART



**Test No: 64**
**Recorder: BK**

## Summary of One Bolt Lap Connection Tests

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 1.3 | -0.001 | -0.001 | -0.001 | 0.000 | -0.001 | -0.001 | -0.001 | -0.001 | 0.001 |
| 2 | 2.6 | -0.001 | -0.002 | 0.001 | 0.001 | -0.002 | -0.002 | -0.001 | -0.001 | 0.001 |
| 3 | 5.1 | -0.002 | -0.002 | 0.001 | 0.001 | -0.005 | -0.005 | -0.001 | -0.001 | 0.002 |
| 4 | 7.3 | -0.002 | -0.004 | -0.001 | 0.001 | -0.007 | -0.006 | -0.001 | -0.001 | 0.003 |
| 5 | 10.8 | -0.002 | -0.004 | -0.001 | 0.001 | -0.009 | -0.007 | -0.001 | -0.001 | 0.003 |
| 6 | 14.0 | -0.002 | -0.007 | -0.001 | -0.001 | -0.012 | -0.009 | -0.003 | 0.000 | 0.004 |
| 7 | 17.9 | -0.002 | -0.010 | 0.001 | -0.004 | -0.014 | -0.009 | -0.004 | 0.000 | 0.005 |
| 8 | 21.6 | -0.008 | -0.058 | 0.008 | -0.016 | -0.031 | -0.020 | -0.021 | -0.014 | 0.020 |
| 9 | 24.3 | -0.006 | -0.064 | 0.012 | -0.023 | -0.032 | -0.020 | -0.022 | -0.014 | 0.021 |
| 10 | 27.3 | -0.002 | -0.074 | 0.015 | -0.031 | -0.034 | -0.021 | -0.023 | -0.015 | 0.023 |
| 11 | 32.4 | 0.004 | -0.092 | 0.022 | -0.051 | -0.042 | -0.027 | -0.030 | -0.018 | 0.029 |
| 12 | 37.9 | 0.007 | -0.112 | 0.026 | -0.070 | -0.054 | -0.038 | -0.042 | -0.028 | 0.039 |
| 13 | 44.5 | 0.003 | -0.141 | 0.021 | -0.101 | -0.081 | -0.061 | -0.067 | -0.051 | 0.060 |
| 14 | 47.6 | -0.004 | -0.158 | 0.013 | -0.121 | -0.108 | -0.088 | -0.094 | -0.077 | 0.080 |
| 15 | 52.3 | -0.021 | -0.188 | -0.007 | -0.152 | -0.154 | -0.135 | -0.140 | -0.125 | 0.115 |
| 16 | 54.9 | -0.042 | -0.214 | -0.030 | -0.181 | -0.189 | -0.170 | -0.177 | -0.161 | 0.145 |
| 17 | 58.5 | -0.090 | -0.267 | -0.079 | -0.236 | -0.256 | -0.236 | -0.246 | -0.229 | 0.205 |
| 18 | 60.5 | -0.136 | -0.316 | -0.128 | -0.285 | -0.312 | -0.294 | -0.306 | -0.289 | 0.258 |

**Test No: 65** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/8X1/8X3/4 Date: 4/9/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 1.75 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.125 | 1.125 | SAW | 17 |
| Bottom: | 5 | 0.125 | 1.125 | SAW | 17 |

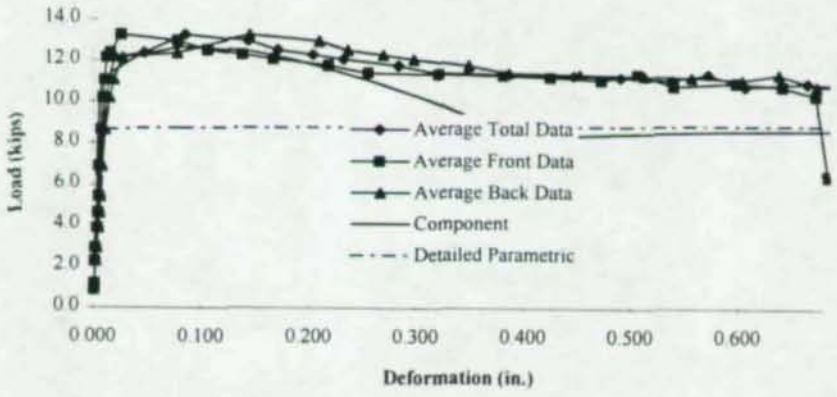
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bearing/Tearout | | |
| | Maximum: | 0.085 | 13.3 |
| | Failure: | 0.743 | 10.3 |
| | Other: | 0.16 | 12.7 |
| | | 0.25 | 12 |
| | | 0.34 | 11.4 |

## COMMENTS

* PL-17 yielded at a load of 12200 lbs with a deformation of 0.02 in.
* A decrease in strength observed after yielding.

## CHART



**Test No: 65**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 0.9 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | 0.001 |
| 2 | 1.2 | -0.001 | -0.002 | -0.001 | -0.001 | -0.002 | -0.002 | -0.001 | -0.001 | 0.001 |
| 3 | 2.3 | 0.000 | -0.002 | -0.001 | -0.002 | -0.004 | -0.003 | -0.002 | -0.001 | 0.002 |
| 4 | 2.9 | 0.000 | -0.003 | -0.001 | -0.003 | -0.005 | -0.004 | -0.003 | -0.001 | 0.002 |
| 5 | 3.9 | -0.004 | -0.004 | -0.001 | -0.005 | -0.008 | -0.004 | -0.006 | -0.001 | 0.004 |
| 6 | 4.6 | -0.004 | -0.005 | -0.002 | -0.007 | -0.009 | -0.005 | -0.006 | -0.003 | 0.005 |
| 7 | 5.4 | -0.004 | -0.006 | -0.002 | -0.008 | -0.009 | -0.006 | -0.007 | -0.004 | 0.006 |
| 8 | 6.9 | -0.002 | -0.008 | -0.002 | -0.011 | -0.011 | -0.007 | -0.009 | -0.007 | 0.007 |
| 9 | 8.6 | -0.002 | -0.011 | -0.002 | -0.015 | -0.012 | -0.011 | -0.011 | -0.011 | 0.009 |
| 10 | 10.2 | -0.002 | -0.014 | -0.002 | -0.018 | -0.014 | -0.016 | -0.014 | -0.017 | 0.012 |
| 11 | 11.1 | -0.002 | -0.016 | -0.002 | -0.020 | -0.016 | -0.020 | -0.017 | -0.022 | 0.014 |
| 12 | 12.2 | -0.002 | -0.020 | -0.003 | -0.023 | -0.021 | -0.030 | -0.023 | -0.032 | 0.019 |
| 13 | 12.4 | -0.002 | -0.026 | -0.004 | -0.029 | -0.070 | -0.081 | -0.073 | -0.085 | 0.046 |
| 14 | 13.3 | -0.006 | -0.042 | -0.007 | -0.045 | -0.137 | -0.148 | -0.140 | -0.151 | 0.085 |
| 15 | 13.0 | -0.051 | -0.104 | -0.049 | -0.105 | -0.200 | -0.214 | -0.204 | -0.217 | 0.143 |
| 16 | 12.5 | -0.080 | -0.131 | -0.077 | -0.133 | -0.228 | -0.240 | -0.231 | -0.244 | 0.170 |
| 17 | 12.3 | -0.111 | -0.163 | -0.109 | -0.166 | -0.261 | -0.274 | -0.264 | -0.277 | 0.203 |
| 18 | 12.1 | -0.140 | -0.192 | -0.138 | -0.195 | -0.290 | -0.303 | -0.293 | -0.305 | 0.232 |
| 19 | 11.8 | -0.191 | -0.243 | -0.190 | -0.247 | -0.341 | -0.355 | -0.344 | -0.356 | 0.283 |
| 20 | 11.4 | -0.228 | -0.280 | -0.227 | -0.284 | -0.378 | -0.393 | -0.380 | -0.393 | 0.321 |
| 21 | 11.4 | -0.294 | -0.347 | -0.292 | -0.350 | -0.443 | -0.460 | -0.446 | -0.460 | 0.387 |
| 22 | 11.3 | -0.355 | -0.408 | -0.352 | -0.410 | -0.504 | -0.522 | -0.507 | -0.519 | 0.447 |
| 23 | 11.2 | -0.399 | -0.452 | -0.396 | -0.453 | -0.546 | -0.566 | -0.551 | -0.563 | 0.491 |
| 24 | 11.1 | -0.447 | -0.500 | -0.443 | -0.500 | -0.593 | -0.614 | -0.599 | -0.610 | 0.538 |
| 25 | 11.4 | -0.481 | -0.534 | -0.477 | -0.534 | -0.627 | -0.647 | -0.632 | -0.645 | 0.572 |
| 26 | 10.8 | -0.514 | -0.568 | -0.510 | -0.569 | -0.663 | -0.682 | -0.666 | -0.680 | 0.606 |
| 27 | 10.9 | -0.572 | -0.626 | -0.569 | -0.627 | -0.720 | -0.742 | -0.724 | -0.736 | 0.664 |
| 28 | 10.8 | -0.615 | -0.669 | -0.612 | -0.670 | -0.763 | -0.786 | -0.769 | -0.778 | 0.708 |
| 29 | 10.3 | -0.646 | -0.699 | -0.642 | -0.701 | -0.803 | -0.826 | -0.810 | -0.820 | 0.743 |
| 30 | 6.4 | -0.657 | -0.712 | -0.653 | -0.712 | -0.921 | -0.921 | -0.932 | -0.920 | 0.804 |

**Test No: 66** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X1/4X3/4 Date: 4/9/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | | |
|---|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned | |
| Bolt Hole: | Std | Length (in.): | 2 | by Turn of Nut Method | |
| Shear Plane: | X | Nut Washer: | X | | |
| | | Bolt Head Washer: | X | | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.25 | 1.125 | SAW | 40 |
| Bottom: | 4 | 0.25 | 1.125 | SAW | 40 |

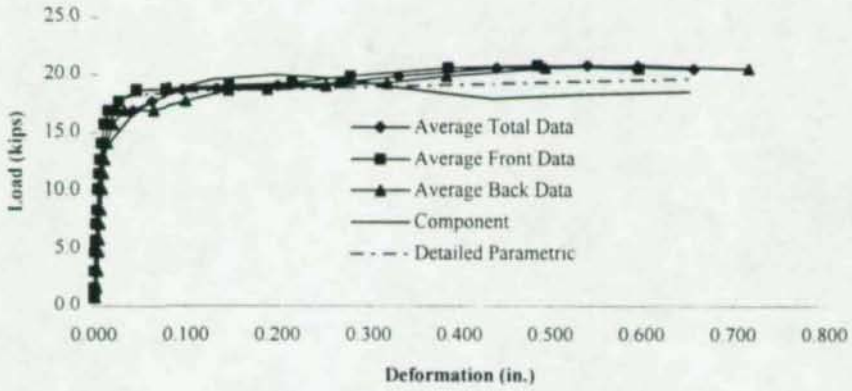
## TEST RESULTS

| | | | Deformation (in.) | Load (kips) |
|---|---|---|---|---|
| Limit State: | Bearing/Tearout | Maximum: | 0.541 | 20.8 |
| | | Failure: | 0.657 | 20.5 |
| | | Other: | 0.16 | 18.9 |
| | | | 0.25 | 19.2 |
| | | | 0.34 | 19.9 |

## COMMENTS

* PL-40 yielded at a load of 14200 lbs with a deformation of 0.012 in.
* Bulging started at a load of 17000 lbs with a deformation of 0.025 in.
* The connection maintained its strength after yielding point.

## CHART



**Test No: 66**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 0.7 | -0.001 | -0.001 | 0.000 | 0.000 | -0.002 | -0.003 | 0.000 | 0.000 | 0.001 |
| 2 | 1.6 | -0.001 | -0.001 | 0.000 | 0.000 | -0.005 | -0.006 | 0.001 | 0.000 | 0.001 |
| 3 | 3.1 | -0.001 | -0.001 | 0.000 | 0.000 | -0.008 | -0.009 | 0.001 | 0.000 | 0.002 |
| 4 | 4.8 | -0.001 | -0.001 | -0.001 | -0.002 | -0.010 | -0.011 | 0.000 | 0.000 | 0.003 |
| 5 | 5.8 | -0.001 | -0.002 | -0.002 | -0.003 | -0.011 | -0.012 | 0.000 | 0.000 | 0.004 |
| 6 | 7.2 | -0.001 | -0.002 | -0.003 | -0.004 | -0.012 | -0.014 | 0.000 | 0.000 | 0.005 |
| 7 | 8.3 | -0.002 | -0.003 | -0.004 | -0.005 | -0.013 | -0.017 | 0.000 | -0.001 | 0.006 |
| 8 | 10.2 | -0.002 | -0.004 | -0.006 | -0.007 | -0.015 | -0.018 | -0.001 | -0.002 | 0.007 |
| 9 | 11.5 | -0.002 | -0.006 | -0.007 | -0.008 | -0.016 | -0.021 | -0.001 | -0.003 | 0.008 |
| 10 | 12.7 | -0.003 | -0.007 | -0.008 | -0.010 | -0.018 | -0.023 | -0.002 | -0.005 | 0.009 |
| 11 | 14.1 | -0.004 | -0.008 | -0.009 | -0.013 | -0.021 | -0.027 | -0.004 | -0.007 | 0.012 |
| 12 | 15.8 | -0.004 | -0.012 | -0.010 | -0.018 | -0.027 | -0.033 | -0.010 | -0.013 | 0.016 |
| 13 | 16.9 | -0.004 | -0.021 | -0.012 | -0.026 | -0.042 | -0.043 | -0.024 | -0.023 | 0.024 |
| 14 | 16.9 | -0.004 | -0.028 | -0.012 | -0.035 | -0.077 | -0.073 | -0.059 | -0.053 | 0.043 |
| 15 | 17.7 | -0.004 | -0.043 | -0.011 | -0.051 | -0.112 | -0.106 | -0.094 | -0.086 | 0.063 |
| 16 | 18.7 | -0.006 | -0.078 | -0.013 | -0.087 | -0.159 | -0.152 | -0.142 | -0.134 | 0.097 |
| 17 | 18.8 | -0.034 | -0.116 | -0.041 | -0.125 | -0.202 | -0.192 | -0.185 | -0.176 | 0.134 |
| 18 | 19.1 | -0.105 | -0.185 | -0.111 | -0.190 | -0.266 | -0.256 | -0.251 | -0.240 | 0.200 |
| 19 | 19.3 | -0.174 | -0.255 | -0.179 | -0.258 | -0.334 | -0.322 | -0.318 | -0.307 | 0.268 |
| 20 | 19.9 | -0.238 | -0.318 | -0.243 | -0.322 | -0.400 | -0.386 | -0.383 | -0.373 | 0.333 |
| 21 | 20.6 | -0.346 | -0.426 | -0.350 | -0.428 | -0.510 | -0.495 | -0.493 | -0.479 | 0.441 |
| 22 | 20.8 | -0.444 | -0.525 | -0.450 | -0.525 | -0.612 | -0.595 | -0.595 | -0.579 | 0.541 |
| 23 | 20.5 | -0.556 | -0.638 | -0.560 | -0.635 | -0.734 | -0.718 | -0.717 | -0.700 | 0.657 |

Test No: 67 **Summary of One Bolt Lap Connection Tests**
Recorder: BK

## TEST DESIGNATION

Test Designation: 3/8X3/8X3/4 Date: 4/9/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | |
|---|---|---|---|
| Type: | A325 | Diameter (in.): 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): 2 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: X | |
| | | Bolt Head Washer: X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.375 | 1.125 | SHEAR | 25 |
| Bottom: | 5 | 0.375 | 1.125 | SHEAR | 25 |

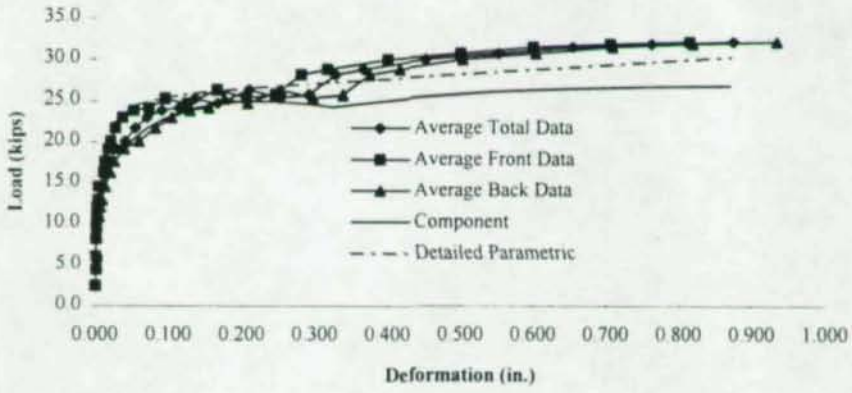
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bearing/Tearout | | |
| | Maximum: | 0.876 | 32.2 |
| | Failure: | 0.876 | 32.2 |
| | Other: | 0.16 | 24.8 |
| | | 0.25 | 25.4 |
| | | 0.34 | 28.3 |

## COMMENTS

* PL-25 yielded at a load of 19000 lbs with a deformation of 0.02 in.
* Bulging started at a load of 23500 lbs with deformation 0.15 in.

## CHART



**Test No: 67**
**Recorder: BK**

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 2.4 | -0.002 | 0.000 | -0.001 | -0.001 | -0.002 | -0.002 | 0.000 | 0.000 | 0.001 |
| 2 | 4.5 | -0.003 | 0.000 | -0.003 | -0.002 | -0.004 | -0.004 | -0.001 | -0.001 | 0.002 |
| 3 | 6.0 | -0.003 | -0.001 | -0.004 | -0.004 | -0.006 | -0.004 | -0.001 | -0.001 | 0.003 |
| 4 | 8.2 | -0.004 | -0.001 | -0.005 | -0.004 | -0.007 | -0.006 | -0.002 | -0.001 | 0.004 |
| 5 | 9.7 | -0.004 | -0.001 | -0.006 | -0.006 | -0.009 | -0.007 | -0.002 | -0.001 | 0.004 |
| 6 | 10.8 | -0.005 | -0.001 | -0.006 | -0.006 | -0.012 | -0.010 | -0.005 | -0.002 | 0.006 |
| 7 | 12.0 | -0.006 | -0.001 | -0.007 | -0.006 | -0.015 | -0.011 | -0.007 | -0.003 | 0.007 |
| 8 | 12.9 | -0.007 | -0.002 | -0.009 | -0.006 | -0.019 | -0.013 | -0.010 | -0.005 | 0.009 |
| 9 | 14.5 | -0.009 | -0.001 | -0.010 | -0.007 | -0.025 | -0.015 | -0.017 | -0.006 | 0.011 |
| 10 | 16.2 | -0.019 | -0.005 | -0.020 | -0.011 | -0.037 | -0.017 | -0.028 | -0.009 | 0.018 |
| 11 | 16.3 | -0.019 | -0.005 | -0.020 | -0.011 | -0.037 | -0.017 | -0.028 | -0.008 | 0.018 |
| 12 | 17.6 | -0.021 | -0.005 | -0.023 | -0.012 | -0.045 | -0.021 | -0.036 | -0.011 | 0.022 |
| 13 | 19.1 | -0.027 | -0.008 | -0.028 | -0.016 | -0.063 | -0.029 | -0.054 | -0.020 | 0.031 |
| 14 | 20.1 | -0.031 | -0.012 | -0.031 | -0.020 | -0.086 | -0.045 | -0.079 | -0.036 | 0.042 |
| 15 | 21.6 | -0.037 | -0.018 | -0.038 | -0.027 | -0.110 | -0.065 | -0.104 | -0.056 | 0.057 |
| 16 | 22.9 | -0.046 | -0.028 | -0.047 | -0.037 | -0.134 | -0.085 | -0.128 | -0.077 | 0.073 |
| 17 | 23.8 | -0.061 | -0.043 | -0.062 | -0.052 | -0.159 | -0.109 | -0.155 | -0.099 | 0.093 |
| 18 | 24.1 | -0.082 | -0.064 | -0.083 | -0.072 | -0.186 | -0.134 | -0.182 | -0.125 | 0.116 |
| 19 | 25.2 | -0.104 | -0.086 | -0.104 | -0.093 | -0.206 | -0.154 | -0.205 | -0.145 | 0.137 |
| 20 | 24.7 | -0.135 | -0.117 | -0.134 | -0.124 | -0.239 | -0.186 | -0.237 | -0.178 | 0.169 |
| 21 | 26.2 | -0.176 | -0.159 | -0.174 | -0.163 | -0.285 | -0.230 | -0.283 | -0.222 | 0.212 |
| 22 | 25.3 | -0.216 | -0.198 | -0.213 | -0.204 | -0.329 | -0.274 | -0.328 | -0.266 | 0.253 |
| 23 | 25.7 | -0.256 | -0.239 | -0.253 | -0.243 | -0.370 | -0.314 | -0.370 | -0.306 | 0.294 |
| 24 | 28.1 | -0.290 | -0.275 | -0.288 | -0.278 | -0.407 | -0.350 | -0.407 | -0.342 | 0.330 |
| 25 | 28.8 | -0.326 | -0.312 | -0.323 | -0.314 | -0.448 | -0.391 | -0.451 | -0.383 | 0.368 |
| 26 | 30.0 | -0.408 | -0.396 | -0.405 | -0.399 | -0.534 | -0.477 | -0.537 | -0.469 | 0.453 |
| 27 | 30.7 | -0.508 | -0.497 | -0.504 | -0.500 | -0.635 | -0.578 | -0.638 | -0.570 | 0.554 |
| 28 | 31.5 | -0.606 | -0.599 | -0.602 | -0.599 | -0.740 | -0.682 | -0.745 | -0.674 | 0.656 |
| 29 | 31.9 | -0.711 | -0.706 | -0.706 | -0.706 | -0.850 | -0.792 | -0.857 | -0.784 | 0.764 |
| 30 | 32.2 | -0.819 | -0.815 | -0.814 | -0.816 | -0.964 | -0.909 | -0.971 | -0.897 | 0.876 |

**Test No: 68** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X1/2X3/4 Date: 2/17/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | | |
|---|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned | |
| Bolt Hole: | Std | Length (in.): | 2 | by Turn of Nut Method | |
| Shear Plane: | X | Nut Washer: | X | | |
| | | Bolt Head Washer: | X | | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 4 | 0.25 | 1.125 | SAW | 40 |
| Bottom: | 5 | 0.5 | 1.125 | SAW | 42 |

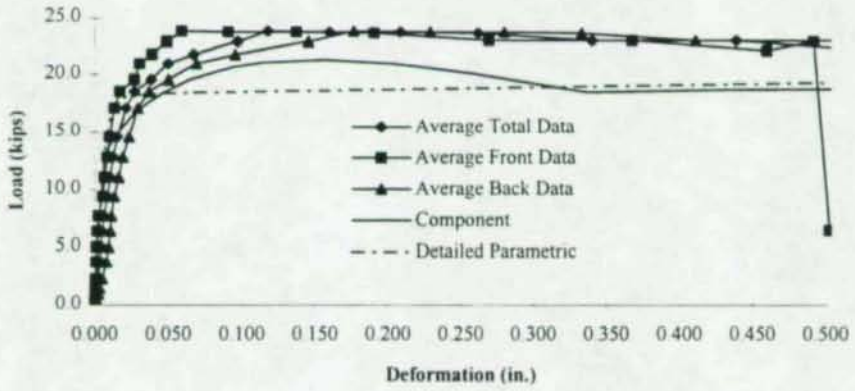
## TEST RESULTS

| | | | Deformation (in.) | Load (kips) |
|---|---|---|---|---|
| Limit State: | Bearing/Tearout | Maximum: | 0.118 | 23.8 |
| | | Failure: | 0.565 | 22.9 |
| | | Other: | 0.16 | 23.7 |
| | | | 0.25 | 23.7 |
| | | | 0.34 | 23 |

## COMMENTS

* PL-40 yielded at a load of 15000 lbs with 0.015 in. of deformation.
* Bulging started at 0.07 in. on PL-40.

## CHART



**Test No: 68**
**Recorder: BK**

## Summary of One Bolt Lap Connection Tests

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.5 | 0.000 | 0.000 | -0.001 | -0.001 | -0.002 | -0.001 | 0.000 | 0.001 | 0.000 |
| 2 | 1.0 | -0.001 | 0.000 | -0.001 | -0.001 | -0.005 | -0.003 | 0.000 | 0.002 | 0.001 |
| 3 | 1.5 | -0.001 | 0.000 | -0.001 | -0.001 | -0.006 | -0.006 | 0.000 | 0.002 | 0.001 |
| 4 | 2.3 | -0.001 | -0.001 | -0.001 | -0.001 | -0.009 | -0.009 | 0.000 | 0.002 | 0.002 |
| 5 | 3.7 | -0.001 | -0.002 | -0.001 | -0.001 | -0.014 | -0.014 | 0.001 | 0.003 | 0.004 |
| 6 | 5.0 | -0.002 | -0.002 | -0.001 | -0.001 | -0.016 | -0.017 | 0.001 | 0.003 | 0.004 |
| 7 | 6.4 | -0.001 | -0.002 | -0.001 | -0.002 | -0.019 | -0.020 | 0.002 | 0.002 | 0.005 |
| 8 | 7.7 | 0.000 | -0.002 | -0.003 | -0.005 | -0.020 | -0.023 | 0.002 | 0.000 | 0.006 |
| 9 | 9.4 | -0.006 | -0.003 | -0.006 | -0.009 | -0.021 | -0.028 | 0.003 | -0.002 | 0.009 |
| 10 | 11.1 | -0.006 | -0.004 | -0.007 | -0.011 | -0.022 | -0.034 | 0.004 | -0.006 | 0.011 |
| 11 | 12.8 | -0.005 | -0.005 | -0.010 | -0.015 | -0.023 | -0.039 | 0.006 | -0.010 | 0.013 |
| 12 | 14.6 | -0.003 | -0.006 | -0.012 | -0.020 | -0.026 | -0.048 | 0.005 | -0.015 | 0.016 |
| 13 | 17.1 | -0.001 | -0.011 | -0.013 | -0.029 | -0.035 | -0.059 | 0.000 | -0.024 | 0.021 |
| 14 | 18.5 | -0.003 | -0.016 | -0.014 | -0.037 | -0.044 | -0.067 | -0.006 | -0.031 | 0.027 |
| 15 | 19.6 | -0.006 | -0.029 | -0.019 | -0.054 | -0.057 | -0.080 | -0.023 | -0.040 | 0.039 |
| 16 | 21.0 | -0.003 | -0.035 | -0.020 | -0.064 | -0.078 | -0.098 | -0.043 | -0.058 | 0.050 |
| 17 | 21.8 | -0.005 | -0.048 | -0.024 | -0.080 | -0.106 | -0.122 | -0.073 | -0.082 | 0.067 |
| 18 | 22.9 | -0.003 | -0.064 | -0.028 | -0.102 | -0.156 | -0.172 | -0.123 | -0.131 | 0.097 |
| 19 | 22.9 | -0.003 | -0.064 | -0.028 | -0.102 | -0.156 | -0.172 | -0.123 | -0.131 | 0.097 |
| 20 | 23.8 | -0.007 | -0.077 | -0.035 | -0.118 | -0.188 | -0.204 | -0.153 | -0.162 | 0.118 |
| 21 | 23.7 | -0.032 | -0.113 | -0.063 | -0.157 | -0.240 | -0.257 | -0.206 | -0.214 | 0.160 |
| 22 | 23.7 | -0.076 | -0.160 | -0.109 | -0.205 | -0.292 | -0.308 | -0.256 | -0.265 | 0.209 |
| 23 | 23.7 | -0.128 | -0.212 | -0.163 | -0.260 | -0.345 | -0.363 | -0.308 | -0.317 | 0.262 |
| 24 | 23.0 | -0.205 | -0.292 | -0.241 | -0.341 | -0.423 | -0.442 | -0.386 | -0.394 | 0.341 |
| 25 | 23.0 | -0.302 | -0.390 | -0.339 | -0.440 | -0.523 | -0.542 | -0.484 | -0.492 | 0.439 |
| 26 | 22.1 | -0.394 | -0.481 | -0.432 | -0.533 | -0.616 | -0.635 | -0.576 | -0.584 | 0.531 |
| 27 | 22.9 | -0.424 | -0.513 | -0.464 | -0.566 | -0.650 | -0.672 | -0.612 | -0.620 | 0.565 |
| 28 | 6.4 | -0.440 | -0.519 | -0.481 | -0.569 | -0.828 | -0.808 | -0.823 | -0.790 | 0.657 |

**Test No: 69** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/2X1/2X3/4 Date: 4/10/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.25 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.5 | 1.125 | SAW | 42 |
| Bottom: | 5 | 0.5 | 1.125 | SAW | 42 |

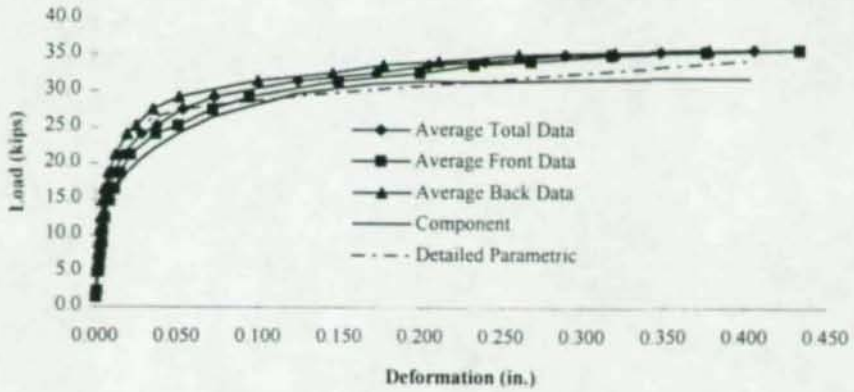
## TEST RESULTS

| | | Deformation (in.) | Load (kips) |
|---|---|---|---|
| Limit State: | Bolt Shear | | |
| | Maximum: | 0.406 | 35.8 |
| | Failure: | 0.406 | 35.8 |
| | Other: | 0.16 | 32.2 |
| | | 0.25 | 34.4 |
| | | 0.34 | 35.4 |

## COMMENTS

* PL-42 yielded at 0.02 in. of deformation with 21000 lbs.

## CHART



Test No: 69
Recorder: BK

**Summary of One Bolt Lap Connection Tests**

**DATA**

| | | Potentiometer Readings (in.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Data Point | Load per Plate (kips) | F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
| 1 | 1.4 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | 0.001 |
| 2 | 2.3 | -0.001 | -0.001 | -0.002 | -0.002 | -0.001 | 0.000 | -0.001 | 0.000 | 0.001 |
| 3 | 5.0 | -0.001 | -0.001 | -0.004 | -0.003 | -0.001 | -0.001 | -0.001 | -0.001 | 0.002 |
| 4 | 5.0 | -0.001 | -0.001 | -0.004 | -0.003 | -0.001 | -0.001 | -0.001 | -0.001 | 0.002 |
| 5 | 5.8 | -0.002 | -0.001 | -0.004 | -0.004 | -0.002 | -0.001 | -0.001 | -0.001 | 0.002 |
| 6 | 7.4 | -0.002 | -0.002 | -0.005 | -0.005 | -0.002 | -0.002 | -0.002 | -0.001 | 0.003 |
| 7 | 9.0 | -0.003 | -0.002 | -0.006 | -0.006 | -0.003 | -0.002 | -0.002 | -0.001 | 0.003 |
| 8 | 10.7 | -0.003 | -0.002 | -0.007 | -0.006 | -0.004 | -0.004 | -0.002 | -0.001 | 0.004 |
| 9 | 12.5 | -0.005 | -0.003 | -0.009 | -0.007 | -0.005 | -0.004 | -0.002 | -0.002 | 0.005 |
| 10 | 14.8 | -0.009 | -0.004 | -0.014 | -0.009 | -0.007 | -0.006 | -0.002 | -0.002 | 0.007 |
| 11 | 16.5 | -0.013 | -0.006 | -0.018 | -0.011 | -0.008 | -0.008 | -0.003 | -0.002 | 0.009 |
| 12 | 18.7 | -0.018 | -0.009 | -0.023 | -0.014 | -0.010 | -0.013 | -0.005 | -0.007 | 0.012 |
| 13 | 21.2 | -0.024 | -0.015 | -0.029 | -0.021 | -0.015 | -0.018 | -0.008 | -0.011 | 0.018 |
| 14 | 24.1 | -0.036 | -0.034 | -0.042 | -0.039 | -0.022 | -0.026 | -0.013 | -0.018 | 0.029 |
| 15 | 25.3 | -0.048 | -0.050 | -0.053 | -0.053 | -0.027 | -0.032 | -0.019 | -0.023 | 0.038 |
| 16 | 27.5 | -0.067 | -0.073 | -0.072 | -0.077 | -0.038 | -0.044 | -0.028 | -0.033 | 0.054 |
| 17 | 29.2 | -0.088 | -0.098 | -0.093 | -0.100 | -0.056 | -0.061 | -0.043 | -0.048 | 0.073 |
| 18 | 31.4 | -0.141 | -0.156 | -0.144 | -0.156 | -0.104 | -0.109 | -0.090 | -0.096 | 0.125 |
| 19 | 32.5 | -0.190 | -0.208 | -0.194 | -0.208 | -0.150 | -0.155 | -0.136 | -0.142 | 0.173 |
| 20 | 33.7 | -0.222 | -0.242 | -0.227 | -0.242 | -0.181 | -0.188 | -0.167 | -0.173 | 0.205 |
| 21 | 34.2 | -0.257 | -0.278 | -0.262 | -0.278 | -0.215 | -0.222 | -0.201 | -0.208 | 0.240 |
| 22 | 35.1 | -0.307 | -0.328 | -0.311 | -0.328 | -0.266 | -0.272 | -0.250 | -0.256 | 0.290 |
| 23 | 35.5 | -0.364 | -0.386 | -0.369 | -0.388 | -0.325 | -0.331 | -0.310 | -0.315 | 0.349 |
| 24 | 35.8 | -0.421 | -0.443 | -0.426 | -0.446 | -0.382 | -0.390 | -0.369 | -0.374 | 0.406 |

**Test No: 70** **Summary of One Bolt Lap Connection Tests**
**Recorder: BK**

## TEST DESIGNATION

Test Designation: 1/4X5/8X3/4 Date: 4/10/95

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

| | | | | |
|---|---|---|---|---|
| Type: | A325 | Diameter (in.): | 0.75 | Bolt Fully Pretensioned |
| Bolt Hole: | Std | Length (in.): | 2.5 | by Turn of Nut Method |
| Shear Plane: | X | Nut Washer: | X | |
| | | Bolt Head Washer: | X | |

### PLATES

| | Width (in.) | Thickness (in.) | Le(in.) | Edge Condition | Coupon No. |
|---|---|---|---|---|---|
| Top: | 5 | 0.25 | 1.125 | SAW | 41 |
| Bottom: | 5 | 0.625 | 1.125 | SAW | 43 |

## TEST RESULTS

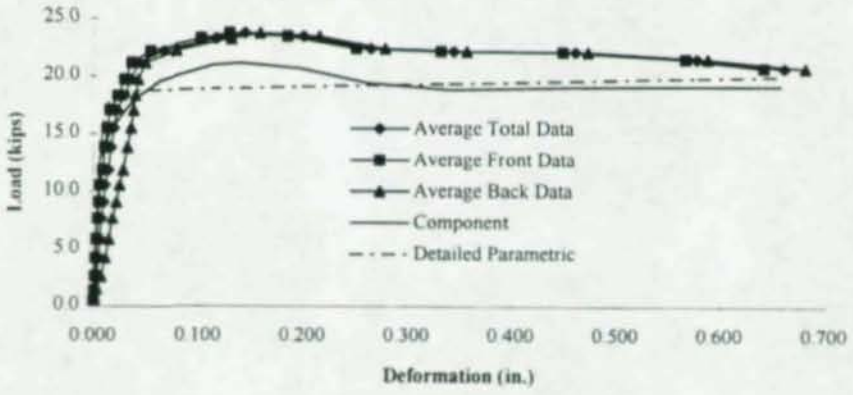
Limit State: Bearing/Tearout

| | Deformation (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.144 | 23.7 |
| Failure: | 0.662 | 20.8 |
| Other: | 0.16 | 23.7 |
| | 0.25 | 22.7 |
| | 0.34 | 22.2 |

## COMMENTS

* At 26000 lbs, PL-41 yielded with 0.025 in. of deformation.

## CHART



Test No: 70
Recorder: BK

## Summary of One Bolt Lap Connection Tests

**DATA**

| Data Point | Load per Plate (kips) | Potentiometer Readings (in.) F1 90 | F2 91 | F3 92 | F4 93 | R1 94 | R2 95 | R3 96 | R4 97 | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.5 | -0.001 | -0.001 | -0.001 | -0.001 | -0.003 | -0.003 | -0.001 | 0.000 | 0.001 |
| 2 | 1.5 | 0.000 | -0.001 | -0.001 | -0.002 | -0.005 | -0.007 | 0.000 | 0.001 | 0.002 |
| 3 | 2.6 | 0.000 | -0.001 | -0.003 | -0.003 | -0.012 | -0.014 | 0.002 | 0.002 | 0.004 |
| 4 | 4.2 | 0.000 | -0.001 | -0.004 | -0.005 | -0.018 | -0.020 | 0.004 | 0.004 | 0.005 |
| 5 | 5.9 | 0.000 | -0.002 | -0.006 | -0.007 | -0.024 | -0.026 | 0.006 | 0.006 | 0.007 |
| 6 | 7.7 | 0.000 | -0.002 | -0.007 | -0.009 | -0.029 | -0.031 | 0.007 | 0.007 | 0.008 |
| 7 | 9.1 | 0.000 | -0.003 | -0.009 | -0.011 | -0.035 | -0.038 | 0.008 | 0.007 | 0.010 |
| 8 | 10.5 | 0.001 | -0.004 | -0.009 | -0.013 | -0.040 | -0.044 | 0.010 | 0.007 | 0.011 |
| 9 | 11.9 | -0.006 | -0.005 | -0.010 | -0.015 | -0.046 | -0.051 | 0.011 | 0.007 | 0.014 |
| 10 | 13.9 | -0.008 | -0.006 | -0.012 | -0.018 | -0.052 | -0.059 | 0.013 | 0.007 | 0.017 |
| 11 | 15.5 | -0.009 | -0.007 | -0.014 | -0.022 | -0.058 | -0.066 | 0.014 | 0.006 | 0.020 |
| 12 | 17.1 | -0.013 | -0.009 | -0.017 | -0.026 | -0.062 | -0.072 | 0.015 | 0.005 | 0.022 |
| 13 | 18.3 | -0.020 | -0.016 | -0.023 | -0.035 | -0.071 | -0.080 | 0.007 | 0.001 | 0.029 |
| 14 | 19.7 | -0.024 | -0.023 | -0.028 | -0.045 | -0.079 | -0.087 | 0.002 | -0.002 | 0.036 |
| 15 | 21.2 | -0.028 | -0.031 | -0.032 | -0.056 | -0.092 | -0.097 | -0.004 | -0.005 | 0.043 |
| 16 | 22.2 | -0.042 | -0.049 | -0.048 | -0.079 | -0.125 | -0.127 | -0.032 | -0.031 | 0.067 |
| 17 | 23.3 | -0.113 | -0.091 | -0.083 | -0.124 | -0.180 | -0.183 | -0.083 | -0.081 | 0.117 |
| 18 | 23.2 | -0.113 | -0.091 | -0.083 | -0.124 | -0.179 | -0.183 | -0.083 | -0.080 | 0.117 |
| 19 | 23.7 | -0.138 | -0.118 | -0.109 | -0.153 | -0.208 | -0.212 | -0.109 | -0.106 | 0.144 |
| 20 | 23.4 | -0.193 | -0.174 | -0.165 | -0.209 | -0.266 | -0.269 | -0.166 | -0.161 | 0.200 |
| 21 | 22.4 | -0.259 | -0.241 | -0.230 | -0.275 | -0.329 | -0.333 | -0.228 | -0.225 | 0.265 |
| 22 | 22.2 | -0.341 | -0.321 | -0.311 | -0.356 | -0.409 | -0.412 | -0.306 | -0.303 | 0.345 |
| 23 | 22.1 | -0.456 | -0.438 | -0.428 | -0.474 | -0.525 | -0.530 | -0.421 | -0.416 | 0.461 |
| 24 | 21.5 | -0.574 | -0.555 | -0.546 | -0.592 | -0.641 | -0.646 | -0.535 | -0.530 | 0.577 |
| 25 | 21.5 | -0.574 | -0.555 | -0.546 | -0.592 | -0.641 | -0.646 | -0.535 | -0.531 | 0.578 |
| 26 | 20.8 | -0.647 | -0.629 | -0.621 | -0.670 | -0.730 | -0.739 | -0.631 | -0.626 | 0.662 |

# Appendix C

## Single Bolt Lap Plate Connection Tests Reported By Gillet (1978)

## Table C - 1
## Connection Geometry And Material Parameters

| Report Test Number | Bolt | | | Plate 1 | | | | | | Plate 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $d_b$ (in.) | Bolt Grade* | Was Bolt Pre-tensioned | $t_1$ (in.) | Width (in.) | $L_e$ (in.) | Edge Condition | $f_y$ ** (ksi) | $f_u$ ** (ksi) | $t_2$ (in.) | Width (in.) | $L_e$ (in.) | Edge Condition | $f_y$ ** (ksi) | $f_u$ ** (ksi) |
| 1 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | Sheared | 42.0 | 53.0 | 0.2500 | 4.00 | 1.250 | Sheared | 42.0 | 53.0 |
| 2 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | Sheared | 42.0 | 53.0 | 0.2500 | 4.00 | 1.250 | Sheared | 42.0 | 53.0 |
| 3 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | Sheared | 42.0 | 53.0 | 0.2500 | 4.00 | 1.250 | Sheared | 42.0 | 53.0 |
| 4 | 0.75 | A325-X | Yes | 0.3125 | 4.00 | 1.250 | Sheared | 41.0 | 62.0 | 0.3125 | 4.00 | 1.250 | Sheared | 41.0 | 62.0 |
| 5 | 0.75 | A325-X | Yes | 0.3750 | 4.00 | 1.250 | Sheared | 48.0 | 74.0 | 0.3750 | 4.00 | 1.250 | Sheared | 48.0 | 74.0 |
| 6 | 0.75 | A325-X | Yes | 0.3750 | 4.00 | 1.250 | Sheared | 48.0 | 74.0 | 0.3750 | 4.00 | 1.250 | Sheared | 48.0 | 74.0 |
| 7 | 0.75 | A325-X | Yes | 0.3750 | 4.00 | 1.250 | Sheared | 48.0 | 74.0 | 0.3750 | 4.00 | 1.250 | Sheared | 48.0 | 74.0 |
| 8 | 0.75 | A325-X | Yes | 0.4375 | 4.00 | 1.250 | Sheared | 41.2 | 68.3 | 0.4375 | 4.00 | 1.250 | Sheared | 41.2 | 68.3 |
| 9 | 0.75 | A325-X | Yes | 0.4375 | 4.00 | 1.250 | Sheared | 41.2 | 68.3 | 0.4375 | 4.00 | 1.250 | Sheared | 41.2 | 68.3 |
| 10 | 0.75 | A325-X | Yes | 0.4375 | 4.00 | 1.250 | Sheared | 41.2 | 68.3 | 0.4375 | 4.00 | 1.250 | Sheared | 41.2 | 68.3 |
| 11 | 0.75 | A325-X | Yes | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 |
| 12 | 0.75 | A325-X | Yes | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 |
| 13 | 0.75 | A325-X | Yes | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 |
| 14 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | Sheared | 42.0 | 53.0 | 0.3750 | 4.00 | 1.250 | Sheared | 48.0 | 74.0 |
| 15 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | Sheared | 42.0 | 53.0 | 0.3750 | 4.00 | 1.250 | Sheared | 48.0 | 74.0 |
| 16 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | Sheared | 42.0 | 53.0 | 0.3750 | 4.00 | 1.250 | Sheared | 48.0 | 74.0 |
| 17 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | Sheared | 42.0 | 53.0 | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 |
| 18 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | Sheared | 42.0 | 53.0 | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 |
| 19 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | Sheared | 42.0 | 53.0 | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 |
| 20 | 0.75 | A325-X | Yes | 0.3750 | 4.00 | 1.250 | Sheared | 48.0 | 74.0 | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 |
| 21 | 0.875 | A325-X | Yes | 0.3125 | 4.00 | 1.500 | Sheared | 41.0 | 62.0 | 0.3125 | 4.00 | 1.500 | Sheared | 41.0 | 62.0 |
| 22 | 0.875 | A325-X | Yes | 0.3125 | 4.00 | 1.500 | Sheared | 41.0 | 62.0 | 0.3125 | 4.00 | 1.500 | Sheared | 41.0 | 62.0 |
| 23 | 0.875 | A325-X | Yes | 0.3750 | 4.00 | 1.500 | Sheared | 48.0 | 74.0 | 0.3750 | 4.00 | 1.500 | Sheared | 48.0 | 74.0 |
| 24 | 0.875 | A325-X | Yes | 0.3750 | 4.00 | 1.500 | Sheared | 48.0 | 74.0 | 0.3750 | 4.00 | 1.500 | Sheared | 48.0 | 74.0 |
| 25 | 0.875 | A325-X | Yes | 0.3750 | 4.00 | 1.500 | Sheared | 48.0 | 74.0 | 0.3750 | 4.00 | 1.500 | Sheared | 48.0 | 74.0 |
| 26 | 0.875 | A325-X | Yes | 0.4375 | 4.00 | 1.500 | Sheared | 41.2 | 68.3 | 0.4375 | 4.00 | 1.500 | Sheared | 41.2 | 68.3 |
| 27 | 0.875 | A325-X | Yes | 0.4375 | 4.00 | 1.500 | Sheared | 41.2 | 68.3 | 0.4375 | 4.00 | 1.500 | Sheared | 41.2 | 68.3 |
| 28 | 0.875 | A325-X | Yes | 0.4375 | 4.00 | 1.500 | Sheared | 41.2 | 68.3 | 0.4375 | 4.00 | 1.500 | Sheared | 41.2 | 68.3 |
| 29 | 0.875 | A325-X | Yes | 0.5000 | 4.00 | 1.500 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.500 | Sheared | 43.0 | 64.0 |
| 30 | 0.875 | A325-X | Yes | 0.5000 | 4.00 | 1.500 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.500 | Sheared | 43.0 | 64.0 |
| 31 | 0.875 | A325-X | Yes | 0.2500 | 4.00 | 1.500 | Sheared | 42.0 | 53.0 | 0.3750 | 4.00 | 1.500 | Sheared | 48.0 | 74.0 |
| 32 | 0.875 | A325-X | Yes | 0.2500 | 4.00 | 1.500 | Sheared | 42.0 | 53.0 | 0.5000 | 4.00 | 1.500 | Sheared | 43.0 | 64.0 |
| 33 | 0.875 | A325-X | Yes | 0.3750 | 4.00 | 1.500 | Sheared | 48.0 | 74.0 | 0.5000 | 4.00 | 1.500 | Sheared | 43.0 | 64.0 |
| 34 | 1 | A325-X | Yes | 0.5000 | 4.00 | 1.750 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.750 | Sheared | 43.0 | 64.0 |
| 35 | 1 | A325-X | Yes | 0.5000 | 4.00 | 1.750 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.750 | Sheared | 43.0 | 64.0 |
| 36 | 1 | A325-X | Yes | 0.5000 | 4.00 | 1.750 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.750 | Sheared | 43.0 | 64.0 |

## Table C - 1
## Connection Geometry And Material Parameters

| Report Test Number | Bolt | | | Plate 1 | | | | | | Plate 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $d_b$ (in.) | Bolt Grade* | Was Bolt Pre-tensioned | $t_1$ (in.) | Width (in.) | $L_e$ (in.) | Edge Condition | $f_y$** (ksi) | $f_u$** (ksi) | $t_2$ (in.) | Width (in.) | $L_e$ (in.) | Edge Condition | $f_y$** (ksi) | $f_u$** (ksi) |
| 37 | 1 | A325-X | Yes | 0.6250 | 4.00 | 1.750 | Sheared | 44.0 | 64.0 | 0.6250 | 4.00 | 1.750 | Sheared | 44.0 | 64.0 |
| 38 | 1 | A325-X | Yes | 0.6250 | 4.00 | 1.750 | Sheared | 44.0 | 64.0 | 0.6250 | 4.00 | 1.750 | Sheared | 44.0 | 64.0 |
| 39 | 1 | A325-X | Yes | 0.6250 | 4.00 | 1.750 | Sheared | 44.0 | 64.0 | 0.6250 | 4.00 | 1.750 | Sheared | 44.0 | 64.0 |
| 40 | 0.75 | A325-X | Yes | 0.3750 | 4.00 | 1.250 | Sheared | 54.0 | 76.2 | 0.3750 | 4.00 | 1.250 | Sheared | 54.0 | 76.2 |
| 41 | 0.75 | A325-X | Yes | 0.3750 | 4.00 | 1.250 | Sheared | 54.0 | 76.2 | 0.3750 | 4.00 | 1.250 | Sheared | 54.0 | 76.2 |
| 42 | 0.75 | A325-X | Yes | 0.3750 | 4.00 | 1.250 | Sheared | 54.0 | 76.2 | 0.3750 | 4.00 | 1.250 | Sheared | 54.0 | 76.2 |
| 43 | 0.875 | A325-X | Yes | 0.3750 | 4.00 | 1.500 | Sheared | 54.0 | 76.2 | 0.3750 | 4.00 | 1.500 | Sheared | 54.0 | 76.2 |
| 44 | 0.875 | A325-X | Yes | 0.3750 | 4.00 | 1.500 | Sheared | 54.0 | 76.2 | 0.3750 | 4.00 | 1.500 | Sheared | 54.0 | 76.2 |
| 45 | 0.875 | A325-X | Yes | 0.3750 | 4.00 | 1.500 | Sheared | 54.0 | 76.2 | 0.3750 | 4.00 | 1.500 | Sheared | 54.0 | 76.2 |
| 46 | 0.75 | A490-X | Yes | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 |
| 47 | 0.75 | A490-X | Yes | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 |
| 48 | 0.75 | A490-X | Yes | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.250 | Sheared | 43.0 | 64.0 |
| 49 | 0.75 | A490-X | Yes | 0.6250 | 4.00 | 1.250 | Sheared | 44.0 | 64.0 | 0.6250 | 4.00 | 1.250 | Sheared | 44.0 | 64.0 |
| 50 | 0.75 | A490-X | Yes | 0.6250 | 4.00 | 1.250 | Sheared | 44.0 | 64.0 | 0.6250 | 4.00 | 1.250 | Sheared | 44.0 | 64.0 |
| 51 | 0.75 | A490-X | Yes | 0.6250 | 4.00 | 1.250 | Sheared | 44.0 | 64.0 | 0.6250 | 4.00 | 1.250 | Sheared | 44.0 | 64.0 |
| 52 | 0.875 | A490-X | Yes | 0.5000 | 4.00 | 1.500 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.500 | Sheared | 43.0 | 64.0 |
| 53 | 0.875 | A490-X | Yes | 0.5000 | 4.00 | 1.500 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.500 | Sheared | 43.0 | 64.0 |
| 54 | 0.875 | A490-X | Yes | 0.5000 | 4.00 | 1.500 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.500 | Sheared | 43.0 | 64.0 |
| 55 | 0.875 | A490-X | Yes | 0.6250 | 4.00 | 1.500 | Sheared | 44.0 | 64.0 | 0.6250 | 4.00 | 1.500 | Sheared | 44.0 | 64.0 |
| 56 | 0.875 | A490-X | Yes | 0.6250 | 4.00 | 1.500 | Sheared | 44.0 | 64.0 | 0.6250 | 4.00 | 1.500 | Sheared | 44.0 | 64.0 |
| 57 | 0.875 | A490-X | Yes | 0.6250 | 4.00 | 1.500 | Sheared | 44.0 | 64.0 | 0.6250 | 4.00 | 1.500 | Sheared | 44.0 | 64.0 |
| 58 | 1 | A490-X | Yes | 0.5000 | 4.00 | 1.750 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.750 | Sheared | 43.0 | 64.0 |
| 59 | 1 | A490-X | Yes | 0.5000 | 4.00 | 1.750 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.750 | Sheared | 43.0 | 64.0 |
| 60 | 1 | A490-X | Yes | 0.5000 | 4.00 | 1.750 | Sheared | 43.0 | 64.0 | 0.5000 | 4.00 | 1.750 | Sheared | 43.0 | 64.0 |
| 61 | 1 | A490-X | Yes | 0.6250 | 4.00 | 1.750 | Sheared | 44.0 | 64.0 | 0.6250 | 4.00 | 1.750 | Sheared | 44.0 | 64.0 |
| 62 | 1 | A490-X | Yes | 0.6250 | 4.00 | 1.750 | Sheared | 44.0 | 64.0 | 0.6250 | 4.00 | 1.750 | Sheared | 44.0 | 64.0 |
| 63 | 1 | A490-X | Yes | 0.6250 | 4.00 | 1.750 | Sheared | 44.0 | 64.0 | 0.6250 | 4.00 | 1.750 | Sheared | 44.0 | 64.0 |
| 64 | 0.875 | A490-X | Yes | 0.5000 | 4.00 | 1.500 | Sheared | 57.0 | 83.3 | 0.5000 | 4.00 | 1.500 | Sheared | 57.0 | 83.3 |
| 65 | 0.875 | A490-X | Yes | 0.5000 | 4.00 | 1.500 | Sheared | 57.0 | 83.3 | 0.5000 | 4.00 | 1.500 | Sheared | 57.0 | 83.3 |
| 66 | 0.875 | A490-X | Yes | 0.5000 | 4.00 | 1.500 | Sheared | 57.0 | 83.3 | 0.5000 | 4.00 | 1.500 | Sheared | 57.0 | 83.3 |

* Report did not indicate whether threads were included or exclude. The excluded condition has been assumed.

** Yield and Ultimate strengths given as average reported values.
For 5/8" thick plates no tensile data was given, the values indicated are assumed based on similar grade plate properties.

## Table C - 2
## Test Results And Equation Coefficients

| Report Test Number | General: Failure Mode | $R_{ult}$ (kips) | $\Delta_{max}$ (in.) | $R_f$ (kips) | $\Delta_f$ (in.) | $K_i$ (k/in.) | Loads @ Various Test Deformations: @ 0.16 in. (kips) | @ 0.25 in. (kips) | @ 0.34 in. (kips) | @ 0.50 in (kips) | Fisher Equation Coefficients: $R_{ult}$ (kips) | $\mu$ (1/in.) | $\lambda$ | Richard Equation Coefficients: K (k/in.) | $K_p$ (k/in.) | $R_o$ (kips) | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Splitting | 17.3 | 0.105 | 16.2 | 0.308 | 1894 | 17.0 | 16.7 | 0.0 | 0.0 | 16.7 | 225.3 | 1.089 | 3527 | 0.1 | 19.3 | 1.325 |
| 2 | Splitting | 21.5 | 0.259 | 20.4 | 0.312 | 3315 | 21.4 | 21.5 | 0.0 | 0.0 | 20.9 | 95.9 | 0.593 | 3527 | 0.1 | 19.3 | 1.325 |
| 3 | Splitting | 20.2 | 0.307 | 20.2 | 0.307 | 3138 | 20.0 | 20.2 | 0.0 | 0.0 | 19.6 | 77.7 | 0.721 | 3527 | 0.1 | 19.3 | 1.325 |
| 4 | Splitting | 23.9 | 0.097 | 23.1 | 0.306 | 3538 | 23.5 | 23.5 | 0.0 | 0.0 | 23.0 | 141.3 | 0.677 | 4237 | 3.0 | 22.8 | 1.588 |
| 5 | Bearing* | 34.0 | 0.321 | 34.0 | 0.321 | 3905 | 30.6 | 33.0 | 0.0 | 0.0 | 35.0 | 7.2 | 0.346 | 7487 | 20.3 | 28.2 | 0.730 |
| 6 | Splitting* | 34.0 | 0.382 | 34.0 | 0.382 | 3381 | 29.3 | 31.8 | 33.4 | 0.0 | 31.9 | 15.9 | 0.358 | 7487 | 20.3 | 28.2 | 0.730 |
| 7 | Splitting* | 32.0 | 0.315 | 31.8 | 0.359 | 3451 | 29.1 | 31.1 | 31.9 | 0.0 | 31.0 | 16.5 | 0.357 | 7487 | 20.3 | 28.2 | 0.730 |
| 8 | Bolt Shear | 35.3 | 0.282 | 35.3 | 0.282 | 3218 | 33.3 | 35.1 | 0.0 | 0.0 | 33.3 | 30.2 | 0.426 | 5027 | 32.9 | 26.4 | 1.225 |
| 9 | Bolt Shear | 34.8 | 0.311 | 34.8 | 0.311 | 4382 | 32.3 | 34.2 | 0.0 | 0.0 | 32.5 | 27.0 | 0.386 | 5027 | 32.9 | 26.4 | 1.225 |
| 10 | Bolt Shear | 34.6 | 0.299 | 34.6 | 0.299 | 3105 | 32.0 | 34.1 | 0.0 | 0.0 | 33.7 | 15.1 | 0.400 | 5027 | 32.9 | 26.4 | 1.225 |
| 11 | Bolt Shear | 31.6 | 0.145 | 31.6 | 0.145 | 3121 | 32.0 | 0.0 | 0.0 | 0.0 | 27.8 | 111.4 | 0.742 | 3565 | 52.6 | 24.0 | 2.286 |
| 12 | Bolt Shear | 31.3 | 0.203 | 31.3 | 0.203 | 3094 | 30.2 | 0.0 | 0.0 | 0.0 | 29.8 | 24.7 | 0.376 | 3565 | 52.6 | 24.0 | 2.286 |
| 13 | Bolt Shear | 34.1 | 0.157 | 34.1 | 0.157 | 3359 | 34.1 | 0.0 | 0.0 | 0.0 | 31.8 | 102.5 | 0.708 | 3565 | 52.6 | 24.0 | 2.286 |
| 14 | Splitting | 22.2 | 0.137 | 19.6 | 0.283 | 4380 | 22.1 | 20.3 | 0.0 | 0.0 | 21.1 | 75.6 | 0.546 | 4817 | -14.5 | 24.3 | 0.843 |
| 15 | Splitting | 21.1 | 0.168 | 18.6 | 0.314 | 2281 | 21.1 | 19.5 | 0.0 | 0.0 | 19.9 | 109.0 | 0.746 | 4817 | -14.5 | 24.3 | 0.843 |
| 16 | Splitting | 20.3 | 0.174 | 18.1 | 0.280 | 2360 | 20.3 | 18.5 | 0.0 | 0.0 | 19.2 | 74.2 | 0.598 | 4817 | -14.5 | 24.3 | 0.843 |
| 17 | Bearing* | 19.0 | 0.027 | 17.2 | 0.280 | 1593 | 17.8 | 17.3 | 0.0 | 0.0 | 18.0 | 196.9 | 0.916 | 3194 | -18.4 | 24.1 | 1.082 |
| 18 | Splitting* | 22.1 | 0.111 | 18.8 | 0.274 | 1647 | 21.6 | 19.3 | 0.0 | 0.0 | 20.7 | 112.3 | 0.696 | 3194 | -18.4 | 24.1 | 1.082 |
| 19 | Splitting* | 21.7 | 0.120 | 19.9 | 0.278 | 3221 | 21.6 | 20.6 | 0.0 | 0.0 | 20.8 | 121.6 | 0.710 | 3194 | -18.4 | 24.1 | 1.082 |
| 20 | Bolt Shear | 32.4 | 0.279 | 32.4 | 0.279 | 3719 | 30.4 | 32.2 | 0.0 | 0.0 | 31.7 | 16.7 | 0.372 | 7419 | 21.8 | 28.4 | 0.759 |
| 21 | Splitting | 29.8 | 0.290 | 29.8 | 0.290 | 3686 | 28.3 | 29.4 | 0.0 | 0.0 | 27.1 | 147.5 | 0.935 | 4044 | 14.1 | 24.8 | 2.003 |
| 22 | Splitting | 27.6 | 0.198 | 25.7 | 0.292 | 3615 | 27.3 | 26.9 | 0.0 | 0.0 | 25.9 | 181.7 | 0.917 | 4044 | 14.1 | 24.8 | 2.003 |
| 23 | Bearing | 39.0 | 0.302 | 39.0 | 0.302 | 4006 | 34.3 | 37.7 | 0.0 | 0.0 | 39.3 | 7.8 | 0.333 | 9055 | 40.5 | 29.2 | 0.704 |
| 24 | Bearing | 39.0 | 0.301 | 39.0 | 0.301 | 3764 | 34.1 | 37.7 | 0.0 | 0.0 | 40.7 | 5.8 | 0.324 | 9055 | 40.5 | 29.2 | 0.704 |
| 25 | Bearing | 39.0 | 0.324 | 39.0 | 0.324 | 3757 | 33.8 | 37.2 | 0.0 | 0.0 | 44.3 | 3.3 | 0.306 | 9055 | 40.5 | 29.2 | 0.704 |
| 26 | Bolt Shear | 39.9 | 0.306 | 39.9 | 0.306 | 4542 | 36.7 | 39.2 | 0.0 | 0.0 | 39.2 | 12.0 | 0.363 | 7715 | 34.1 | 32.1 | 0.839 |
| 27 | Bolt Shear | 40.0 | 0.242 | 40.0 | 0.242 | 4297 | 37.7 | 0.0 | 0.0 | 0.0 | 37.1 | 33.3 | 0.452 | 7715 | 34.1 | 32.1 | 0.839 |
| 28 | Bolt Shear | 39.1 | 0.303 | 39.1 | 0.303 | 4095 | 36.4 | 38.6 | 0.0 | 0.0 | 39.2 | 10.8 | 0.365 | 7715 | 34.1 | 32.1 | 0.839 |
| 29 | Bolt Shear | 40.0 | 0.203 | 40.0 | 0.203 | 4364 | 38.4 | 0.0 | 0.0 | 0.0 | 36.6 | 116.3 | 0.785 | 4630 | 44.2 | 31.5 | 2.170 |
| 30 | Bolt Shear | 39.3 | 0.203 | 39.3 | 0.203 | 4015 | 39.1 | 0.0 | 0.0 | 0.0 | 36.1 | 139.4 | 0.957 | 4630 | 44.2 | 31.5 | 2.170 |
| 31 | Bearing | 26.0 | 0.062 | 22.4 | 0.280 | 4060 | 24.2 | 22.8 | 0.0 | 0.0 | 23.9 | 251.4 | 1.187 | 5196 | -13.1 | 26.4 | 1.394 |
| 32 | Bearing | 28.4 | 0.063 | 24.5 | 0.311 | 3928 | 25.8 | 25.0 | 0.0 | 0.0 | 26.2 | 286.2 | 1.329 | 4404 | -13.4 | 28.4 | 2.085 |
| 33 | Bolt Shear | 38.7 | 0.298 | 38.7 | 0.298 | 3843 | 35.5 | 38.2 | 0.0 | 0.0 | 38.1 | 12.0 | 0.371 | 7617 | 36.4 | 30.6 | 0.811 |
| 34 | Splitting | 46.2 | 0.275 | 46.2 | 0.275 | 4286 | 40.7 | 44.8 | 0.0 | 0.0 | 45.9 | 9.7 | 0.368 | 11536 | 41.9 | 36.9 | 0.683 |
| 35 | Splitting | 46.2 | 0.295 | 46.2 | 0.295 | 6144 | 40.8 | 44.8 | 0.0 | 0.0 | 46.2 | 8.3 | 0.308 | 11536 | 41.9 | 36.9 | 0.683 |
| 36 | Splitting | 43.7 | 0.241 | 43.7 | 0.241 | 4359 | 40.3 | 43.7 | 0.0 | 0.0 | 42.9 | 13.9 | 0.396 | 11536 | 41.9 | 36.9 | 0.683 |
| 37 | Bolt Shear* | 50.9 | 0.248 | 50.9 | 0.248 | 4784 | 47.8 | 0.0 | 0.0 | 0.0 | 51.0 | 12.0 | 0.358 | 6479 | 67.2 | 38.7 | 1.146 |
| 38 | Bolt Shear* | 58.4 | 0.326 | 58.4 | 0.326 | 4404 | 51.3 | 55.8 | 0.0 | 0.0 | 59.8 | 6.4 | 0.322 | 6479 | 67.2 | 38.7 | 1.146 |
| 39 | Bolt Shear* | 58.7 | 0.319 | 58.7 | 0.319 | 4043 | 51.3 | 56.0 | 0.0 | 0.0 | 57.1 | 10.2 | 0.355 | 6479 | 67.2 | 38.7 | 1.146 |

## Table C - 2
## Test Results And Equation Coefficients

| Report Test Number | General: Failure Mode | $R_{ult}$ (kips) | $\Delta_{max}$ (in.) | $R_f$ (kips) | $\Delta_f$ (in.) | $K_i$ (k/in.) | Loads @ Various Test Deformations: @ 0.16 in. (kips) | @ 0.25 in. (kips) | @ 0.34 in. (kips) | @ 0.50 in (kips) | Fisher Equation Coefficients: $R_{ult}$ (kips) | $\mu$ (1/in.) | $\lambda$ | Richard Equation Coefficients: K (k/in.) | $K_p$ (k/in.) | $R_o$ (kips) | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | Bolt Shear | 34.7 | 0.318 | 34.7 | 0.318 | 2290 | 32.1 | 33.9 | 0.0 | 0.0 | 34.2 | 13.3 | 0.334 | 3395 | 21.6 | 28.7 | 1.070 |
| 41 | Bolt Shear | 34.9 | 0.313 | 34.9 | 0.313 | 2290 | 32.0 | 34.0 | 0.0 | 0.0 | 33.8 | 16.1 | 0.388 | 3395 | 21.6 | 28.7 | 1.070 |
| 42 | Bolt Shear | 33.2 | 0.299 | 33.2 | 0.299 | 2456 | 30.5 | 32.6 | 0.0 | 0.0 | 32.0 | 20.2 | 0.412 | 3395 | 21.6 | 28.7 | 1.070 |
| 43 | Bolt Shear | 37.2 | 0.305 | 37.2 | 0.305 | 2793 | 35.1 | 36.7 | 0.0 | 0.0 | 37.4 | 11.4 | 0.347 | 4198 | 20.5 | 33.1 | 0.942 |
| 44 | Bolt Shear | 39.2 | 0.308 | 39.2 | 0.308 | 2541 | 36.1 | 38.0 | 0.0 | 0.0 | 37.5 | 23.3 | 0.471 | 4198 | 20.5 | 33.1 | 0.942 |
| 45 | Bolt Shear | 37.0 | 0.312 | 37.0 | 0.312 | 2450 | 34.4 | 36.2 | 0.0 | 0.0 | 36.5 | 13.2 | 0.333 | 4198 | 20.5 | 33.1 | 0.942 |
| 46 | Splitting | 36.0 | 0.265 | 36.0 | 0.265 | 2722 | 34.3 | 35.9 | 0.0 | 0.0 | 35.7 | 17.4 | 0.445 | 14864 | -9.2 | 55.1 | 0.418 |
| 47 | Splitting | 36.7 | 0.310 | 36.7 | 0.310 | 3393 | 34.4 | 36.2 | 0.0 | 0.0 | 36.6 | 12.6 | 0.375 | 14864 | -9.2 | 55.1 | 0.418 |
| 48 | Splitting | 33.7 | 0.298 | 33.7 | 0.298 | 4954 | 32.8 | 33.6 | 0.0 | 0.0 | 33.9 | 16.5 | 0.452 | 14864 | -9.2 | 55.1 | 0.418 |
| 49 | Bolt Shear | 43.9 | 0.301 | 43.9 | 0.301 | 4581 | 40.1 | 42.9 | 0.0 | 0.0 | 42.6 | 15.0 | 0.379 | 15022 | 13.8 | 51.9 | 0.469 |
| 50 | Bolt Shear | 44.5 | 0.305 | 44.5 | 0.305 | 3525 | 39.4 | 42.6 | 0.0 | 0.0 | 45.3 | 8.1 | 0.390 | 15022 | 13.8 | 51.9 | 0.469 |
| 51 | Bolt Shear | 44.7 | 0.297 | 44.7 | 0.297 | 3738 | 40.3 | 43.6 | 0.0 | 0.0 | 44.9 | 9.6 | 0.376 | 15022 | 13.8 | 51.9 | 0.469 |
| 52 | Splitting | 40.4 | 0.187 | 40.4 | 0.187 | 3161 | 39.3 | 0.0 | 0.0 | 0.0 | 39.0 | 24.7 | 0.489 | 6283 | 12.2 | 41.8 | 0.710 |
| 53 | Splitting | 40.4 | 0.295 | 40.4 | 0.295 | 3260 | 38.6 | 40.0 | 0.0 | 0.0 | 39.6 | 19.3 | 0.462 | 6283 | 12.2 | 41.8 | 0.710 |
| 54 | Splitting | 41.7 | 0.307 | 41.7 | 0.307 | 3734 | 38.4 | 41.3 | 0.0 | 0.0 | 41.1 | 14.3 | 0.387 | 6283 | 12.2 | 41.8 | 0.710 |
| 55 | Bolt Shear | 52.2 | 0.301 | 52.2 | 0.301 | 3489 | 46.0 | 50.5 | 0.0 | 0.0 | 50.5 | 12.1 | 0.387 | 7960 | 48.5 | 39.9 | 0.786 |
| 56 | Bolt Shear | 43.5 | 0.178 | 43.5 | 0.178 | 6000 | 42.9 | 0.0 | 0.0 | 0.0 | 44.4 | 15.2 | 0.414 | 7960 | 48.5 | 39.9 | 0.786 |
| 57 | Bolt Shear | 45.0 | 0.184 | 45.0 | 0.184 | 4445 | 44.3 | 0.0 | 0.0 | 0.0 | 44.1 | 24.2 | 0.423 | 7960 | 48.5 | 39.9 | 0.786 |
| 58 | Splitting | 46.7 | 0.273 | 46.7 | 0.273 | 4681 | 42.2 | 46.0 | 0.0 | 0.0 | 44.3 | 16.8 | 0.374 | 8045 | 51.6 | 33.5 | 1.007 |
| 59 | Splitting | 47.1 | 0.301 | 47.1 | 0.301 | 6351 | 40.4 | 45.3 | 0.0 | 0.0 | 46.8 | 7.8 | 0.322 | 8045 | 51.6 | 33.5 | 1.007 |
| 60 | Splitting | 47.6 | 0.298 | 47.6 | 0.298 | 4721 | 42.7 | 46.2 | 0.0 | 0.0 | 46.2 | 12.0 | 0.348 | 8045 | 51.6 | 33.5 | 1.007 |
| 61 | Bearing | 60.0 | 0.236 | 60.0 | 0.236 | 4216 | 55.7 | 60.0 | 0.0 | 0.0 | 55.1 | 31.0 | 0.489 | 5513 | 64.4 | 43.7 | 1.477 |
| 62 | Bearing | 61.8 | 0.305 | 61.8 | 0.305 | 5230 | 55.2 | 59.7 | 0.0 | 0.0 | 56.4 | 26.9 | 0.480 | 5513 | 64.4 | 43.7 | 1.477 |
| 63 | Bearing | 62.0 | 0.319 | 62.0 | 0.319 | 4247 | 53.8 | 59.1 | 0.0 | 0.0 | 57.4 | 17.1 | 0.427 | 5513 | 64.4 | 43.7 | 1.477 |
| 64 | Splitting* | 55.4 | 0.292 | 55.4 | 0.292 | 3392 | 50.5 | 54.4 | 0.0 | 0.0 | 53.4 | 16.1 | 0.449 | 4914 | 45.9 | 44.2 | 0.979 |
| 65 | Bolt Shear* | 52.0 | 0.235 | 52.0 | 0.235 | 3638 | 49.5 | 0.0 | 0.0 | 0.0 | 49.0 | 34.3 | 0.560 | 4914 | 45.9 | 44.2 | 0.979 |
| 66 | Bolt Shear* | 48.0 | 0.172 | 48.0 | 0.172 | 3080 | 48.0 | 0.0 | 0.0 | 0.0 | 48.7 | 18.3 | 0.493 | 4914 | 45.9 | 44.2 | 0.979 |

* Not explicitly given, has been assumed based on given data.

# Appendix D

## Single Bolt Lap Plate Connection Tests Reported By Caccavale (1975)

## Table D - 1
## Connection Geometry And Material Parameters

| Report Test Number | Bolt | | | Plate 1 | | | | | | Plate 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $d_b$ (in.) | Bolt Grade | Was Bolt Pre-tensioned | $t_1$ (in.) | Width (in.) | $L_e$ (in.) | Edge Condition | $f_y$ (ksi) | $f_u$ (ksi) | $t_2$ (in.) | Width (in.) | $L_e$ (in.) | Edge Condition | $f_y$ (ksi) | $f_u$ (ksi) |
| 1 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | ? | 49.8 | 72.8 | 0.2500 | 4.00 | 1.250 | ? | 49.8 | 72.8 |
| 2 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | ? | 49.8 | 72.8 | 0.2500 | 4.00 | 1.250 | ? | 49.8 | 72.8 |
| 3 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | ? | 49.8 | 72.8 | 0.2500 | 4.00 | 1.250 | ? | 49.8 | 72.8 |
| 4 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | ? | 49.8 | 72.8 | 0.2500 | 4.00 | 1.250 | ? | 49.8 | 72.8 |
| 5 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | ? | 49.8 | 72.8 | 0.3750 | 4.00 | 1.250 | ? | 48.2 | 69.0 |
| 6 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | ? | 49.8 | 72.8 | 0.3750 | 4.00 | 1.250 | ? | 48.2 | 69.0 |
| 7 | 0.75 | A325-X | Yes | 0.2500 | 4.00 | 1.250 | ? | 49.8 | 72.8 | 0.3750 | 4.00 | 1.250 | ? | 48.2 | 69.0 |
| 8 | 0.75 | A325-X | Yes | 0.1875 | 4.00 | 1.250 | ? | 48.0 | 64.0 | 0.1875 | 4.00 | 1.250 | ? | 48.0 | 64.0 |
| 9 | 0.75 | A325-X | Yes | 0.1875 | 4.00 | 1.250 | ? | 48.0 | 64.0 | 0.1875 | 4.00 | 1.250 | ? | 48.0 | 64.0 |
| 10 | 0.75 | A325-X | Yes | 0.3125 | 4.00 | 1.250 | ? | 45.1 | 66.2 | 0.3125 | 4.00 | 1.250 | ? | 45.1 | 66.2 |
| 11 | 0.75 | A325-X | Yes | 0.3125 | 4.00 | 1.250 | ? | 45.1 | 66.2 | 0.3125 | 4.00 | 1.250 | ? | 45.1 | 66.2 |

## Table D - 2
## Test Results And Equation Coefficients

| Report Test Number | General: Failure Mode | $R_{ult}$ (kips) | $\Delta_{max}$ (in.) | $R_f$ (kips) | $\Delta_f$ (in.) | $K_i$ (k/in.) | Loads @ Various Test Deformations: @ 0.16 in. (kips) | @ 0.25 in. (kips) | @ 0.34 in. (kips) | @ 0.50 in (kips) | Fisher Equation Coefficients: $R_{ult}$ (kips) | $\mu$ (1/in.) | $\lambda$ | Richard Equation Coefficients: K (k/in.) | $K_p$ (k/in.) | $R_o$ (kips) | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Bearing * | 20.0 | 0.119 | 20.0 | 0.119 | 263 | 0.0 | 0.0 | 0.0 | 0.0 | 35.4 | 2.7 | 0.415 | N/A | N/A | N/A | N/A |
| 2 | Bearing * | 23.8 | 0.287 | 23.8 | 0.287 | 341 | 20.7 | 22.9 | 0.0 | 0.0 | 22.6 | 21.4 | 1.335 | N/A | N/A | N/A | N/A |
| 3 | Bearing * | 24.8 | 0.390 | 24.8 | 0.390 | 302 | 20.4 | 22.6 | 24.1 | 0.0 | 23.6 | 13.0 | 0.700 | N/A | N/A | N/A | N/A |
| 4 | Bearing * | 25.0 | 0.364 | 25.0 | 0.364 | 250 | 21.3 | 23.4 | 24.7 | 0.0 | 24.8 | 10.7 | 0.647 | N/A | N/A | N/A | N/A |
| 5 | Bearing * | 23.8 | 0.286 | 22.5 | 0.380 | 469 | 21.6 | 23.3 | 23.0 | 0.0 | 23.3 | 16.2 | 1.012 | N/A | N/A | N/A | N/A |
| 6 | Bearing * | 25.0 | 0.332 | 25.0 | 0.332 | 440 | 21.6 | 23.3 | 0.0 | 0.0 | 23.6 | 22.8 | 1.902 | N/A | N/A | N/A | N/A |
| 7 | Bearing * | 24.8 | 0.360 | 24.8 | 0.360 | 472 | 23.0 | 24.1 | 24.6 | 0.0 | 24.2 | 22.3 | 1.213 | N/A | N/A | N/A | N/A |
| 8 | Bearing * | 18.8 | 0.387 | 18.8 | 0.387 | 273 | 14.7 | 15.7 | 16.9 | 0.0 | 16.9 | 20.4 | 0.859 | N/A | N/A | N/A | N/A |
| 9 | Bearing * | 17.4 | 0.391 | 17.4 | 0.391 | 352 | 15.7 | 16.8 | 17.2 | 0.0 | 16.2 | 49.9 | 2.782 | N/A | N/A | N/A | N/A |
| 10 | Bearing * | 27.2 | 0.357 | 27.2 | 0.357 | 344 | 22.7 | 25.5 | 27.0 | 0.0 | 27.6 | 9.2 | 0.693 | N/A | N/A | N/A | N/A |
| 11 | Bearing * | 26.3 | 0.248 | 26.3 | 0.248 | 691 | 23.0 | 26.3 | 0.0 | 0.0 | 26.1 | 12.2 | 0.618 | N/A | N/A | N/A | N/A |

* Not explicitly given, has been assumed based on given data.

# Appendix E

## Single Bolt Lap Plate Connection Tests Reported By Sarkar and Wallace (1992)

## Table E - 1
## Connection Geometry And Material Parameters

| Report Test Number | Bolt | | | Plate 1 | | | | | | Plate 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $d_b$ (in.) | Bolt Grade | Was Bolt Pre-tensioned | $t_1$ (in.) | Width (in.) | $L_e$ (in.) | Edge Condition | $f_y$ (ksi) | $f_u$ (ksi) | $t_2$ (in.) | Width (in.) | $L_e$ (in.) | Edge Condition | $f_y$ (ksi) | $f_u$ (ksi) |
| 1 | 0.75 | A325-N | No* | 0.3750 | ? | 2.000 | ? | 47.6 | 67.1 | 0.3750 | ? | 2.000 | ? | 47.6 | 67.1 |
| 2 | 0.75 | A325-N | No* | 0.3750 | ? | 2.000 | ? | 47.6 | 67.1 | 0.3750 | ? | 2.000 | ? | 47.6 | 67.1 |
| 3 | 0.75 | A325-N | No* | 0.3750 | ? | 2.000 | ? | 47.6 | 67.1 | 0.3750 | ? | 2.000 | ? | 47.6 | 67.1 |
| 4 | 0.75 | A325-N | No* | 0.3750 | ? | 1.500 | ? | 47.6 | 67.1 | 0.3750 | ? | 1.500 | ? | 47.6 | 67.1 |
| 5 | 0.75 | A325-N | No* | 0.3750 | ? | 1.500 | ? | 47.6 | 67.1 | 0.3750 | ? | 1.500 | ? | 47.6 | 67.1 |
| 6 | 0.75 | A325-N | No* | 0.3750 | ? | 1.500 | ? | 47.6 | 67.1 | 0.3750 | ? | 1.500 | ? | 47.6 | 67.1 |
| 7 | 0.75 | A325-N | No* | 0.3125 | ? | 2.000 | ? | 47.3 | 65.5 | 0.3125 | ? | 2.000 | ? | 47.3 | 65.5 |
| 8 | 0.75 | A325-N | No* | 0.3125 | ? | 2.000 | ? | 47.3 | 65.5 | 0.3125 | ? | 2.000 | ? | 47.3 | 65.5 |
| 9 | 0.75 | A325-N | No* | 0.3125 | ? | 2.000 | ? | 47.3 | 65.5 | 0.3125 | ? | 2.000 | ? | 47.3 | 65.5 |
| 10 | 0.75 | A325-N | No* | 0.2500 | ? | 2.000 | ? | 47.5 | 65.9 | 0.2500 | ? | 2.000 | ? | 47.5 | 65.9 |
| 11 | 0.75 | A325-N | No* | 0.2500 | ? | 2.000 | ? | 47.5 | 65.9 | 0.2500 | ? | 2.000 | ? | 47.5 | 65.9 |
| 12 | 0.75 | A325-N | No* | 0.2500 | ? | 2.000 | ? | 47.5 | 65.9 | 0.2500 | ? | 2.000 | ? | 47.5 | 65.9 |
| 13 | 0.75 | A325-N | No* | 0.3125 | ? | 2.000 | ? | 47.3 | 65.5 | 0.3125 | ? | 2.000 | ? | 47.3 | 65.5 |
| 14 | 0.75 | A325-N | No* | 0.3125 | ? | 2.000 | ? | 47.3 | 65.5 | 0.3125 | ? | 2.000 | ? | 47.3 | 65.5 |
| 15 | 0.75 | A325-N | No* | 0.3125 | ? | 2.000 | ? | 47.3 | 65.5 | 0.3125 | ? | 2.000 | ? | 47.3 | 65.5 |
| 16 | 0.75 | A490-N | No* | 0.3750 | ? | 2.000 | ? | 47.6 | 67.1 | 0.3750 | ? | 2.000 | ? | 47.6 | 67.1 |
| 17 | 0.75 | A490-N | No* | 0.3750 | ? | 2.000 | ? | 47.6 | 67.1 | 0.3750 | ? | 2.000 | ? | 47.6 | 67.1 |
| 18 | 0.75 | A490-N | No* | 0.3750 | ? | 2.000 | ? | 47.6 | 67.1 | 0.3750 | ? | 2.000 | ? | 47.6 | 67.1 |
| 19 | 0.75 | A490-N | No* | 0.3125 | ? | 2.000 | ? | 47.3 | 65.5 | 0.3125 | ? | 2.000 | ? | 47.3 | 65.5 |

* Method of tightening was not reported. Based on data the snug tight condition was assumed.

## Table E - 2
## Test Results And Equation Coefficients

| Report Test Number | General: Failure Mode | $R_{ult}$ (kips) | $\Delta_{max}$ (in.) | $R_f$ (kips) | $\Delta_f$ (in.) | $K_i$ (k/in.) | Loads @ Various Test Deformations: @ 0.16 in. (kips) | @ 0.25 in. (kips) | @ 0.34 in. (kips) | @ 0.50 in (kips) | Fisher Equation Coefficients: $R_{ult}$ (kips) | $\mu$ (1/in.) | $\lambda$ | Richard Equation Coefficients: K (k/in.) | $K_p$ (k/in.) | $R_o$ (kips) | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Bolt Shear | 25.3 | 0.181 | 25.3 | 0.181 | 323 | 25.0 | 0.0 | 0.0 | 0.0 | 28.1 | 17.1 | 1.365 | N/A | N/A | N/A | N/A |
| 2 | Bolt Shear | 28.4 | 0.227 | 28.4 | 0.227 | 255 | 25.7 | 0.0 | 0.0 | 0.0 | 28.1 | 17.1 | 1.365 | N/A | N/A | N/A | N/A |
| 3 | Bolt Shear | 27.0 | 0.193 | 27.0 | 0.193 | 224 | 25.6 | 0.0 | 0.0 | 0.0 | 28.1 | 17.1 | 1.365 | N/A | N/A | N/A | N/A |
| 4 | Bolt Shear | 30.1 | 0.298 | 29.2 | 0.359 | 254 | 26.5 | 29.3 | 29.5 | 0.0 | 29.1 | 16.1 | 1.413 | N/A | N/A | N/A | N/A |
| 5 | Bolt Shear | 28.2 | 0.250 | 28.2 | 0.250 | 241 | 25.4 | 0.0 | 0.0 | 0.0 | 29.1 | 16.1 | 1.413 | N/A | N/A | N/A | N/A |
| 6 | Bolt Shear | 29.5 | 0.306 | 28.2 | 0.326 | 244 | 26.0 | 28.7 | 0.0 | 0.0 | 29.1 | 16.1 | 1.413 | N/A | N/A | N/A | N/A |
| 7 | Bolt Shear | 26.4 | 0.200 | 26.4 | 0.200 | 207 | 25.0 | 0.0 | 0.0 | 0.0 | 28.3 | 18.0 | 1.612 | N/A | N/A | N/A | N/A |
| 8 | Bolt Shear | 29.1 | 0.281 | 29.1 | 0.281 | 261 | 25.9 | 28.7 | 0.0 | 0.0 | 28.3 | 18.0 | 1.612 | N/A | N/A | N/A | N/A |
| 9 | Bolt Shear | 28.0 | 0.257 | 28.0 | 0.257 | 231 | 25.1 | 27.9 | 0.0 | 0.0 | 28.3 | 18.0 | 1.612 | N/A | N/A | N/A | N/A |
| 10 | Bolt Shear | 29.1 | 0.674 | 28.8 | 0.674 | 215 | 20.7 | 23.6 | 25.1 | 26.8 | 23.9 | 13.2 | 1.157 | N/A | N/A | N/A | N/A |
| 11 | Bolt Shear | 27.6 | 0.601 | 27.6 | 0.601 | 222 | 20.2 | 23.1 | 24.8 | 26.6 | 23.9 | 13.2 | 1.157 | N/A | N/A | N/A | N/A |
| 12 | Splitting | 27.1 | 0.591 | 26.9 | 0.634 | 203 | 20.7 | 23.5 | 25.2 | 26.6 | 23.9 | 13.2 | 1.157 | N/A | N/A | N/A | N/A |
| 13 | Bolt Shear | 29.8 | 0.600 | 29.8 | 0.600 | 148 | 20.1 | 23.5 | 25.8 | 28.5 | 26.1 | 10.0 | 1.204 | N/A | N/A | N/A | N/A |
| 14 | Bolt Shear | 29.6 | 0.548 | 29.6 | 0.548 | 169 | 21.5 | 24.8 | 26.9 | 29.1 | 26.1 | 10.0 | 1.204 | N/A | N/A | N/A | N/A |
| 15 | Bolt Shear | 30.2 | 0.667 | 30.2 | 0.667 | 185 | 19.8 | 23.6 | 25.8 | 28.3 | 26.1 | 10.0 | 1.204 | N/A | N/A | N/A | N/A |
| 16 | Bolt Shear | 35.2 | 0.407 | 34.2 | 0.446 | 197 | 25.4 | 30.9 | 34.0 | 0.0 | 32.6 | 11.4 | 1.202 | N/A | N/A | N/A | N/A |
| 17 | Bolt Shear | 36.6 | 0.466 | 35.3 | 0.493 | 247 | 26.4 | 31.8 | 34.8 | 0.0 | 32.6 | 11.4 | 1.202 | N/A | N/A | N/A | N/A |
| 18 | Bolt Shear | 37.7 | 0.434 | 36.4 | 0.463 | 261 | 27.6 | 33.1 | 36.2 | 0.0 | 32.6 | 11.4 | 1.202 | N/A | N/A | N/A | N/A |
| 19 | Splitting | 31.2 | 0.701 | 31.2 | 0.701 | 139 | 19.3 | 22.9 | 25.4 | 28.2 | 24.8 | 10.4 | 1.367 | N/A | N/A | N/A | N/A |

Test No: 1 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 1-a Date: 8/8/92

## GEOMETRIC AND MATERIAL PROPERTIES

**BOLT**

Type: A325 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

**PLATES**

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.375 | 2 | - | ? | 47.57 | 67.07 |
| - | ? | 0.375 | 2 | - | ? | 47.57 | 67.07 |

## TEST RESULTS

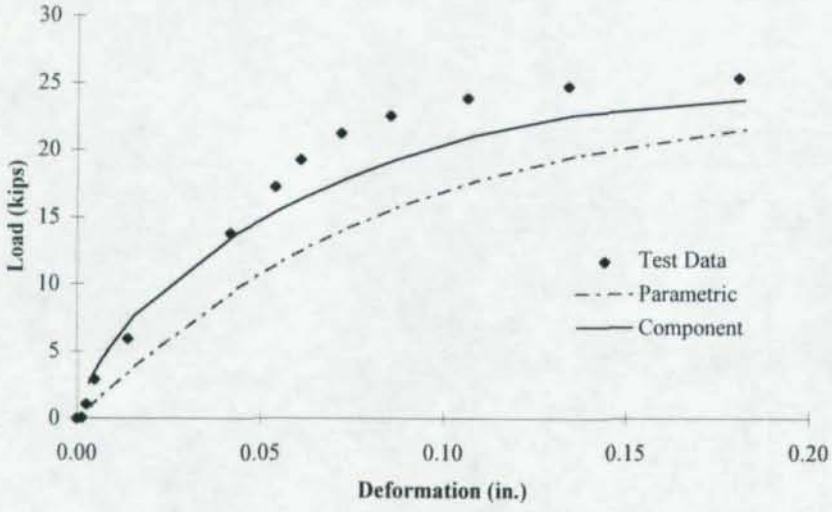
Limit State: Bolt Shear
Ki: 323 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.1807 | 25.3 |
| Other: | 0.2500 | N/A |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0013 | 0.1 |
| 0.0024 | 1.0 |
| 0.0047 | 2.9 |
| 0.0139 | 5.9 |
| 0.0418 | 13.7 |
| 0.0540 | 17.2 |
| 0.0609 | 19.2 |
| 0.0719 | 21.2 |
| 0.0854 | 22.5 |
| 0.1065 | 23.8 |
| 0.1342 | 24.7 |
| 0.1807 | 25.3 |

## LOAD Vs. DEFORMATION CHART



Test No: 2 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 1-b Date: 8/8/92

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

Type: A325 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

### PLATES

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.375 | 2 | - | ? | 47.57 | 67.07 |
| - | ? | 0.375 | 2 | - | ? | 47.57 | 67.07 |

## TEST RESULTS

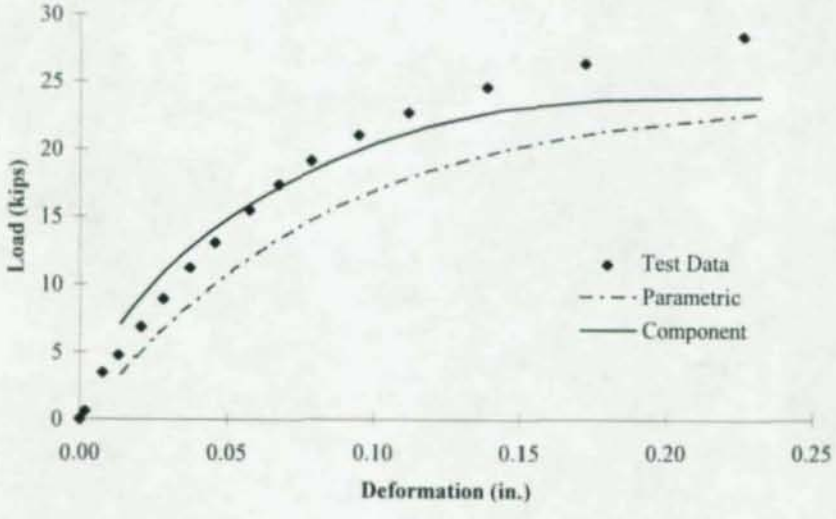
Limit State: Bolt Shear
Ki: 255 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.2266 | 28.4 |
| Other: | 0.2500 | N/A |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0017 | 0.6 |
| 0.0077 | 3.4 |
| 0.0131 | 4.8 |
| 0.0207 | 6.8 |
| 0.0282 | 8.9 |
| 0.0375 | 11.2 |
| 0.0460 | 13.1 |
| 0.0577 | 15.5 |
| 0.0677 | 17.4 |
| 0.0788 | 19.1 |
| 0.0949 | 21.0 |
| 0.1121 | 22.7 |
| 0.1390 | 24.6 |
| 0.1722 | 26.3 |
| 0.2266 | 28.4 |

## LOAD Vs. DEFORMATION CHART



Test No: 3 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 1-c Date: 8/8/92

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

Type: A325 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

### PLATES

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.375 | 2 | - | ? | 47.57 | 67.07 |
| - | ? | 0.375 | 2 | - | ? | 47.57 | 67.07 |

## TEST RESULTS

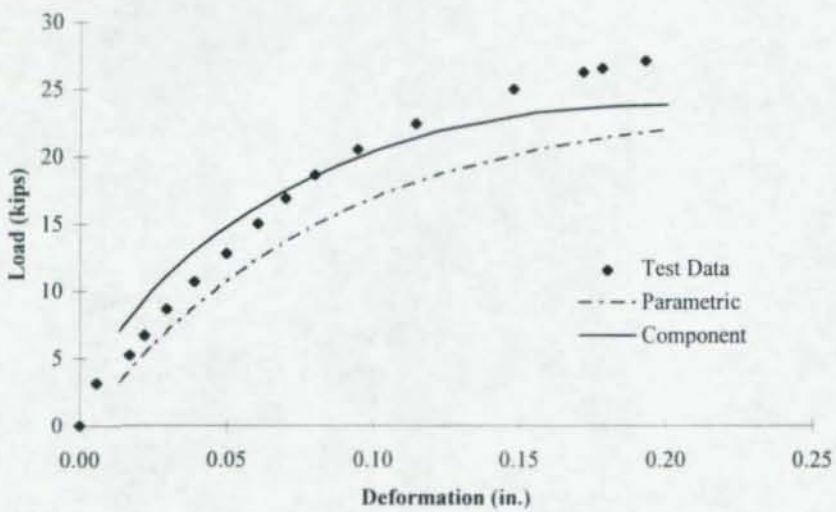
Limit State: Bolt Shear
Ki: 224 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.1929 | 27.0 |
| Other: | 0.2500 | N/A |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0057 | 3.1 |
| 0.0170 | 5.2 |
| 0.0220 | 6.6 |
| 0.0296 | 8.6 |
| 0.0390 | 10.7 |
| 0.0498 | 12.7 |
| 0.0606 | 15.0 |
| 0.0700 | 16.8 |
| 0.0800 | 18.6 |
| 0.0947 | 20.5 |
| 0.1145 | 22.4 |
| 0.1479 | 24.9 |
| 0.1717 | 26.2 |
| 0.1782 | 26.5 |
| 0.1929 | 27.0 |

## LOAD Vs. DEFORMATION CHART



Test No: 4 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 2-a Date: 8/8/92

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

Type: A325 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

### PLATES

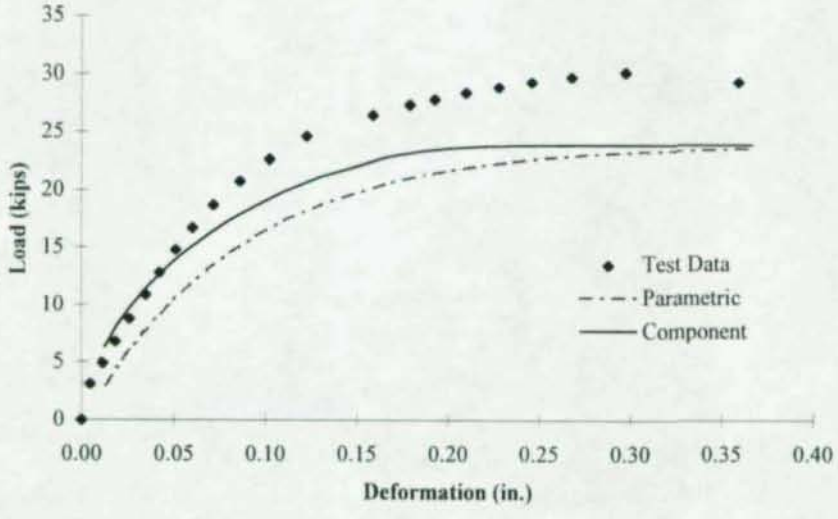
| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.375 | 1.5 | - | ? | 47.57 | 67.07 |
| - | ? | 0.375 | 1.5 | - | ? | 47.57 | 67.07 |

## TEST RESULTS

Limit State: Bolt Shear
Ki: 254 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.2975 | 30.1 |
| Other: | 0.2500 | 29.3 |

## LOAD Vs. DEFORMATION CHART




## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0046 | 3.1 |
| 0.0114 | 4.9 |
| 0.0186 | 6.8 |
| 0.0263 | 8.7 |
| 0.0350 | 10.9 |
| 0.0425 | 12.8 |
| 0.0513 | 14.8 |
| 0.0604 | 16.7 |
| 0.0718 | 18.7 |
| 0.0863 | 20.7 |
| 0.1023 | 22.6 |
| 0.1227 | 24.6 |
| 0.1590 | 26.4 |
| 0.1792 | 27.3 |
| 0.1928 | 27.8 |
| 0.2101 | 28.3 |
| 0.2282 | 28.8 |
| 0.2462 | 29.2 |
| 0.2681 | 29.7 |
| 0.2975 | 30.1 |
| 0.3594 | 29.2 |

Test No: 5 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 2-b Date: 8/8/92

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

Type: A325 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

### PLATES

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.375 | 1.5 | - | ? | 47.57 | 67.07 |
| - | ? | 0.375 | 1.5 | - | ? | 47.57 | 67.07 |

## TEST RESULTS

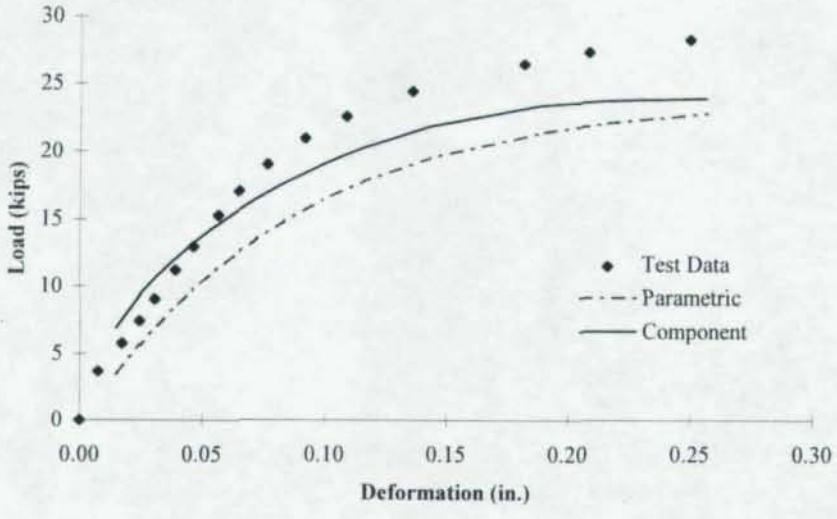
Limit State: Bolt Shear
Ki: 241 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.2496 | 28.2 |
| Other: | 0.2500 | 28.2 |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0075 | 3.7 |
| 0.0172 | 5.8 |
| 0.0243 | 7.4 |
| 0.0304 | 9.0 |
| 0.0392 | 11.2 |
| 0.0465 | 13.0 |
| 0.0565 | 15.3 |
| 0.0650 | 17.0 |
| 0.0766 | 19.0 |
| 0.0920 | 20.9 |
| 0.1089 | 22.5 |
| 0.1359 | 24.4 |
| 0.1817 | 26.4 |
| 0.2082 | 27.3 |
| 0.2496 | 28.2 |

## LOAD Vs. DEFORMATION CHART



Test No: 6 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 2-c Date: 8/8/92

## GEOMETRIC AND MATERIAL PROPERTIES

**BOLT**

Type: A325 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

**PLATES**

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.375 | 1.5 | - | ? | 47.57 | 67.07 |
| - | ? | 0.375 | 1.5 | - | ? | 47.57 | 67.07 |

## TEST RESULTS

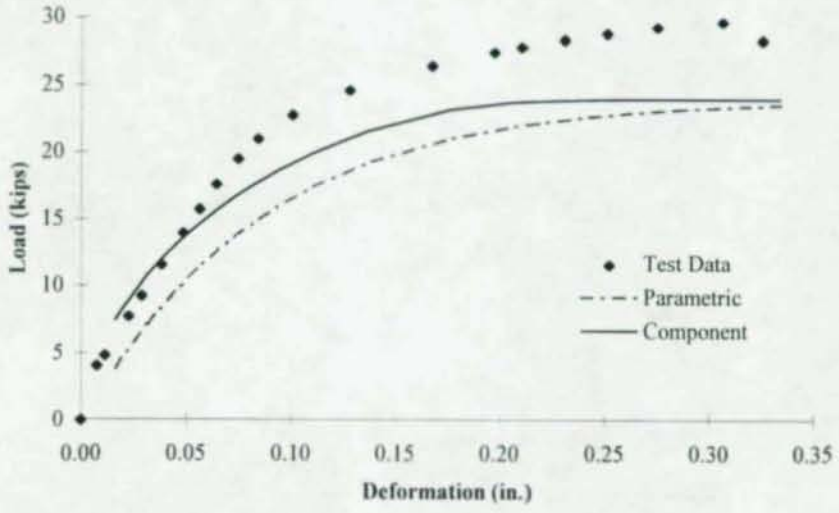
Limit State: Bolt Shear
Ki: 244 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.3064 | 29.5 |
| Other: | 0.2500 | 28.7 |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0075 | 4.0 |
| 0.0114 | 4.8 |
| 0.0227 | 7.6 |
| 0.0288 | 9.2 |
| 0.0383 | 11.5 |
| 0.0486 | 13.9 |
| 0.0563 | 15.7 |
| 0.0643 | 17.5 |
| 0.0748 | 19.4 |
| 0.0843 | 20.9 |
| 0.1006 | 22.6 |
| 0.1280 | 24.5 |
| 0.1675 | 26.3 |
| 0.1974 | 27.3 |
| 0.2104 | 27.7 |
| 0.2307 | 28.2 |
| 0.2510 | 28.7 |
| 0.2751 | 29.1 |
| 0.3064 | 29.5 |
| 0.3255 | 28.2 |

## LOAD Vs. DEFORMATION CHART



Test No: 7 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 3-a Date: 8/10/92

## GEOMETRIC AND MATERIAL PROPERTIES

**BOLT**

Type: A325 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

**PLATES**

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.3125 | 2 | - | ? | 47.31 | 65.52 |
| - | ? | 0.3125 | 2 | - | ? | 47.31 | 65.52 |

## TEST RESULTS

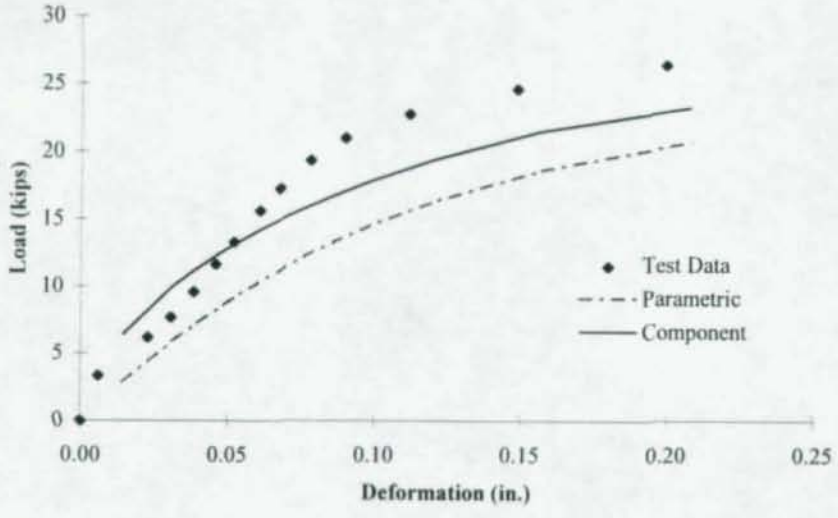
Limit State: Bolt Shear
Ki: 207 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.1997 | 26.4 |
| Other: | 0.2500 | N/A |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0062 | 3.3 |
| 0.0230 | 6.2 |
| 0.0307 | 7.7 |
| 0.0385 | 9.6 |
| 0.0459 | 11.6 |
| 0.0522 | 13.3 |
| 0.0611 | 15.6 |
| 0.0678 | 17.3 |
| 0.0782 | 19.3 |
| 0.0900 | 20.9 |
| 0.1119 | 22.7 |
| 0.1488 | 24.6 |
| 0.1997 | 26.4 |

## LOAD Vs. DEFORMATION CHART



Test No: 8 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 3-b Date: 8/10/92

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

Type: A325 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

### PLATES

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.3125 | 2 | - | ? | 47.31 | 65.52 |
| - | ? | 0.3125 | 2 | - | ? | 47.31 | 65.52 |

## TEST RESULTS

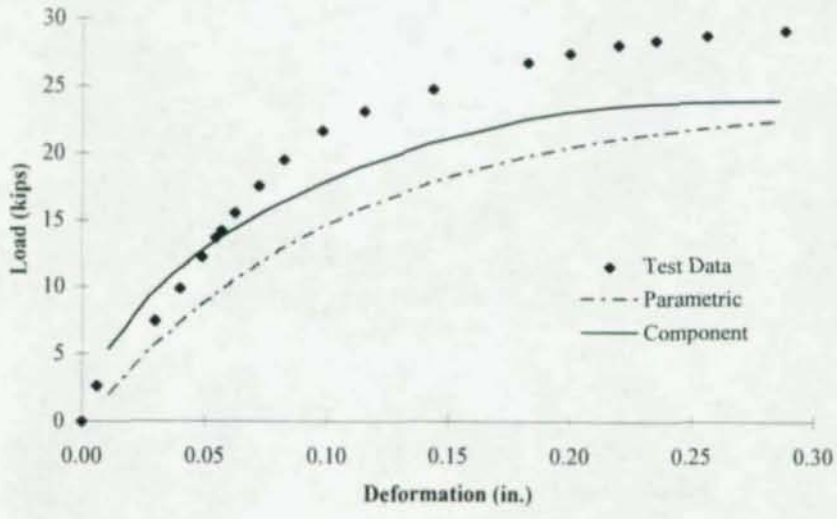
Limit State: Bolt Shear
Ki: 261 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.2882 | 29.1 |
| Other: | 0.2500 | 28.6 |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0060 | 2.6 |
| 0.0296 | 7.4 |
| 0.0398 | 9.9 |
| 0.0491 | 12.2 |
| 0.0547 | 13.6 |
| 0.0570 | 14.2 |
| 0.0626 | 15.5 |
| 0.0722 | 17.5 |
| 0.0824 | 19.5 |
| 0.0982 | 21.6 |
| 0.1153 | 23.1 |
| 0.1436 | 24.7 |
| 0.1827 | 26.7 |
| 0.1999 | 27.4 |
| 0.2198 | 28.0 |
| 0.2351 | 28.3 |
| 0.2561 | 28.7 |
| 0.2882 | 29.1 |

## LOAD Vs. DEFORMATION CHART



Test No: 9 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 3-c Date: 8/10/92

## GEOMETRIC AND MATERIAL PROPERTIES

**BOLT**

Type: A325 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

**PLATES**

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.3125 | 2 | - | ? | 47.31 | 65.52 |
| - | ? | 0.3125 | 2 | - | ? | 47.31 | 65.52 |

## TEST RESULTS

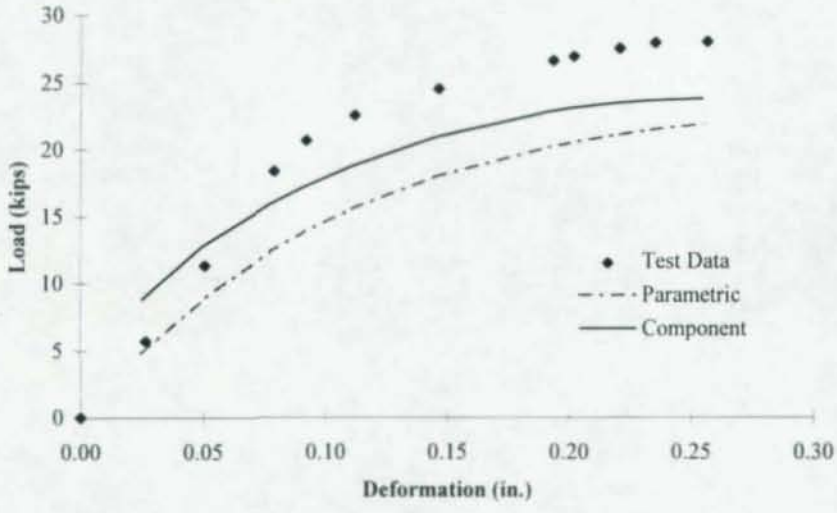
Limit State: Bolt Shear
Ki: 231 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.2568 | 28.0 |
| Other: | 0.2500 | 27.9 |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0267 | 5.7 |
| 0.0509 | 11.3 |
| 0.0792 | 18.4 |
| 0.0925 | 20.6 |
| 0.1122 | 22.5 |
| 0.1468 | 24.5 |
| 0.1938 | 26.6 |
| 0.2022 | 26.9 |
| 0.2210 | 27.5 |
| 0.2355 | 27.9 |
| 0.2568 | 28.0 |

## LOAD Vs. DEFORMATION CHART



Test No: 10 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 4-a Date: 8/10/92

## GEOMETRIC AND MATERIAL PROPERTIES

**BOLT**

Type: A325 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

**PLATES**

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.25 | 2 | - | ? | 47.54 | 65.87 |
| - | ? | 0.25 | 2 | - | ? | 47.54 | 65.87 |

## TEST RESULTS

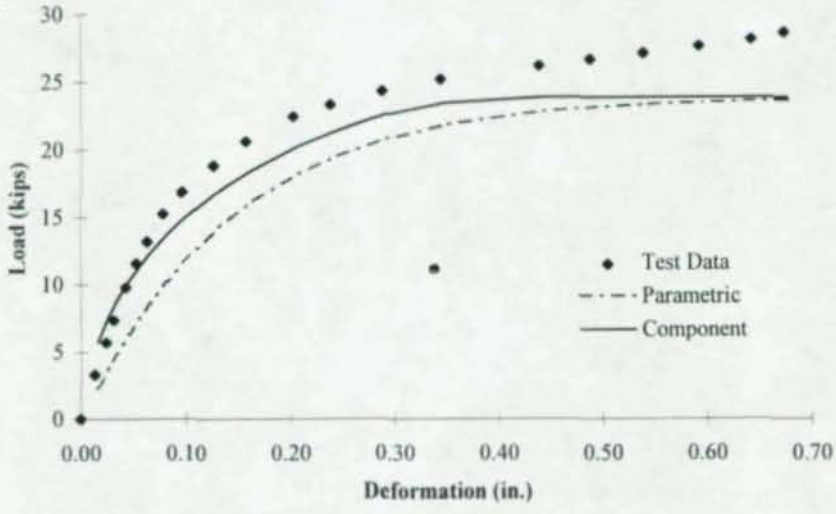
Limit State: Bolt Shear
Ki: 215 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.6734 | 28.7 |
| Other: | 0.2500 | 23.6 |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0127 | 3.3 |
| 0.0237 | 5.7 |
| 0.0311 | 7.3 |
| 0.0427 | 9.8 |
| 0.0526 | 11.6 |
| 0.0630 | 13.2 |
| 0.0785 | 15.2 |
| 0.0960 | 16.9 |
| 0.1258 | 18.8 |
| 0.1570 | 20.6 |
| 0.2024 | 22.4 |
| 0.2381 | 23.3 |
| 0.2879 | 24.3 |
| 0.3439 | 25.2 |
| 0.4387 | 26.2 |
| 0.4877 | 26.7 |
| 0.5389 | 27.1 |
| 0.5921 | 27.6 |
| 0.6421 | 28.2 |
| 0.6734 | 28.7 |

## LOAD Vs. DEFORMATION CHART



Test No: 11 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 4-b Date: 8/10/92

## GEOMETRIC AND MATERIAL PROPERTIES

**BOLT**

Type: A325 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

**PLATES**

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.25 | 2 | - | ? | 47.54 | 65.87 |
| - | ? | 0.25 | 2 | - | ? | 47.54 | 65.87 |

## TEST RESULTS

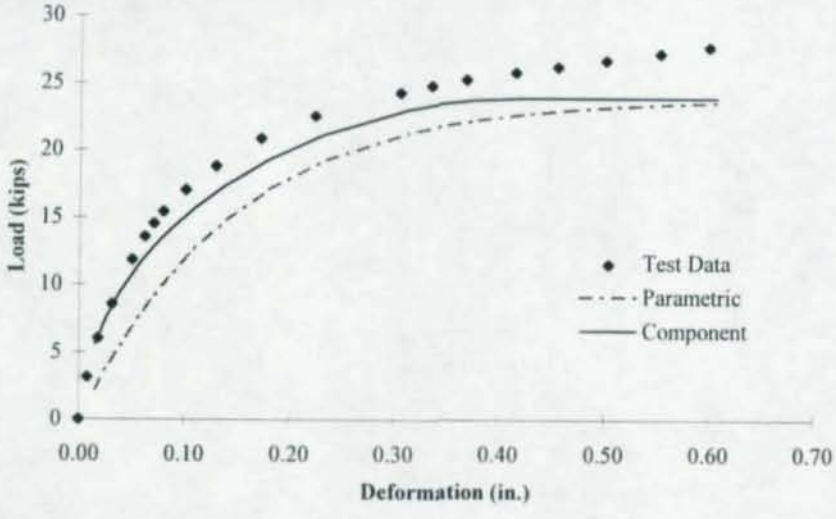
Limit State: Bolt Shear
Ki: 222 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.5995 | 27.6 |
| Other: | 0.2500 | 23.1 |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0081 | 3.2 |
| 0.0180 | 6.0 |
| 0.0313 | 8.6 |
| 0.0502 | 11.8 |
| 0.0623 | 13.6 |
| 0.0708 | 14.6 |
| 0.0796 | 15.4 |
| 0.1008 | 17.0 |
| 0.1297 | 18.8 |
| 0.1721 | 20.8 |
| 0.2240 | 22.5 |
| 0.3055 | 24.3 |
| 0.3355 | 24.8 |
| 0.3684 | 25.2 |
| 0.4157 | 25.7 |
| 0.4550 | 26.2 |
| 0.5008 | 26.7 |
| 0.5525 | 27.1 |
| 0.5995 | 27.6 |

## LOAD Vs. DEFORMATION CHART



**Test No: 12** **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 4-c Date: 8/10/92

## GEOMETRIC AND MATERIAL PROPERTIES

**BOLT**

Type: A325 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

**PLATES**

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.25 | 2 | - | ? | 47.54 | 65.87 |
| - | ? | 0.25 | 2 | - | ? | 47.54 | 65.87 |

## TEST RESULTS

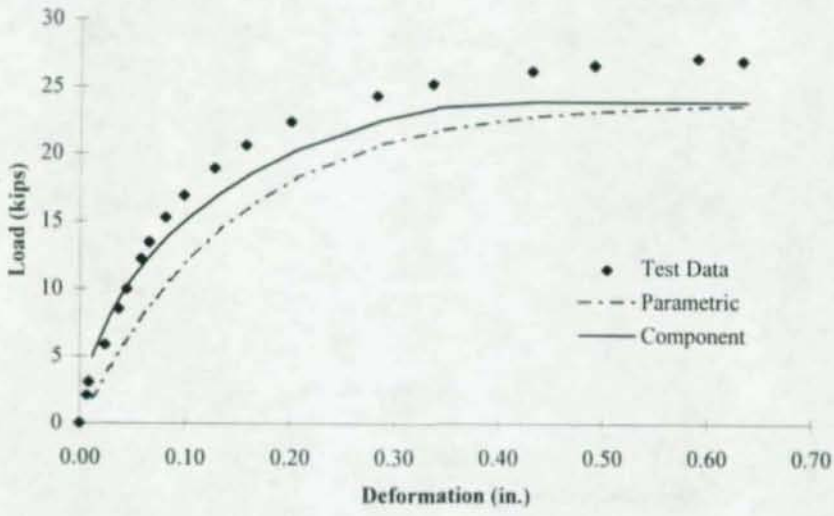
Limit State: Tension Tearing
Ki: 203 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.5908 | 27.1 |
| Other: | 0.2500 | 23.5 |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0069 | 2.1 |
| 0.0086 | 3.1 |
| 0.0238 | 5.9 |
| 0.0367 | 8.5 |
| 0.0444 | 10.0 |
| 0.0579 | 12.2 |
| 0.0657 | 13.4 |
| 0.0811 | 15.3 |
| 0.0986 | 16.9 |
| 0.1279 | 18.9 |
| 0.1578 | 20.6 |
| 0.2005 | 22.3 |
| 0.2831 | 24.3 |
| 0.3368 | 25.2 |
| 0.4321 | 26.2 |
| 0.4916 | 26.6 |
| 0.5908 | 27.1 |
| 0.6337 | 26.9 |

## LOAD Vs. DEFORMATION CHART



Test No: 13 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 5-a (not reported in reference) Date: 8/15/92

## GEOMETRIC AND MATERIAL PROPERTIES

**BOLT**

Type: A325 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

**PLATES**

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.3125 | 2 | - | ? | 47.31 | 65.52 |
| - | ? | 0.3125 | 2 | - | ? | 47.31 | 65.52 |

## TEST RESULTS

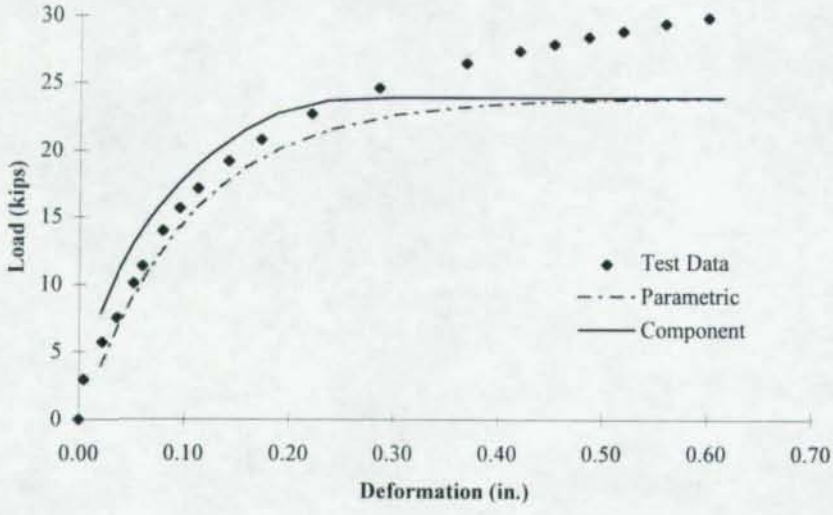
Limit State: Bolt Shear
Ki: 148 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.6003 | 29.8 |
| Other: | 0.2500 | 23.5 |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0047 | 2.9 |
| 0.0221 | 5.7 |
| 0.0360 | 7.5 |
| 0.0519 | 10.1 |
| 0.0599 | 11.3 |
| 0.0795 | 13.9 |
| 0.0953 | 15.6 |
| 0.1128 | 17.1 |
| 0.1418 | 19.1 |
| 0.1728 | 20.8 |
| 0.2209 | 22.6 |
| 0.2855 | 24.5 |
| 0.3688 | 26.4 |
| 0.4198 | 27.3 |
| 0.4529 | 27.8 |
| 0.4859 | 28.3 |
| 0.5187 | 28.8 |
| 0.5594 | 29.3 |
| 0.6003 | 29.8 |

## LOAD Vs. DEFORMATION CHART



Test No: 14 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 5-b (not reported in reference) Date: 8/14/92

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

Type: A325 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

### PLATES

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.3125 | 2 | - | ? | 47.31 | 65.52 |
| - | ? | 0.3125 | 2 | - | ? | 47.31 | 65.52 |

## TEST RESULTS

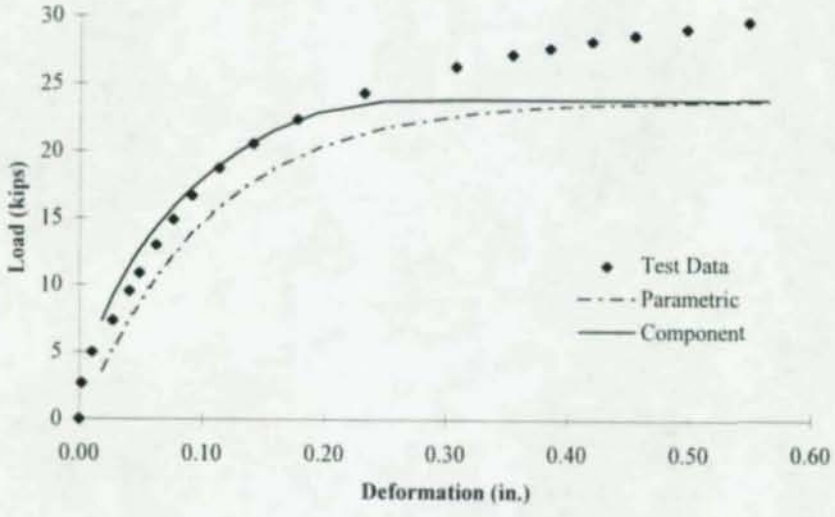
Limit State: Bolt Shear
Ki: 169 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.5483 | 29.6 |
| Other: | 0.2500 | 24.8 |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0019 | 2.6 |
| 0.0103 | 5.0 |
| 0.0270 | 7.3 |
| 0.0404 | 9.5 |
| 0.0487 | 10.9 |
| 0.0623 | 13.0 |
| 0.0761 | 14.9 |
| 0.0914 | 16.6 |
| 0.1134 | 18.7 |
| 0.1414 | 20.5 |
| 0.1775 | 22.3 |
| 0.2324 | 24.3 |
| 0.3078 | 26.3 |
| 0.3543 | 27.2 |
| 0.3850 | 27.6 |
| 0.4196 | 28.2 |
| 0.4549 | 28.6 |
| 0.4977 | 29.1 |
| 0.5483 | 29.6 |

## LOAD Vs. DEFORMATION CHART



Test No: 15 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 5-c (not reported in reference) Date: 8/14/92

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

Type: A325 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

### PLATES

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.3125 | 2 | - | ? | 47.31 | 65.52 |
| - | ? | 0.3125 | 2 | - | ? | 47.31 | 65.52 |

## TEST RESULTS

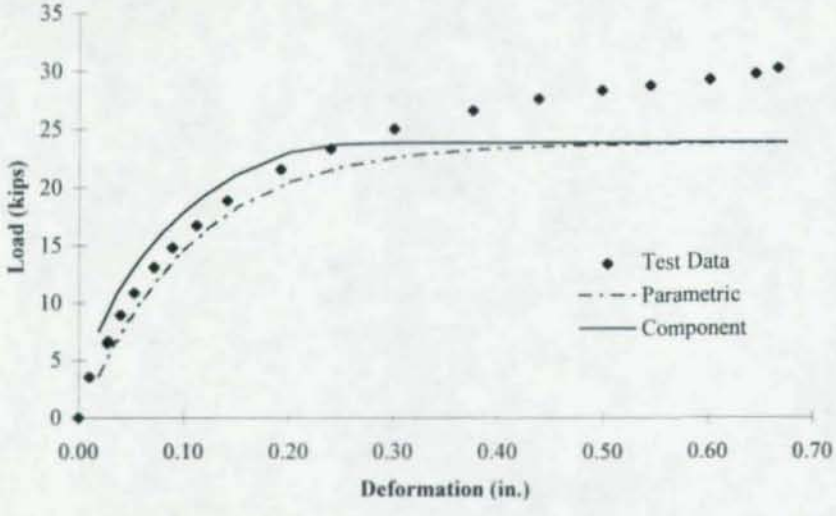
Limit State: Bolt Shear
Ki: 185 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.6667 | 30.2 |
| Other: | 0.2500 | 23.6 |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0103 | 3.5 |
| 0.0271 | 6.5 |
| 0.0278 | 6.6 |
| 0.0395 | 8.9 |
| 0.0528 | 10.9 |
| 0.0713 | 13.1 |
| 0.0888 | 14.8 |
| 0.1117 | 16.7 |
| 0.1411 | 18.8 |
| 0.1920 | 21.5 |
| 0.2397 | 23.3 |
| 0.3008 | 25.0 |
| 0.3762 | 26.6 |
| 0.4380 | 27.6 |
| 0.4987 | 28.3 |
| 0.5449 | 28.7 |
| 0.6015 | 29.2 |
| 0.6455 | 29.7 |
| 0.6667 | 30.2 |

## LOAD Vs. DEFORMATION CHART



Test No: 16 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 6-a (called 5-a in reference) Date: 8/15/92

## GEOMETRIC AND MATERIAL PROPERTIES

**BOLT**

Type: A490 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

**PLATES**

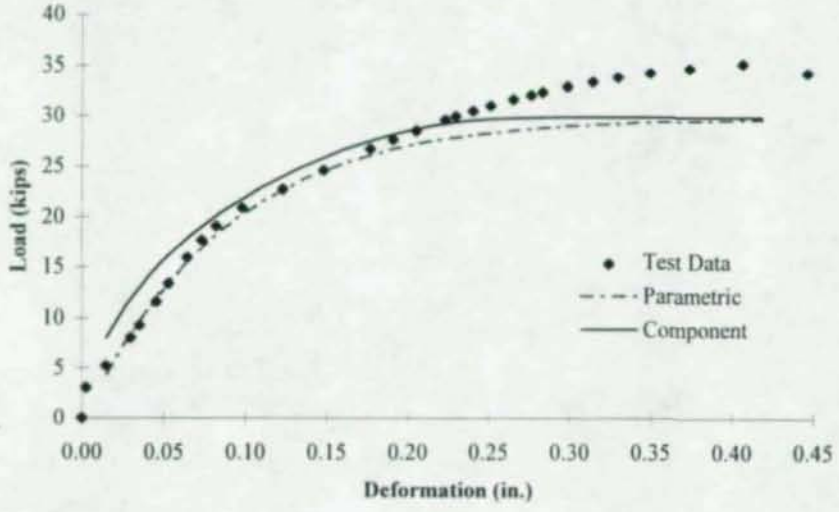
| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.375 | 2 | - | ? | 47.57 | 67.07 |
| - | ? | 0.375 | 2 | - | ? | 47.57 | 67.07 |

## TEST RESULTS

Limit State: Bolt Shear
Ki: 197 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.4067 | 35.2 |
| Other: | 0.2500 | 30.9 |

## LOAD Vs. DEFORMATION CHART




## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0027 | 3.1 |
| 0.0145 | 5.2 |
| 0.0297 | 8.0 |
| 0.0353 | 9.2 |
| 0.0455 | 11.6 |
| 0.0531 | 13.4 |
| 0.0644 | 15.9 |
| 0.0734 | 17.7 |
| 0.0822 | 19.1 |
| 0.0981 | 20.9 |
| 0.1231 | 22.7 |
| 0.1482 | 24.6 |
| 0.1771 | 26.7 |
| 0.1912 | 27.6 |
| 0.2053 | 28.5 |
| 0.2233 | 29.5 |
| 0.2298 | 29.9 |
| 0.2404 | 30.4 |
| 0.2513 | 31.0 |
| 0.2654 | 31.6 |
| 0.2764 | 32.0 |
| 0.2833 | 32.3 |
| 0.2987 | 32.8 |
| 0.3144 | 33.3 |
| 0.3299 | 33.8 |
| 0.3498 | 34.3 |
| 0.3739 | 34.7 |
| 0.4067 | 35.2 |
| 0.4464 | 34.2 |

Test No: 17 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 6-b (called 5-b in reference) Date: 8/15/92

## GEOMETRIC AND MATERIAL PROPERTIES

**BOLT**

Type: A490 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

**PLATES**

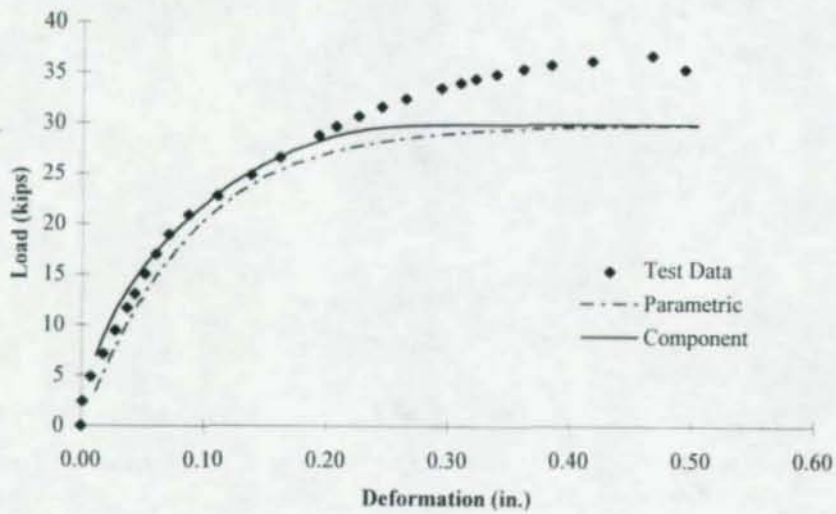
| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.375 | 2 | - | ? | 47.57 | 67.07 |
| - | ? | 0.375 | 2 | - | ? | 47.57 | 67.07 |

## TEST RESULTS

Limit State: Bolt Shear
Ki: 247 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.4664 | 36.6 |
| Other: | 0.2500 | 31.8 |

## LOAD Vs. DEFORMATION CHART




## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0011 | 2.4 |
| 0.0075 | 4.8 |
| 0.0177 | 7.1 |
| 0.0272 | 9.4 |
| 0.0367 | 11.7 |
| 0.0430 | 13.1 |
| 0.0511 | 15.0 |
| 0.0601 | 17.0 |
| 0.0704 | 18.9 |
| 0.0863 | 20.9 |
| 0.1107 | 22.7 |
| 0.1380 | 24.8 |
| 0.1616 | 26.6 |
| 0.1933 | 28.7 |
| 0.2075 | 29.6 |
| 0.2258 | 30.6 |
| 0.2448 | 31.5 |
| 0.2644 | 32.4 |
| 0.2937 | 33.4 |
| 0.3093 | 33.9 |
| 0.3217 | 34.3 |
| 0.3388 | 34.8 |
| 0.3609 | 35.3 |
| 0.3837 | 35.7 |
| 0.4174 | 36.1 |
| 0.4664 | 36.6 |
| 0.4933 | 35.3 |

Test No: 18 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 6-c (called 5-c in reference) Date: 8/15/92

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

Type: A490 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

### PLATES

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.375 | 2 | - | ? | 47.57 | 67.07 |
| - | ? | 0.375 | 2 | - | ? | 47.57 | 67.07 |

## TEST RESULTS

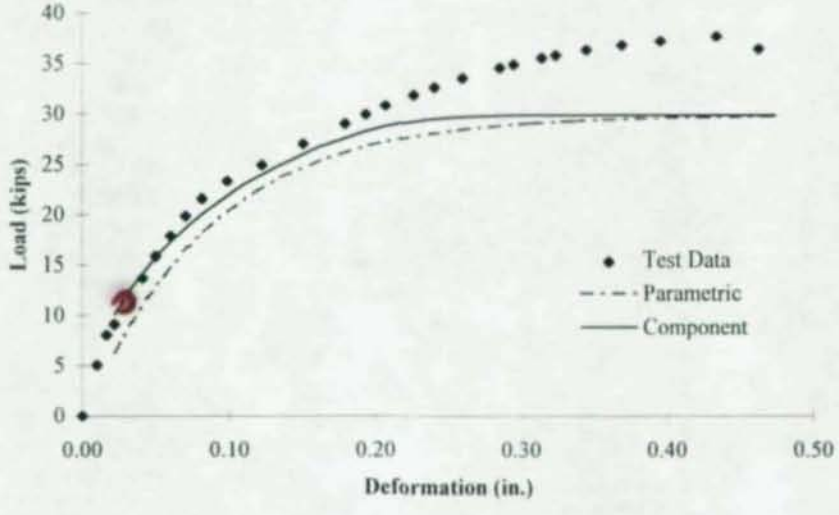
Limit State: Bolt Shear
Ki: 261 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.4339 | 37.7 |
| Other: | 0.2500 | 33.1 |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0001 | 0.0 |
| 0.0100 | 5.0 |
| 0.0167 | 8.1 |
| 0.0220 | 9.1 |
| 0.0333 | 11.6 |
| 0.0412 | 13.7 |
| 0.0502 | 15.8 |
| 0.0602 | 17.8 |
| 0.0705 | 19.8 |
| 0.0816 | 21.5 |
| 0.0988 | 23.2 |
| 0.1225 | 24.9 |
| 0.1509 | 27.0 |
| 0.1795 | 29.0 |
| 0.1936 | 29.9 |
| 0.2072 | 30.8 |
| 0.2266 | 31.9 |
| 0.2407 | 32.6 |
| 0.2600 | 33.5 |
| 0.2855 | 34.5 |
| 0.2951 | 34.9 |
| 0.3143 | 35.5 |
| 0.3239 | 35.8 |
| 0.3449 | 36.3 |
| 0.3692 | 36.8 |
| 0.3956 | 37.2 |
| 0.4339 | 37.7 |
| 0.4628 | 36.4 |

## LOAD Vs. DEFORMATION CHART



Test No: 19 **Summary of Lap Connection Tests Reported By Sarkar And Wallace**

## TEST DESIGNATION

Test Designation: 7-a (called 5-d in reference) Date: 8/14/92

## GEOMETRIC AND MATERIAL PROPERTIES

### BOLT

Type: A490 Diameter (in): 0.75 Hole Was Drilled
Bolt Hole: std Shear Plane: N

### PLATES

| No. | Width (in.) | Thickness (in.) | Le (in.) | S (in.) | Edge Condition | Fy (ksi) | Fu (ksi) |
|---|---|---|---|---|---|---|---|
| - | ? | 0.3125 | 2 | - | ? | 47.31 | 65.52 |
| - | ? | 0.3125 | 2 | - | ? | 47.31 | 65.52 |

## TEST RESULTS

Limit State: Bolt Shear
Ki: 139 (kips/in.)

| | δ (in.) | Load (kips) |
|---|---|---|
| Maximum: | 0.7014 | 31.2 |
| Other: | 0.2500 | 22.9 |

## DATA

| δ (in.) | Load (kips) |
|---|---|
| 0.0000 | 0.0 |
| 0.0010 | 2.6 |
| 0.0100 | 3.5 |
| 0.0350 | 7.0 |
| 0.0437 | 8.6 |
| 0.0559 | 10.6 |
| 0.0718 | 12.6 |
| 0.0889 | 14.4 |
| 0.1113 | 16.3 |
| 0.1421 | 18.4 |
| 0.1772 | 20.2 |
| 0.2325 | 22.4 |
| 0.3045 | 24.5 |
| 0.3388 | 25.4 |
| 0.3872 | 26.3 |
| 0.4426 | 27.3 |
| 0.4761 | 27.8 |
| 0.5086 | 28.3 |
| 0.5403 | 28.8 |
| 0.5719 | 29.2 |
| 0.6082 | 29.7 |
| 0.6432 | 30.2 |
| 0.6835 | 30.7 |
| 0.7014 | 31.2 |

## LOAD Vs. DEFORMATION CHART