SANDWICH PLATE SYSTEM BRIDGE DECK TESTS

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By

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(ABSTRACT)

Three series of tests were conducted on a sandwich plate bridge deck, which consisted of two steel plates and an elastomer core. The first series of testing was conducted by applying a static load on a full scale sandwich plate bridge deck panel. Local strains and deflections were measured to determine the panel's behavior under two loading conditions. Next, fatigue tests were performed on the longitudinal weld between two sandwich plate panels. Two connections were tested to 10 million cycles, one connection was tested to 5 million cycles, and one connection was tested to 100,000 cycles. The fatigue class of the weld was determined and an S-N curve was created for the longitudinal weld group. Finally, a series of experiments was performed on a half scale continuous bridge deck specimen. The maximum positive and negative flexural bending moments were calculated and the torsional properties were examined.

Finite element models were created for every load case in a given test series to predict local strains and deflections. All finite element analyses were preformed by Intelligent Engineering, Ltd. A comparison of measured values and analytical values was preformed for each test series. Most measured values were within five to ten percent of the predicted values.

Shear lag in the half scale bridge was studied, and an effective width to be used for design purposes was determined. The effective width of the half scale simple span sandwich plate bridge deck was determined to be the physical width.

Finally, supplemental research is recommended and conclusions are drawn.

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CHAPTER 1

INTRODUCTION

1.1 Introduction and Background

A sandwich plate consisting of two steel plates bonded to a solid elastomer core, as shown in Figure 1.1, has been proposed for bridge decks. The use of an elastomer core has a number of advantages. The elastomer core prevents the steel plate from buckling. Also, the steel plates are entirely reinforced so that intermediate stiffeners are not required. Another advantage of a sandwich plate is the size of each steel plate and the core can be adjusted to any thickness based on the structural load requirements. A sandwich plate bridge deck has advantages over a reinforced concrete deck. The sandwich plate bridge deck is lighter than a concrete deck with similar thickness. A considerable amount of money can be saved by using a sandwich plate bridge deck panel. The savings come from the increased stiffness of the composite deck, ease of construction, and savings in repair costs over the life time of the structure.

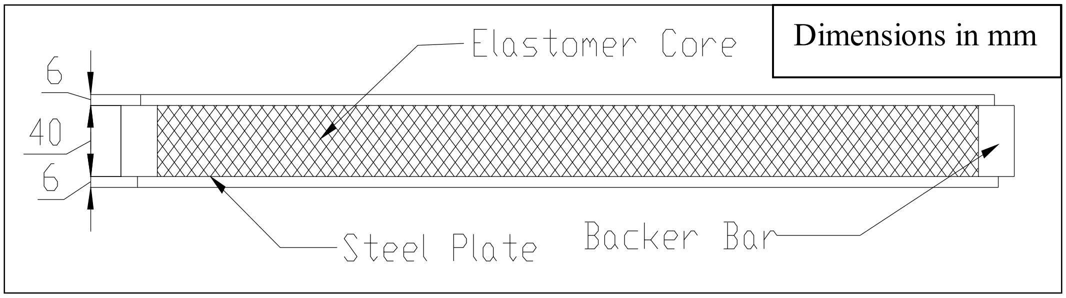


FIGURE 1.1: SANDWICH PLATE BRIDGE DECK

Intelligent Engineering Limited, Ottawa, Ontario, Canada, in conjunction with BASF Group/Elastogram, Lemforde, Lower Saxony, Germany, developed a product similar to the system described above for use in maritime applications. A sandwich plate was used instead of traditional stiffened steel plate for ship hulls and decks. After the successful completion of numerous ship repairs and new construction, a sandwich plate was proposed for use in civil engineering applications such as bridge decks and floor systems due to the cost effectiveness of the product.

A bridge deck consisting of sandwich plate panels has been proposed as an alternative to traditional reinforced concrete bridge decks. A perimeter box comprised of steel is constructed and the elastomer is injected using standard pumping equipment. The transverse ends of the box are cross stringers. To construct the bridge, the cross stringers are bolted to steel girders and the panels are bolted to each other using ¾ in. A325-SC bolts. After the bolts are pretensioned, a groove weld is placed in the field to develop full composite action. Figure 1.2 shows the connection between two sandwich plate panels. Figure 1.3 is a photograph of the Shenley Bridge in the municipality of Saint-Martin, Ontario, Canada under construction.

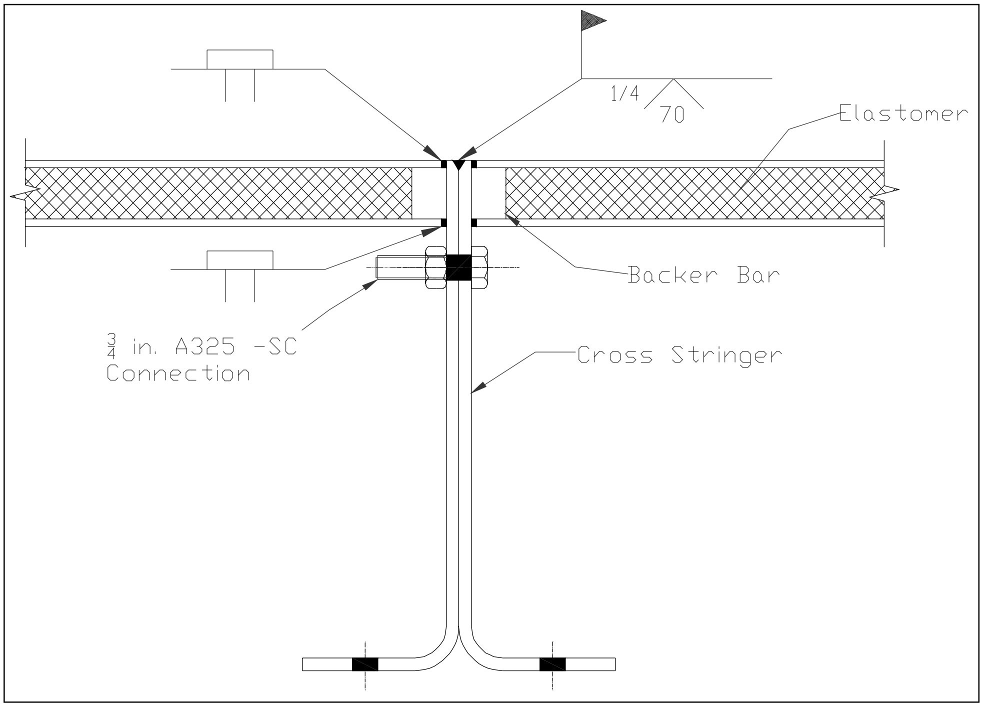


FIGURE 1.2: CONNECTION BETWEEN TWO SANDWICH PANELS

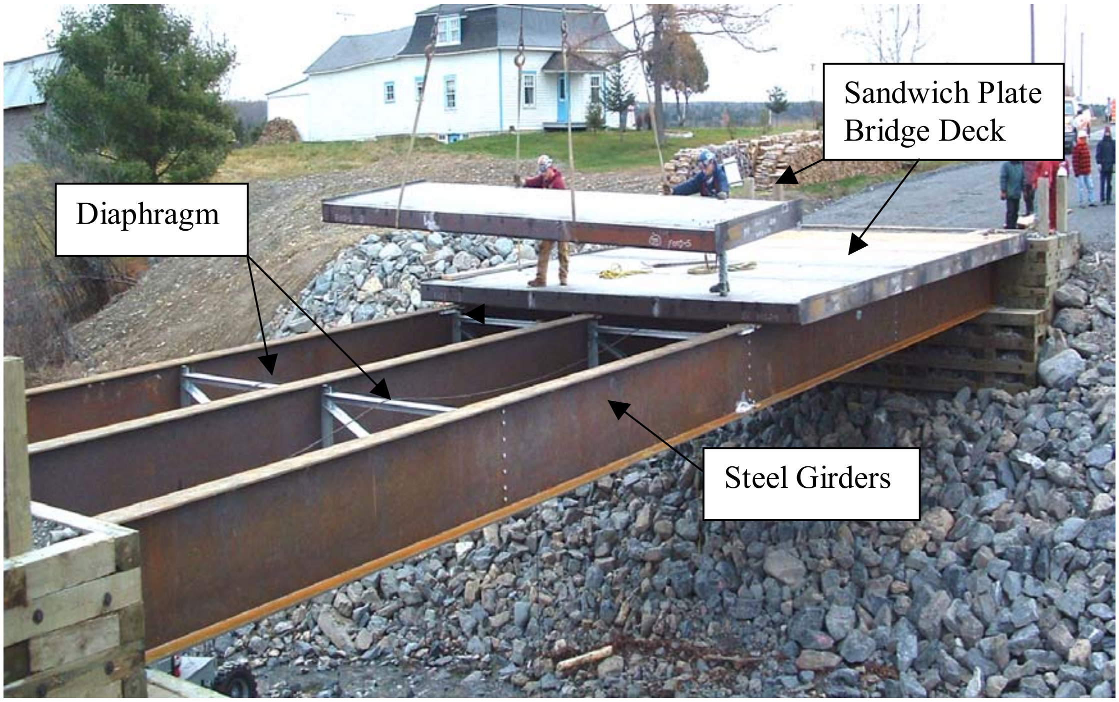


FIGURE 1.3: SHENLEY BRIDGE (COURTESY OF INTELLIGENT ENGINEERING)

A testing program was developed by Intelligent Engineering in conjunction with Virginia Tech to study a sandwich plate bridge deck. The research was conducted because, to date, very little experimental testing has been done on sandwich plate bridge deck panels with an elastomeric core. The local behavior of the sandwich panel bridge deck under static loading needed to be examined, and it was considered necessary to fatigue test the connection between adjacent panels to determine the weld group's classification. The effect of torsion and shear lag on the bridge deck required investigation. Another research necessity was to determine whether or not the sandwich plate deck and the steel girders act compositely. Finally, the experimental testing would be used to verify that the finite element analysis performed by Intelligent Engineering was accurate.

The following sections describe the local behavior of a sandwich plate bridge deck panel, the fatigue properties of the connection between two bridge deck panels, the composite action developed between the sandwich plate deck and steel girders, and the effect of shear lag on the bridge deck.

1.2 Literature Review

Currently, there is a minimal literature on bridge decks consisting of the sandwich plate system described above. The test program at Virginia Tech was the beginning of experimental laboratory testing on a sandwich plate bridge deck system. Due to the unique nature of the elastomeric core, it was not possible to find another composite orthotropic sandwich to compare with the Sandwich Plate System (SPS); however, Intelligent Engineering has published numerous testing and technical reports, which are reviewed in the following discussion.

Kennedy et al. (2002) discuss the need for a lightweight, cost efficient bridge deck for movable and military bridge decks. Traditional steel plate orthotropic bridge decks are expensive due to the type and amount of welding required. A traditional steel box girder is compared to a stiffened sandwich plate box girder and a composite core sandwich plate box girder. In their study, only the effects of traffic loads were examined on the different deck configurations. Both sandwich plate alternatives were more cost efficient and satisfied the required ultimate, fatigue, and serviceability limit states. They concluded that the system as described above is an attractive alternative to traditional bridge decks due to reduced welding and ease of erection.

A technical bulletin published by Lloyd's Register (2000) found the Sandwich Plate System had numerous advantages over a stiffened steel plate in maritime applications. They determined a composite sandwich plate distributed stress over a larger area than a conventional steel plate for a double-hull oil tanker design. Crack formation is less likely to occur due to the elimination of stiffeners. Also, the simplified structural system was easier to coat and maintain; other advantages of a sandwich plate are the integrated acoustic and thermal insulation and increased impact resistance.

Intelligent Engineering (2002) prepared a technical report for the Austrian Military where a "5-40-5 Sandwich Plate System Bridge Deck Panel" was used to replace a traditional stiffened bridge deck panel. The 5-40-5 numbering indicates the thickness of the steel plate, elastomer core, and steel plate, respectively, in millimeters. Three static tests were performed on the 5-40-5 sandwich plate system in Ludwigshafen, Germany, and the results showed the sandwich plate panel carried 1.29 times the design load applied at the maximum eccentricity. A fatigue test was conducted to 5 million cycles without any cracks forming. A finite element analysis was performed using ANSYS and a discrepancy of only 7% was found between the experimental and predicted deflections. The experimental strains were found to be in reasonable agreement with the analytical model, and there was no sign of creep during any of the experimental testing. Prior to the fatigue testing, an asphalt wearing surface was applied to the deck;

no evidence of debonding was found between the steel plate and elastomer core at the completion of fatigue testing. Intelligent Engineering determined that the 5-40-5 Sandwich Plate System design to be acceptable, and to perform better than a stiffened steel plate deck.

Intelligent Engineering (2003) conducted an analytical study using a 6-40-6 SPS for the top flange of a box girder for the proposed Mexico City Elevated Ring Road. Due to the soil conditions in Mexico City, a light, cost efficient alternative to a traditional reinforced concrete deck is required. The structural design was based on the Canadian Highway Bridge Code (2000a), and all the code requirements were met. A finite element model was created to determine the local behavior of the guard rail structure, the SPS bridge deck, and the longitudinal weld group. They concluded that the dead weight of the structure would be reduced by nearly 50% using the Sandwich Plate System. The reduction in dead weight reduces the load transferred to the foundation as well as reduces the earthquake forces applied to the structure.

Intelligent Engineering (2004) performed static and dynamic tests on the Shenley Bridge in the municipality of Saint-Martin, Ontario, Canada (see Figure 1.3). The Shenley Bridge was the first bridge to be constructed using the system described above as the bridge deck. A test truck with a weight of 519 kN (117 kips) was used in five different testing configurations, causing a maximum bending moment of 1398 kN-m (95.8 kip-ft). This was approximately 20% of the maximum moment that could be applied to the bridge deck. A finite element analysis was performed using ANSYS and the measured strains and deflections were found to be in good agreement with the predicted values. To meet the requirements established by the Canadian Highway Bridge Design Code, a dynamic test was also conducted. The first mode due to bending occurred at 5.8 Hz, and the second mode caused by torsion occurred at 6.0 Hz. The Shenley Bridge exhibited a damping ratio of 0.8% for the first bending mode. When compared to a reinforced concrete deck with the same 200 mm (7.87 in.) thickness, the sandwich plate bridge deck is 57% lighter, and the stiffness is greater than a traditional orthotropic bridge deck resulting in less deflection and deck curvature.

Occasionally, orthotropic bridge decks with a large amount of welding experience problems. Wolchuk (1990) investigated weld cracks on three European orthotropic bridge decks. The Haseltal and Sinntal Bridges in Germany developed cracks in the welds joining the steel deck to the V-shaped ribs. The cause of the cracks was not due to fatigue, but to weld shrinkage occurring immediately after the weld cooled. Wolchuk (1990) concluded that the best welders and welding sequence could not have prevented the cracks from forming between the deck and discontinuous ribs. Wolchuk (1990) also examined weld cracks in the Severn Crossing Bridge in the United Kingdom, and he found the cracks were caused because fillet welds were used in lieu of 80% penetration welds. The fillet welds caused the connection between the ribs and cross beam to experience eccentricity, which increased the propensity for fatigue cracks.

Tsakopoulos and Fisher (2003) investigated the Williamsburg Bridge in New York City, New York. Fatigue cracks in the deck to rib welds were discovered during rehabilitation of the bridge. They proposed two connections for the rib-to-deck welds. The first connection consisted entirely of fillet welds, and the second connection was a combination of a partial joint penetration weld and fillet welds. After conducting fatigue tests on the weld options, they concluded the connection with only fillet welds had inconsistent performance and cracks developed in both the tension and compression regions well below the AASHTO LRFD Bridge Design Specifications (1994) stress range.

1.3 Objective and Scope of Research

Three static tests were conducted on a full scale sandwich plate bridge deck panel to determine local strains and deflections. The connection between two sandwich plate bridge deck panels was tested to various cycle lengths to investigate the fatigue characteristics of the longitudinal weld group and to develop an S-N curve for the weld group. A one-half scale bridge was constructed using eight sandwich plate bridge deck panels to examine the effects of shear lag and the response in the positive and negative moment regions.

Another objective of this study is to verify the assumptions in the finite element modeling procedures. The results obtained from experimental testing were compared to a finite element analyses preformed by Intelligent Engineering. The effect of support deflections on the finite element analyses was also investigated.

A comparison of effective widths was performed using current standards in common practice today. The effective width for design purposes for the sandwich plate bridge was determined using the experimental results and compared to a composite concrete deck and steel girder system.

The experimental test procedure, experimental results, finite element analyses, and discussions of the experimental measurements versus the predicted measurements for the static panel tests are presented in Chapter 2. Chapter 3 contains the experimental data and finite element results for the longitudinal joint fatigue tests. Chapter 4 contains information on the half scale bridge tests. Three shear lag theories are reviewed and effective width design calculations are made in Chapter 5. Chapter 6 presents conclusions and suggestions for future research.

1.4 Introduction to Experimental Testing

The experimental testing program consisted of three series of tests on a sandwich plate bridge deck panel. The first series was conducted by applying static loads on a full scale panel, Tests E1-A, E1-B, and P1-A. Next, fatigue tests were performed on the longitudinal weld group between bridge deck sections. Tests were conducted to 10 million cycles, 5 million cycles, and 100,000 cycles at increasing maximum strain to develop an S-N curve. Finally, a series of experiments was performed on a half scale, simple span bridge, Series C1, C2, C3, C4.

1.5 Overview of Finite Element Analysis

The finite element analyses were conducted by Intelligent Engineering Ltd., Ottawa, Ontario, Canada. All three experimental testing series were modeled using ANSYS. The models were used to predict strains and deflections for each load case. Each of the chapters discussing experimental testing also includes an overview of each finite element model including modeling techniques, material properties, and model results.

CHAPTER 2

STATIC PANEL TESTS

2.1 General

The objective of the static panel testing was to determine the local strains and deflections under a factored load as well as the ultimate load of a full scale sandwich plate bridge deck panel. Also, the measured strains and deflections were to be compared to finite element model predictions to verify the finite element modeling assumptions.

For all the static panel tests, a full scale sandwich plate bridge deck panel was used as the test specimen. The test specimen was provided by Intelligent Engineering, as fabricated by the Canam Manac Group, Quebec, Canada. A plan view of the test specimen is shown in Figure 2.1. The specimen was a 6.4-38.1-6.4 sandwich plate enclosed with steel face plates and cross stringers that measured 3000 mm (9.84 ft) by 9000 mm (29.53 ft). For all tests, the panel was supported by two W690x125 (W27x84) beams, which were bolted to the reaction floor in the Virginia Tech Structures and Materials Research Laboratory. All steel was grade 350, which corresponds to material yield strength of 350 MPa (50 ksi). Mill certificates were not available and steel coupon tests were not conducted.

The first test series conducted on the sandwich plate bridge panel was Elastic Test E1-A, in which two load points were placed on either side of the first support beam to determine the effect of negative moment on the panel. Negative moment is defined as moment which causes tension in the top plate of the panel. The second test, Elastic Test E1-B, was similar to Elastic Test E1-A, but the two load points were situated between the two supports causing positive moment. The objective of this test was to study the local behavior of the panel when the top plate is in compression. The final test was Plastic Test P1-A. This test was used to determine the ultimate load and failure mode of the full scale sandwich plate.

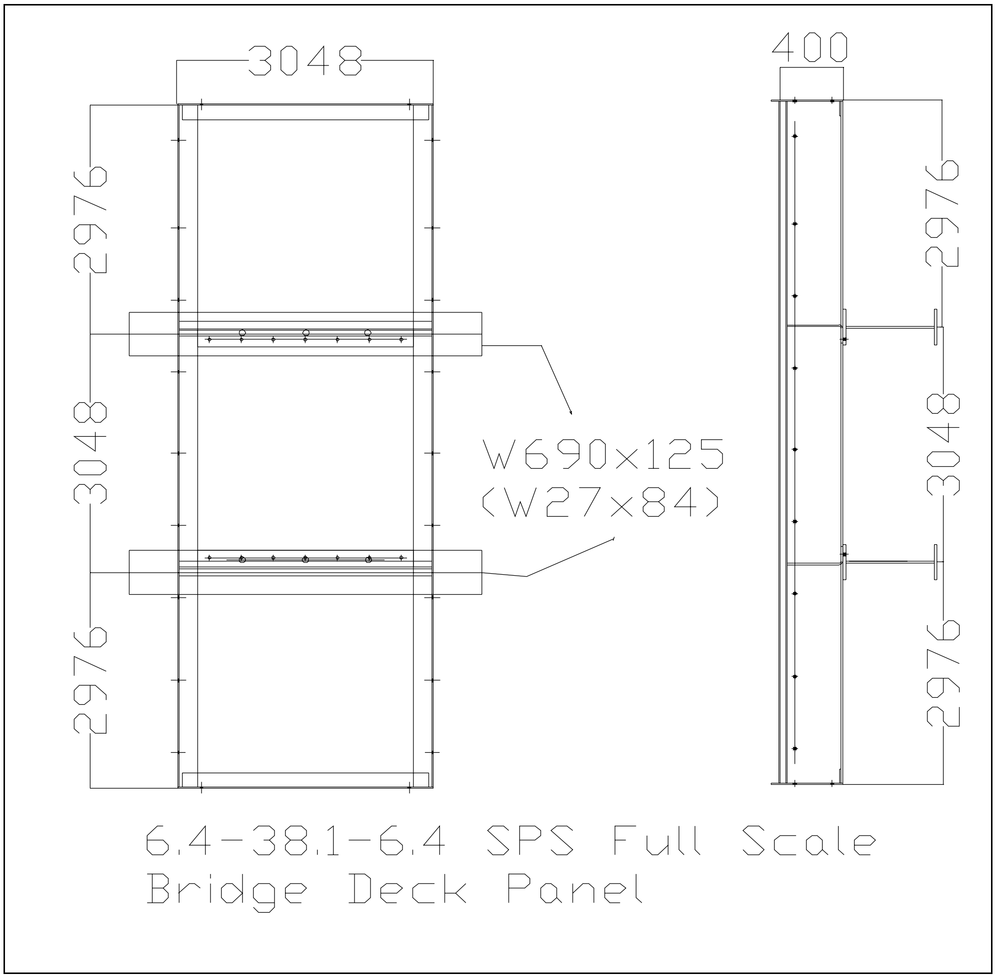


FIGURE 2.1: SANDWICH PLATE SYSTEM BRIDGE DECK PANEL

2.2 Elastic Test E1-A

2.2.1 Test Setup

For static panel test E1-A, a support beam was placed 2976 mm (9.76 ft) from each free edge of the panel leaving a simple span of 3048 mm (10 ft) between support beams, and the load points were applied at the center of the 3000 mm (9.84 ft) width. The two load points were positioned 1800 mm (5.91 ft) apart, straddling the first support beam. As shown in Figure 2.2, a spreader beam was positioned between the two load points to distribute the load.

FIGURE 2.2: ELASTIC TEST E1-A SETUP

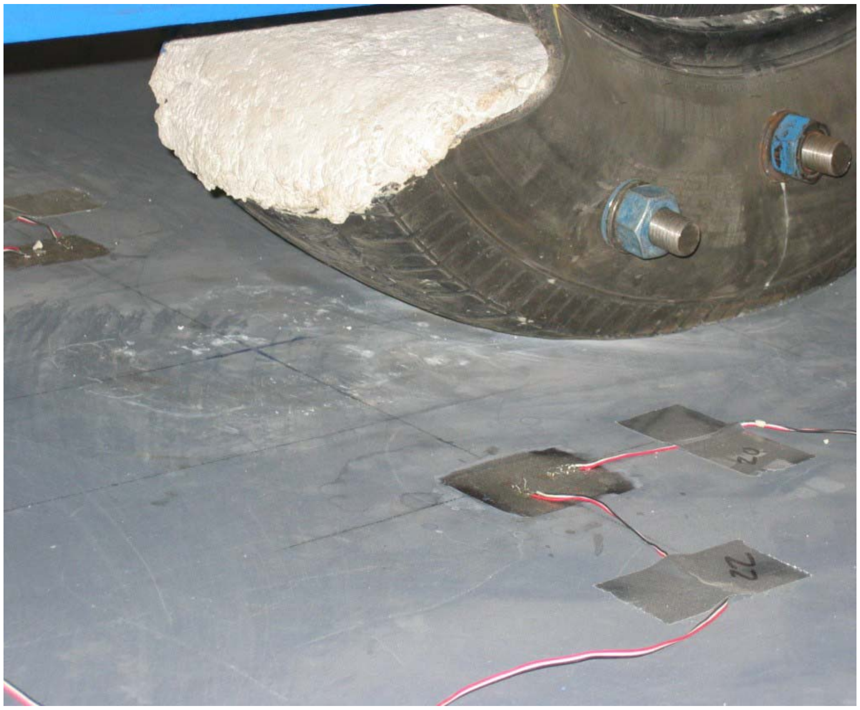


FIGURE 2.3: TIRE LOAD PATCH USED IN ELASTIC TEST E1-A AND E1-B

The two load locations were sections of used tires cut into quarters and filled with concrete as shown in Figure 2.3. Tires were used instead of bearing pads because the tire tread provides a more realistic stress distribution on the top plate of the steel deck as investigated by Coleman (2002).

Figure 2.4 shows the location of the load locations. To reduce the effect of the unevenness of the laboratory floor, the two support beams were set on steel plates. The bolts used to secure the support beams to the reaction floor were snug tight.

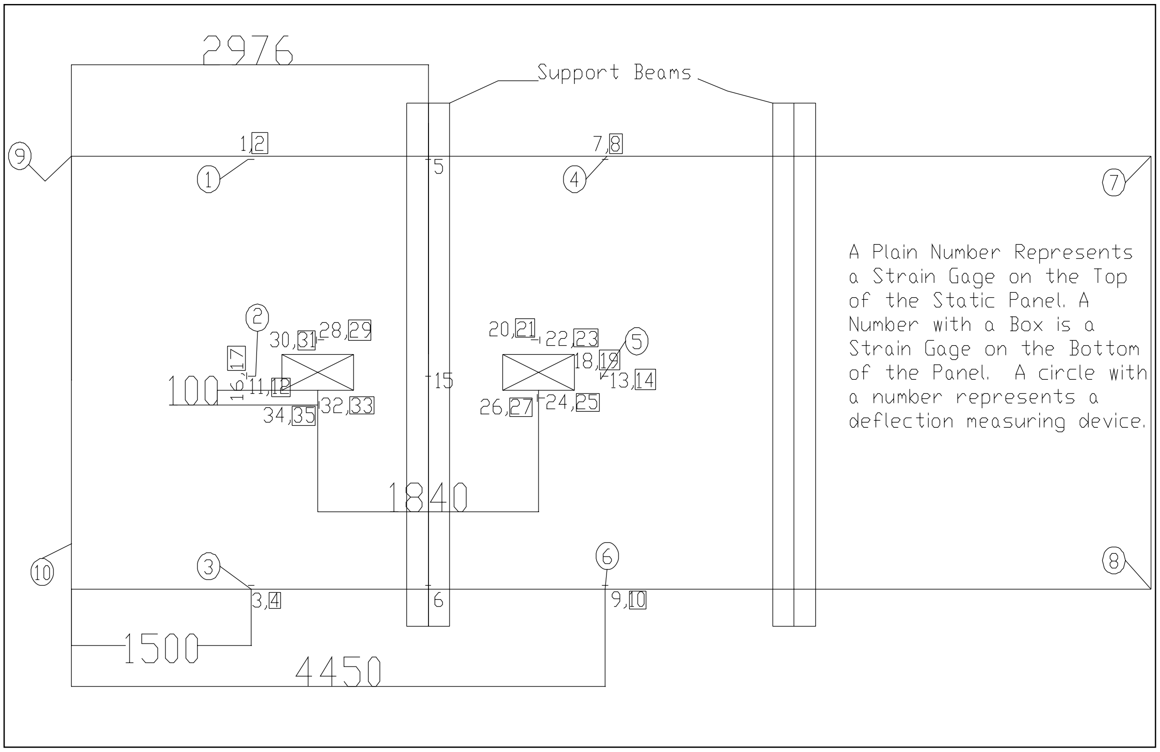


FIGURE 2.4: LOAD POSITIONS AND INSTRUMENTATION FOR STATIC TEST E1-A

2.2.2 Instrumentation

The instrumentation layout for static test E1-A is shown in Figure 2.4. A PC-based data acquisition system was used to collect data from the strain gages and “string-type” displacement potentiometers. Dial gages were used when the deflections were too small to be recorded by the potentiometers. All dial gages readings were manually recorded. A total of thirty-five strain gages were used to determine local plate behavior. A combination of potentiometers and dial gages were used to measure the local deflections of the panel as well as support movement.

For static test E1-A, a single hydraulic ram was used to apply load. The load from the hydraulic ram was measured using a compression load cell. The load cell was calibrated prior to testing using a SATEC Universal Testing Machine.

2.2.3 Test Procedure

After connecting the instrumentation to the data acquisition system, the instrumentation was set to zero. Lead wire resistance in the strain gages was accounted for by shunt calibrating the strain gages. The potentiometers were calibrated using a Mitutoyo height gage with a dual directional digital counter. After setting the instrumentation to zero again, the calibration of the potentiometers was again checked using a ½ in. precision parallel steel bar. All dial gages were set to zero to record a downward deflection. A seating load of approximately 20% of the full scale testing load was applied and all instrumentation was checked for correct output. Necessary adjustments were made before any testing continued. (Note: This test procedure was used for all subsequent static tests as well.)

Using the analytical data from the finite element analysis, a theoretical load versus deflection line was plotted. The experimental load versus deflection line was plotted in real time and compared to the theoretical line at each load interval. The specimen was loaded in 22 kN (5 kips) increments and strain and deflection measurements were taken at every interval. The total maximum test load for static panel test E1-A was 332 kN (74.6 kips). The maximum test load was based on the tandem axel provisions in *Canadian Highway Bridge Design Code* (2000a) including a live load factor (1.7).

2.2.4 Test Results

Figure 2.5 is a photograph of the test specimen under maximum loading, and Figure 2.6 is a plot of applied load versus measured deflections at Point 2. Dial gage and transducer measurements, as well as the predicted deflection from the finite element analysis are shown. The maximum deflection was 11.4 mm (0.45 in) downward measured at Point 2. The dial gage and transducer measurements are located in the same position and, therefore, should be in good agreement. Figure 2.6 shows both experimental measurements had good agreement with the predicted deflection from the finite element analysis and with each other. The finite element model deflection predictions were corrected to account for support beam deflection, and the maximum measured deflection of the support beams was 0.41 mm (0.016 in.).

Table 2.1 shows the measured strains at the 35 strain gage locations under maximum loading. The maximum strain, 942 $\mu\varepsilon$, was measured half way between the two load points on the top plate.

After the load was removed from the test specimen, the specimen returned to its initial position with no permanent deformation.

FIGURE 2.5: TEST SPECIMEN UNDER MAXIMUM LOADING - ELASTIC TEST E1-A

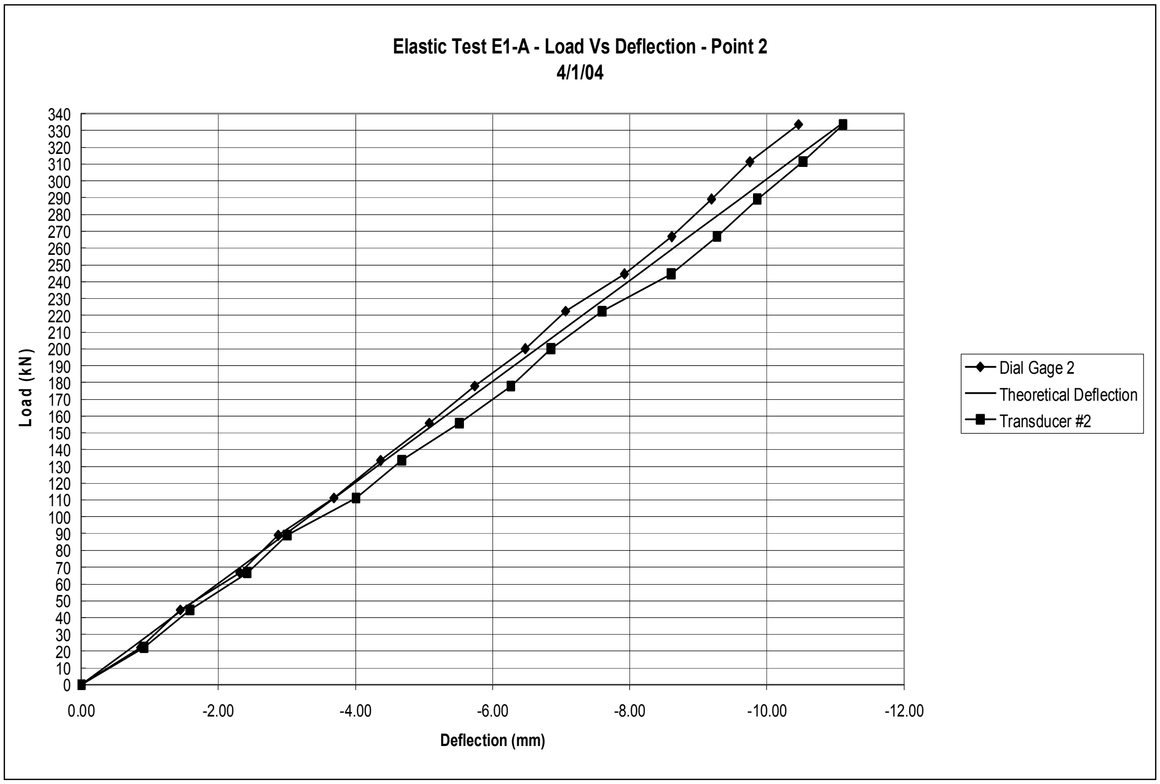


FIGURE 2.6: LOAD VERSUS DEFLECTION MEASURED AT POINT 2

TABLE 2.1: MEASURED STRAINS AT MAXIMUM LOADING FOR TEST E1-A

Strain Measurement Location (Figure 2.4)	Test E1-A: Max Load 74.6 kips
	Measured Strain x 10^{-6} (in/in)
1	-18
2	-82
3	-28
4	-81
5	101
6	118
7	-43
8	-75
9	-16
10	-82
11	-66
12	136
13	-37
14	116
15	942
16	-344
17	301
18	-292
19	286
20	-511
21	519
22	-122
23	172
24	-527
25	556
26	-137
27	199
28	-490
29	506
30	-152
31	215
32	-137
33	202
34	-467
35	518

Note: $\varepsilon_y = 1700 \times 10^{-6}$ (in/in)

2.2.5 Finite Element Analysis

The finite element analysis was conducted by Intelligent Engineering Ltd, Ottawa, Ontario, Canada. The analysis was conducted using the commercial software ANSYS, version 9.0. The finite element analysis was a linear elastic model. This section describes the material properties, modeling techniques, and results.

The steel elements of the sandwich plate panel were assigned a modulus of elasticity of 200 GPa (29000 ksi), a Poisson's ratio of 0.287, a yield strain of 1700 $\mu\varepsilon$, and a yield stress of 350 MPa (51 ksi). The elastomeric core was assigned a modulus of elasticity of 750 MPa (109 ksi) and a Poisson's ratio of 0.36.

The steel plates and elastomeric core elements were modeled using HYPER 58 and SOLID 45 brick elements. Cross bracing members were modeled with BEAM 188 line elements. A 5 mm (0.2 in.) thick SHELL 63 element with rubber material properties was used to model the tires. The load was applied to the tires as a surface pressure on the tire area. The wheel loads were applied to the deck using contact elements TARGE 170 and CONTA 173. (Note: This procedure was used for all finite element models in the static panel test series.)

Figure 2.7 shows the deflected surface for Elastic Test E1-A. The maximum predicted deflection was at Point 2, 11.5 mm (0.45 in.).

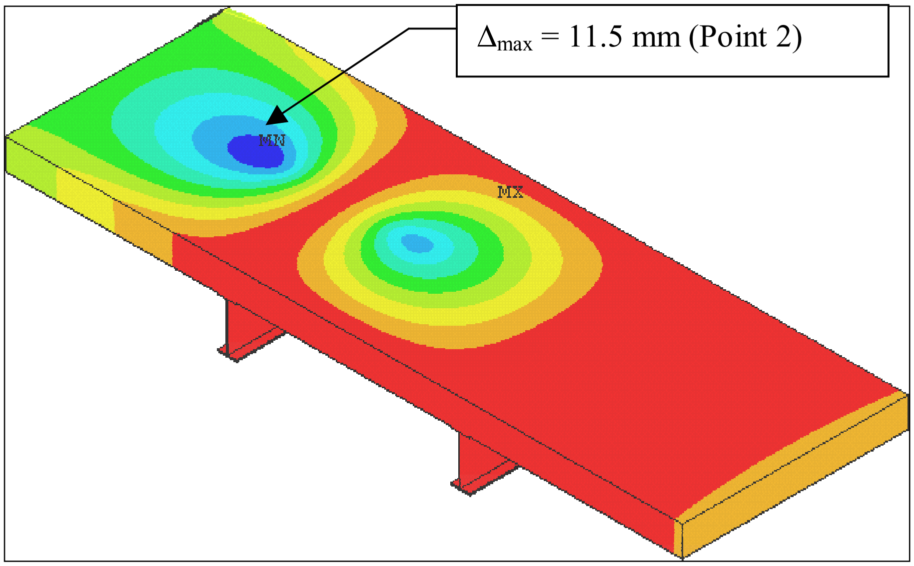


FIGURE 2.7: FINITE ELEMENT ANALYSIS DEFLECTION CONTOURS

2.2.6 Comparison of Experimental and Predicted Results

Table 2.2 is a comparison of the measured and predicted deflections. The table shows the measured and predicted deflection had good agreement at Point 2 (see Figure 2.4), which is the location of maximum deflection for Elastic Test E1-A. The discrepancy between the measured deflections at Locations 7 and 8 was probably caused by a support rotation. For instance, if the support beam rotated 0.05 degrees, the deflection measured at the end of the test specimen would be 2.6 mm (0.10 in.) higher than the finite element model predictions. Another explanation of the discrepancy between the predicted and the measured deflection is a small gap between the bent angle and the steel girder closing after loading was applied. The panel is assumed to be perfectly glued to the girders in the finite element model, but if a small gap is closing this assumption is not valid. In Table 2.2, a positive value is an upward deflection and a negative value is a downward deflection. (This convention is followed for every testing series.)

TABLE 2.2: DEFLECTIONS UNDER MAXIMUM LOADING

Displacement Measurement Location (Figure 2.4)	Load Case 1 - Max Load 332 kN (75 kips)		
	Measured Deflections (mm)	Predicted Deflections (mm)	Test/Predicted
1	-2.8	-3	0.93
2	-11.4	-11.1	1.03
3	-2.7	-3	0.9
4	-0.3	0.1	-3
5	-9	-7.6	1.18
6	-0.4	0.1	-4
7	0.8	-1	-0.8
8	0.8	-1	-0.8
9	-4.8	-5.9	0.81
10	-4.8	-5.9	0.81

Table 2.3 is a comparison of the measured and predicted strains at maximum loading. The measured and predicted values are in reasonable agreement between at most of the locations where strain was measured. A reasonable difference between the measured and predicted strains is 35 $\mu\varepsilon$ or 6.9 MPa (1 ksi) using an assumed modulus of elasticity of 200 GPa (29000 ksi).

TABLE 2.3: STRAINS UNDER MAXIMUM LOADING

Strain Measurement Location (Figure 2.4)	Load Case 1 - Max Load 332 kN (75 kips)		
	Measured Strain x 10^{-6} (in/in)	Predicted Strain x 10^{-6} (in/in)	Difference (in/in)
1	-18	-11	-7
2	-82	-116	34
3	-28	-11	-17
4	-81	-116	35
5	101	146	-45
6	118	146	-28
7	-43	-9	-34
8	-75	-137	62
9	-16	-9	-7
10	-82	-138	56
11	-66	-62	-4
12	136	119	17
13	-37	-34	-3
14	116	106	10
15	942	1119	-177
16	-344	-455	111
17	301	447	-146
18	-292	-448	156
19	286	432	-146
20	-511	-381	-130
21	519	440	79
22	-122	-162	40
23	172	202	-30
24	-527	-381	-146
25	556	440	116
26	-137	-162	25
27	199	202	-3
28	-490	-388	-102
29	506	437	69
30	-152	167	-319
31	215	214	1
32	-137	-167	30
33	202	214	-12
34	-467	-388	-79
35	518	437	81

Note: ε_y =1700x10^{-6} (in/in)

Overall, the results from the experimental testing and finite element analysis are in good agreement; therefore, the assumptions used in modeling the static test panel are considered valid.

2.3 Elastic Test E1-B

2.3.1 Test Setup

The load areas for static test E1-B, shown in Figure 2.8, were positioned 1800 mm (5.91 ft) apart, between the two support beams. The two support beams remained in the same location as for static test E1-A.

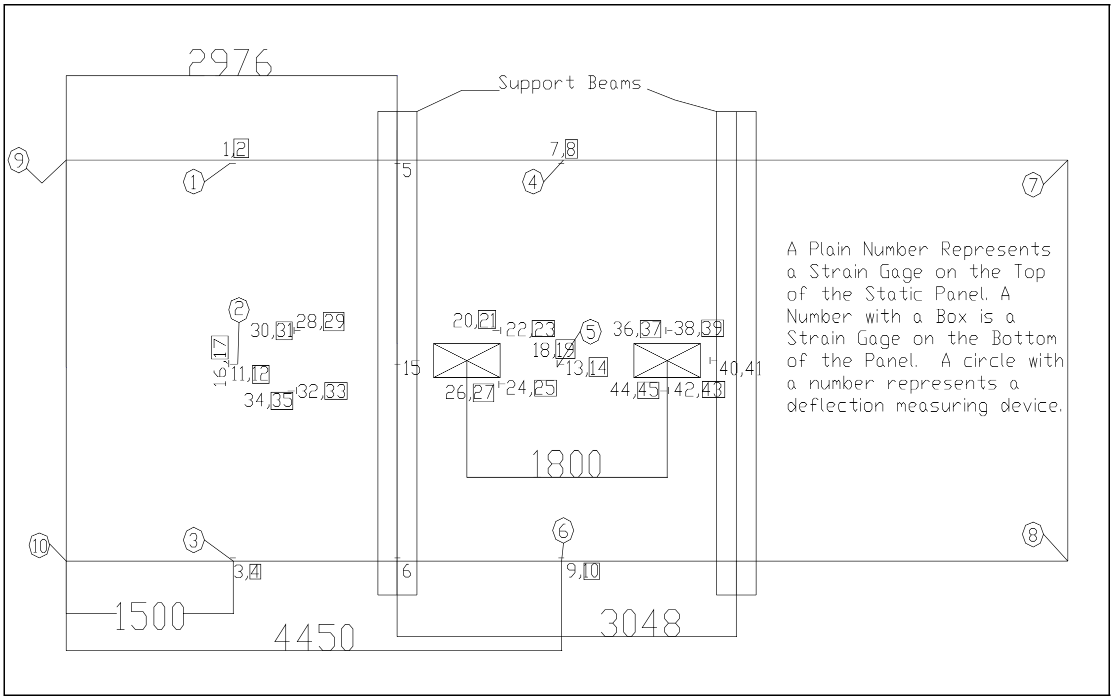


FIGURE 2.8: LOAD POSITIONS AND INSTRUMENTATION FOR STATIC TEST E1-B

2.3.2 Instrumentation

For test E1-B, forty-five strain gages were used to examine local plate behavior, located as shown in Figure 2.8. Dial gages were used to measure deflections of the sandwich plate bridge deck panel and the support beams.

2.3.3 Test Procedure

The test procedure followed closely the procedure used for test E1-A. The dial gages located in the outside spans were set to 12.7 mm (0.5 in.) initially so that the upward movement of the bridge deck panel could be recorded. The dial gages between the support beams were set to zero so that the downward movement of the panel could be recorded. The dial gages used to measure the support movement were also set to zero.

Load was applied to the bridge deck in 22kN (5 kips) increments. Dial gage readings and strain measurements were recorded at every interval before another load step was applied. The maximum applied load was 346 kN (77.8 kips). The maximum test load was based on the tandem axel provisions in *Canadian Highway Bridge Design Code* (2000a) including a live load factor (1.7), a dynamic load factor (1.25), and a multilane use factor (0.9).

2.3.4 Test Results

Figure 2.9 is a photograph of the test specimen under maximum loading, and Figure 2.10 is a plot of applied load versus measured deflections at Point 5, which was located midway between the support beams. Dial gage measurements and the predicted deflection from the finite element analysis are shown. The maximum deflection at Point 5 was 14 mm (0.55 in) downward. Figure 2.10 shows that the experimental results are in good agreement with the predicted deflection from the finite element analysis. The finite element model deflection predictions were corrected to account for support beam deflection, and the maximum measured deflection of the support beams was 0.50 mm (0.02 in.).

The maximum strain was measured on the bottom plate below the second load area with a maximum value of 651 $\mu\varepsilon$. Table 2.4 shows the experimental strains at the 45 strain gage locations measured under maximum loading.

After the load was removed from the test specimen, the specimen returned to its initial position with no permanent deformation.

FIGURE 2.9: TEST SPECIMEN UNDER MAXIMUM LOADING - ELASTIC TEST E1-B

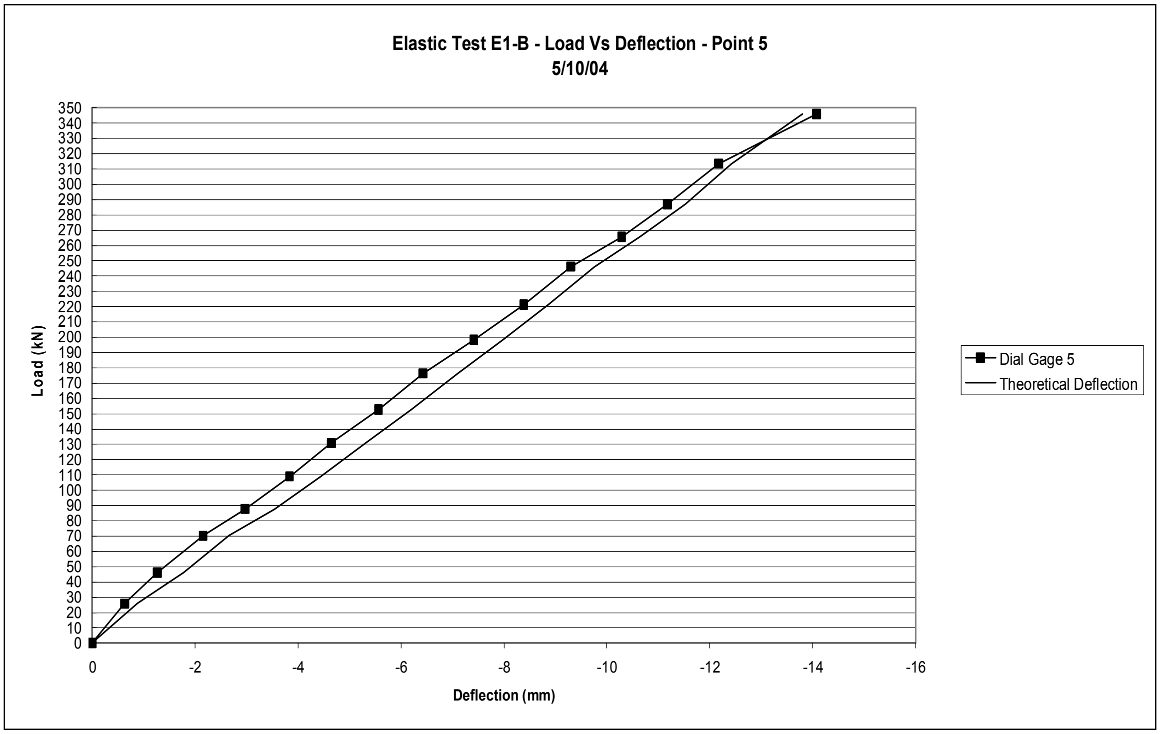


FIGURE 2.10: LOAD VERSUS DEFLECTION MEASURED AT POINT 5

TABLE 2.4: MESURED STRAINS AT MAXIMUM LOADING FOR TEST E1-B

Strain Measurement Location (Figure 2.7)	Test E1-B: Max Load 332 kN
	Measured Strain x 10^{-6} (in/in)
1	13
2	21
3	17
4	22
5	-17
6	-34
7	-148
8	228
9	-143
10	221
11	24
12	-38
13	-84
14	145
15	636
16	39
17	-33
18	-390
19	362
20	-260
21	354
22	-350
23	348
24	-244
25	341
26	-352
27	314
28	79
29	-86
30	21
31	-44
32	21
33	-45
34	78
35	-86
36	-138
37	199
38	-541
39	579
40	-191
41	651
42	-156
43	198
44	-509
45	573

Note: ε_y =1700x10^{-6} (in/in)

2.3.5 Finite Element Analysis

The finite element analyses were conducted by Intelligent Engineering Ltd, Ottawa, Ontario, Canada. The modeling procedure for this test followed the procedure for Elastic Test E1-A.

Figure 2.11 shows the deflected surface for Elastic Test E1-B. The maximum predicted deflection was at Point 5, 13.8 mm (0.54 in.).

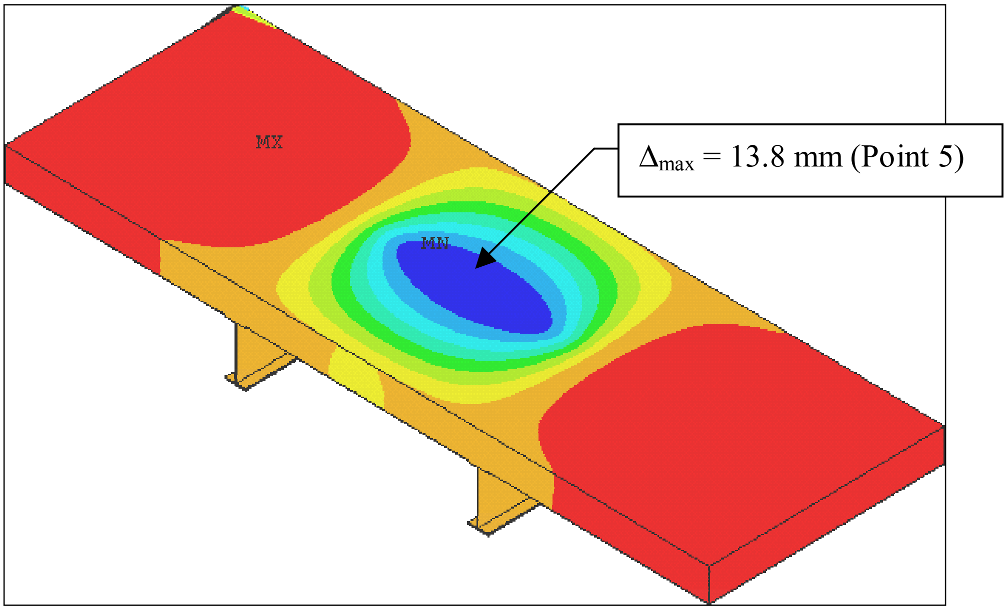


FIGURE 2.11: FINITE ELEMENT ANALYSIS DEFLECTION CONTOURS

2.3.6 Comparison of Experimental and Predicted Results

Table 2.5 is a comparison of the measured and predicted deflections. The table shows the measured and predicted deflection had good agreement at Point 5 (see Figure 2.8), which is the location of maximum deflection for Elastic Test E1-B. The load was applied to the test specimen symmetrically (see Figure 2.8); therefore, the deflection measured at Points 1 and 3, Points 4 and 6, Points 7 and 8, and Points 9 and 10 should have been similar. Table 2.5 shows that the deflections have good agreement with each other. The discrepancy between the measured and predicted deflections was probably caused by a support beam rotation. Since the load was applied between the transverse supports, the measured deflections at the end of the test specimen are more affected by the support rotation than for Elastic Test E1-A. If the support beam rotated 0.05 degrees, the deflection measured at the ends of the test specimen would be 2.6 mm (0.10 in.) higher than the finite element model predictions.

TABLE 2.5: DEFLECTIONS UNDER MAXIMUM LOADING

Displacement Measurement Location (Figure 2.8)	Load Case 2 - Max Load 346 kN (78 kips)		
	Measured Deflections (mm)	Predicted Deflections (mm)	Test/Predicted
1	1.8	0.1	18.00
2	3.3	1.32	2.50
3	1.7	0.09	18.89
4	-1.8	-1.94	0.93
5	-14.1	-13.8	1.02
6	-1.7	-1.94	0.88
7	3	1.03	2.91
8	3.5	1.02	3.43
9	3.4	1.03	3.30
10	3.2	1.02	3.14

Table 2.6 is a comparison of the measured and predicted strains at maximum loading. The measured and predicted values are in reasonable agreement between at most of the locations where strain was measured. A reasonable difference between the measured and predicted strains is 35 $\mu\varepsilon$ or 6.9 MPa (1 ksi) using an assumed modulus of elasticity of 200 GPa (29000 ksi).

TABLE 2.6: STRAINS UNDER MAXIMUM LOADING

Strain Measurement Location (Figure 4.8)	Load Case 2 - Max Load 347 kN (78 kips)		
	Measured Strain x 10^{-6} (in/in)	Predicted Strain x 10^{-6} (in/in)	Difference (in/in)
1	13	12	1
2	21	-6	27
3	17	12	5
4	22	-6	28
5	-17	21	-38
6	-34	21	-55
7	-148	-111	-37
8	228	145	83
9	-143	-111	-32
10	221	145	76
11	24	18	6
12	-38	-23	-15
13	-84	-78	-6
14	145	126	19
15	636	786	-150
16	39	34	5
17	-33	-36	3
18	-390	-410	20
19	362	370	-8
20	-260	-271	11
21	354	311	43
22	-350	-320	-30
23	348	313	35
24	-244	-271	27
25	341	311	30
26	-352	-320	-32
27	314	313	1
28	79	76	3
29	-86	-78	-8
30	21	30	-9
31	-44	-40	-4
32	21	30	-9
33	-45	-40	-5
34	78	76	2
35	-86	-78	-8

Note: $\varepsilon_y = 1700 \times 10^{-6}$ (in/in)

Overall, the results from the experimental testing and finite element analysis are in good agreement with the exception of the deflections measured on the ends of the static panel test specimen; therefore, the assumptions used in modeling the static test panel are considered valid.

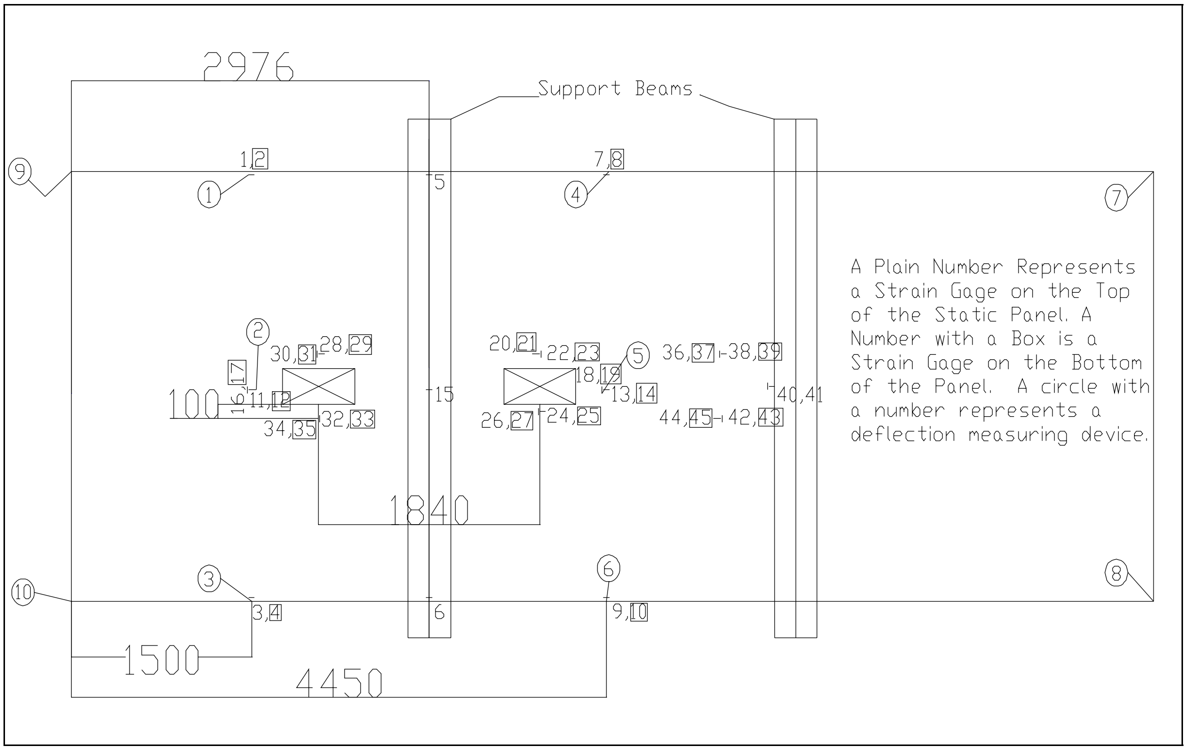
2.4 Plastic Test P1-A

2.4.1 Test Setup

For Plastic Test P1-A, the load positioning of Elastic Test EA-1 was used because it represented the worst case scenario of the two elastic tests. The two tires used as wheel loads were replaced with bearing pads because of the required load level. The two support beams remained in the same location as for the elastic tests. A single load frame was used.

2.4.2 Instrumentation

For test P1-A, forty-five strain gages were used to examine local plate behavior. The instrumentation layout is shown in Figure 2.12. A combination of dial gages and potentiometers were used to measure deflections of the sandwich plate bridge panel and the support beams.



A Plain Number Represents a Strain Gage on the Top of the Static Panel. A Number with a Box is a Strain Gage on the Bottom of the Panel. A circle with a number represents a deflection measuring device.

FIGURE 2.12: LOAD POSITION AND INSTRUMENTATION LAYOUT FOR TEST P1-A

2.4.3 Test Procedure

Using the analytical data from the finite element analysis, a theoretical load versus deflection line was plotted. The experimental load versus deflection line was plotted in real time and compared to the theoretical line at each load interval. The specimen was loaded in 44 kN (10 kips) increments and strain and deflection measurements were taken at every interval. All dial gage readings were recorded and then the next load step was applied. The maximum test load for static panel test P1-A was 1156 kN (260 kips). At this load the capacity of the structural loading frame was reached and testing ceased without failing the bridge deck panel.

2.4.4 Test Results

Figure 2.13 is a photograph taken directly underneath the stiffener of the spreader beam at maximum loading. The sandwich plate panel experienced some localized deflection on the top steel plate around the bearing pads. This was the only distortion visible to the human eye during the static panel testing series. Figure 2.14 is a photograph of the bottom steel plate; no bending was visible under maximum loading.

The maximum deflection was 30.8 mm (1.21 in) downward at Point 2. Figure 2.15 is a load versus deflection plot where dial gage and transducer measurements, as well as the predicted deflection from the finite element analysis are shown. The dial gage and transducer measurements are located in the same position and, therefore, should be in good agreement. Figure 2.15 shows both experimental measurements had a discrepancy of approximately 8.0% with the predicted deflection from the finite element analysis. The deflection values were not corrected to account for support beam deflection. The maximum measured deflection of the support beams was 0.76 mm (0.03 in.), and this support displacement is probably a reason for the discrepancy between the measured deflection and the predicted values.

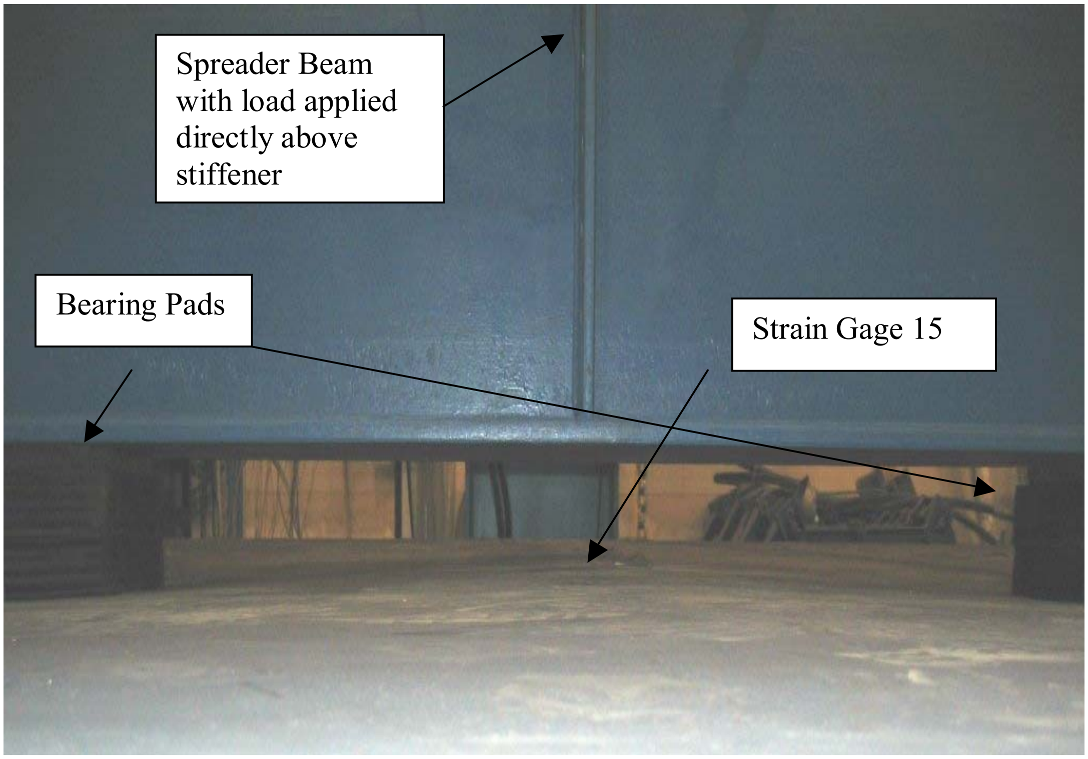


FIGURE 2.13: BENDING OF TOP PLATE UNDER MAXIMUM LOADING

FIGURE 2.14: BOTTOM STEEL PLATE AT LOCATION OF MAXIMUM DEFLECTION

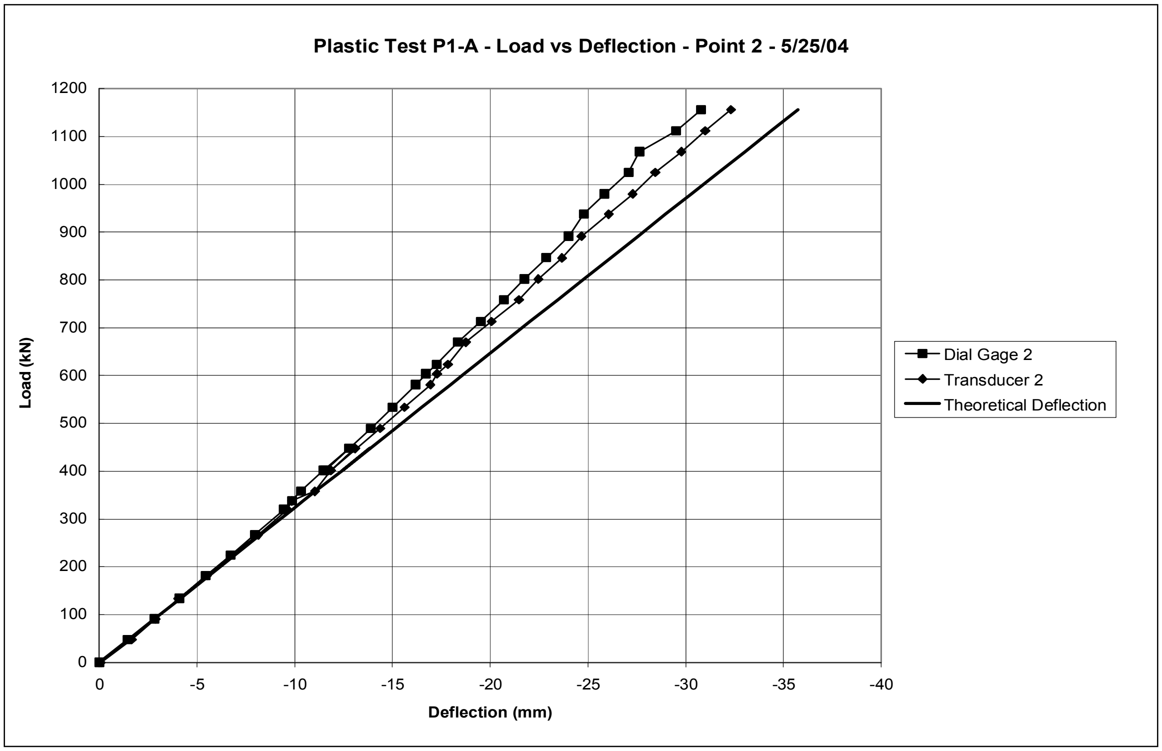


FIGURE 2.15: LOAD VERSUS DEFLECTION PLOT MEASURED AT POINT 2

Table 2.7 is the measured strain under the maximum loading for Plastic Test P1-A. The maximum strain was measured half way between the two load points on the top plate. Figure 2.16 is a plot of load versus strain at Strain Gage 15 where the maximum strain was recorded. The maximum measured strain was 5213 με, which is greater than an assumed yield strain of 1700 με. The yield strain of 1700 με is based on an assumed steel yield stress of 350 MPa (50 ksi), which is approximately 6 % greater than the plate material specified minimum yield stress of 330 MPa (48 ksi). For strain hardening to occur, the measured strain would need to be 10 to 15 times the yield strain. Since the measured strains are well below this limit, strain hardening did not occur. Although local yielding occurred at six locations near the load points (see Table 2.7), the overall behavior of the panel remained in the linear-elastic range.

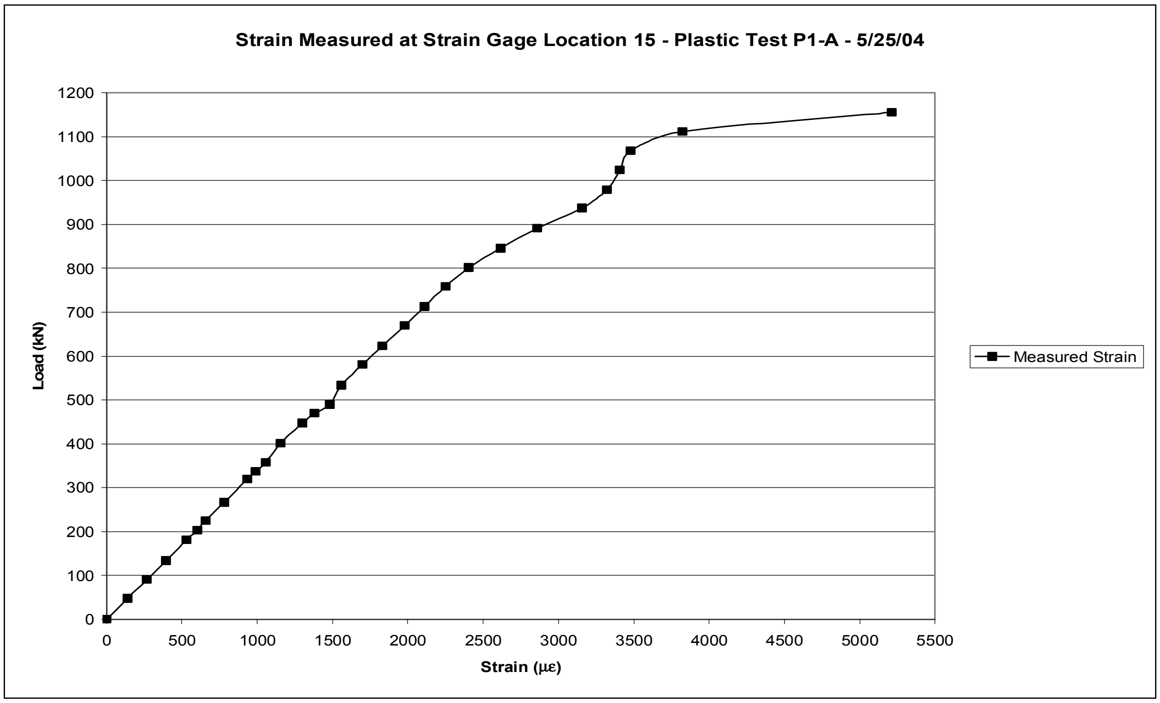


FIGURE 2.16: MEASURED STRAIN AT STRAIN GAGE 15

After the load was removed from the test specimen, permanent deformation was seen in the same six locations where strains greater than the yield strain was recorded. Figure 2.17 is a photograph of the test specimen after test P1-A.

FIGURE 2.17: SANDWICH PLATE BRIDGE DECK AFTER TEST P1-A

TABLE 2.7: MEASURED STRAINS AT MAXIMUM LOADING FOR TEST P1-A

Strain Measurement Location (Figure 2.10)	P1-A: Max Load of 1156 kN
	Measured Strain x 10^{-6} (in/in)
1	-150
2	-265
3	-185
4	-257
5	337
6	393
7	-242
8	-242
9	-194
10	-283
11	52
12	544
13	72
14	494
15	5213
16	-1109
17	914
18	-954
19	865
20	-1291
21	1799
22	-137
23	625
24	-1263
25	1868
26	-131
27	611
28	-1211
29	1665
30	-235
31	762
32	-182
33	784
34	-1180
35	1691
36	-367
37	148
38	227
39	-26
40	-148
41	475
42	-380
43	127
44	229
45	-22

Note: $\varepsilon_y = 1700 \times 10^{-6}$ (in/in)

2.4.5 Finite Element Analysis

The finite element analyses were conducted by Intelligent Engineering Ltd, Ottawa, Ontario, Canada. The modeling procedure for this test was the same as for the two previous elastic tests with the exception of the finite element analysis was inelastic.

2.4.6 Comparison of Experimental and Predicted Results

Table 2.8 is a comparison of the measured and predicted deflections. The table shows the measured and predicted deflection had good agreement at Point 2, which is the location of maximum deflection for Plastic Test P1-A. The deflections measured at Points 1 and 3, on the outside edge of the panel, under a load of 1156 kN (260 kips) were only 8 mm (0.31 in.). The load was applied in the center of the test specimen (see Figure 2.8); therefore, the deflection measured at Points 1 and 3, Points 4 and 6, Points 7 and 8, and Points 9 and 10 should have been similar. Table 2.8 shows reasonable agreement between measured and predicted deflections. Some of the deflections do not agree with the predicted deflection from the finite element analysis. A possible explanation for the discrepancy is that the support rotation was not measured during testing.

TABLE 2.8: DEFLECTIONS UNDER MAXIMUM LOADING

Displacement Measurement Location (Figure 4.12)	Plastic Test P1-A - Maximum Loading of 1156 kN		
	Measured Deflections (mm)	Predicted Deflections (mm)	Test/Predicted
1	-7.7	-8	1.0
2	-32.3	-35	0.9
3	-8.08	-8	1.0
4	-1.3	-0.18	7.2
5	-29	-25.9	1.1
6	-0.9	-0.18	5.0
7	2.2	0.23	9.6
8	2.9	0.23	12.6
9	-13	-15.3	0.8
10	-13.9	-15.3	0.9

Table 2.9 is a comparison of the measured and predicted strains at maximum loading. The measured and predicted deflections are in good agreement at most strain measurement locations. The measured strains have better agreement with the predicted strain due to the amount of load applied to the test specimen. Some of the strain predictions do not agree with the measured strains. A reasonable difference between the measured and predicted strains is 35 $\mu\varepsilon$ or 6.9 MPa (1 ksi) using an assumed modulus of elasticity of 200 GPa (29000 ksi).

Overall, the results from the experimental testing and finite element analysis are in good agreement with the exception of the measured deflections at the Points 7 and 8 at the far end of the test specimen; therefore, the assumptions used in modeling the static test panel are valid

TABLE 2.9: STRAINS UNDER MAXIMUM LOADING

Strain Measurement Location (Figure 4.12)	Load Case 1 - Load of 1156 kN		
	Measured Strain x 10^{-6} (in/in)	Predicted Strain x 10^{-6} (in/in)	Difference
1	-150	-141	-9
2	-265	-340	75
3	-185	-141	-44
4	-257	-340	83
5	337	411	-74
6	393	411	-18
7	-242	-145	-97
8	-242	-337	95
9	-194	-145	-49
10	-283	-337	54
11	52	-12	64
12	544	473	71
13	72	39	33
14	494	434	60
15	5213	7965	-2752
16	-1109	-1557	448
17	914	1747	-833
18	-954	-1536	582
19	865	1659	-794
20	-1291	-1238	-53
21	1799	1735	64
22	-137	-164	27
23	625	554	71
24	-1263	-1238	-25
25	1868	1735	133
26	-131	-164	33
27	611	554	57
28	-1211	-1250	39
29	1665	1741	-76
30	-235	-167	-68
31	762	573	189
32	-182	-167	-15
33	784	573	211
34	-1180	-1250	70
35	1691	1741	-50
36	-367	-333	-34
37	148	148	0
38	227	196	31
39	-26	-20	-6
40	-148	-206	58
41	475	305	170
42	-380	-333	-47
43	127	148	-21
44	229	196	33
45	-22	-20	-2

Note: $\varepsilon_y = 1700 \times 10^{-6}$ (in/in)

2.5 Summary of Static Panel Experimental Testing

The testing objectives for each series of testing were achieved. The local strains and deflections were investigated using two elastic load cases on a full scale sandwich plate bridge deck panel. The same test specimen was loaded to 1156 kN (260 kips) and still exhibited linear-elastic behavior. The local behavior of the static panel tests specimen is acceptable. The experiential results reasonably match the analytical results from the finite element analysis provided by Intelligent Engineering.

CHAPTER 3

LONGITUDINAL BRIDGE DECK JOINT - FATIGUE TESTS

3.1 General

The objective of fatigue testing was to determine the fatigue class of the longitudinal weld using fatigue testing to various cycle lengths, and to develop the S-N curve for the longitudinal weld joint. This was accomplished by conducting fatigue tests to three cycle lengths using an increasing strain (stress) range for each test. Each sandwich plate connection had a longitudinal weld group that consisted of a partial joint penetration groove weld between the cross stringers and four square butt welds that join the top and bottom steel plate to both sides of the cross stringers as shown in Figure 3.1. The partial joint penetration groove weld is a field weld used to develop composite action between bridge deck panels. The square butt welds are required to build the perimeter box which contains the elastomer core during injection.

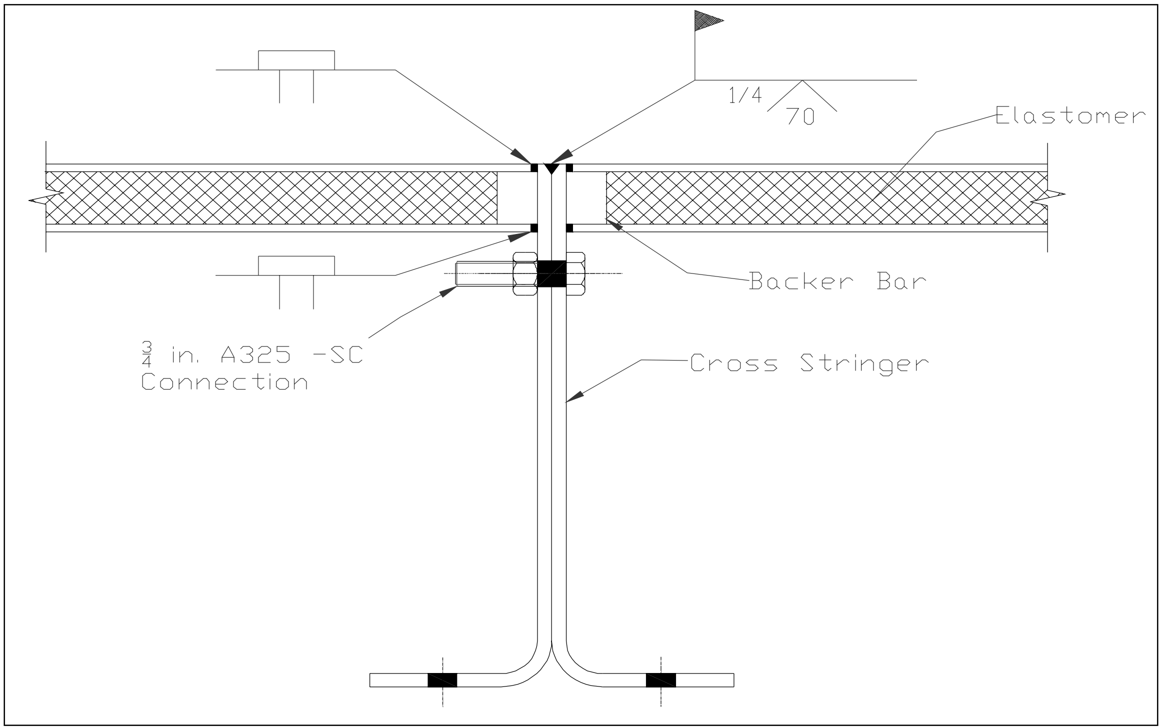


FIGURE 3.1: LONGITUDINAL WELD GROUP

A single sandwich plate panel measuring 2930 mm (115 in.) by 2500 mm (98.4 in.) was fabricated and then saw cut into five specimens. Each specimen consisted of a 500 mm (19.67 in) by 2100 mm (6.89 ft) sandwich plate 6.4-38.1-6.4 panel with the longitudinal joint at the center of the 2100 mm (6.89 ft) span. The depth of the partial joint penetration groove weld was 7.94 mm (5/16 in.) and the square butt welds were 6.35 mm (1/4 in.) deep. The test specimens were provided by Intelligent Engineering, Ottawa, Ontario, Canada, and they fabricated by the Canam Manac Group, Quebec, Canada. All steel was grade 300W.

The finite element analyses were conducted by Intelligent Engineering Ltd, Ottawa, Ontario, Canada. The analyses were conducted using the commercial software ANSYS. This section will describe the material properties, modeling techniques, and results.

The steel elements of the sandwich plate panel were given a modulus of elasticity of 200 GPa (29000 ksi), a Poisson's ratio of 0.287, a yield strain of 1500 $\mu\varepsilon$, and a yield stress of 300 MPa (43.5 ksi). The elastomeric core was given a modulus of elasticity of 750 MPa (109 ksi) and a Poisson's ratio of 0.36.

The steel plates and elastomeric core elements were modeled using HYPER 58 and SOLID 45 brick elements. The loads were applied to the deck using contact elements TARGE 170 and CONTA 173.

Figure 3.2 shows the finite element model used to predict the stresses for the groove weld. Figure 3.3 shows the results from the finite element analysis. The stress on the top of the groove weld was predicted to be 25 MPa (3.6 ksi) and the stress at the root of the weld was 22 MPa (3.2 ksi). The stress on the butt welds was predicted to be 50 MPa (7.3 ksi) using the tandem axel loadings from the *Canadian Highway Bridge Design Code* (2000a).

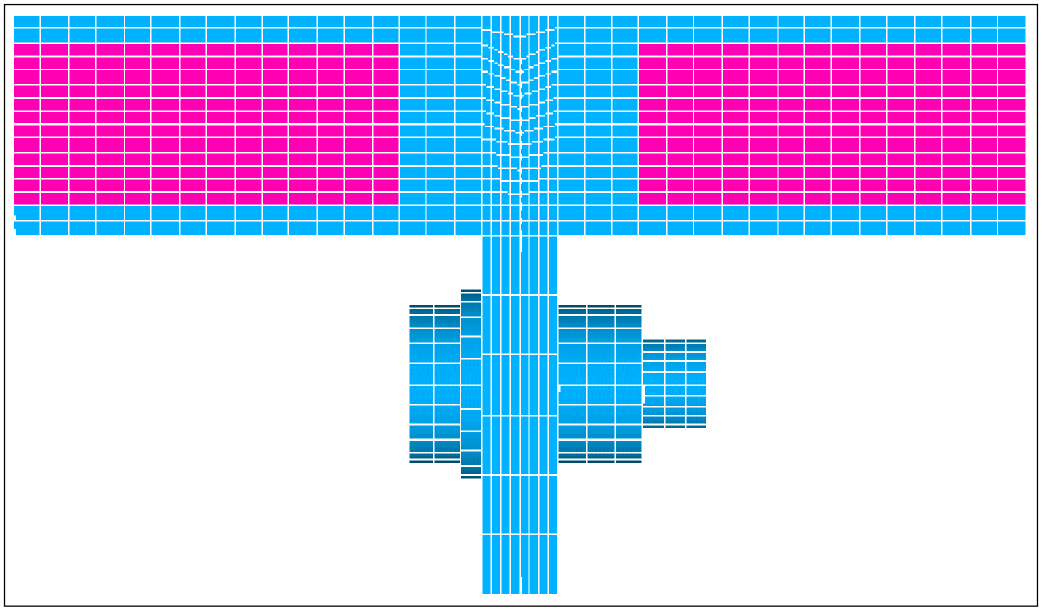


FIGURE 3.2: FINITE ELEMENT MODEL OF WELD GROUP

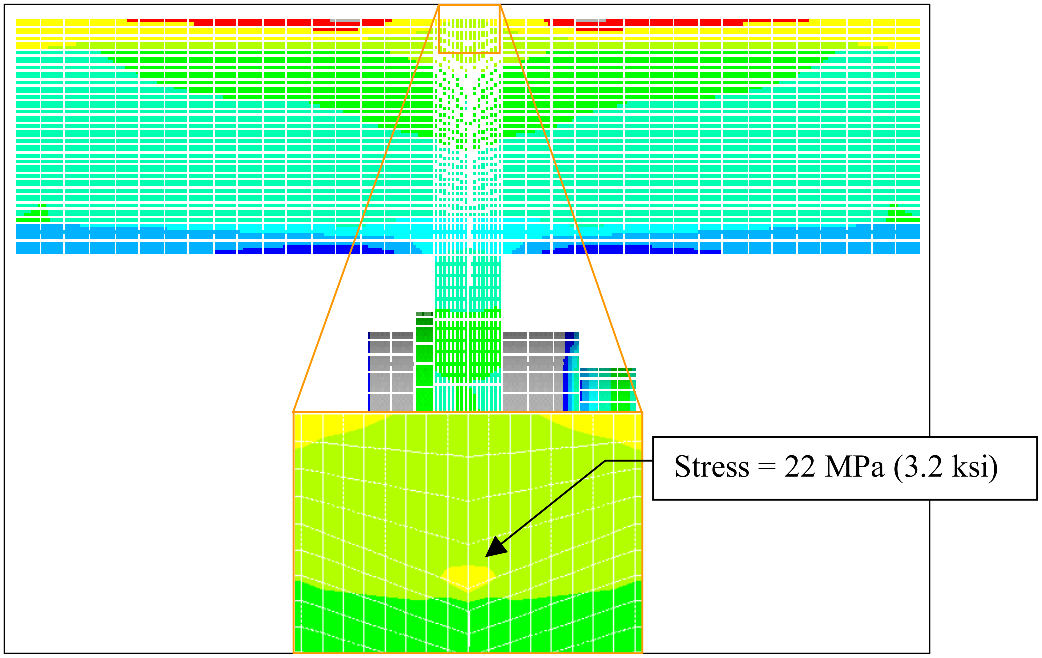


FIGURE 3.3: FINITE ELEMENT ANALYSIS STRESS CONTOURS

The finite element analyses predicted a strain of 125 με across the face of the groove weld for the two specimens fatigue tested to 10 million cycles. The average strain measured on the groove weld was 162 με. Load was applied until all four strain gages had the desired amount of strain on the weld surface. This caused a portion of the weld to be tested at a higher stress range than desired due to a non-uniform pattern of strain across the weld surface, which caused the poor agreement between the measured and predicted strains. Finite element models were not created for the remaining two fatigue tests.

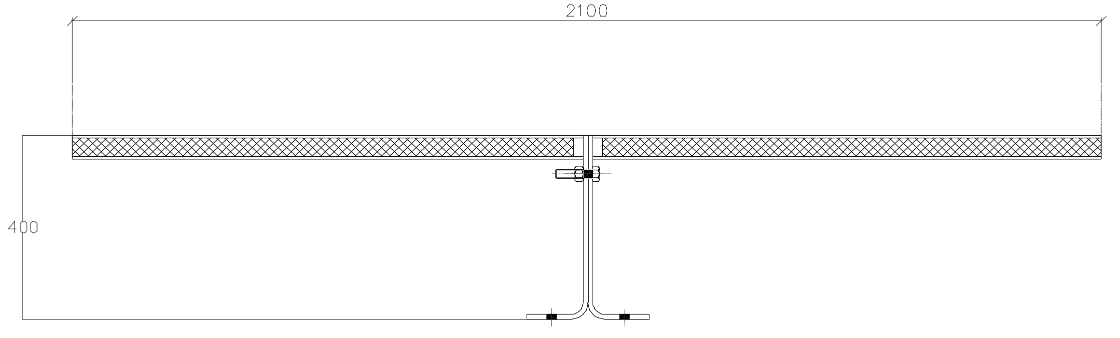


FIGURE 3.4: SPECIMEN TESTED TO 10 MILLION CYCLES

3.2 Connections Tested to 10 Million Cycles

3.2.1 Test Setup

Two sandwich plate panel connections, as shown in Figure 3.4, were tested simultaneously to 10 million cycles. A spreader beam carried the load from the actuator to the inverted SPS panels. The panels rested on rollers that were placed on top of support beams, which sat on the reaction floor. Each connection was loaded in tension using a Material Testing System (MTS) cyclic testing actuator. Figure 3.5 is a photograph of the test setup.

3.2.2 Instrumentation

Two strain gages were applied to the groove welds of the two fatigue specimens. Each strain gage was located 100 mm (3.94 in.) from the free edge of the sandwich plate connection. A dial gage was used to measure deflections during periodic static testing. A PC based data acquisition system was used to view real time strains during cyclic loading and to record strain data during the static stiffness tests. The MTS actuator included a load cell and an LVDT to measure load and deflection, respectively. These measurements were viewed using a MTS 458.10 Micro console.

FIGURE 3.5: TEST SETUP FOR CONNECTIONS TESTED TO 10 MILLION CYCLES

3.2.3 Test Procedure

To establish the stress range desired across the weld surface, an initial seating load was applied to the connection and the strains were recorded. For the 10 million cycle fatigue testing, a stress range of 25 MPa (3.6 ksi) equivalent to a strain of 120 $\mu\varepsilon$ using an assumed modulus of elasticity of 200 GPa (29,000 ksi) was desired on the groove weld. Load was applied until all four strain gages had a reading of 120 $\mu\varepsilon$. This caused a portion of the weld to be tested at a higher stress range than desired due to a non-uniform pattern of strain across the weld surface. The average strain measured on the groove weld was 162 $\mu\varepsilon$, which is equivalent to 32.2 MPa (4.7 ksi) using the above modulus of elasticity. The maximum strain measured on the groove weld was 218 $\mu\varepsilon$, which is equivalent to 43.6 MPa (6.3 ksi).

After seating the test specimens, half of the maximum load was applied to the specimens to force them to the "set point." The sinusoidal testing program was then started and the span of the sine wave was adjusted so that the specimens cycled from the maximum stress range to zero at 4 Hz. A PC based data acquisition system was used to view the cyclic loading in real time.

Stiffness tests were conducted in accordance with a logarithmic scale. A measurement was taken after completing 1, 10, 100, 1,000, 10,000, 100,000, and then every 100,000 cycles until 10 million cycles were completed. After the set number of cycles was completed, all load was removed from the specimens. A dial gage was placed in the center of each specimen and set to zero. All strain measurements were set to zero in the data acquisition system. Load was applied using the MTS actuator in 1112 N (250 lbs.) intervals. The dial gage readings and the strain measurements were recorded at every load step. The maximum load applied was 15.6 kN (3.5 kips). This generated a minimum strain of 120 $\mu\varepsilon$ for all four strain gages. After the first 100,000 cycles, a stiffness test was conducted approximately every seven hours and the results are discussed in the following section.

After 10 million cycles, each panel was loaded statically to failure to determine the effect of fatigue loading on the weld group. After seating the panel, load was applied in 5 kN (1.12 kips) increments until failure occurred. The strains on the groove weld were recorded at every load step, and a potentiometer was used to measure deflection in the center of the panel. The experimental load versus deflection line was plotted in real time and compared to a theoretical line at each load interval.

In both specimens the square butt weld failed before the groove weld. Specimens 1 and 2 failed at 94 kN (21.1 kips) and 111 kN (25 kips), respectively. The nominal strength of the weld is 300 MPa (43.5 ksi), and the loads applied to cause failure created a stress of 322 MPa (46.7 ksi). This implies the effect of fatigue testing the weld group to 10 million cycles had no effect on the strength of the weld group.

3.2.4 Test Results

The two sandwich plate connections tested to 10 million cycles showed little to no loss in stiffness over the course of the fatigue testing. Figure 3.6 is a logarithmic plot and Figure 3.7 is a linear plot of the stress variation versus number of cycles for strain gages 1 through 4. The figure shows the stress range remains nearly constant over the entire 10 million cycles. At 2.1 million, strain gages 3 and 4 on specimen 2 were replaced because the glue between the strain gages and groove weld failed. After grinding off and replacing the old strain gages, testing was resumed and a spike in measured strain occurred. The increase in strain can be attributed to the new strain gages being closer to the root of the weld due to the grinding or the strain gages not being applied in the exact same location as they were previously.

Figure 3.8 is a photograph of specimen 2 during the static loading to failure, taken after the square butt weld had already failed. In both specimens the square butt weld failed before the groove weld. Specimens 1 and 2 failed at 94 kN (21.1 kips) and 111 kN (25 kips), respectively. The nominal strength of the weld is 300 MPa (43.5 ksi). The loads applied to cause failure created a stress of 322 MPa (46.7 ksi), which implies that testing had no effect on the ultimate strength of the weld group. The maximum applied stress of 322 MPa (46.7 ksi) was determined from statics and fundamental mechanics of materials. Also, loading the panels to failure brought about the realization that the square butt weld is the critical weld in the SPS panel weld group.

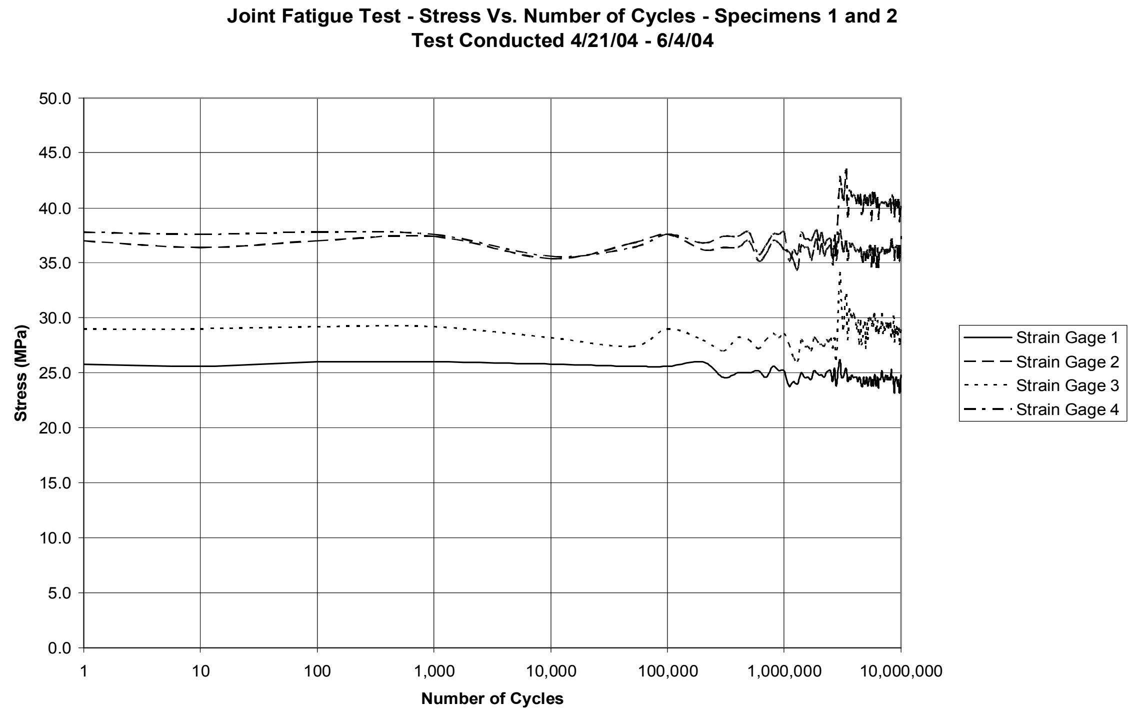


FIGURE 3.6: STRESS VERSUS NUMBER OF CYCYES – LOG SCALE

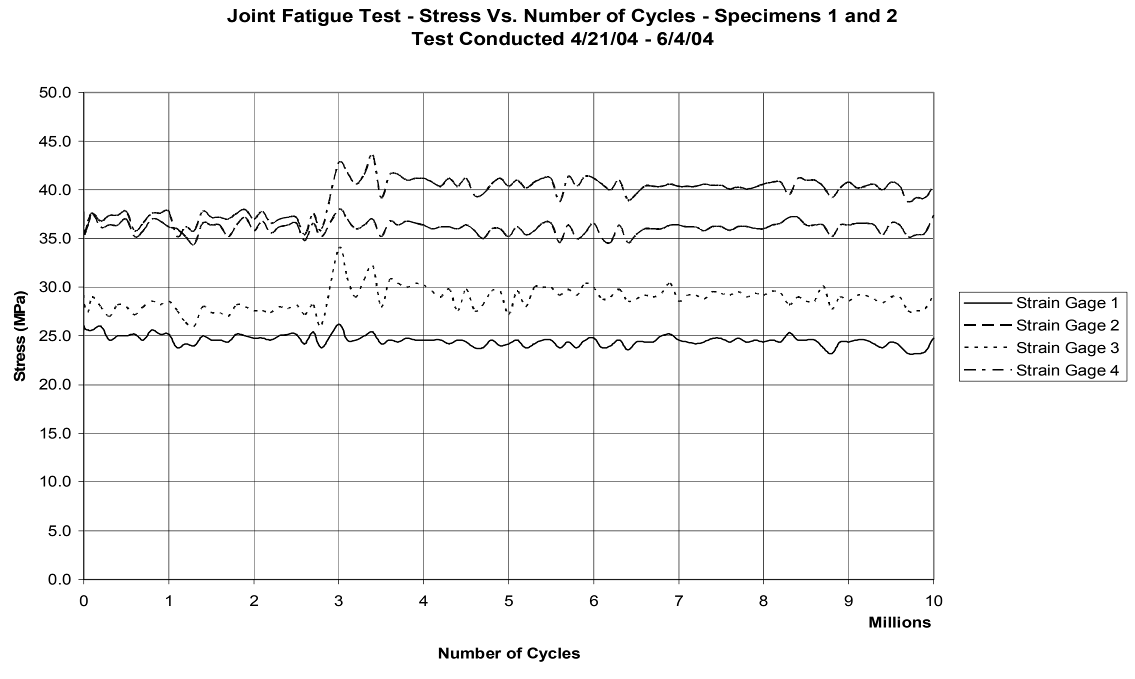


FIGURE 3.7: STRESS VERSUS NUMBER OF CYCLES – LINEAR SCALE

FIGURE 3.8: SPECIMEN 2 AFTER FAILURE

3.3 Connection tested to 5 Million Cycles

3.3.1 Test Setup

Only one sandwich plate connection was fatigue tested to 5 million cycles. The connection was inverted and had the same dimensions as the previous tests. The test setup is shown in Figure 3.9. For this test series, the spreader beam was removed and replaced with a load block. The load block was fabricated to transfer the load from the MTS actuator to the sandwich plate connection. The load block consisted of 4 – 25.4 mm (1 in.) thick A36 steel plates welded together, and was used to fill the gap between the specimen and the actuator. Steel angles were used to keep the MTS actuator head from rotating. Two angles were clamped to the test specimen to stabilize the actuator head as shown in Figure 3.10. The angles were greased to minimize friction between the MTS actuator and the angles.

FIGURE 3.9: 5 MILLION CYCLES FATIGUE TEST SETUP

FIGURE 3.10: LOAD BLOCK AND STABILIZING ANGLES

3.3.2 Instrumentation

The instrumentation for this test varied slightly from the instrumentation used in the previous fatigue testing. Instrumentation details are illustrated in Figure 3.11. A strain gage was attached to each side of the 6.35 mm (1/4 in.) butt weld in the center of the sandwich plate connection. Additional strain gages were added to examine the effects of fatigue loading on the butt welds because the previous load tests to failure showed that the butt weld is the critical detail in the weld group. A fifth strain gage was placed 12 mm (1/2 in.) from strain gage one. The extra strain gage was installed to verify the measured strains at the gage one location. A dial gage was used during static testing to measure deflection in the center of the specimen.

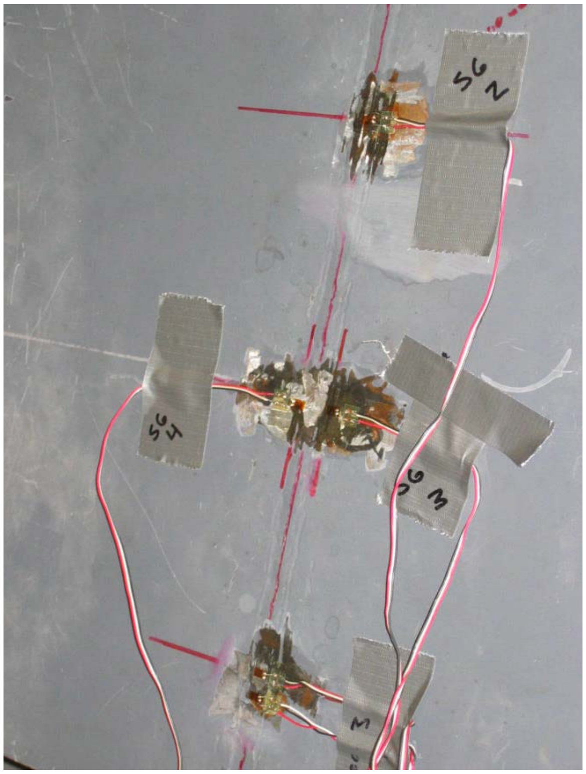


FIGURE 3.11: INSTRUMENTATION LAYOUT FOR CONNECTION TESTED TO 5 MILLION CYCLES

3.3.3 Test Procedure

The testing procedure for the 5 million cycle test followed closely to the testing procedure for the 10 million cycle testing. For this test, a stress range of 42 MPa (6.1 ksi) equivalent to a strain of 174 με using an assumed modulus of elasticity of 200 GPa (29,000 ksi) was desired on the groove weld. Load was applied until all five strain gages had a reading of 174 με. This caused a portion of the weld to be tested at a higher stress range than desired due to a non-uniform pattern of strain across the weld group. The average strain measured on the weld group was 248 με, which is equivalent to 50 MPa (7.2 ksi). This stress is the average of all five strain measurements recorded over 5 million cycles. The maximum strain measured on the groove weld was 363 $\mu\varepsilon$, which is equivalent to 72.6 MPa (10.5 ksi).

The same sinusoidal testing program was used for this test as in previous testing. This fatigue test was also conducted at 4 Hertz. Again stiffness tests were conducted at intervals consistent with a logarithmic scale, and then at every 100,000 cycles. The load was applied in 1112 N (250 lbs) increments until a strain equal to 174 $\mu\varepsilon$ was developed across the weld group. The maximum applied load was 14.5 kN (3.25 kips).

A drop in strain was observed on the butt weld after 2.1 million cycles had been completed. This indicates some micro cracking could have occurred, but no crack was visible. Testing continued to 5 million cycles with the stiffness of the butt weld continuing to decrease. The specimen was not loaded statically to failure.

3.3.4 Test Results

Figure 3.12 is a logarithmic plot and Figure 3.13 is a linear plot of stress versus number of cycles. From Figure 3.12, strain gages 1 and 5 experienced a higher level of strain during the fatigue testing than strain gage 2. Strain gage 5 was bonded to the groove weld 12.7 mm (1/2 in.) below strain gage 1 to determine if strain gage 1 was working correctly. The inconsistency in the strain data could be due to a hidden eccentricity in the test setup or the test specimen being warped. The inconsistency in the measured strains was attempted to be solved by adding additional strain instrumentation, using a load block to transfer load over the entire cross stringer area, replacing the roller supports, and by checking the position of the test specimen in the testing set up to ensure that the load was applied symmetrically. None of the attempts solved the problem. Also shown in Figure 3.12, the test connection experienced stress on the average of 69.9 MPa (10.1 ksi) near strain gage 1 and 5 with no little change in strain over 5 million cycles. This indicates the weld is of good quality.

Figure 3.13 shows strain gages 3 and 4 on the butt weld have good agreement throughout the fatigue test. Around 2.1 million cycles strain gage 4 experienced a drop in stress of 11.5% and never recovered. This indicates some micro cracking could have occurred, but no visible crack had formed. Dye penetration testing was not conducted to verify this result.

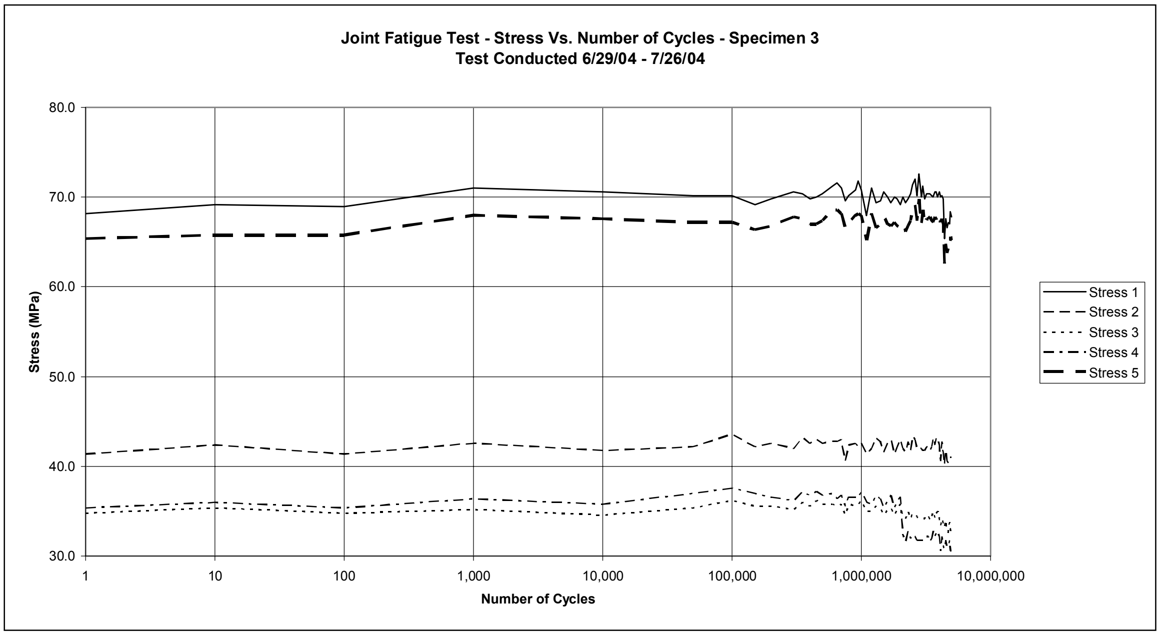


FIGURE 3.12: STRESS VERSUS NUMBER OF CYCLES – LOGARITHMIC SCALE

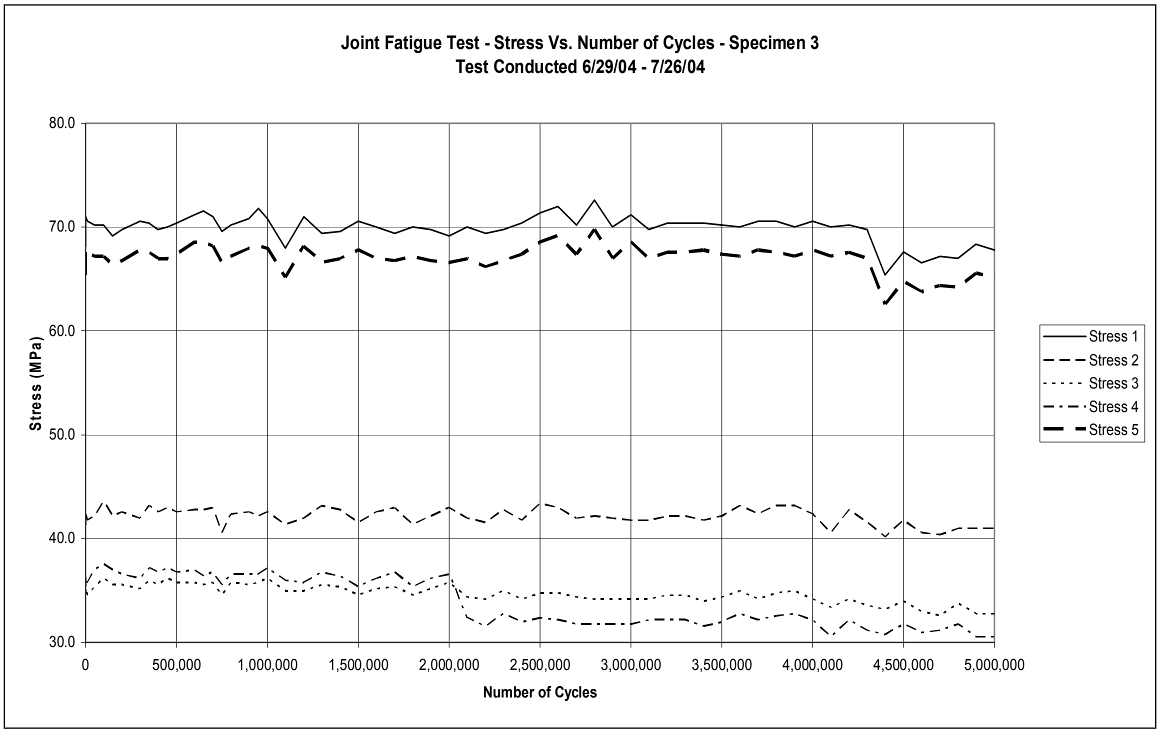


FIGURE 3.13: STRESS VERSUS NUMBER OF CYCLES – LINEAR SCALE

3.4 Connection Tested to 100,000 cycles

3.4.1 Test Setup

The final fatigue test conducted on the sandwich plate connection was run to 100,000 cycles. The test setup used was the same as the fatigue test conducted to 5 million cycles. Only one connection was tested, and the load block was used again.

3.4.2 Instrumentation

The instrumentation details are illustrated in Figure 3.14. Six strain gages were used to determine the weld group behavior. Two strain gages were placed 100 mm (3.94 in.) from the free edge of each side of the specimen on the groove weld. Two strain gages were placed on the butt weld in the center of the specimen, and two additional strain gages were placed 175 mm (6.89 in.) from the free edge of each side of the specimen on the groove weld. A dial gage was used during static testing to measure deflection in the center of the specimen.

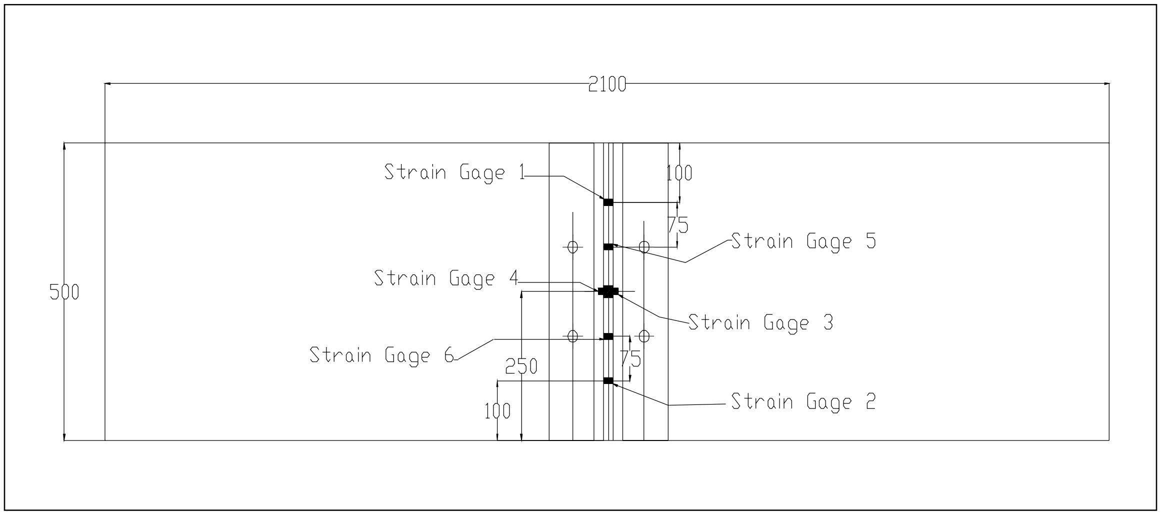


FIGURE 3.14: STRAIN GAGE LAYOUT FOR THE CONNECTION TESTED TO 100,000 CYCLES

3.4.3 Test Procedure

The testing procedure for the 100,000 cycle fatigue test was similar to the previous two fatigue tests. A stress range of 100 MPa (14.5 ksi) equivalent to a strain of 505 $\mu\varepsilon$ using an assumed modulus of elasticity of 200 GPa (29,000 ksi) was desired on the weld group. Load was applied until all six strain gages had a minimum reading of 505 $\mu\varepsilon$. This caused a portion of the weld to be tested at a higher stress range than desired due to a non-uniform pattern of strain across the weld group. The average strain measured on the weld group was 690 $\mu\varepsilon$, which is equivalent to 137.7 MPa (20 ksi) using the modulus of elasticity above. The 137.7 MPa (20 ksi) is an average of all six strain measurements recorded over 100,000 cycles. The maximum strain measured on the groove weld was 1506 $\mu\varepsilon$, which is equivalent to 301MPa (43.7 ksi).

The same sinusoidal testing program was used for this test as in previous testing. This fatigue test was conducted at 2 Hertz. Testing was run at a slower frequency due to the large amount of load required to reach the desired stress range. A stiffness test was conducted after 1, 10, 100, 1,000, 10,000, 50,000, and 100,000 cycles were completed. The panel was loaded in 4.45 kN (1 kip) intervals until a maximum load of 57.8 kN (13 kips) was reached.

A cracked developed on the butt weld between 50,000 and 100,000 cycles. The crack extended from the edge of the panel near strain gage one and terminated in the center of the test specimen. The crack in the weld was considered a failure due to fatigue loading.

3.4.4 Test Results

Specimen 4 was cycled at the highest stress range of the sandwich plate connections in the testing series. A crack became visible on the square butt weld at the completion of 100,000 cycles. Figure 3.15 is a logarithmic plot of stress variation versus number of cycles. A crack formed directly underneath strain gage 4 on the butt weld between 50,000 and 100,000 cycles. The highest strain was recorded on strain gage 1. The stress in the groove weld near strain gage 1 increased until 1,000 cycles were completed. Then, the stress dropped by 32.7% after 10,000 cycles had been completed. Although the specimen experienced a loss in strain, no visible crack had formed and the cyclic loading continued until 100,000 cycles had been completed. After the cracked formed on the butt weld, the static loading was redistributed causing the groove weld near strain gage 6 to yield during the final stiffness test. Strain gage 5 showed a drop in strain after 50,000 cycles (see Figure 3.15). This indicates the crack began at the edge of the panel on the butt weld and moved past strain gage 1 and 5, and then underneath strain gage 4 until terminating around the center of the test specimen. Figure 3.16 is a photograph of the crack in the butt weld taken after the specimen had been removed from the test setup.

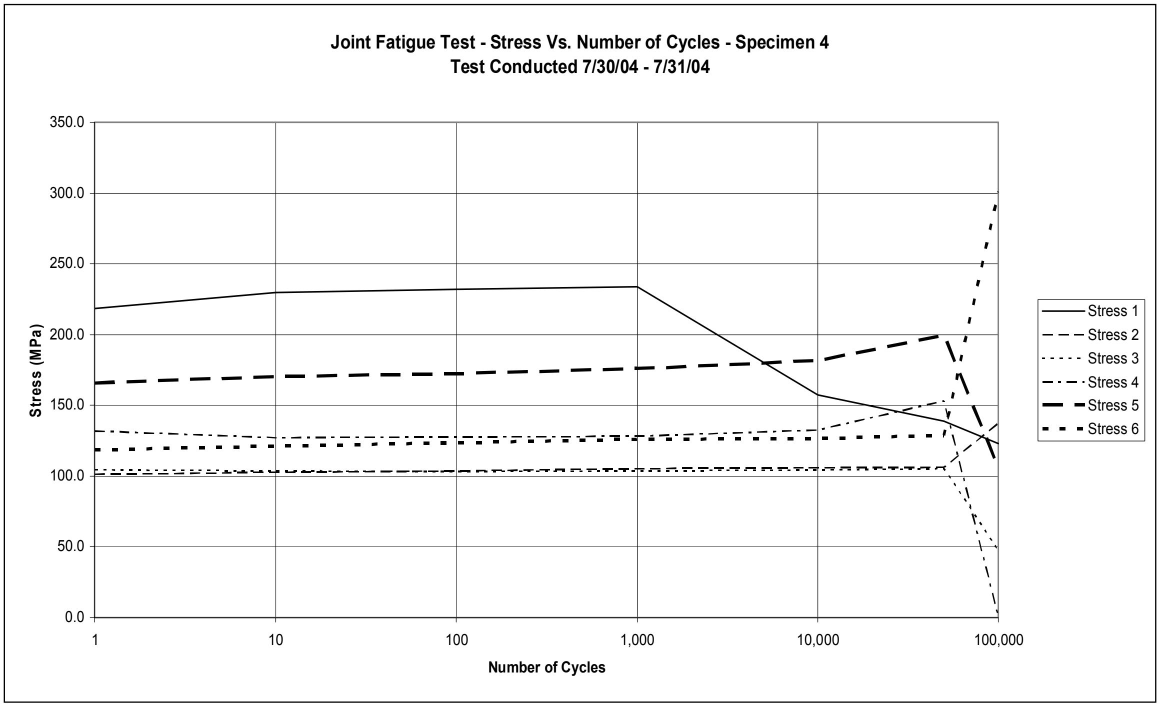


FIGURE 3.15: STRESS VERSUS NUMBER OF CYCLES – LOGARITHMIC SCALE

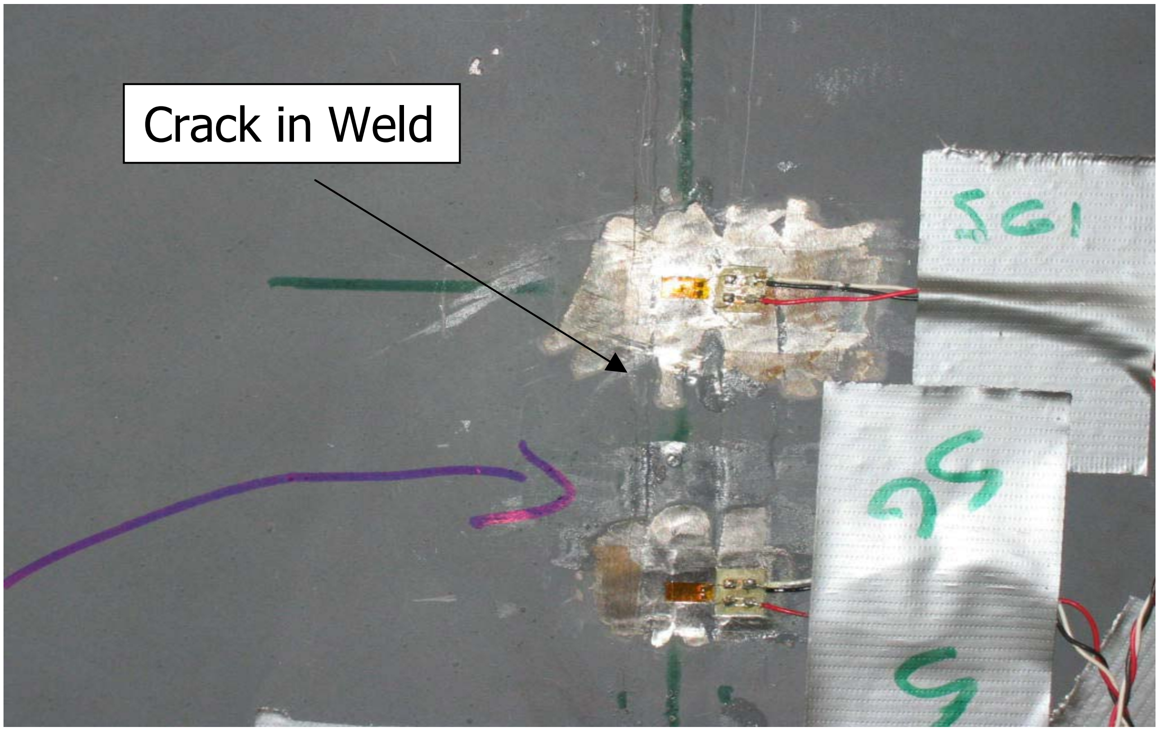


FIGURE 3.16: CRACK IN SQUARE BUTT WELD AFTER 100,000 CYCLES

3.5 Discussion of Results

Both the groove weld and each butt weld are considered to be at least fatigue category E based on the written description of welds in the *AASHTO LRFD Bridge Design Specification* (1998). Figure 3.17 is the standard S-N curve from the Canadian Highway Bridge Design Code (2000a). The locations of the measured stress from all three series of fatigue tests are plotted as filled in circles. For the fatigue test conducted to 10 million cycles, the stress range indicates the weld is at least a fatigue category E, and the weld will have an infinite life at a stress range of 32 MPa (4.6 ksi).

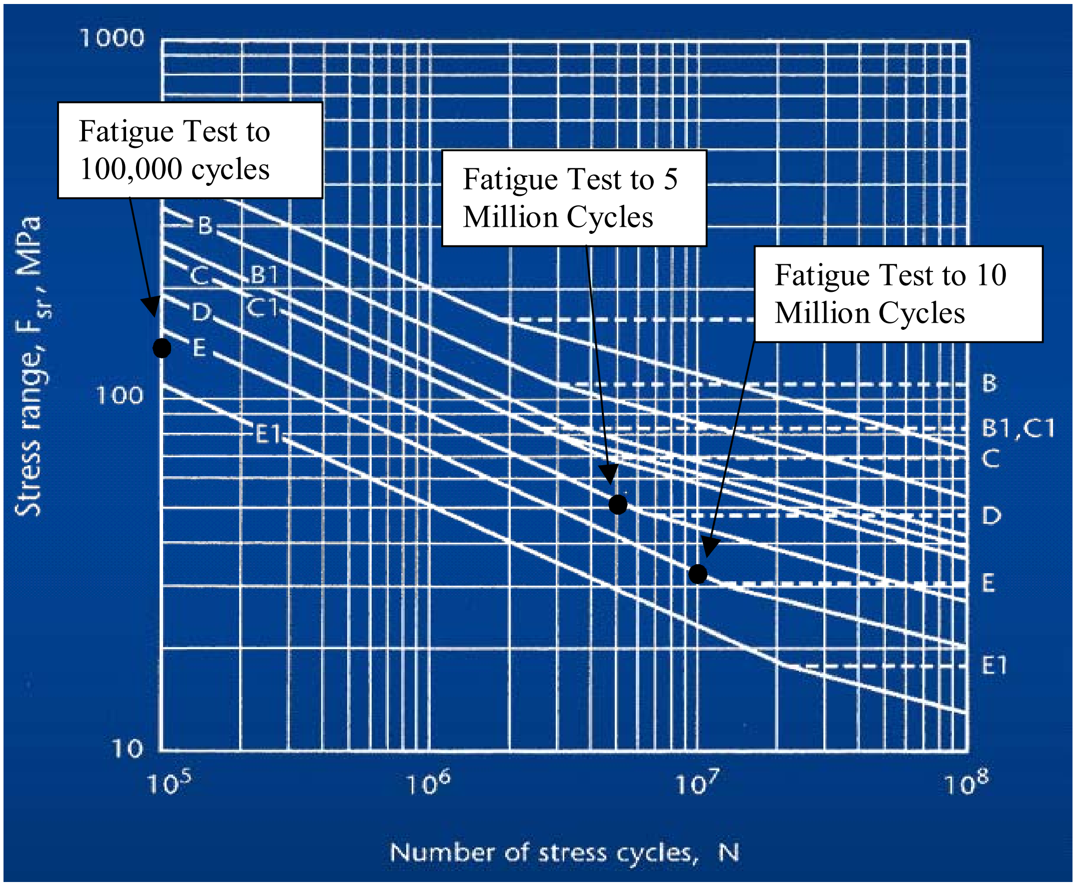


FIGURE 3.17: EXPERIMENTAL STRESS RESULTS PLOTTED ON A TYPICAL S-N CURVE

3.6 Summary of Longitudinal Joint – Fatigue Testing

All the welds in the longitudinal weld group can be classified as at least a fatigue detail E. The stresses measured on the welds after 10 million cycles are less than the corresponding stresses from the AASHTO (1998) standard S-N Curve for fatigue detail E indicating the weld is of good quality. The square butt weld controls the ultimate strength of the weld group because the square butt weld has a smaller effective throat. The grove welds are a field weld in a typical bridge erection. However, the groove welds tested in the Joint Fatigue Tests were made in the Canam Manac Group shop in Quebec, Canada. A groove weld placed in the field might behave differently due to the uncontrollable field conditions.

CHAPTER 4

HALF SCALE SIMPLE SPAN BRIDGE TESTS

4.1 General

The continuous deck testing had three objectives. The first objective was to determine if the sandwich plate bridge deck acts compositely with the supporting girders in both the positive and the negative moment regions. The second objective was to determine the effect of shear lag on the deck. Third, the effect of load on the longitudinal weld group and the torsion properties of the bridge deck were investigated. To accomplish these objectives four elastic tests C1, C2, C3, and C4 were conducted on a half scale sandwich plate simple span bridge.

Figure 4.1 is the cross section of the half scale simple span bridge. The continuous deck specimen was eight half-scale sandwich plate bridge deck panels bolted to two steel girders spanning 12192 mm (40 ft.). Each panel consisted of a top and bottom steel plate nominally 3.2 mm (1/8 in.) thick with an elastomer core 19.1mm (3/4 in.) thick. Each deck panel measured 1524 mm (5 ft) by 4500 mm (14.76 ft). The sandwich was enclosed with steel perimeter bars and cross stringers. Each cross stringers was a bent steel plate nominally 4.8 x 200 x 4500 mm (3/16 x 7.87 x 177.2 in.)

Two girders were located 1475 mm (4.84 ft) from both edges of the panels leaving a distance of 1550 mm (5.09 ft) between girders. Both steel girders were built up members that consisted of three steel plates. The top flange was 15.9 mm (5/8 in.) thick, and the bottom flange was 25.4 mm (1 in.) thick. The flanges were connected to the 6.4 mm (1/4 in.) thick web using fillet welds on both sides of the web. The web was 544 mm (21.42 in.) deep. A diaphragm was used to connect the steel girders together every 3048 mm (120 in.). The diaphragm consisted of steel angles nominally 51 x 51 x 7.9 mm (2 x 2 x 5/16 in.) An end diaphragm is shown in Figure 4.2.

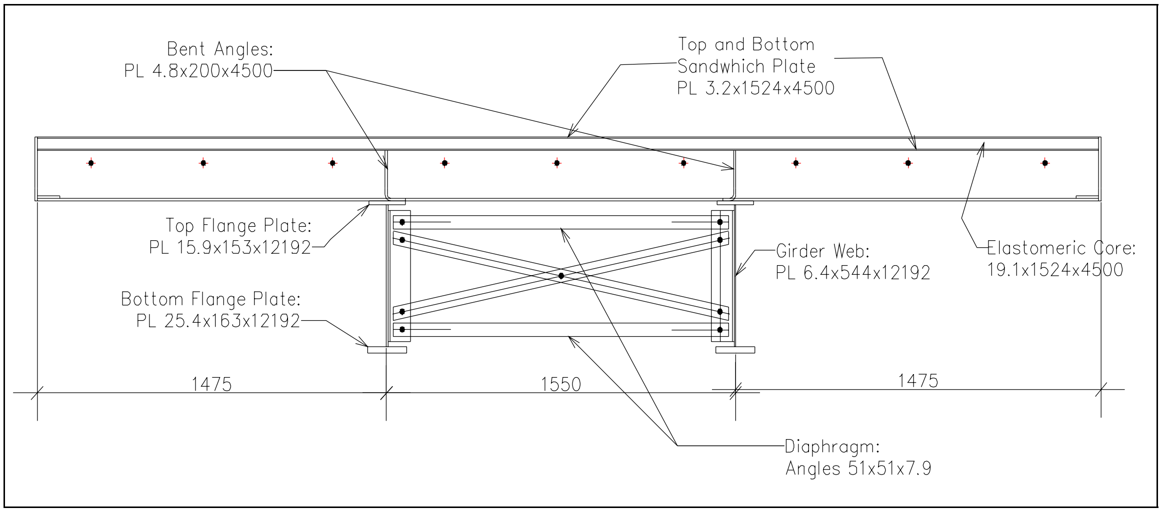


FIGURE 4.1: CROSS SECTION OF HALF SCALE SIMPLE SPAN BRIDGE

The test specimen components were provided by Intelligent Engineering, Ottawa, Ontario, Canada, and were fabricated by the Canam Manac Group, Quebec, Canada. All steel was grade 350W. Figure 4.2 shows an overview of a typical test setup.

FIGURE 4.2: HALF SCALE CONTINUOUS BRIDGE DECK TEST SPECIMEN

The panels were bolted together using nine slip critical connections (see Figure 4.1). Each panel was also bolted to each girder using nine slip critical connections. All bolts were M20 (3/4 in.) diameter A325-SC. The bolts were tightened using the turn of the nut method. All connections were made snug-tight using a spud wrench and the full effort of the author. The bolt and nut were marked with a paint marker and allowed to dry. The head of each bolt was restrained with a spud wrench while the nut was turned another ½ turn. The connection between the panels was pretensioned first, starting in the middle span and then alternating to the exterior spans to control relaxation. After the bolts connecting the panels together were fully pretensioned, the bolts connecting the deck to the girder were full pretensioned. Starting with Panel 8, the bolts were tightened on Girder 2 then Girder 1 (see Figure 4.3 for locations). After pretensioning all the bolts on a given panel the previous panel was checked for bolt relaxation. This procedure was continued until all the bolts had been pretensioned.

After all the bolts were pretensioned, a 4.76 mm (3/16 in) groove weld was placed between the panels. The welding was performed by Commercial Steel, Roanoke, Virginia. The welding was done manually using an E70 electrode and 4 mm (5/32 in.) rods. All rods were placed in a rod oven before being used. A 406 mm (16 in.) weld was placed at the end of every joint on both sides of the test specimen before any other welding was done. These welds were then ground down and the groove was filled with weld again. This was done to close any gaps in the center of the joint and to ensure a good weld had been placed at the edge of each joint. Weld was then placed in 304 mm (12 in.) increments beginning on the joint between Panels 1 and 2 and Panels 7 and 8 on each side of the joint. The welders moved to the next joint, working toward the center of the test specimen, and placed the same 304 mm (12 in.) length of weld on each side of the joint. This was done to redistribute the heat from welding across the entire test specimen. This procedure was continued until each joint had been fully welded.

4.2 Load Case C1

4.2.1 Test Setup

The test specimen for Load Case C1 had a span of 12192 mm (40 ft) between simple supports. Figure 4.3 shows the ten point loading pattern. The load points were aligned with the steel girders to determine if the sandwich plate deck acted compositely in the positive moment region. Three steel frames were used to apply load to the test specimen. Load cells were used to measure the load applied by the hydraulic rams. A steel plate resting on top of a bearing pad was used at each load block. Two different bearing pad sizes were used. The bearing pads used to apply load from Frame 3 measured 229 mm (9.02 in.) by 457 mm (18 in), and from Frames 1 and 2 measured 229 mm (9.02 in.) by 368 mm (14.5 in.).

Two spreader frames and a spreader beam were used to transfer the load from the hydraulic rams to the bridge deck. The sandwich plate bridge deck panels and steel girders rested on four roller supports. The rollers rested on top of support beams that were in turn bolted to the reaction floor. The bolts used to secure the support beams to the reaction floor were snug tight.

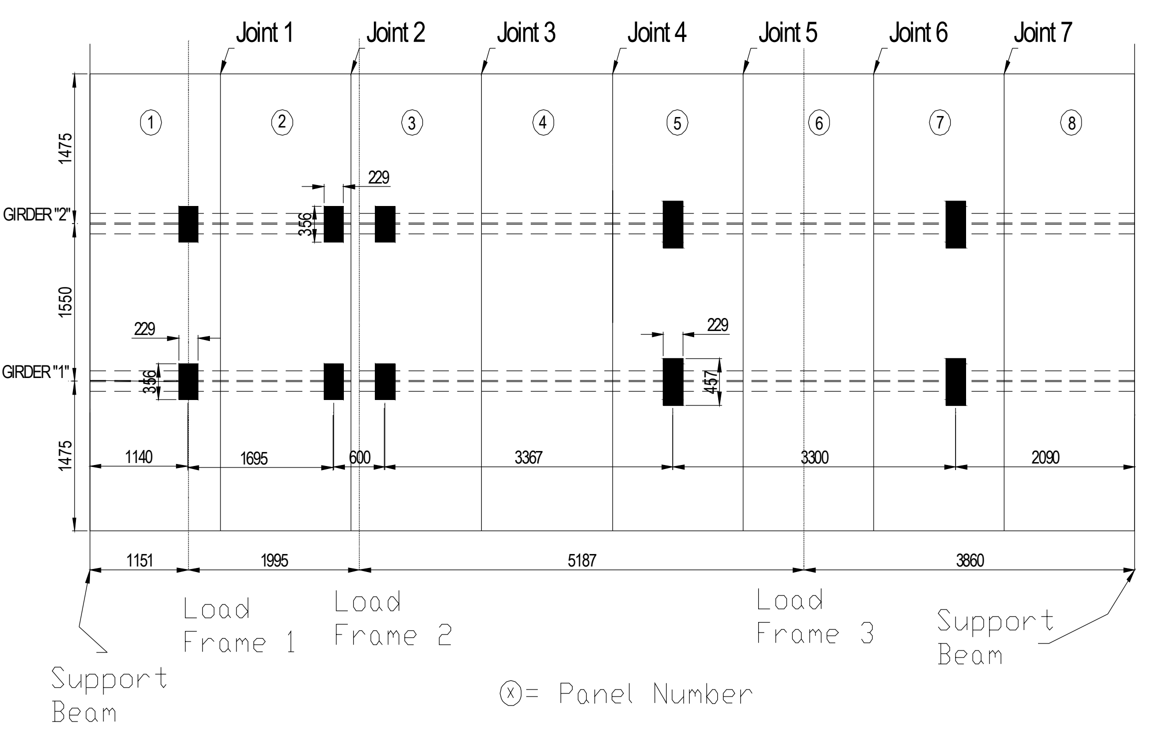


FIGURE 4.3: LOAD CASE C1 – LOADING PATTERN

4.2.2 Instrumentation

A total of 50 strain gages and 14 string type potentiometers were used to study the local behavior of the continuous sandwich plate bridge deck. Strain gages were placed throughout the depth of the sandwich plate bridge deck and steel girders to determine if composite action was being developed. Figure 4.4 shows the instrumentation layout for Load Case C1, and Figure 4.5 shows strain gages versus depth of the test specimen. A PC-based data acquisition system was used to collect data from the strain gages and the string-type potentiometers. For Load Case C1, three hydraulic rams were used to apply load. The load from each hydraulic ram was measured using a compression load cell. Each load cell was calibrated prior to testing using a SATEC Universal Testing Machine.

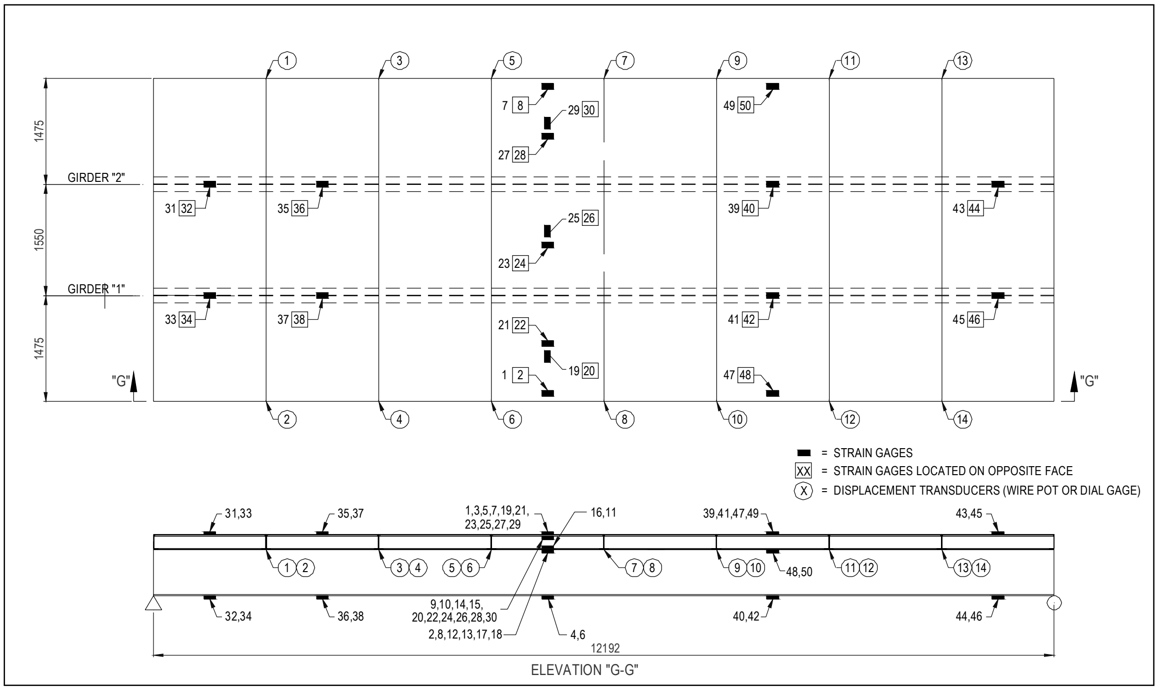


FIGURE 4.4: INSTRUMENTATION LAYOUT FOR LOAD CASE C1

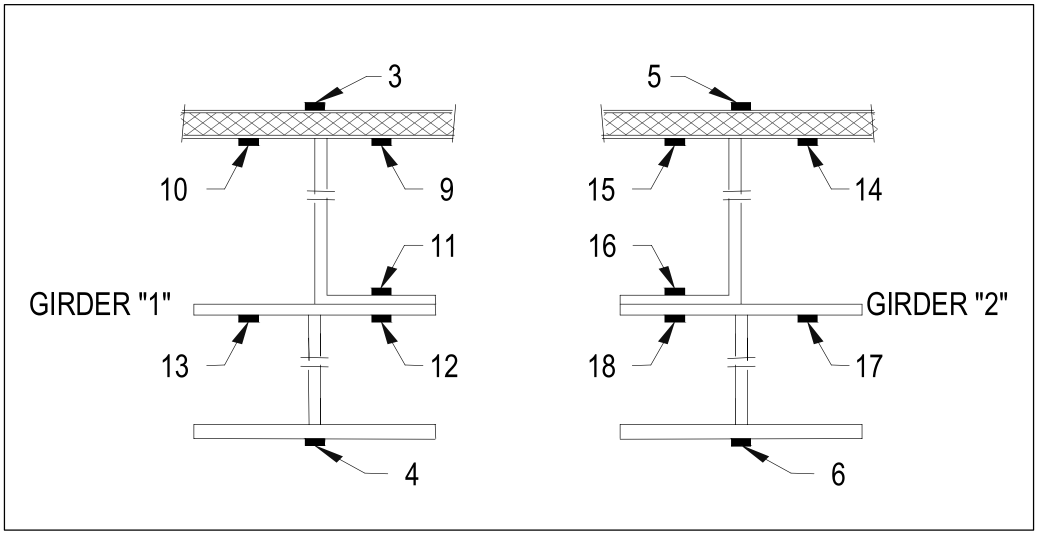


FIGURE 4.5: STRAIN GAGE LAYOUT VERSUS MEMBER DEPTH

4.2.3 Test Procedure

After connecting the instrumentation to the data acquisition system, all the instrumentation was set to zero. Lead wire resistance in the strain gages was accounted for by shunt calibrating the strain gages. The potentiometers were calibrated using a

Mitutoyo height gage with a dual directional digital counter. After setting the instrumentation to zero again, the calibration of the potentiometers was checked again using a ½ in. precision parallel steel bar. A seating load of approximately 20% was applied and all instrumentation was checked for correct output. Necessary adjustments were made before any testing continued.

Using the analytical data from the finite element analysis, a theoretical load versus deflection line was plotted. The experimental load versus deflection line was plotted in real time and compared to the theoretical line at each load interval to ensure the specimen was behaving as expected. Since the loading pattern was symmetrical, the deflections on opposite sides of the panel should be similar. For Load Case C1, the measured deflections for each joint were plotted versus the theoretical data to ensure the deflection reading from both sides of the joint and the analytical predictions were aligning during testing. The specimen was loaded in equal increments based on the maximum loading, and strain and deflection measurements were taken at every interval. The maximum applied load was 65.8 kN (14.8 kips), 321.6 kN (72.3 kips), and 422.1 kN (94.9 kips) on load frames 1, 2, and 3, respectively. The maximum test load was based on the provisions in *Canadian Highway Bridge Design Code* (2000a).

4.2.4 Test Results

Figure 4.6 is a plot of the deflection measured at Joint 4 in the center of the test specimen. The maximum deflection recorded on the outside edge of the panel occurred at Joint 4 (between sandwich plate bridge deck Panels 4 and 5) and was equal to 27.2 mm (1.07 in). Since the loading was symmetric, the deflections measured on the outside edge of the panel should have been similar. Figure 4.6 shows excellent agreement between the two measurements and the predicted deflection from the finite element analysis.

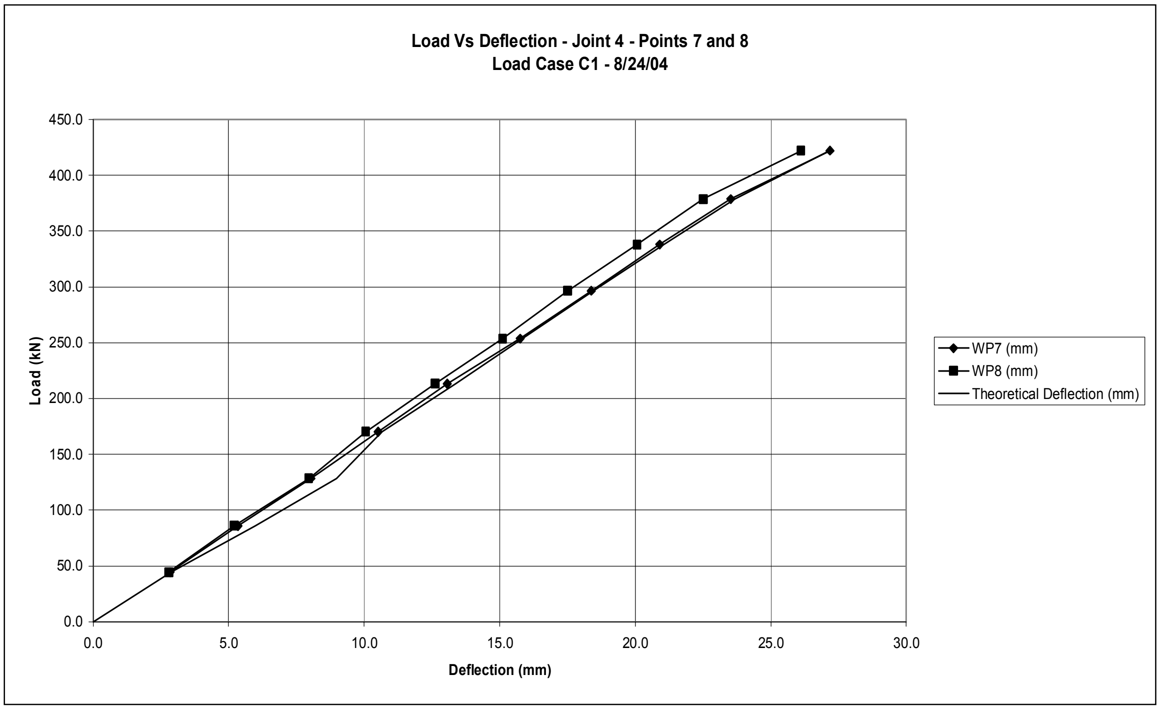


FIGURE 4.6: LOAD VERSUS DEFLECTION AT JOINT 4 – LOAD CASE C1

Figure 4.7 is a plot of strain versus the depth of the member for Panel 4. The strains measured were used to determine the location of the neutral axis and to calculate the maximum positive bending moment applied to the test specimen. The neutral axis was located 219.1mm (8.63 in.) below the top plate of the steel deck, or 2.7 mm (0.106 in.) into the web of the steel girder. If no composite action was present a neutral axis would lie in the center of the steel girder which is 488.4 mm (19.3 in.) below the top plate of the steel deck, and a neutral axis would be present in the sandwich plate deck. Therefore, some composite action was developed between the steel girders and the sandwich plate bridge deck. A slight break in Figure 4.7 indicates the test specimen does not have full composite action. However, since the neutral axis lies above the center of the steel girder some composite action exists.

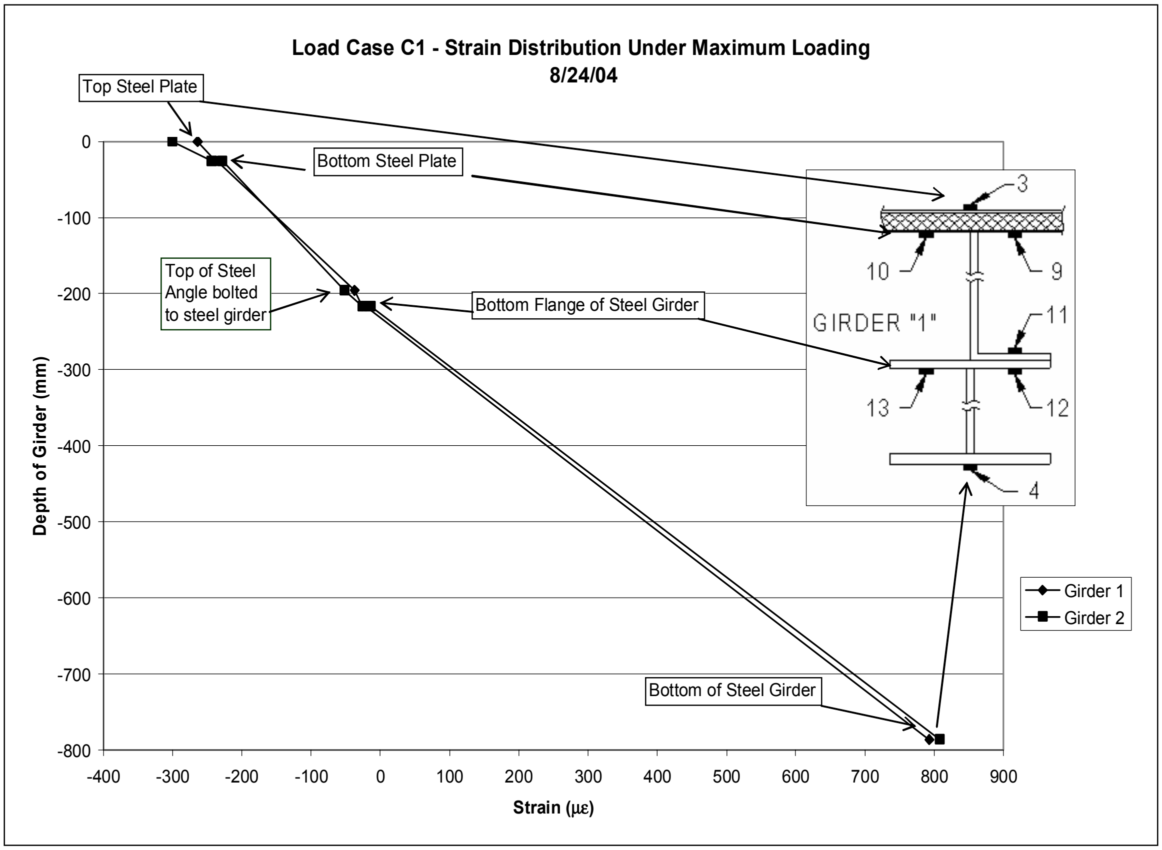


FIGURE 4.7: STRAIN VERSUS SPECIMEN DEPTH – LOAD CASE C1

The maximum moment was calculated from the applied loads to be 2301 kN-m (1697 kip-ft). The positive moment region is defined as loading that causes compression in the top plate of the sandwich plate bridge.

Table 4.1 shows the measured strains at the 50 strain gage locations under maximum loading. The maximum strain, 808 με, was measured in the center of the half scale bridge on the bottom flange of the Girder 2 at Strain Gage 6.

After the load was removed from the test specimen, the specimen returned to its initial position with no permanent deformation.

TABLE 4.1: MEASURED STRAINS AT MAXIMUM LOADING FOR LOAD CASE C1

Strain Measurement Location (Figure 4.4)	Measured Strain x 10^{-6} (in/in)
1	-258
2	101
3	-264
4	793
5	-300
6	808
7	-298
8	111
9	-238
10	-236
11	-37
12	-26
13	-22
14	-244
15	-228
16	-52
17	-26
18	-14
19	46
20	85
21	-263
22	-219
23	-285
24	-257
25	83
26	84
27	-286
28	-207
29	64
30	76
31	3
32	197
33	-39
34	185
35	-156
36	541
37	537
38	-155
39	-232
40	646
41	-216
42	630
43	-50
44	164
45	-45
46	154
47	-202
48	71
49	-212
50	73

Note: $\varepsilon_y = 1700 \times 10^{-6}$ (in/in)

4.2.5 Finite Element Analysis

Finite element analysis was conducted by Intelligent Engineering Ltd, Ottawa, Ontario, Canada. The analysis was conducted using the commercial software ANSYS, version 9.0. This section describes the material properties, modeling techniques, and results. All finite element analyses for the simple span half scale bridge were linear elastic.

The steel elements of the sandwich plate panel were assigned a modulus of elasticity of 200 GPa (29000 ksi), a Poisson's ratio of 0.287, a yield strain of 1700 $\mu\varepsilon$, and a yield stress of 350 MPa (51 ksi). The elastomeric core was assigned a modulus of elasticity of 750 MPa (109 ksi) and a Poisson's ratio of 0.36.

The steel plates and elastomeric core elements were modeled using HYPER 58 and SOLID 45 brick elements. Cross bracing members were modeled with BEAM 188 line elements. A 5 mm (0.2 in.) thick SHELL 63 element with rubber material properties was used to model the tires. The load was applied to the tires as a surface pressure on the tire area. The wheel loads were applied to the deck using contact elements TARGE 170 and CONTA 173.

The elastomer core was divided into three layers with a thickness of 6.36 mm (0.25 in.) each for analysis. The mesh size was based on a maximum aspect ratio of 20 to 1. Eight node solid elements were used to model the steel plates and the elastomer core. The length and width of a typical solid element was 50 mm x 50 mm (2 in. x 2. in), which satisfied the 20 to 1 aspect ratio guidelines. This procedure was used for all finite element models in the half scale simple span bridge tests.

An elastic foundation was used in the model to account for the support beam deflections. The maximum predicted deflection was at Joint 4, 27.2 mm (1.07 in).

Figure 4.8 shows the deflected surface for Load Case C1, and Figure 4.9 is a plot of the Von Mises stress concentration, which is often used to estimate the yield of ductile materials.

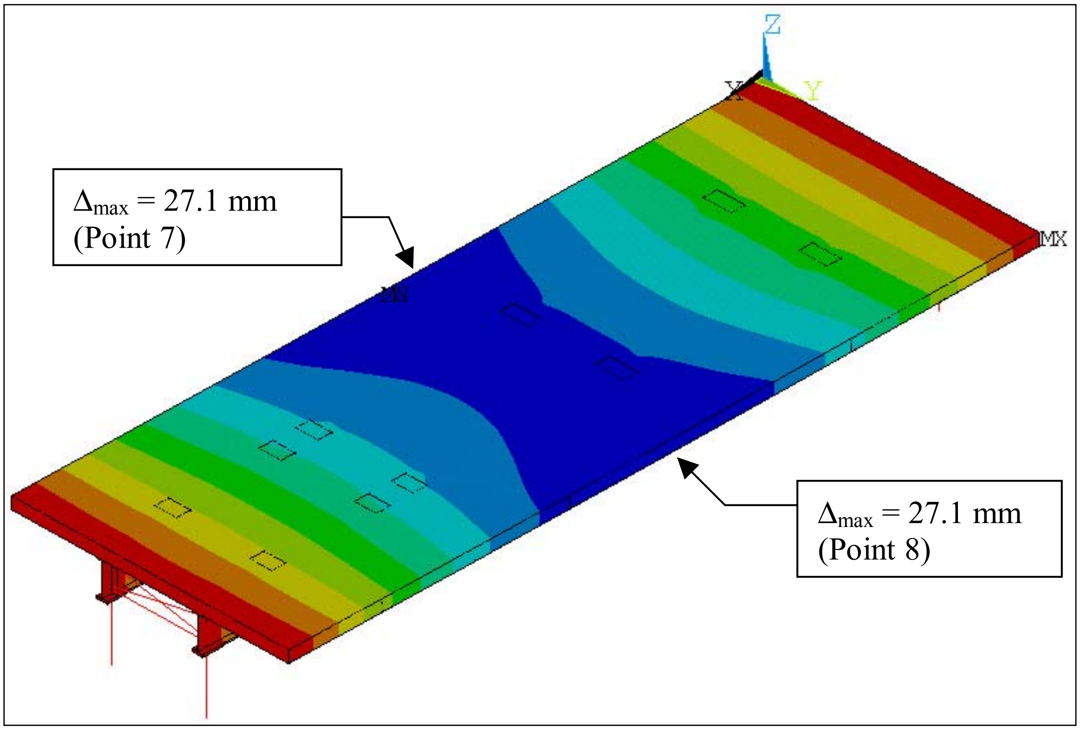


FIGURE 4.8: FINITE ELEMENT ANALYSIS DEFLECTION CONTOURS

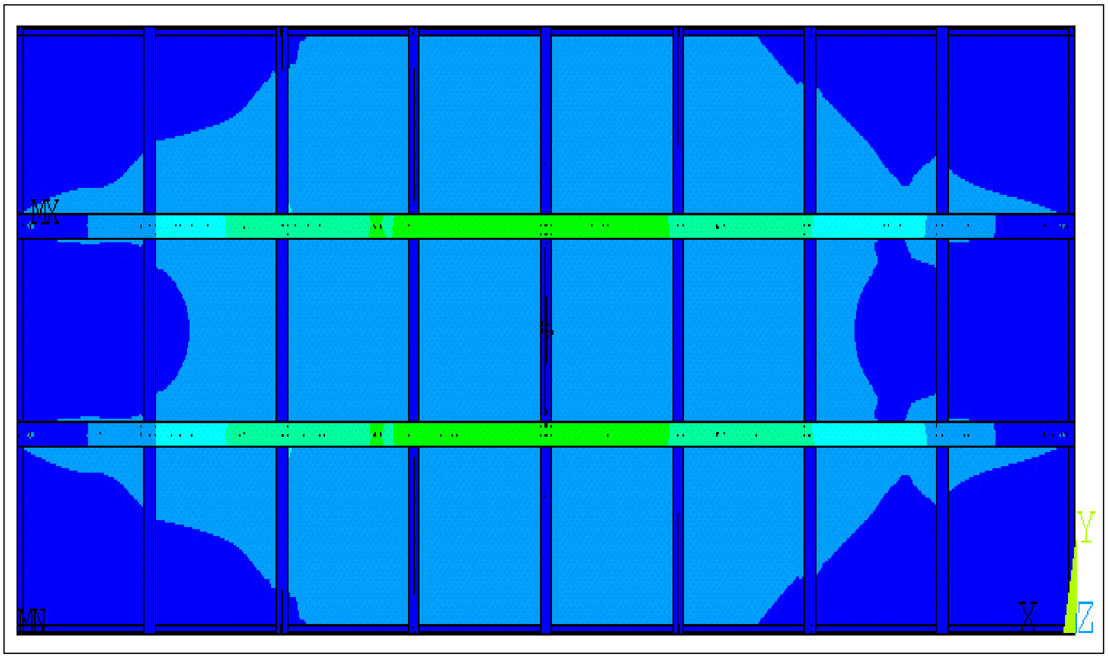


FIGURE 4.9: VON MISES STRESS CONTOUR FOR LOAD CASE C1

4.2.6 Comparison of Experimental and Finite Element Analysis Results

Table 4.2 is a comparison of the measured and finite element analysis predicted deflections. The measured and predicted deflections showed good agreement at every point measured during testing. The range of experimental to predicted ratios ranged from 0.97 to 1.03.

Table 4.3 is a comparison of the measured and predicted strains; there is reasonable agreement between measured and predicted strains. A reasonable difference between the measured and predicted strains is 35 $\mu\varepsilon$ or 6.9 MPa (1 ksi) using an assumed modulus of elasticity of 200 GPa (29000 ksi).

TABLE 4.2: DEFLECTIONS UNDER MAXIMUM LOADING

Displacement Measurement Location (see Figure 4.3)	Load Case C1 - Deflections Under Maximum Load		
	Measured Deflections (mm)	Predicted Deflections (mm)	Test/Predicted
1	-11.4	-10.7	1.03
2	-11.0	-10.7	1.02
3	-20.2	-19.9	1.02
4	-20.2	-19.9	1.00
5	-25.4	-25.5	0.99
6	-25.3	-25.5	1.00
7	-27.2	-27.2	0.96
8	-26.1	-27.2	1.00
9	-24.9	-24.9	0.97
10	-24.0	-24.9	1.02
11	-19.4	-19.0	0.91
12	-18.2	-20.0	1.07
13	-10.9	-10.2	1.03
14	-10.4	-10.1	1.03

TABLE 4.3: STRAINS UNDER MAXIMUM LOADING

Strain Measurement Location (see Figure 4.4)	Measured Strain x 10^{-6} (in/in)	Predicted Strains x 10^{-6} (in/in)	Difference
1	-258	-283	25
2	101	52	49
3	-264	-336	72
4	793	791	2
5	-300	-336	36
6	808	790	18
7	-298	-283	-15
8	111	52	59
9	-238	-301	63
10	-236	-299	63
11	-37	-64	27
12	-26	-33	7
13	-22	-37	15
14	-244	-299	55
15	-228	-301	73
16	-52	-64	12
17	-26	-37	11
18	-14	-34	20
19	46	94	-48
20	85	81	4
21	-263	-311	48
22	-219	-263	44
23	-285	-342	57
24	-257	-298	41
25	83	119	-36
26	84	97	-13
27	-286	-342	56
28	-207	-298	91
29	64	119	-55
30	76	97	-21
31	3	-75	78
32	197	175	22
33	-39	-75	36
34	185	175	10
35	-156	-244	88
36	541	536	5
37	537	-244	781
38	-155	536	-691
39	-232	-282	50
40	646	652	-6
41	-216	-282	66
42	630	652	-22
43	-50	-57	7
44	164	152	12
45	-45	-57	12
46	154	152	2
47	-202	-230	28
48	71	56	15
49	-212	-231	19
50	73	56	17

Note: $\varepsilon_y = 1700 \times 10^{-6}$ (in/in)

Figure 4.10 is a plot of the strain versus the depth of the section including the predicted strains from the finite element model. The finite element model is based on the assumption that full composite action is developed between the sandwich plate bridge deck and the steel girders. The measured strains have reasonable agreement with the predicted strains, and Figure 4.10 shows that the half scale bridge exhibits close to full composite action for Load Case C1. The finite element analysis predicted the neutral axis to be located 237.2 mm (9.3 in.) below the top of the steel plate. The discrepancy between the measured and predicted neutral axes is 18 mm (0.71 in.).

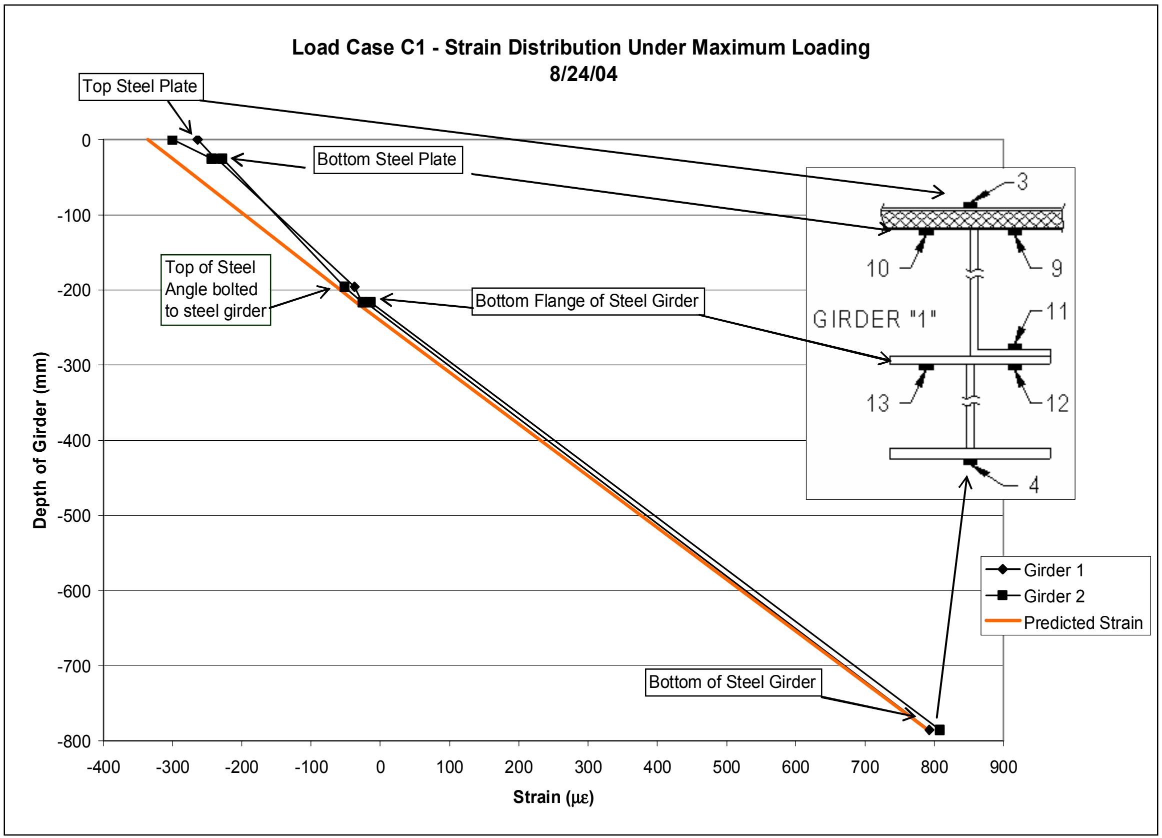


FIGURE 4.10: STRAIN VERSUS DEPTH OF TEST SPECIMEN

Overall, the results from the experimental testing and finite element analysis are in good agreement; therefore, the assumptions used in modeling Load Case C1 on the half scale simple span bridge are considered valid.

4.3 Load Case C2

4.3.1 Test Setup

For Load Case C2, the torsional characteristics of the sandwich plate bridge deck were investigated. The load points remained in the same position as Load Case C1, but only Girder 1 was loaded. Figure 4.11 is a layout of load placement. The test specimen remained in the simple support condition used in Load Case C1. The same support beams and steel rollers were used in Load Case C1 were used again in Load Case C2. Three steel frames were used to apply load to two spreader beams. The spreader beams rested on top of a steel plate above a bearing pad. Two different bearing pad sizes were used. The bearing pads used to apply load from Frames 2 and 3 measured 229 mm (9.02 in.) by 457 mm (18 in), and from Frame 1 measured 229 mm (9.02 in.) by 368 mm (14.5 in.).

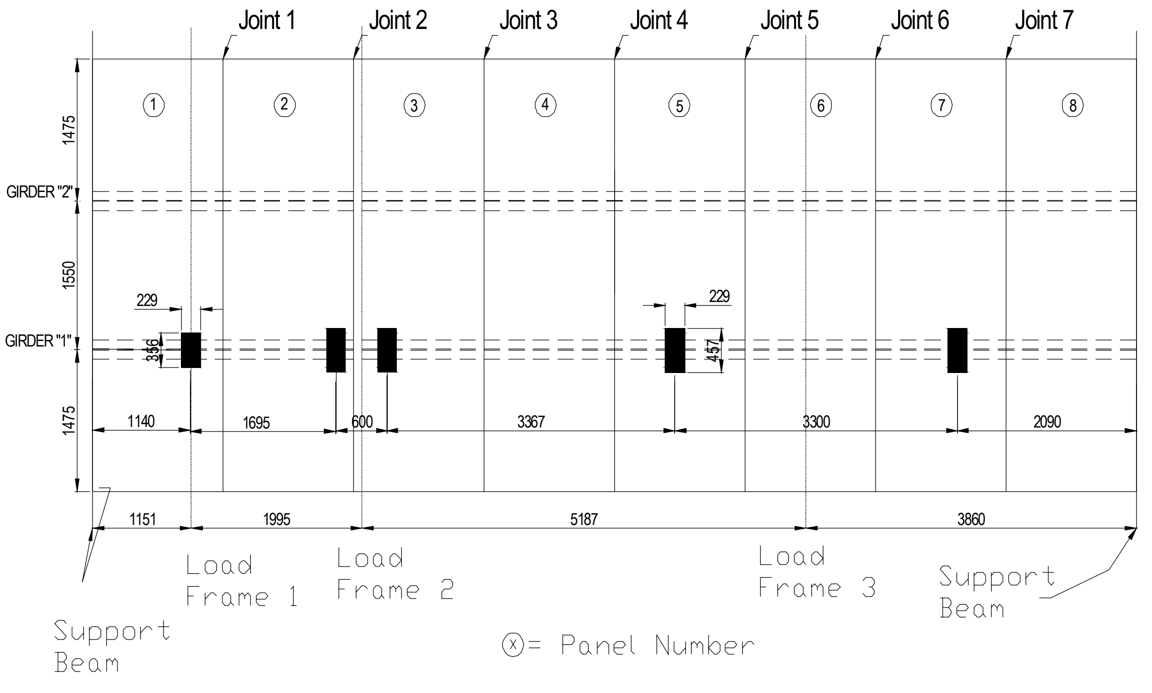


FIGURE 4.11: LOAD BLOCK PATTERN FOR LOAD CASE C2

4.3.2 Instrumentation

All 50 strain gages used in Load Case C1 were used again in Load Case C2. A combination of dial gages and string-type potentiometers were used to measure displacement on the outside edges of the bridge deck. The potentiometers were used on the outside edge near Girder 1. Dial gages were used to measure deflection on the outside edge of Girder 2 because the potentiometers could not measure the small amount of deflection accurately. Figure 4.12 is the instrumentation layout for Load Case C2. A PC-based data acquisition system was used to collect data from the strain gages and the string-type potentiometers. All dial gage readings were recorded manually. Three compression load cells were used to measure the load applied by the hydraulic rams. Each load cell's calibration was checked before testing using a SATEC Universal Testing Machine.

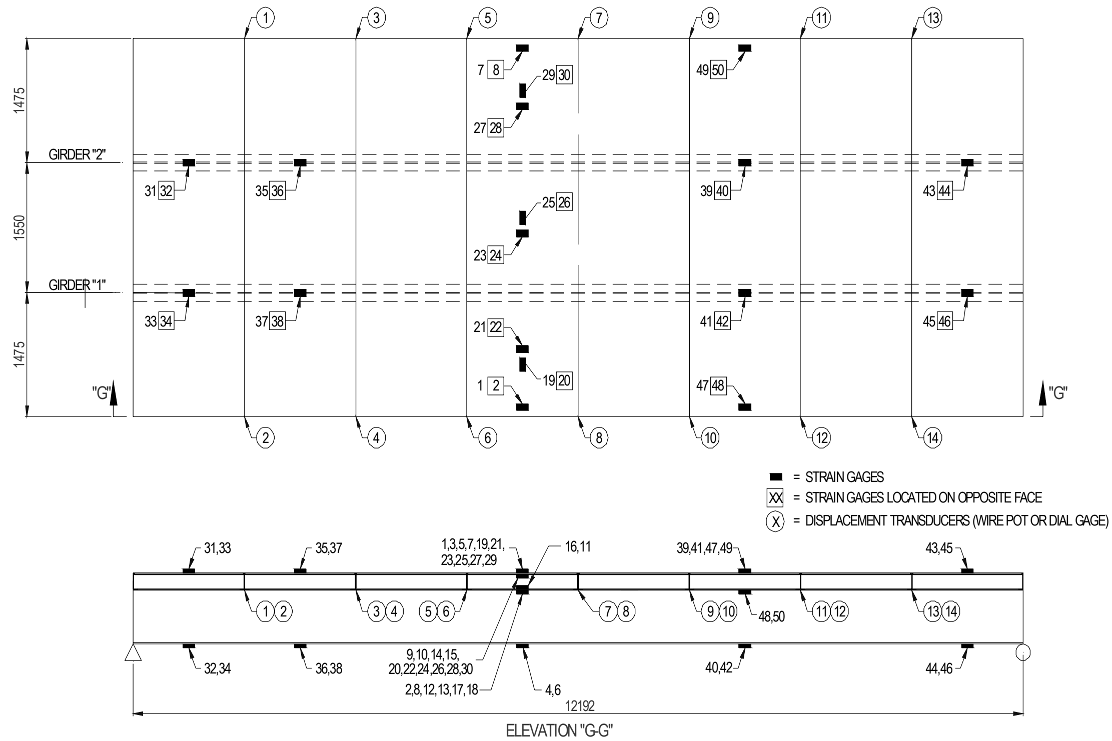


FIGURE 4.12: INSTRUMENTATION LAYOUT FOR LOAD CASE C2

4.3.3 Test Procedure

The testing procedure for Load Case C2 was similar to the procedure used for Load Case C1. All instrumentation was connected to the PC-based data acquisition system and set to zero. The strain gages and string-type potentiometers were calibrated in the same manor as in Load Case C1. The dial gages were set to have an initial deflection of 12.2 mm (1/2 in.) downward. This was done because the edge of the panel near Girder 2 moved upward under the torsional loading applied to Girder 1. A seating load of approximately 20% was applied and all instrumentation was checked for correct output. Necessary adjustments were made before any testing continued.

The specimen was loaded in equal increments based on the maximum loading, and strain and deflection measurements were taken at every interval. The maximum applied load was 36.5 kN (8.2 kips), 181 kN (40.7 kips), and 234 kN (52.6 kips) on load frames 1, 2, and 3, respectively. These values represent approximately half of the maximum load applied in Load Case C1. The maximum test load was based on the provisions in *Canadian Highway Bridge Design Code* (2000a). Experimental load versus deflection from the seven string-type potentiometers was compared to theoretical values in during testing.

4.3.4 Test Results

Figure 4.13 is a photograph of the specimen under the full scale loading. Figure 4.14 is a plot of load versus deflection at Point 8. As shown in Figure 4.14, the measured deflection at the Point 8 showed excellent agreement with the analytical deflections provided by Intelligent Engineering. However, the deflections measured at the odd numbered locations (see Figure 4.12) were not in good agreement with the finite model predictions. An eccentricity that could not be accounted for distorted the deflections. Several steps were taken to remedy this problem. For example, the support beams were placed on steel plates raising them off the reaction floor. After retesting and again having the same problem, the support beams were grouted to the reaction floor. After retesting, the grout had no effect on the deflections. Dial gages were then placed to measure any support deflection, but no support movement was measured during testing. Dial gages were then placed underneath girder one at the ends, quarter points, and mid-point. The eccentricity is problematic because small displacements in the supporting structure may be amplified as rigid body motion in the test specimen. The maximum deflection measured was 43.4 mm (1.71 in) downward at mid-span.

Table 4.4 shows the measured strains at the 50 strain gage locations under maximum loading. The maximum strain, 792 $\mu\varepsilon$, was measured in the center of the half scale bridge on the bottom flange of the Girder 1 at Strain Gage 4.

After the load was removed from the test specimen, the specimen returned to its initial position with no permanent deformation.

FIGURE 4.13: MAXIMUM LOADING – LOAD CASE C2

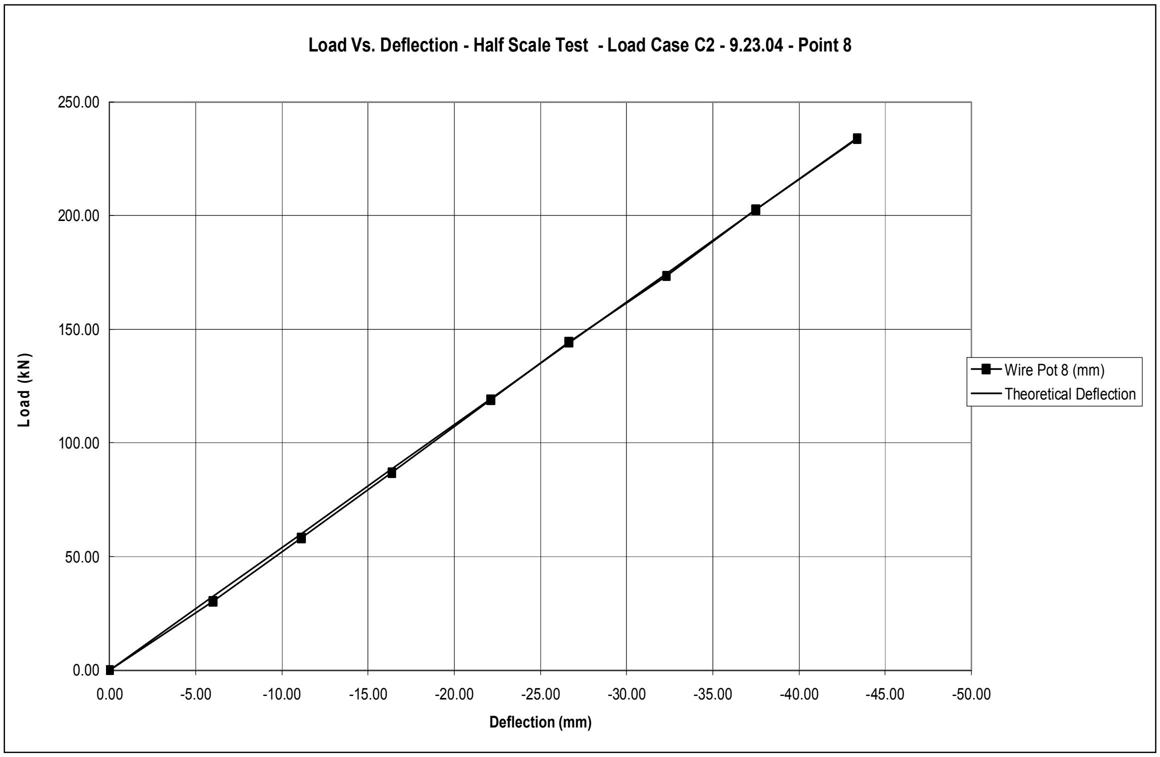


FIGURE 4.14: LOAD VERSUS DEFLECTION FOR POINT 8 – LOAD CASE C2

4.3.5 Finite Element Analysis

The finite element modeling and analysis procedures for Load Case C2 were the same as for Load Case C1.

Figure 4.15 shows the deflected surface for Load Case C2. The maximum predicted deflection was at Point 8, 43.3 mm (1.70 in.). An elastic foundation was used in the model to account for the support beam deflections. The deflections measured underneath Girder 1 were used to create the elastic foundation boundary conditions.

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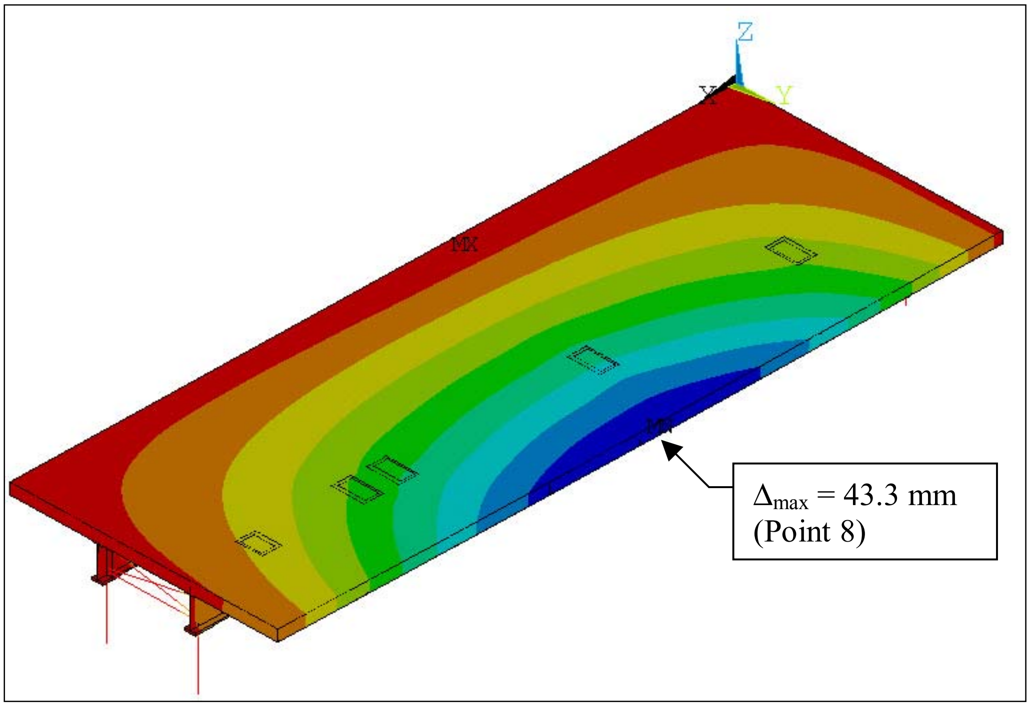
TABLE 4.4: MEASURED STRAINS AT MAXIMUM LOADING FOR LOAD CASE C2

Strain Measurement Location (Figure 4.12)	Measured Strain x 10^{-6} (in/in)
1	-283
2	115
3	-199
4	792
5	-93
6	65
7	12
8	-16
9	-174
10	-175
11	22
12	19
13	17
14	-83
15	-82
16	-61
17	-39
18	-58
19	38
20	80
21	-243
22	-196
23	-154
24	-146
25	53
26	46
27	-43
28	-40
29	17
30	15
31	-28
32	11
33	-31
34	184
35	-58
36	38
37	528
38	-113
39	-74
40	54
41	-168
42	642
43	-19
44	18
45	-24
46	167
47	-219
48	106
49	5
50	-7

Note: $\varepsilon_y = 1700 \times 10^{-6}$ (in/in)



Δ_{max} = 43.3 mm
(Point 8)

FIGURE 4.15: DEFLECTION CONTOURS FOR LOAD CASE C2

4.3.6 Comparison of Experimental and Finite Element Analysis Results

Table 4.5 is a comparison of the measured and predicted deflections. The measured and predicted deflections have reasonable agreement at the even numbered deflection points measured during testing (see Figure 4.12). The experimental-to-predicted ratios ranged from 0.94 to 1.06 for these locations. At the odd numbered locations, the experimental-to-predicted ratios ranged from 3.43 to 7.77. A possible explanation of the large discrepancy in these deflections is that an eccentricity was present in the test setup that a caused a rigid body rotation, which in turn caused the measured deflection to be much greater than the predicted deflections at the odd numbered locations. The finite element analysis did not include any rigid body rotation of the elastic foundation, which is a possible explanation of the difference between the measured deflections and predicted deflections at the North edge of the panel.

TABLE 4.5: DEFLECTIONS UNDER MAXIMUM LOADING

Displacement Measurement Location (see Figure 4.10)	Load Case C2 - Deflections Under Maximum Load		
	Measured Deflections (mm)	Predicted Deflections (mm)	Test/Predicted
1	6.9	1.23	5.56
2	-17.9	-16.80	1.06
3	11.9	1.53	7.77
4	-31.8	-30.53	1.04
5	15.0	2.51	5.96
6	-41.1	-39.75	1.03
7	15.6	3.49	4.46
8	-43.4	-43.31	1.00
9	14.5	3.83	3.78
10	-39.8	-40.37	0.99
11	11.4	3.31	3.45
12	-30.8	-32.75	0.94
13	6.9	2.01	3.43
14	-17.8	-16.90	1.05
Quarter Point of Girder 1	-17.5	-18.749	0.93
Mid-span of Girder 1	-23.3	-26.265	0.89
Three Quarter Point of Girder 1	-17.2	-18.749	0.92

Table 4.6 is a comparison of the measured and predicted strains. The measured and predicted deflections are in reasonable agreement at most strain gages. A reasonable difference between the measured and predicted strains is 35 $\mu\varepsilon$ or 6.9 MPa (1 ksi) using an assumed modulus of elasticity of 200 GPa (29000 ksi).

TABLE 4.6: STRAINS UNDER MAXIMUM LOADING

Strain Measurement Location (Figure 4.10)	Measured Strain x 10^{-6} (jn/in)	Predicted Strains x 10^{-6} (in/in)	Difference
1	-283	-384	101
2	115	145	-30
3	-199	-326	127
4	792	814	-22
5	-93	-167	74
6	65	340	-275
7	12	-28	40
8	-16	-59	43
9	-174	-289	115
10	-175	-293	118
11	22	-48	70
12	19	-17	36
13	17	-37	54
14	-83	-146	63
15	-82	-153	71
16	-61	-48	-13
17	-39	-19	-20
18	-58	-33	-25
19	38	109	-71
20	80	93	-13
21	-243	-359	116
22	-196	-299	103
23	-154	-251	97
24	-146	-219	73
25	53	89	-36
26	46	72	-26
27	-43	-251	208
28	-40	-219	179
29	17	89	-72
30	15	72	-57
31	-28	-69	41
32	11	392	-381
33	-31	-32	1
34	184	-148	332
35	-58	-120	62
36	38	380	-342
37	528	-233	761
38	-113	393	-506
39	-74	-139	65
40	54	230	-176
41	-168	-277	109
42	642	725	-83
43	-19	-20	1
44	18	47	-29
45	-24	-64	40
46	167	176	-9
47	-219	-323	104
48	106	173	-67
49	5	-9	14
50	-7	-82	75

Note: $\varepsilon_y = 1700 \times 10^{-6}$ (in/in)

Figure 4.16 is a plot of the strain versus the depth of the section including the predicted strains from the finite element model. The finite element model is based on the assumption that full composite action is developed between the sandwich plate bridge deck and the steel girders. However, a break is noticeable in the finite element analysis predicted strains measurements, which indicates the finite element model has predicted slip at the interface between the bridge deck and steel girders, which is not possible because the sandwich plate deck and steel girders are perfectly glued together. The neutral axis location determined from measured strains was in the web of the bent angle, but the predicted strains from the finite element model place the neutral axis in the web of the girder. A possible explanation for the difference is the rigid body rotation of the bridge caused tension to develop in the top of the bent angle during experimental testing. The change in measured strain from the top of the bent angle to the top of the bottom flange of the steel girder is only 3 $\mu\varepsilon$. Since the change in strain is very small and within the source of error for a typical strain gage measurement, the test specimen might not have experienced any slip between the bridge deck panel and the steel girder. However, the change in slope of the measured strain in Figure 4.16 indicates full composite action was not developed.

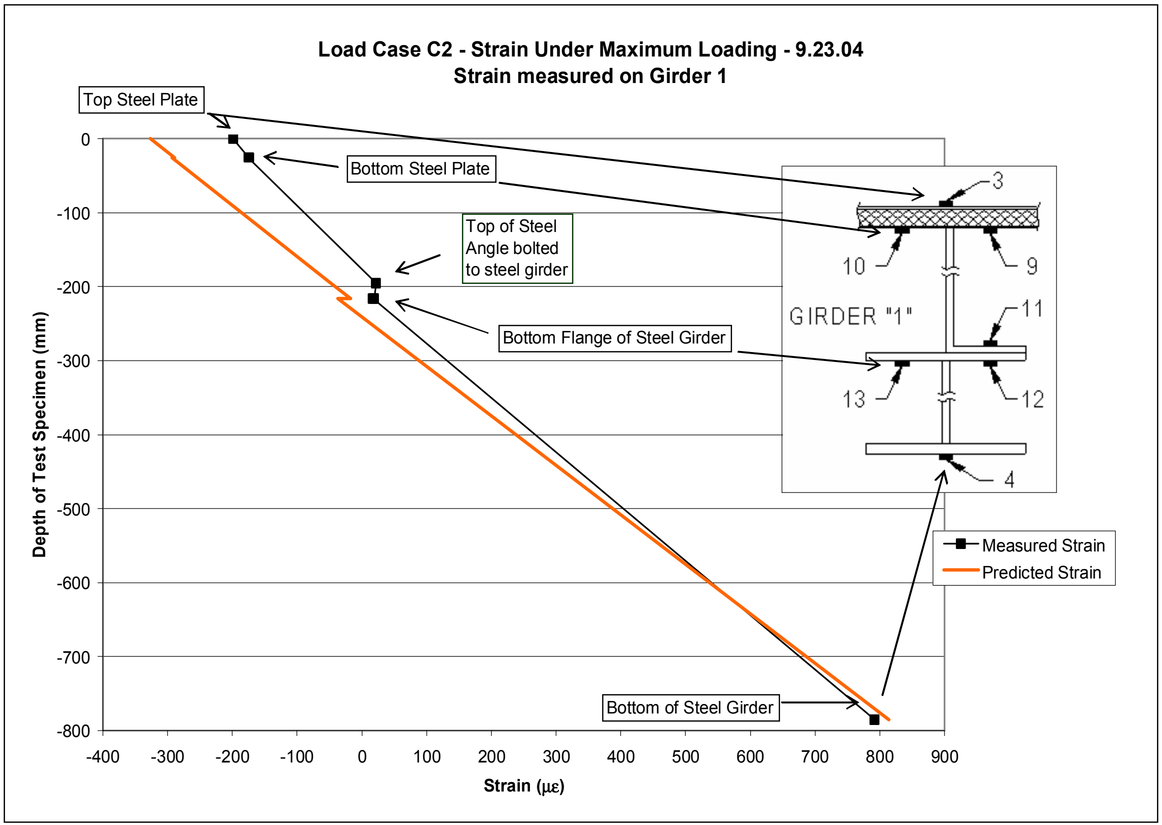


FIGURE 4.16: STRAIN VERSUS DEPTH OF TEST SPECIMEN

For the most part, the results from the experimental testing and finite element analysis are in good agreement. The deflections measured on the South side of the half scale bridge and underneath Girder 1 are within reasonable agreement to the predicted deflection. A rigid body rotation that could not be accounted for, possibly caused a discrepancy between the measured and predicted strains, and the rigid body rotation also possibly raised the location of the neutral axis of Girder 1.

4.4 Load Case C3

4.4.1 Test Setup

Load Case C3 was performed with a three panel cantilever. The support beam underneath deck Panel 1 was moved so that the web of the support beam aligned with the joint between deck Panels 3 and 4. The support underneath Panel 8 remained in the same position. To reduce the effect of the unevenness of the laboratory floor, the two support beams were set on steel plates. Figure 4.17 is a plan view of the load positions. Ten load points were placed in line with the girders to determine if the sandwich plate bridge deck acted compositely in the negative moment region. Three steel frames were used to apply load to two spreader frames and a spreader beam. For Load Case C3, two different bearing pad sizes were used. The bearing pads used to apply load from Frame 3 measured 229 mm (9.02 in.) by 457 mm (18 in), and from Frame 1 measured 229 mm (9.02 in.) by 368 mm (14.5 in.). Tires filled with concrete were used to transfer the load from Frame 2 to the sandwich plate deck.

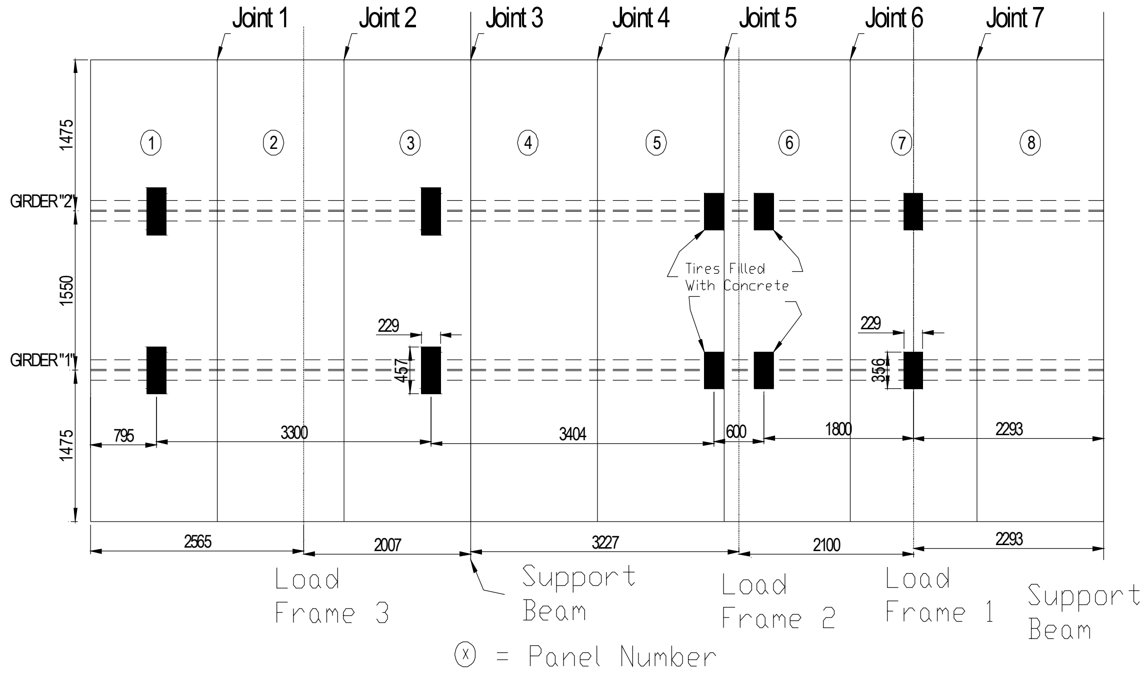


FIGURE 4.17: LOAD POSITIONS FOR LOAD CASE C3

4.4.2 Instrumentation

Figure 4.18 shows the instrumentation layout for Load Case C3. A total of 49 strain gages were used to determine local behavior of the sandwich plate bridge deck. Eighteen stain gages that were used in Load Cases C1 and C2 were reused. Thirty-one new strain gages were applied to the deck solely for Load Case C3. For Load Case C3, a combination of dial gages and string-type potentiometers were used to measure deflection. Deflections were measured on the bottom of the steel girders at the intersection between every panel. Dial gages were also used to measure the deflection of the support beams. A PC-based data acquisition system was used to collect data from the strain gages and the string-type potentiometers. All dial gage readings were recorded manually. Three compression load cells were used to measure the load applied by the hydraulic rams. Each load cell's calibration was checked before testing using a SATEC Universal Testing Machine.

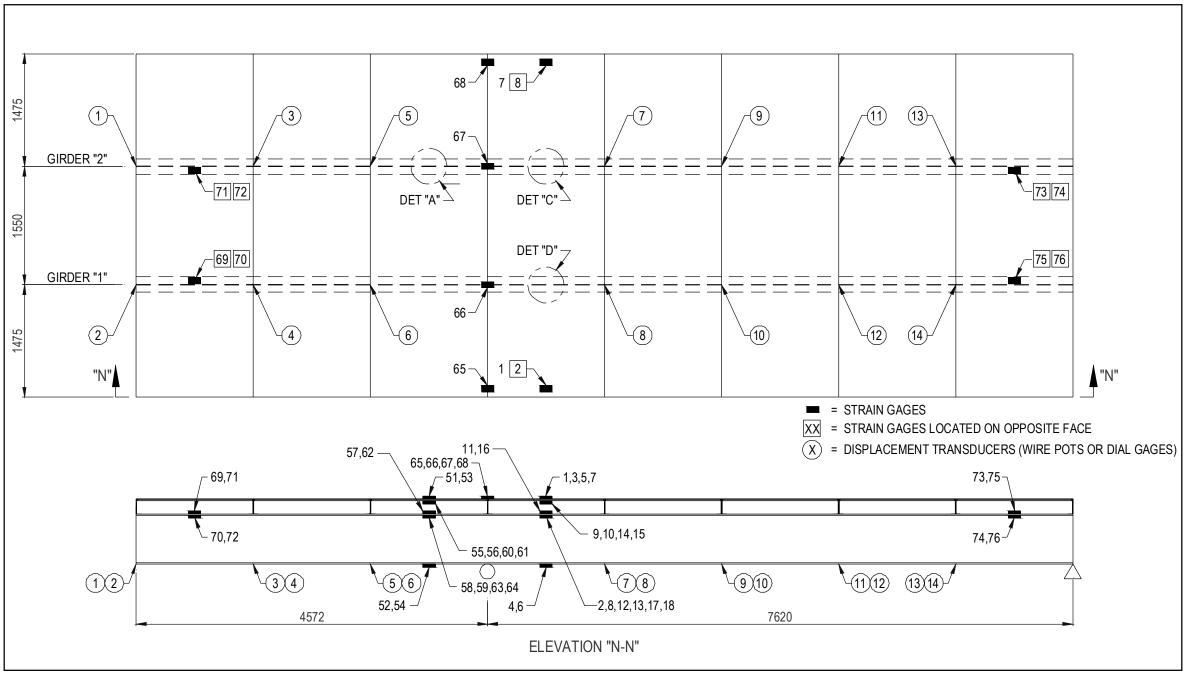


FIGURE 4.18: INSTRUMENTATION LAYOUT FOR LOAD CASE C3

4.4.3 Test Procedure

The test procedure for Load Case C3 was similar to the previous two load cases. The instrumentation was connected to the data acquisition system and set to zero. The strain gages, dial gages, and string-type potentiometers were calibrated in the same manner as described earlier. A seating load of 20% of the maximum loading was applied and the instrumentation output was verified. After unloading the test specimen and setting the instrumentation to zero, the full scale testing load was applied to the bridge deck.

The same maximum load values applied during Load Case C1 were also applied for Load Case C3. The difference between the two load cases is the location of the frames applying load. For Load Case C3, the maximum loading was applied to the cantilever by Frame 1. Frame 2 applied load to either side of Joint 5 between Panels 5 and 6, and Frame 3 applied load in the center of Panel 7. The specimen was loaded in equal increments based on the maximum loading, and strain and deflection measurements were taken at every interval. The maximum applied load was 66.3 kN (14.9 kips), 324.3 kN (72.9 kips), and 422.6 kN (95.0 kips) on load frames 1, 2, and 3, respectively.

Experimental load versus deflection plots were compared to theoretical values in real-time during testing for the six string-type potentiometers. The load applied to the bridge deck was symmetric about the specimen. Therefore, the deflections measured underneath Girder 1 should be similar to the deflection measured underneath Girder 2. For the potentiometers this was verified in real-time by plotting load versus deflection. The dial gages underneath Girder 2 were read first and the output was compared to the deflection measured by the dial gages underneath Girder 1 for each load interval.

4.4.4 Test Results

Figure 4.19 is a load versus deflection plot measured at the end of the cantilever below Girder 2. The deflections measured underneath the girders were greater than the finite element model predicted due to support member deflecting. A 2D finite element model was created using the composite moment of inertia calculated by hand to determine the corrected deflections with the support movement. An elastic foundation was added to the finite element model created by Intelligent Engineering after experimental testing concluded and the measured deflections are within reasonable error as shown in Figure 4.19. The maximum deflection was 12.5 mm (0.492 in).

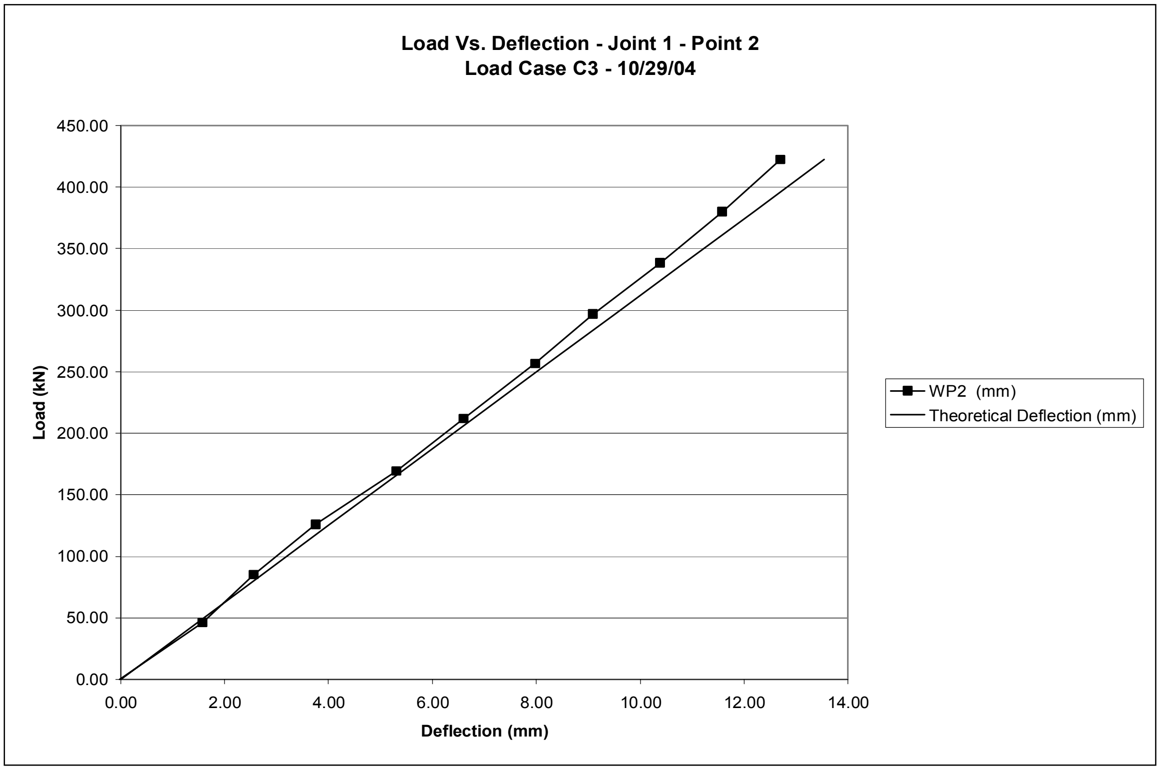


FIGURE 4.19: LOAD VERSUS DEFLECTION FOR JOINT 1 – LOAD CASE C3

Figure 4.20 is a plot of experimental strain versus the depth of the test specimen for Panel 4. The strains measured were used to determine the location of the neutral axis and to calculate the maximum negative bending moment applied to the test specimen. The neutral axis was found to be 246.6 mm (9.71 in.) below the top plate of the steel deck, or 30 mm (1.19 in.) into the web of the steel girder. If no composite action was present the neutral axis would lie in the center of the steel girder which is 488.4 mm (19.228 in.) below the top plate of the steel deck. The break in Figure 4.20 indicates the test specimen does not have full composite action. However, some composite action exists because the neutral axis lies above the center of the steel girder. Also shown in Figure 4.20, the strain measurements on the bottom of the top flange of

Girder 2 and on top of the bent angle was in compression under maximum loading. This indicates the top flange of Girder 2 experienced some local bending or rocking at the location where the strains were measured. The test specimen was not designed for a cantilevered configuration, and the bolts experienced some slip between the bent angle and the top flange of the girder.

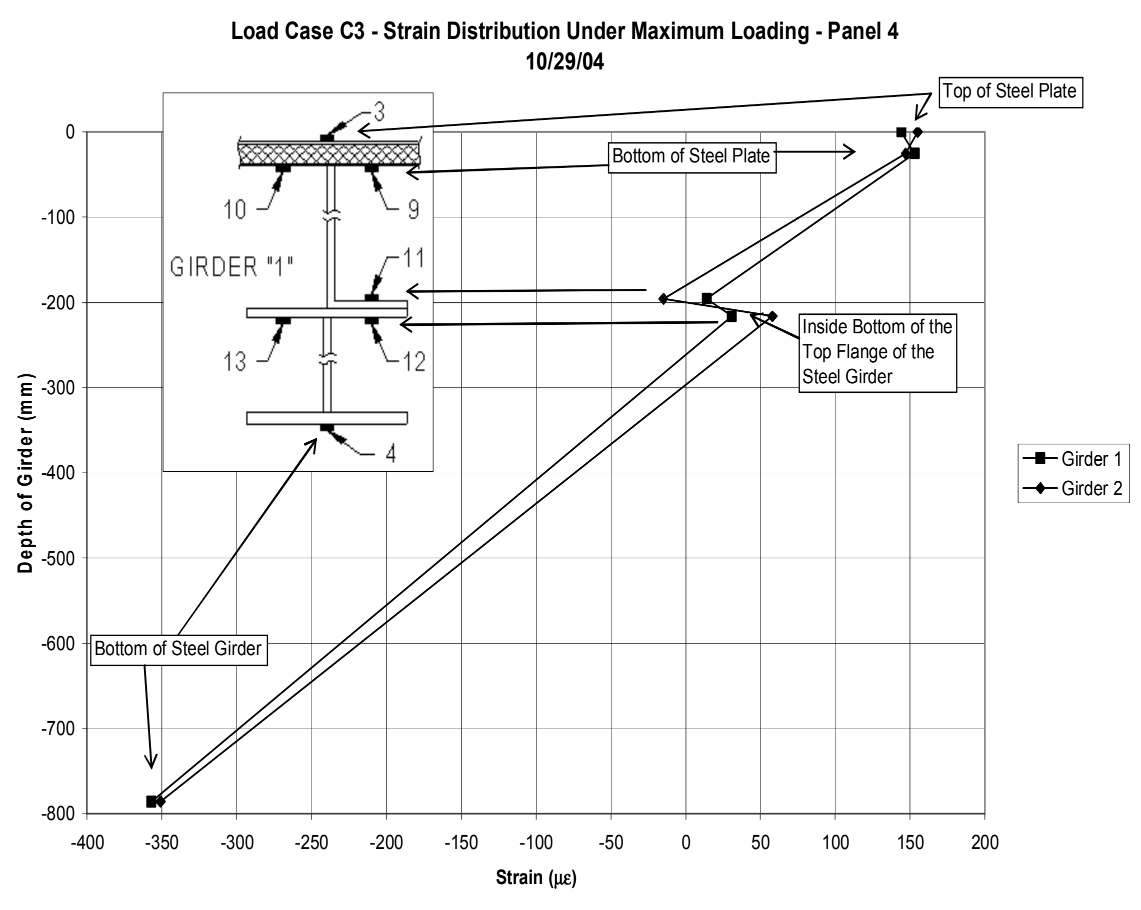


FIGURE 4.20: STRAIN VERSUS DEPTH OF MEMBER – PANEL 4 – LOAD CASE C3

Figure 4.21 is a plot of measured strain versus the depth of the test specimen for Panel 3 under maximum loading. A slight break in Figure 4.21 indicates the test specimen does not have full composite action. However, some composite action exists because the neutral axis lies above the center of the steel girder. The measured strain line plotted in Figure 4.21 should be a linear and have a constant slope if full composite action was developed. The strain remained nearly constant from the bottom of the steel plate to the top of the bent angle, indicating full composite action was not developed.

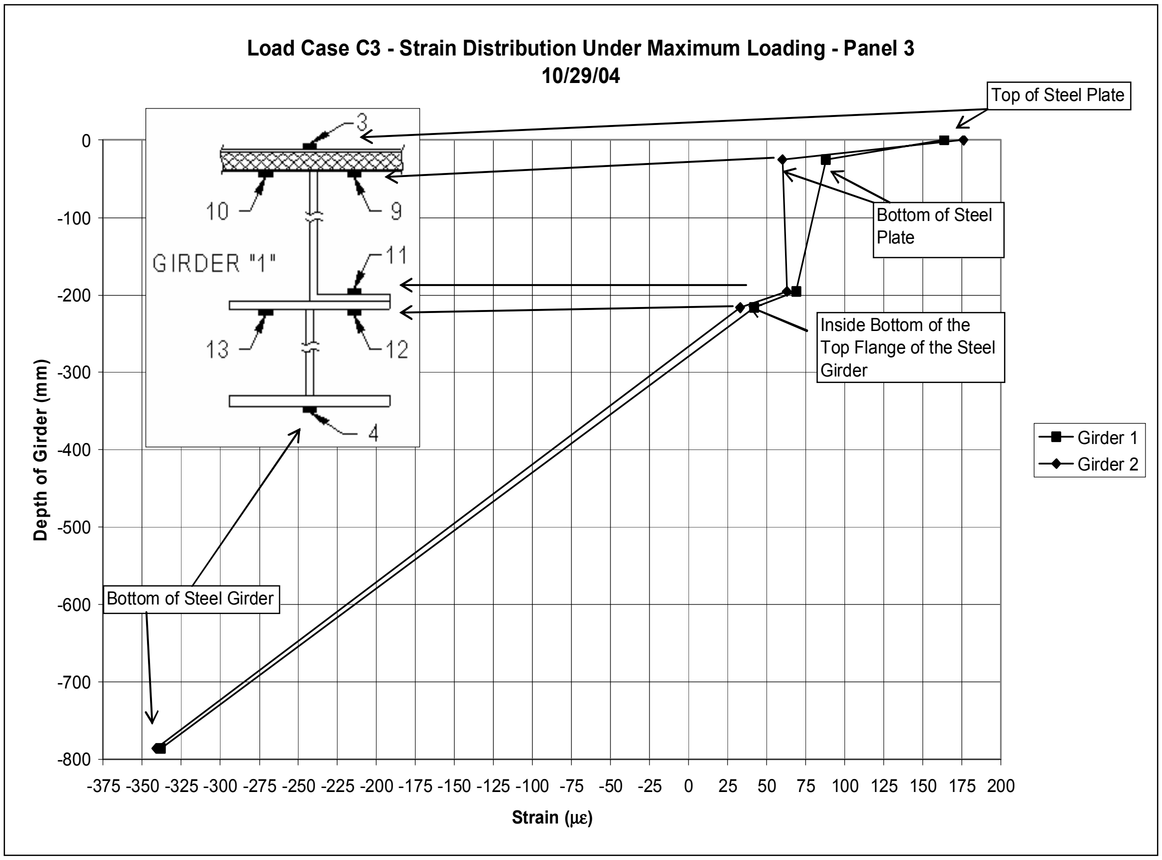


FIGURE 4.21: STRAIN VERSUS DEPTH OF MEMBER – PANEL 3 – LOAD CASE C3

The maximum moment was calculated from the applied loads to be 1718 kN-m (1267 kip-ft). The negative moment region is defined as loading that causes tension in the top plate of the sandwich plate bridge.

Table 4.7 shows the measured strains at the 49 strain gage locations under maximum loading. The maximum strain, 357 με, was measured in the center of the half scale bridge on the bottom flange of the Girder 1 at Strain Gage 4.

After the load was removed from the test specimen, the specimen returned to its initial position with no permanent deformation.

TABLE 4.7: MEASURED STRAINS AT MAXIMUM LOADING FOR LOAD CASE C3

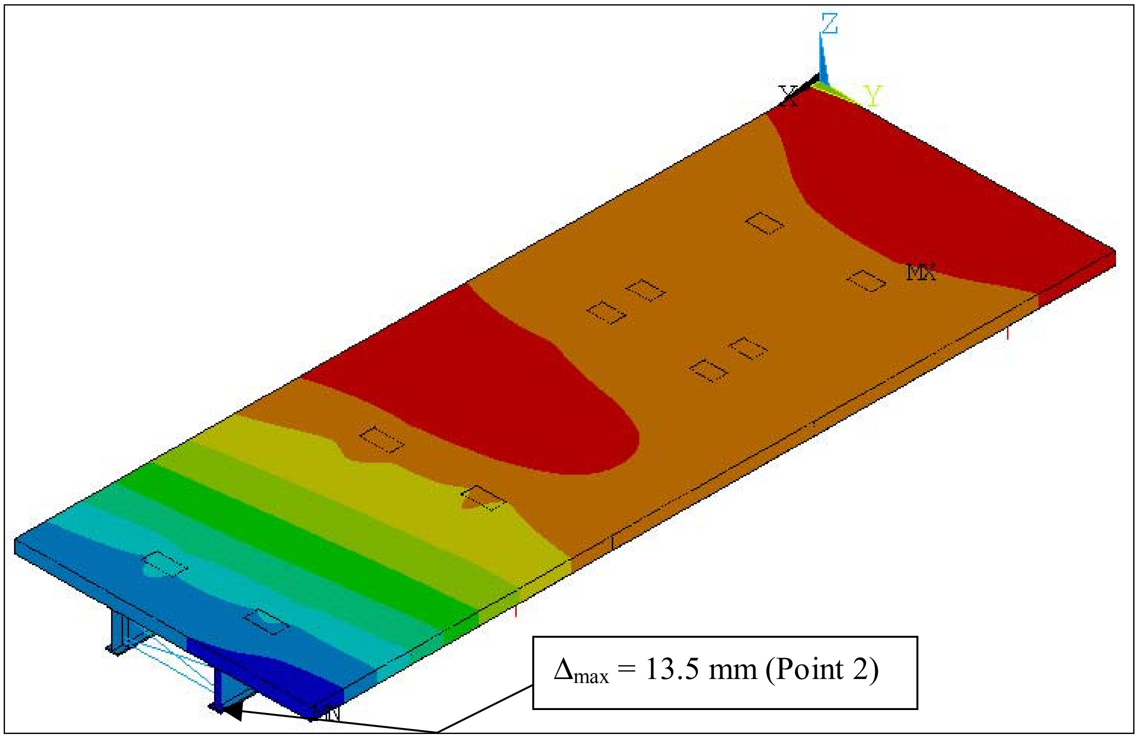
Strain Measurement Location (Figure 4.18)	Measured Strain x 10^{-6} (in/in)
1	71
2	-34
3	144
4	-357
5	155
6	-351
7	77
8	-40
9	153
10	148
11	103
12	14
13	31
14	122
15	147
16	-65
17	58
18	-15
51	164
52	-338
53	176
54	-341
55	88
56	138
57	160
58	69
59	42
60	117
61	60
62	19
63	33
64	63
65	344
66	266
67	286
68	-162
69	65
70	9
71	218
72	27
73	18
74	-13
75	33
76	-10
77	118
78	52
79	189
80	232
81	180

Note: $\varepsilon_y = 1700 \times 10^{-6}$ (in/in)

4.4.5 Finite Element Analysis

The finite element modeling and analysis procedures for Load Case C3 were the same as the previous two load cases.

Figure 4.22 shows the deflected surface for Load Case C3. The maximum predicted deflection was at Point 2, 13.5 mm (0.53 in.). An elastic foundation was used in the finite element model to account for the support beam deflections.



Δ_{max} = 13.5 mm (Point 2)

FIGURE 4.22: PREDICTED DEFLECTIONS FOR LOAD CASE C3

4.4.6 Comparison of Experimental and Predicted Results

Table 4.8 is a comparison of the measured and predicted deflections, which are within reasonable agreement at the even numbered deflection points measured during testing (see Figure 4.18). The experimental-to-predicted ratios ranged from 0.84 to 1.12. The locations where significant deflection was measured had experimental-to-predicted ratios of 0.94 to 0.99. Significant deflection is defined as deflections greater than 8 mm (0.32 in.).

TABLE 4.8: DEFLECTIONS UNDER MAXIMUM LOADING

Displacement Measurement Location (see Figure 4.16)	Load Case C3 - Deflections Under Maximum Load		
	Measured Deflections (mm)	Predicted Deflections (mm)	Test/Predicted
1	-12.5	-12.9	0.97
2	-12.7	-13.5	0.94
3	-8.6	-8.7	0.99
4	-8.6	-9.2	0.94
5	-4.1	-4.5	0.91
6	-4.2	-5.0	0.84
7	-1.5	-1.4	1.09
8	-1.4	-1.6	0.88
9	-2.3	-2.2	1.05
10	-2.2	-2.3	0.98
11	-2.3	-2.2	1.05
12	-2.3	-2.2	1.03
13	-1.6	-1.5	1.04
14	-1.6	-1.5	1.12

Table 4.9 is a comparison of the measured and predicted strains, which again are in reasonable agreement at most strain gages.

Figure 4.23 is a plot of the strain versus the depth of the section including the predicted strains from the finite element model for Panel 4. The finite element model is based on the assumption that full composite action is developed between the sandwich plate bridge deck and the steel girders. The predicted strains from the finite element analysis do not match the measured strains for the sandwich plate bridge deck. The girder flange experienced some local bending on Girder 2 at Panel 4 due to the cantilever span. The outside of the top flange was in tension while the top of the bent angle and the inside of the bottom flange were in compression under maximum loading. A possible solution to fix this problem would be to use a symmetric section, such as a tee, to transfer the load to the girders.

TABLE 4.9: STRAINS UNDER MAXIMUM LOADING

Strain Measurement Location (see Figure 4.18)	Measured Strain x 10^{-6} (in/in)	Predicted Strain x 10^{-6} (in/in)	Difference
1	71	87	-16
2	-34	-78	44
3	144	187	-43
4	-357	-374	17
5	155	189	-34
6	-351	-377	26
7	77	88	-11
8	-40	-81	41
9	153	175	-22
10	148	172	-24
11	103	63	40
12	14	48	-34
13	31	48	-17
14	122	174	-52
15	147	177	-30
16	-65	63	-128
17	58	51	7
18	-15	47	-62
51	164	188	-24
52	-338	-357	19
53	176	190	-14
54	-341	-360	19
55	88	159	-71
56	138	154	-16
57	160	51	109
58	69	38	31
59	42	43	-1
60	117	156	-39
61	60	161	-101
62	19	57	-38
63	33	36	-3
64	63	44	19
65	344	54	290
66	266	134	132
67	286	133	153
68	-162	54	-216
69	65	-16	81
70	9	30	-21
71	218	-16	234
72	27	31	-4
73	18	-9	27
74	-13	-8	-5
75	33	-8	41
76	-10	-7	-3
77	118	106	12
78	52	148	-96
79	189	152	37
80	232	221	11
81	180	211	-31

Note: $\varepsilon_y = 1700 \times 10^{-6}$ (in/in)

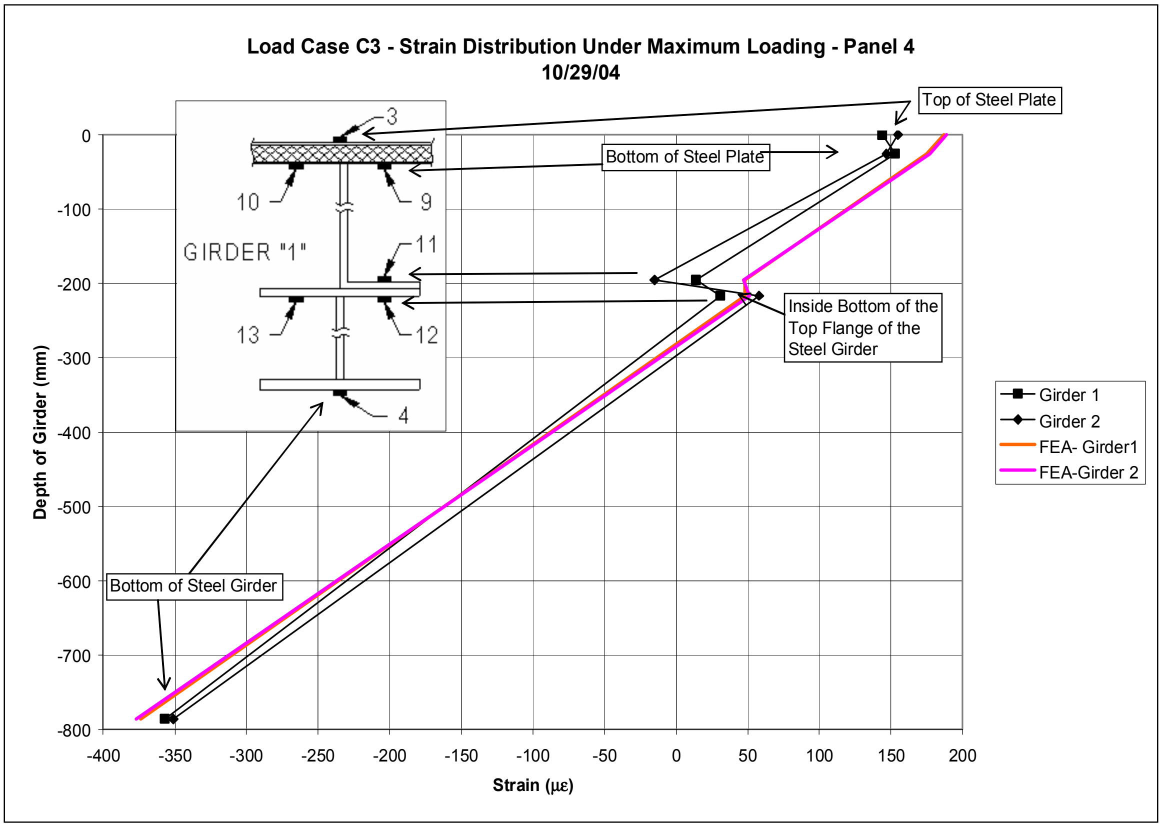


FIGURE 4.23: STRAIN VERSUS DEPTH OF TEST SPECIMEN AT PANEL 4

Figure 4.24 is a plot of the strain versus the depth of the section including the predicted strains from the finite element model for Panel 3. The predicted strains from the finite element analysis do not match the measured strains. The slip critical connections between the bent plate and the girder flange were not designed for a cantilever span and some slip under maximum loading occurred. Also, the measured strain remained nearly constant from the bottom of the steel plate to the top of the bent angle (see Figure 4.24). This indicates the bottom steel plate was not carrying as much load as in the simple span test conditions. The neutral axis of the bridge deck for Load Case C3 was lower than for the Load Case C1, indicating less composite action is present for Load Case C3 than for Load Case C1.

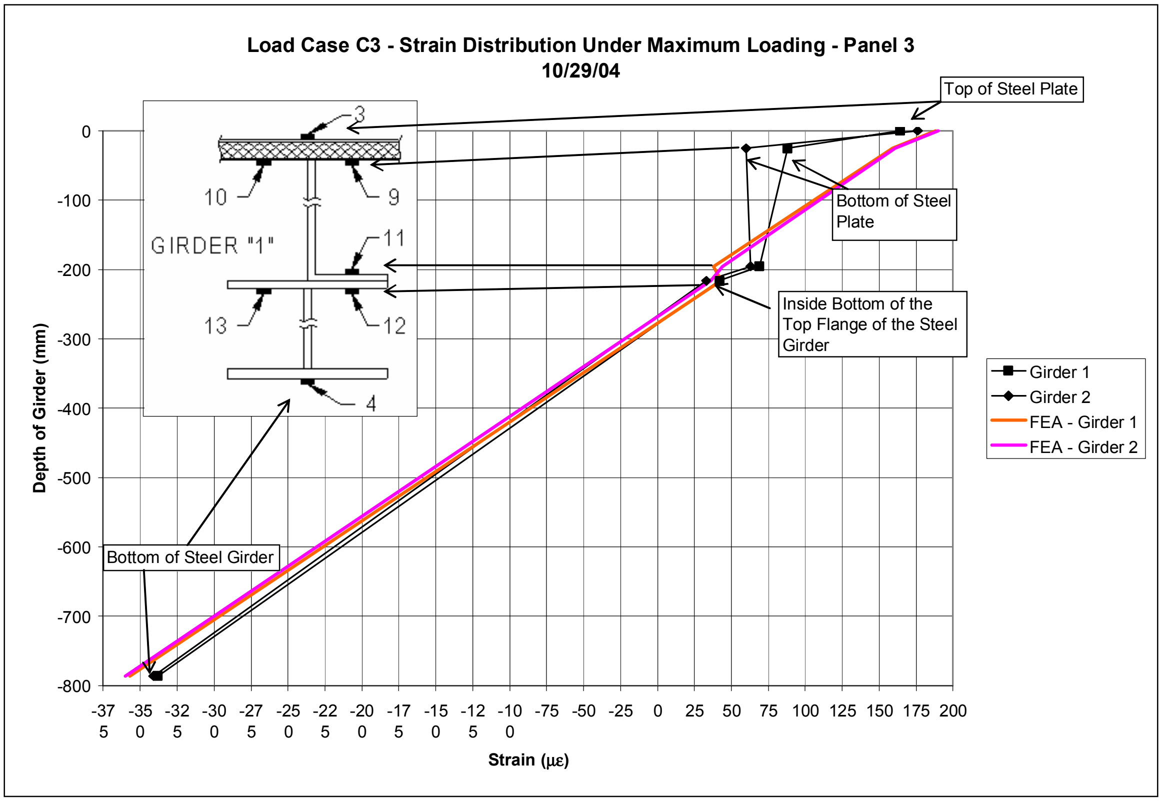


FIGURE 4.24: STRAIN VERSUS DEPTH OF TEST SPECIMEN AT PANEL 3

The measured deflections and finite element analysis predictions are in reasonable agreement, and the measured strains are not in good agreement with the finite element analysis predictions. The slip critical connections between the sandwich plate bridge deck and the girder flange were not designed for a cantilever span and some slip occurred under maximum loading.

4.5 Load Case C4

4.5.1 Test Setup

Load Case C4 was used to determine the local behavior of the longitudinal weld group between Panels 3 and 4. The support beam underneath deck Panels 3 and 4 was aligned so that the web of the support beam coincided with the joint between deck Panels 3 and 4. The support underneath Panel 8 remained in the same position. Load

Case C4, consisted of 5 load points on the top steel plate placed along the centerline of the sandwich plate bridge deck. Figure 4.25 is a plan view of the load positions. Three steel frames were used to apply load to three spreader beams. For Load Case C4, two different bearing pad sizes were used. The bearing pads used to apply load from Frames 1 and 2 measured 229 mm (9.02 in.) by 457 mm (18 in), and from Frame 3 measured 229mm (9.02in.) by 368mm (14.5in.).

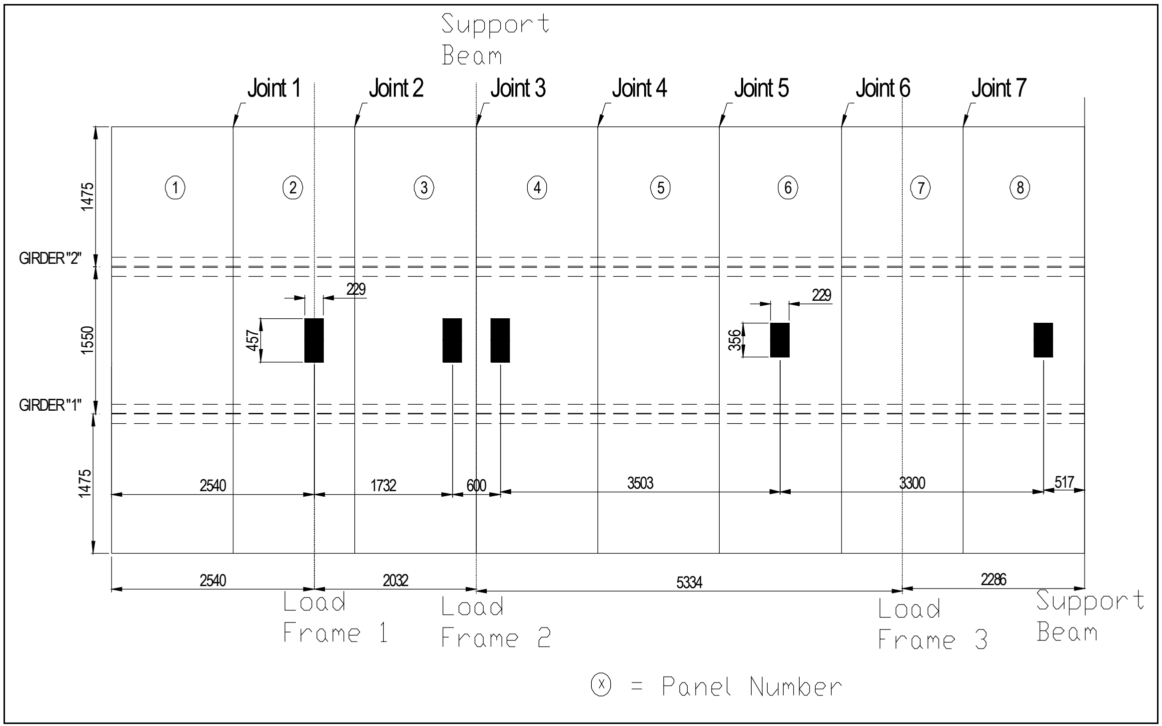


FIGURE 4.25: LOAD POSITIONS FOR LOAD CASE C4

4.5.2 Instrumentation

The instrumentation layout is shown in Figure 4.26. The same strain gages used in Load Case C3 were reused for Load Case C4. Dial gages were used to measure the deflection underneath Girder 2 at the all seven joints, and to measure the support deflection. String-type potentiometers were used to measure the deflection in the center of Panels 2, 3, 4, 6, and 8. A PC-based data acquisition system was used to collect data from the strain gages and the string-type potentiometers. All dial gage readings were manually recorded. For Load Case C4, three hydraulic rams were used to apply load.

The load from each hydraulic ram was measured using a compression load cell. The load cell's accuracy was checked using a SATEC Universal Testing Machine before testing commenced.

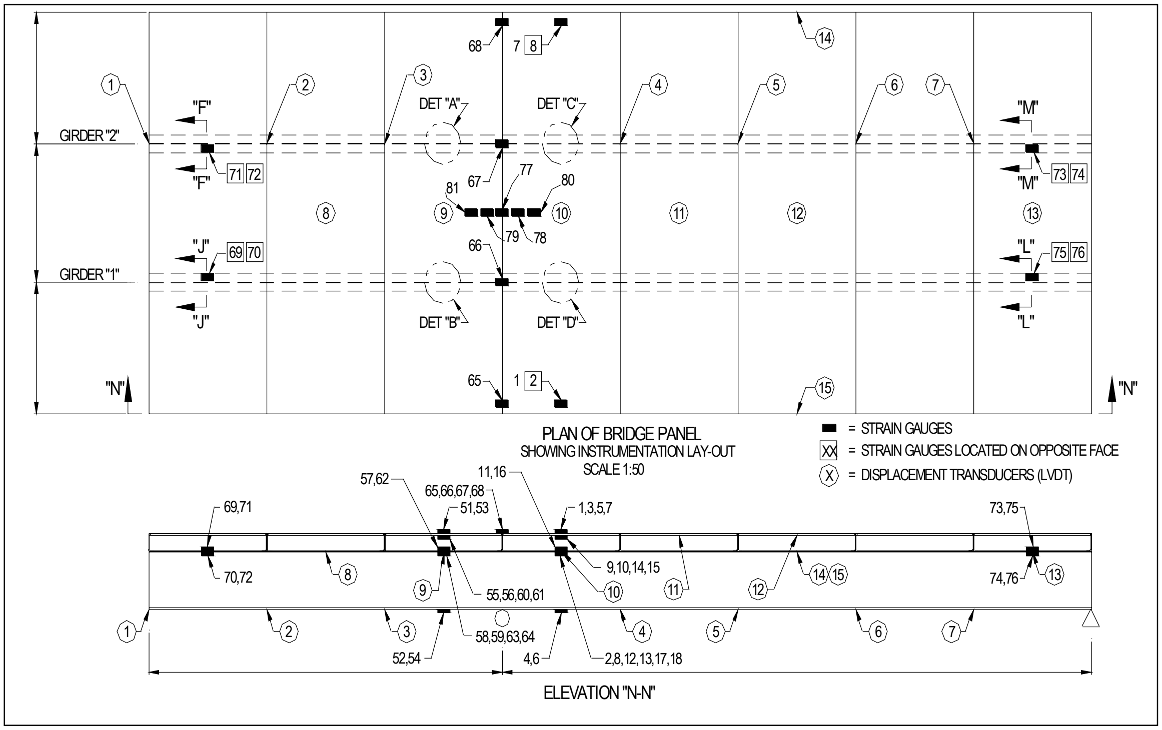


FIGURE 4.26: INSTRUMENTATION LAYOUT FOR LOAD CASE C4

4.5.3 Test Procedure

The test procedure for Load Case C4 was similar to the previous three load cases. The instrumentation was connected to the data acquisition system and set to zero. The strain gages, dial gages, and string-type potentiometers were calibrated in the same manor as described earlier. A seating load of 20% of the maximum loading was applied and the instrumentation output was verified. Necessary adjustments were made before the full scale loading was applied.

Experimental load versus deflection plots were compared to theoretical values in real-time during testing for the five string-type potentiometers. The output from the dial gages underneath Girder 2 was compared to the analytical deflection predicted by the finite element model. The dial gages located on the cantilever side of Girder 2 were set to 12.7 mm (1/2 in.) downward to measure the upward deflection at these locations. The remaining dial gages were set to zero so that downward movement could be recorded.

The sandwich plate bridge deck was loaded in equal increments based on the value of the maximum loading, and strain and deflection measurements were taken at every interval. The maximum applied load was 37.4 kN (8.4 kips), 180.1 kN (40.5 kips), and 233.5 kN (52.5 kips) on load frames 1, 2, and 3, respectively.

4.5.4 Test Results

Figure 4.27 is a photograph taken while the test specimen is fully loaded (Joint 3 between Panels 3 and 4 – See Figure 4.15). Figure 4.28 is a plot of the deflection measured at point 12. The maximum deflection was recorded at the center of the Panel 6 and was equal to 20.78 mm (0.818 in). The support deflections were measured and included in Intelligent Engineering's finite element analysis. Figure 4.28 shows a discrepancy of approximately 30% between the measured and predicted deflections.

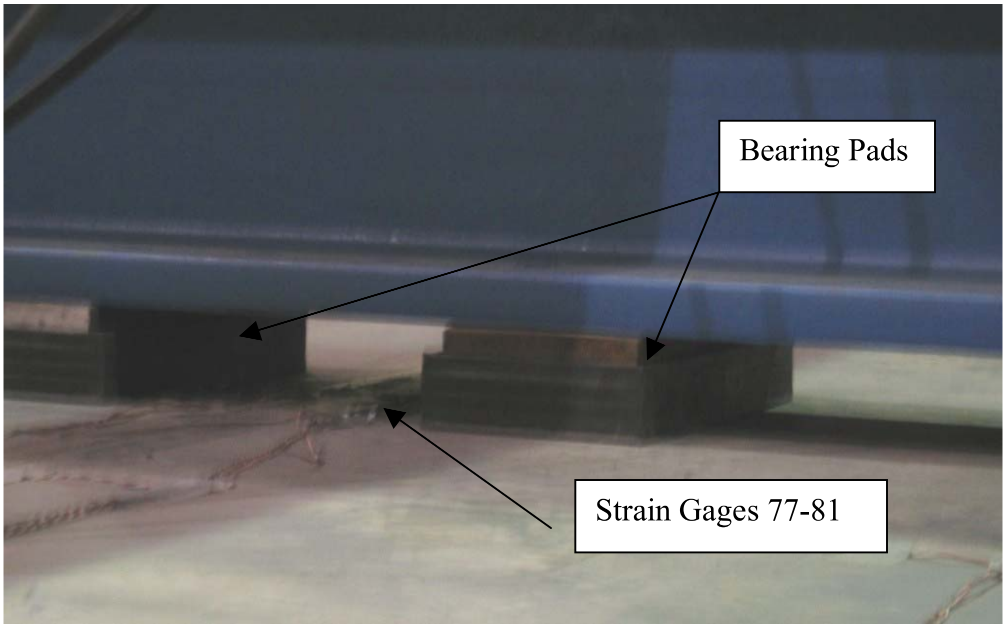


FIGURE 4.27: THE JOINT BETWEEN PANELS 3 AND 4 – FULL SCALE LOADING

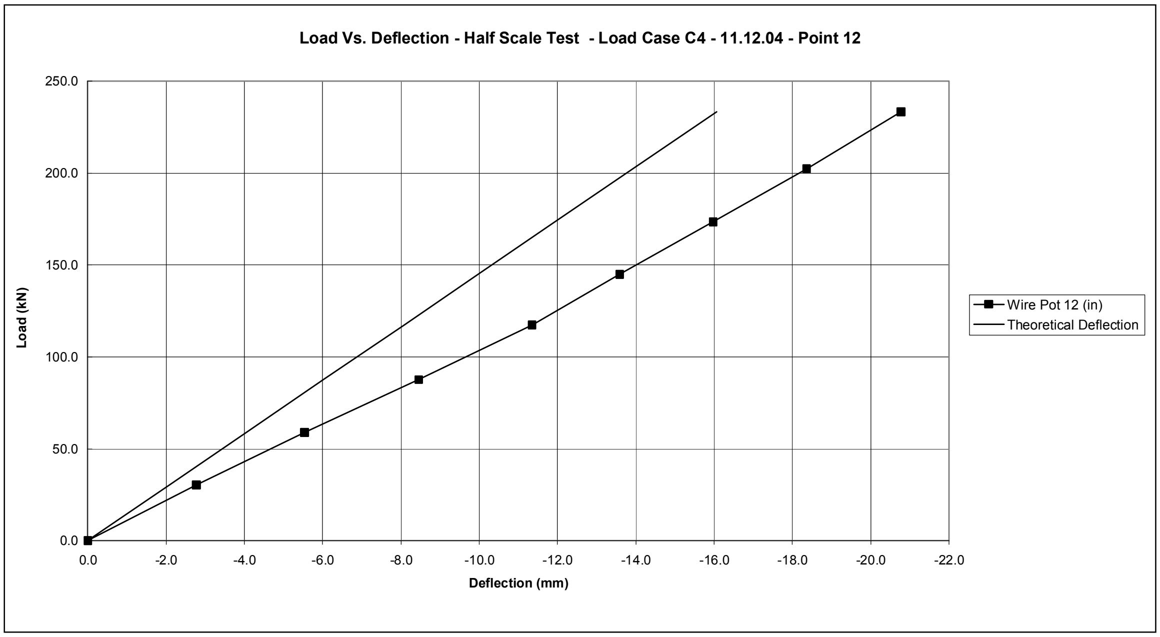


FIGURE 4.28: LOAD VERSUS DEFLECTION FOR POINT 12 – LOAD CASE C4

Table 4.10 is the strain data across Joint 3 (weld between sandwich plate Panels 3 and 4). The strain gages on the butt welds experienced a high level of strain almost to the point of yielding. Since the test specimen is half scale, the butt welds are only 3.175 mm (1/8 in.) thick. The small throat of the butt weld makes it the critical detail in the weld group. The strain gages above the girders (66 and 68) experienced little strain under maximum loading as expected. Strain gage 77 on the groove weld at the center of the specimen experienced more strain than the two strain gages located on the outside of the edge of the weld (65 and 67) as expected. Figure 4.29 is a plot of strain versus load for Strain Gages 78 and 79 located on the butt welds in the center of Joint 3. The maximum strain measured on the butt weld was 1592 $\mu\varepsilon$, which is equivalent to 319 MPa (46.2 ksi).

Table 4.11 shows the measured strains at the 49 strain gage locations under maximum loading. The maximum strain, 1592 $\mu\varepsilon$, was measured on the butt weld near Joint 3 at Strain Gage 78.

After the load was removed from the test specimen, the specimen returned to its initial position with no permanent deformation.

TABLE 4.10: MEASURED STRAINS ALONG THE WELD BETWEEN PANELS 3 AND 4 UNDER MAXIMUM LOADING

LC 1 (kN)	LC 2 (kN)	LC 3 (kN)	SG #65 (με)	SG #66 (με)	SG #67 (με)	SG #68 (με)	SG #77 (με)	SG #78 (με)	SG #79 (με)	SG #80 (με)	SG #81 (με)
0.0	0.0	0.0	1	0	0	0	0	0	0	0	0
5.2	22.4	30.2	84	3	59	5	107	179	181	93	72
10.6	44.9	58.8	168	8	116	14	216	359	376	193	146
13.9	67.9	87.7	255	10	177	21	327	547	572	292	222
17.7	90.5	117.4	345	12	240	25	439	737	768	392	300
23.1	112.0	144.8	429	14	302	29	555	935	965	491	381
26.7	133.4	173.4	512	15	361	31	663	1127	1150	586	459
31.8	156.2	202.3	601	17	424	35	782	1342	1348	688	546
37.2	180.4	233.3	698	20	496	36	915	1592	1564	798	643

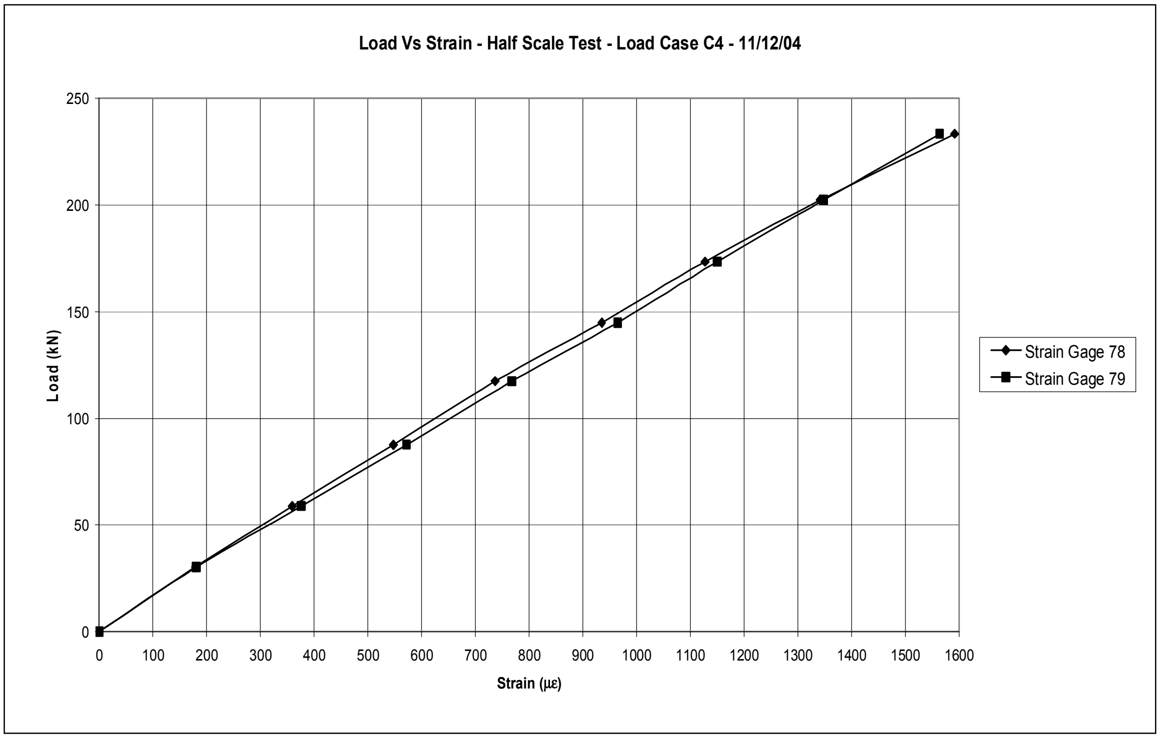


FIGURE 4.29: STRAIN GAGE 78 AND 79 ON THE BUTT WELDS NEAR JOINT 3

TABLE 4.11: MEASURED STRAINS AT MAXIMUM LOADING FOR LOAD CASE C4

Strain Measurement Location (Figure 4.26)	Measured Strain x 10^{-6} (in/in)
1	-14
2	0
3	-28
4	-13
5	-34
6	-3
7	-15
8	8
9	19
10	12
11	10
12	-10
13	23
14	7
15	-4
16	-24
17	20
18	-5
51	8
52	-23
53	44
54	-22
55	29
56	20
57	32
58	23
59	-38
60	12
61	19
62	16
63	-20
64	16
65	698
66	20
67	496
68	36
69	-1
70	29
71	3
72	1
73	-10
74	-4
75	177
76	-13
77	915
78	1592
79	1564
80	798
81	643

Note: $\varepsilon_y = 1700 \times 10^{-6}$ (in/in)

4.5.5 Finite Element Analysis

The finite element modeling and analysis procedures for Load Case C4 were the same as the previous three load cases.

Figure 4.30 shows the deflected surface for Load Case C4. The maximum predicted deflection was at Point 12, 16.1 mm (0.63 in.). Measured support deflections were used to create an elastic foundation for Load Case C4.

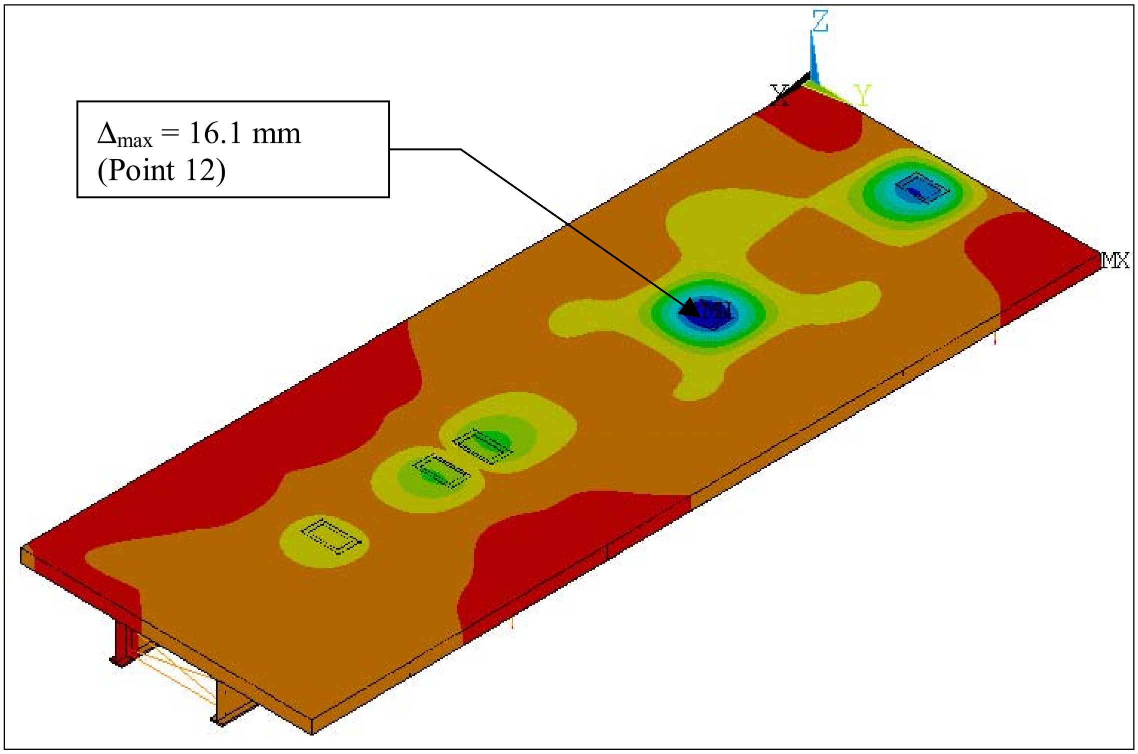


FIGURE 4.30 DEFLECTION CONTOURS FOR LOAD CASE C4

4.5.6 Comparison of Experimental and Predicted Results

Table 4.12 is a comparison of the measured and finite element analysis predicted deflections. The measured and predicted deflections are not in good agreement. The disagreement between the measured and predicted deflections at locations 1, 2, and 3 (see Figure 4.26) is due to support movement and rotation. The measured deflection at Panels 2, 3, and 4 was in reasonable agreement with the finite element analysis predictions, but the deflections did not agree for Panels 6 and 8.

TABLE 4.12: DEFLECTIONS UNDER MAXIMUM LOADING

Displacement Measurement Location (see Figure 4.26)	Load Case C4 - Deflections Under Maximum Load		
	Measured Deflections (mm)	Predicted Deflections (mm)	Test/Predicted
1	0.76	0.03	27.21
2	0.25	-0.21	-1.24
3	-0.33	-0.42	0.79
4	-1.79	-1.54	1.16
5	-2.54	-2.34	1.09
6	-2.57	-2.52	1.02
7	-1.88	-2.00	0.94
8	-3.71	-3.57	1.04
9	-4.65	-4.63	1.00
10	-5.36	-5.46	0.98
11	-1.02	-1.28	0.79
12	-20.78	-16.06	1.29
13	-16.08	-12.84	1.25
14	-0.71	-1.45	0.49
15	-0.79	-1.02	0.77

Table 4.13 is a comparison of the measured and predicted strains, which are in reasonable agreement at most strain gage locations.

Figure 4.31 is a plot of the finite element analysis predicted stress concentration between the two load points at the joint between Panels 3 and 4. The finite element model correctly predicated the stresses in this region, but the predicted strains do not match the measured strains for the strain gages between the two load points at Joint 3 (Strain Gages:77-81). The experimental-to-predicted ratios for Strain Gages 77-81 range from 1.91 to 4.18. A possible explanation of this discrepancy is the location of the predicted strains in the finite element model and the location of the measured strains are not exactly in the same location for the region between the two load points. The change in stress in this area varies from 272 MPa (39.5 ksi) to 38 MPa (5.5 ksi), and if the location of the measurement is off by 1 mm (0.04 in.) the change in stress (strain) would be large.

TABLE 4.13: STRAINS UNDER MAXIMUM LOADING

Strain Measurement Location (see Figure 4.26)	Measured Strain x 10^{-6} (in/in)	Predicted Strain x 10^{-6} (in/in)	Difference
1	-14	5	-19
2	0	-62	62
3	-28	12	-40
4	-13	-31	18
5	-34	13	-47
6	-3	-32	29
7	-15	6	-21
8	8	-63	71
9	19	34	-15
10	12	26	-14
11	10	5	5
12	-10	2	-12
13	23	23	0
14	7	27	-20
15	-4	36	-40
16	-24	5	-29
17	20	25	-5
18	-5	1	-6
51	8	24	-16
52	-23	-47	24
53	44	26	18
54	-22	-49	27
55	29	43	-14
56	20	35	-15
57	32	33	-1
58	23	30	-7
59	-38	-16	-22
60	12	36	-24
61	19	44	-25
62	16	39	-23
63	-20	-23	3
64	16	36	-20
65	698	28	670
66	20	-20	40
67	496	-20	516
68	36	29	7
69	-1	-3	2
70	29	-3	32
71	3	-2	5
72	1	-2	3
73	-10	10	-20
74	-4	12	-16
75	177	12	165
76	-13	13	-26
77	915	398	517
78	1592	822	770
79	1564	817	747
80	798	191	607
81	643	189	454

Note: $\varepsilon_y = 1700 \times 10^{-6}$ (in/in)

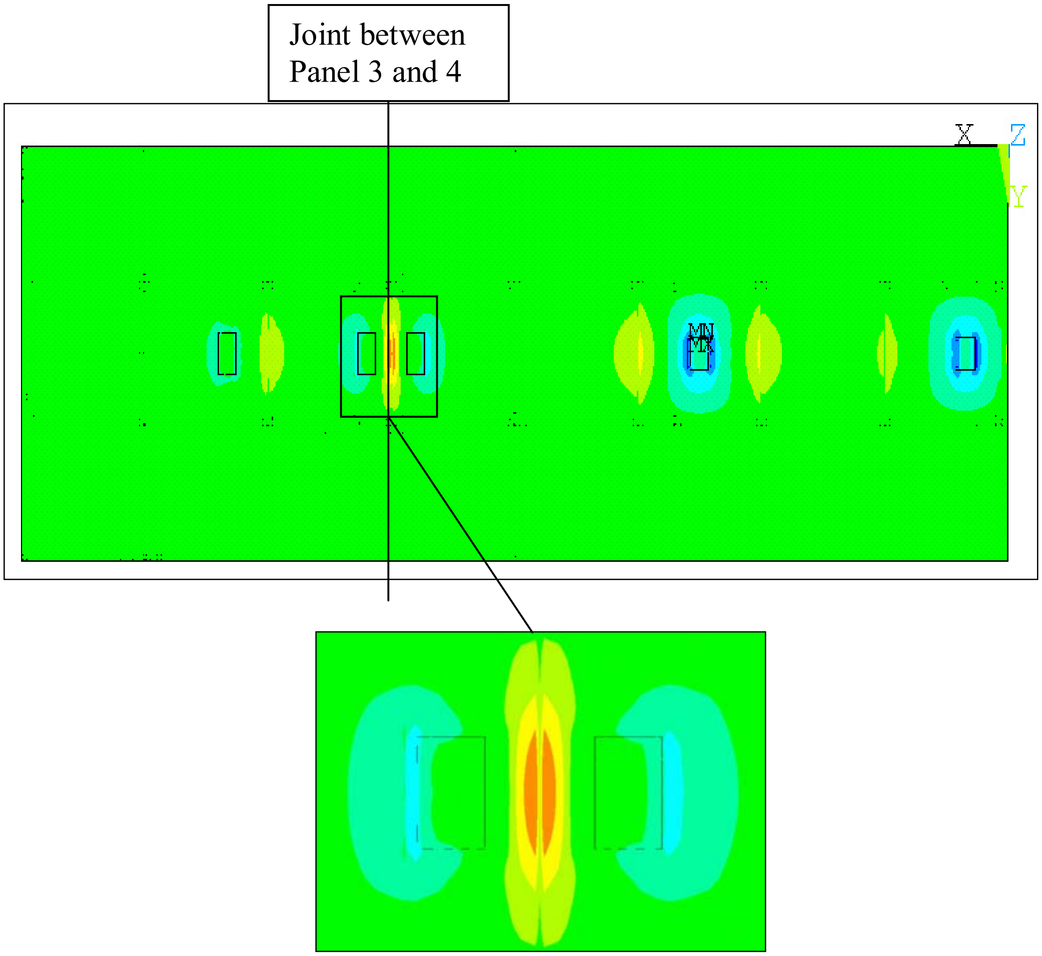


FIGURE 4.31: STRESS CONCENTRATION AT WELD BETWEEN JOINTS 3 AND 4

Table 4.14 is the measured and finite element analysis predicted strains across the weld of Joint 3.

TABLE 4.14: STRAINS ACROSS THE WELD GROUP AT JOINT 3

Strain Measurement Location (see Figure 4.24)	Measured Strain x 10^{-6} (in/in)	Measured Strain x 10^{-6} (in/in)	Test/Predicted
67	496	-20	-24.93
68	36	29	1.26
77	915	398	2.30
78	1592	822	1.94
79	1564	817	1.91
80	798	191	4.17
81	643	189	3.41

The measured and predicted strains are inconsistent at some strain gage locations across the weld between Panels 3 and 4. A possible explanation of this behavior is the weld surface was not level when the strain gages were applied. If the strain gage was installed on a surface that was not level, the strain measurements would not be linear once load was applied. Figure 4.32 is a photograph of the weld surface at Joint 3.

FIGURE 4.32: WELD SURFACE AT JOINT 3

The experimental results are in reasonable agreement with the finite element analysis results with the exception of the measured strains at Joint 3.

4.6 Summary of Half Scale Bridge Experimental Testing

Load Case C1

The sandwich plate deck exhibited almost full composite action with the steel girders for Load Case C1. The neutral axis was found to be above the center of the steel girder indicating composite action is present. The measured deflections and strains had good agreement with the finite element analysis predictions.

Load Case C2

For the most part, the results from the experimental testing and finite element analysis are in good agreement. The deflections measured on the South side of the half scale bridge and underneath Girder 1 are within reasonable agreement to the predicted deflection. A rigid body rotation that could not be accounted for, possibly caused a discrepancy between the measured and predicted strains, and the rigid body rotation also possibly raised the location of the neutral axis of Girder 1. Full composite action was not observed on Girder 1 for Load Case C2. A change in the strain occurred at the interface between the sandwich plate deck and the steel girders indicating some slip occurred.

Load Case C3

The measured and predicted deflections and strains were in reasonable agreement for Load Case C3. The predicted strains from the finite element analysis do not match the measured strains through the depth of the test specimen. The slip critical connections between the bent plate and the girder flange were not designed for a cantilever span and some slip under maximum loading occurred. The neutral axis location for Load Case C3 was lower than for Load Case C1, indicating less composite action is present for Load Case C3 than Load Case C1.

Load Case C4

The measured and predicted deflections are not in good agreement for Load Case C4. The measured strains on the butt welds in the center of the panel around Joint 3 were close to yielding. A possible explanation of the discrepancy in the strains across on the weld of Joint 3 is that the weld surface was not level before the strain gage was applied.

CHAPTER 5

SHEAR LAG AND EFFECTIVE WIDTH

5.1 General

The Bernoulli-Euler general assumption states that plane section remain plane after bending. This assumption is used often in the analysis of beams, and according to this assumption, the longitudinal normal stresses should be uniformly distributed across the width of the flange of a beam. This assumption greatly simplifies beam analysis but it is not appropriate for all structures. In structures with very wide flanges, stresses are generally higher at the flange-web junction than at the edges of the flange. The “lagging” of the stresses on either side of the flange-web junction is called positive shear lag. Shear lag is a phenomenon that occurs in structures such as bridge decks and plate girders due to the nonlinear distribution of stress across a wide top flange.

Shear lag of tees, I-shaped, and box beams has been studied in depth by Winter (1940), Brendel (1964), Sabnis and Lord (1976), Foutch and Chang (1982), Irrcher (1983), Maisel (1986), and Kristec and Bazant (1986). In addition, Kwan (1996) studied shear lag in shear/core walls. Negative shear lag is an anomaly where the stress distribution is opposite from that in positive shear lag, that is, the stresses are the largest somewhere along the width of the flange as opposed to the flange-web junction. Negative shear lag has been investigated by Chang and Zheng (1987), Song and Scordelis (1990), Shushkewich (1991), Luo et al (2001), and Lee et al (2002). A large amount of literature is available for composite steel girder and concrete deck systems; however, very few references to other types of composite systems are available. Keelor et al. (2004) studied a fiber reinforced polymer (FRP) bridge deck that acted compositely with steel girders under service loads. This paper is discussed in detail because the system is best characterized as an orthotropic bridge deck that is flexurally strong in the direction normal to the girders span. The bridge investigated by Keelor et al. (2004) is a comparable to the sandwich plate bridge described in the previous chapters.

Keelor et al. (2004) investigated a composite FRP deck and steel girder bridge in Pennsylvania. The Boyer Bridge consists of five W610x155 (W24x104) girders spaced at 1753 mm (69 in.) which acted compositely with five FRP deck panels. Composite action was achieved by using headed studs welded to the steel girders and grouted to openings in the FRP deck panels every 610 mm (24 in.). The deck overhang is 381 mm (15 in.) on both sides of the bridge. A test truck was used to apply load in three different configurations. Six strain gages were applied to each girder with a strain gage located on the bottom of the top flange of the girder, the middle of the web of the girder, and the top of the bottom flange of the girder on both sides of the member. The measured strains were used to determine the neutral axis location for each girder and each configuration. The effective flange width was calculated using the transformed section properties and the neutral axis location. The effective width was then compared to the provisions in *AISC Load and Resistance Factor Design Specification* (1999) and *AASHTO LRFD Bridge Design Specification* (1998). Under service conditions, it was found that the effective width for the interior girders was 75% of the total girder to girder spacing, and for the exterior girders, 90% of the sum of the girder spacing and deck overhang.

Methods to analyze shear lag are: the folded plate method, the harmonic analysis method, the three-bar method, the energy method, and the finite element method. DeFries-Skene and Scordelis (1964) developed the folded plate method where the bridge deck is treated as an assembly of folded plates connected at longitudinal joints. The loads, forces, and joint displacements are represented by Fourier series, and each term in the Fourier series is evaluated separately and then combined to obtain the total result.

The harmonic analysis method developed by Abdel-Sayed (1964) is similar to the folded-plate method with the exception of only the flange plates are analyzed. This is possible because out of plane bending is neglected and the web is treated as simple bending element.

The three-bar method developed by Evans and Taherian (1977) also considers only the flange plates in the shear lag analysis. The web is assumed to be a simple bending element. The flange plates are analyzed by welding three stringers onto the flange plates to separate the axial and shearing forces making the equations of equilibrium easier to solve.

In the energy method, the solutions to the equations of equilibrium are solved by minimizing the strain energy or the total potential energy of the structure. The energy method requires numerous assumptions and is not as accurate as the other methods presented according to Kwan (1996).

Moffatt and Dowling (1975) used the finite element method to develop design aids to estimate shear lag in steel box girder bridge decks. According to Kwan (1986), the use of computers makes the finite element method the best option for shear lag analysis.

The following sections describe the finite element analyses used to determine the shear lag effect, the effective width guidelines established by the *AISC Specification* (1999) and the *AASHTO Specification* (1998), the calculation of the effective width from experimental measurements, and a comparison of the sandwich plate bridge effective width to current standards.

5.2 Shear Lag Analysis

The shear lag effect on the sandwich plate bridge deck was investigated using finite element analyses conducted by Intelligent Engineering Ltd, Ottawa, Ontario, Canada. Figure 5.1 is the Von Mises stress contours for Load Case C1, symmetrical loading over a simple span conducted on the half scale bridge. Figure 5.2 is the predicted strain data from the finite element model under maximum loading for Load Case C1 at the strain gages across the width of the test specimen in the center of Panel 4 (see Figure 4.3). All of the finite element analysis predicted strains are in compression.

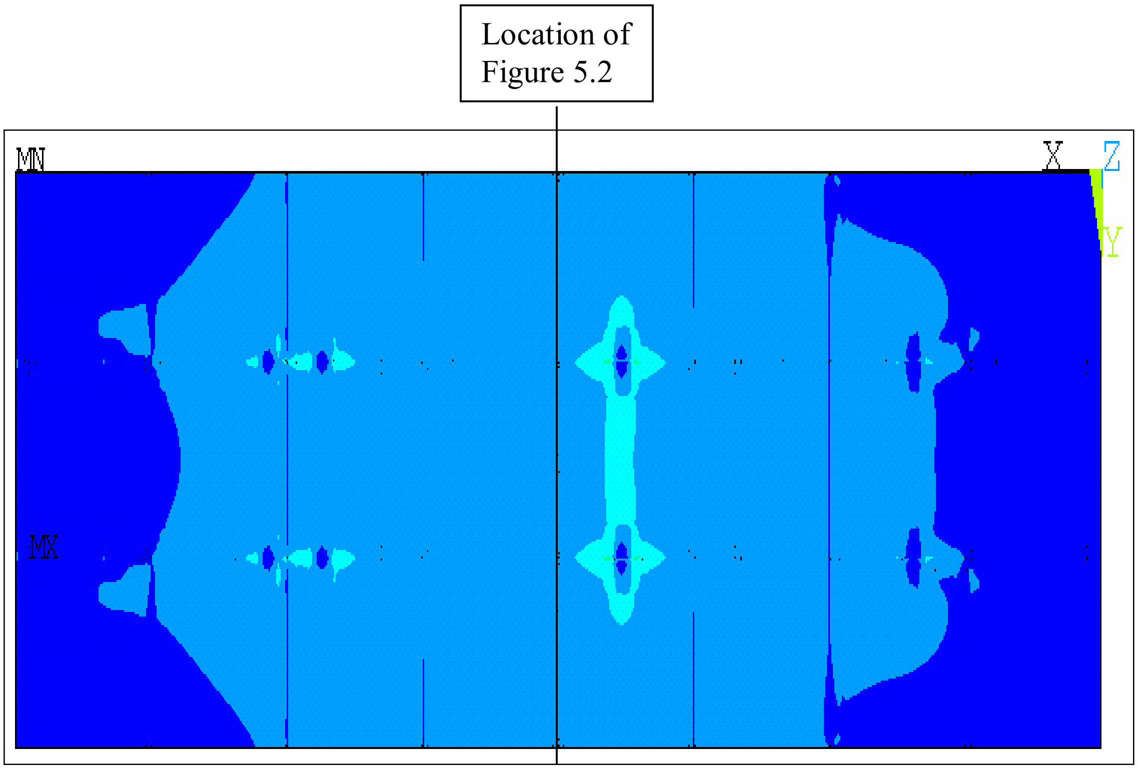


FIGURE 5.1: VON MISES STRESS CONTOURS UNDER MAXIMUM LOADING – LOAD CASE C1

The von Mises stress contours are used to estimate where the sandwich plate deck is about to yield.

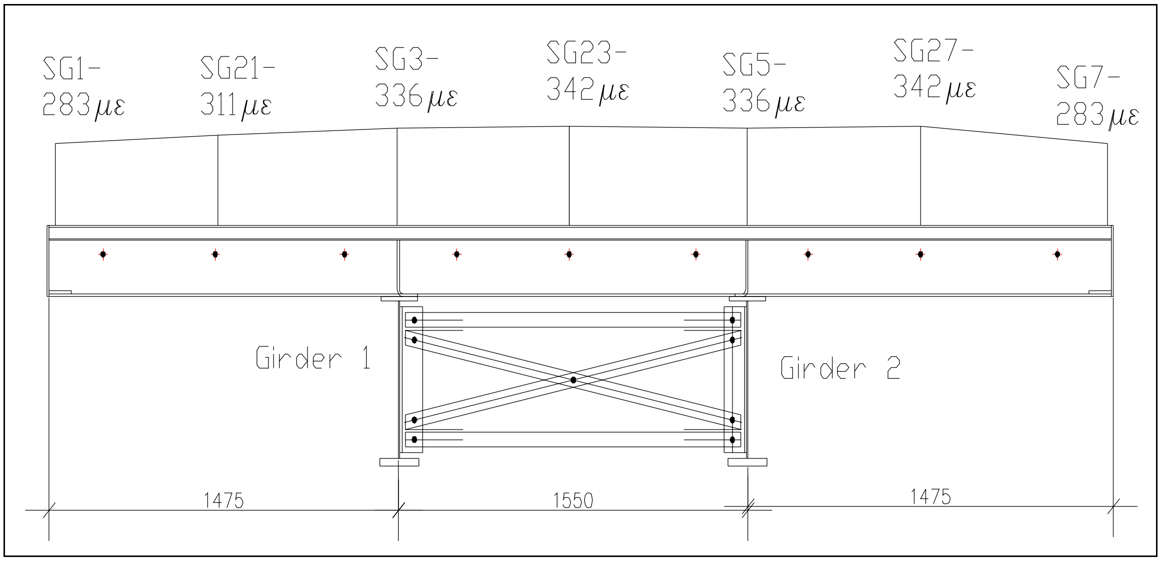


FIGURE 5.2: PREDICTED STRAINS ACROSS THE WIDTH OF PANEL 4 AT MAXIMUM LOADING – LOAD CASE C1

5.3 Effective Width

For design purposes, the concept of effective width was developed to account for the shear lag effect. The basic idea is that a wide top flange is replaced with a narrower effective flange and the new beam is then analyzed using the Bernoulli-Euler assumption. Two sources commonly used to determine the effective width of the compression flange are the *AISC Load and Resistance Factor Design Specification* (1999) and the *AASHTO LRFD Bridge Design Specification* (1998). The rules established in these specifications are based on a system comprised of a concrete deck acting compositely with steel girders. Strain compatibility is obtained by using headed shear studs welded to the steel girder and embedded in the concrete. To determine the effective width of the sandwich plate bridge deck, a method similar to the rules established in the specifications is developed and compared to the specification rules.

In the *AISC Specification* (1999), the effective width is determined by summing the effective width on each side of the beam center-line. The effective width on each side of the centerline of a beam is taken as the minimum of the following three criteria:

one-eighth of the beam span, center-to center of supports; one half the distance to the center-line of the adjacent beam; and the distance to the edge of the slab. The *AISC Specification* (1999) does not specify restrictions based on the flexural restraint at the supports. Based on the above parameters, the effective width of the half scale bridge for the simple support condition of Load Case C1 is 2250 mm (88.6 in.), which is the minimum of (1524 mm (60 in.), 1475 mm (58.1 in.)) and the minimum of (1524 mm (60 in.), 775 mm (30.5 in.)).

The *AASHTO LRFD Bridge Design Specification* (2004) delineates between interior girders and exterior girders. For exterior girders, the effective width on each side of the centerline is calculated as if the girder is located in the interior; This value is then halved and added to the smaller of one-eighth of the effective beam span, six times the average deck thickness plus one-quarter of the top flange width of the steel girder, one-half of the web thickness, or the width of the deck overhang. For an exterior girder, the effective width of the half scale bridge for the simple support condition of Load Case C1 is 153 mm (6.0 in.). The effective width calculated from the *AASHTO Specification* (1998) is based on a concrete deck not a sandwich plate bridge deck.

To accurately compare the *AASHTO Specification* (1998) effective width provisions to the half scale bridge deck, the sandwich plate bridge deck was replaced with an equivalent concrete deck. The concrete was assumed to have a unit weight of 23.6 kN/m^3 (150 lbs/ft^3) and a compressive strength of 27.6 MPa (4 ksi). The modulus of elasticity was determined to be 25.3 GPa (3674 ksi). Using the same steel girders and keeping the neutral axis in the same location as the transformed bridge section, the equivalent concrete deck thickness is 165 mm (6.5 in.). Based on this deck thickness, the effective width from the *AASHTO Specification* (1998) is 991 mm (39 in.).

5.4 Experimental Determination of Effective Width

Table 5.1 lists the section properties of one half of the cross section of the half scale simple span bridge. The contribution of the elastomeric core to resisting the compression component is included by transforming the material to steel. The assumed modulus of elasticity of the elastomeric core, 750 MPa (109 ksi), results in a modular ratio, n, of 266, which was used to convert the elastomeric core to steel for the transformed section calculations. The experimental effective width is determined using the transformed section properties.

TABLE 5.1: SECTION PROPERTIES USED TO DETERMINE THE EFFECTIVE WIDTH

Section	Area (mm^2)	y_i (mm)*	Ay_i (mm^3)
Top Steel Plate	$3.2b_{eff}$	784	$2509b_{eff}$
Elastomeric Core	$19.1(b_{eff}/n)$	773	$56b_{eff}$
Bottom Steel Plate	$3.2b_{eff}$	762	$2438b_{eff}$
Bent Angle - Vert.	817	675	551611
Bent Angle – Horz.	302	588	177721
Top Flange of Girder	2512	577	1450419
Girder Web	3482	297	1035428
Bottom Flange of Girder	4522	13	57419
Sum of Table Properties	$11635+6.5b_{eff}$		$3272598+5003b_{eff}$

* With respect to the bottom of the bottom flange

With

$$(Area)(\overline{Y}) = (Area)(y_i) \tag{5.1}$$

where Area is the area of each section, y_i is the distance to the centroid of each piece, $\overline{Y}$ is the location of the neutral axis, and b_{eff} is the effective width. Using the neutral axis location determined in Chapter 4 from strain gage data, that is, 566.7 mm (22.3 in.) from the bottom of the bottom of the flange of the steel girder Equation 5.1 becomes:

$$\left(11634 + 6.5b_{eff}\right)(566.7) = 3272598 + \left(5003b_{eff}\right) \tag{5.2}$$

and:

$$b_{eff} = 2487 \text{ mm } (97.9 \text{ in.}) \tag{5.3}$$

However, the value of b_{eff} is grater than the physical width, that is, 2250 mm (88.6 in.), which is not possible.

Figure 5.3 shows the strain measurements taken at maximum loading during the simple span, symmetric loading of Load Case C1 and the finite element model strain predictions for the strain gages across the width of the test specimen in the center of Panel 4 (see Figure 4.3). All the strain measurements were in compression. The location of the strain gages is shown in Figure 4.3. The strains remain nearly constant over each half of the test specimen. A typical shear lag effect would have had strain peaks at the above the center line of the girders (SG 3 and SG 5) with the lowest strain measured between the girders (SG 23) and the quarter points (SG 21 and SG27).

Using the effective width of 2250 mm (88.6 in.), the neutral axis location of the half scale, simple span bridge was determined to be 554.6 mm (21.8 in) above the bottom of the bottom flange of the steel girder. The discrepancy between the experimental neutral axis and the neutral axis back calculated from the experimental effective width is 12.1 mm (0.48 in.), and therefore, the neutral axes are in reasonable agreement. The contribution of the elastomeric core to resisting the compression force in the compression/tension couple can be neglected when calculating the neutral axis location and the effective width because the modular ratio is very large.

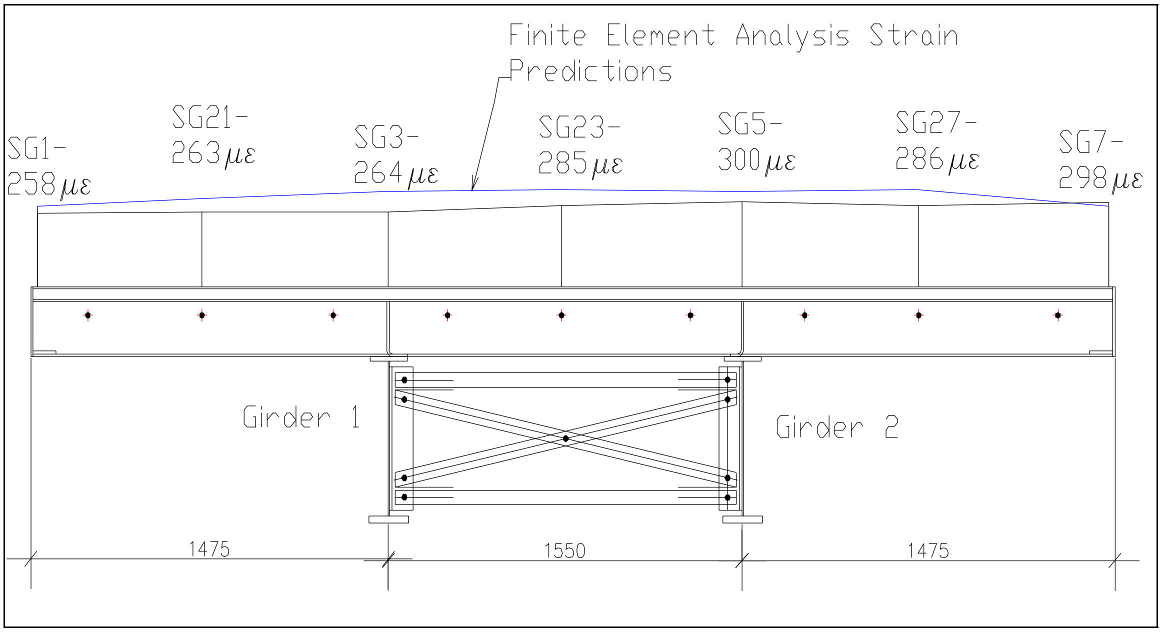


FIGURE 5.3: MEASURED STRAINS IN THE CENTER OF PANEL 4 – LOAD CASE C1

Table 5.2 is a comparison of the measured and predicted strains. The measured and predicted strains have reasonable agreement across the width of Panel 4 under maximum loading for Load Case C1. The experimental test to predicted ratios range from 0.79 to 1.05 for the strain gages used to determine the shear lag effect.

TABLE 5.2: MEASURED AND PREDICTED STRAINS AT MAXIMUM LOADING FOR LOAD CASE C1

Strain Measurement Location (see Figure 4.10)	Measured Strain x 10^{-6} (in/in)	Predicted Strains x 10^{-6} (in/in)	Test/Predicted
1	-258	-283	0.91
21	-263	-311	0.85
3	-264	-336	0.79
23	-285	-342	0.83
5	-300	-336	0.89
27	-286	-342	0.84
7	-298	-283	1.05

5.5 Comparison of Sandwich Plate Bridge Effective Width to Current Standards

The effective width determined from the *AISC Specification* (1999) is the same as the effective width calculated from experimental measurements, and the effective width based on the *AASHTO Specification* (1998) is less than the experimental effective width.

5.6 Summary

The previous sections were used to develop a brief history of shear lag and to calculate the effective width of the half scale bridge deck based on the *AISC Specification* (1999) and the *AASHTO Specification* (1998). The experimental effective width was calculated based on the transformed section properties and the location of the neutral axis as discussed in Chapter 4. The effective width determined from the *AISC Specification* (1999) is the same as the experimental effective width, and the effective width from the *AASHTO Specification* (1998), determined from an equivalent concrete deck, is smaller than the experimental effective width. The neutral axis location determined from strain gage measurement is in good agreement with the neutral axis back calculated from the experimental effective width.

CHAPTER 6

CONCLUSIONS

6.1 Summary

Three static tests were conducted on a full scale sandwich plate bridge deck panel to determine local strains and deflections. The connection between two sandwich plate bridge deck panels was tested to various cycle lengths to investigate the fatigue characteristics of the longitudinal weld group and to develop an S-N curve for the weld group. A one-half scale bridge was constructed using eight sandwich plate bridge deck panels to examine the effects of shear lag and the response in the positive and negative moment regions.

The results obtained from experimental testing were compared to a finite element analysis preformed by Intelligent Engineering.

A comparison of effective widths was performed using current standards in common practice today. The effective width for design purposes for the sandwich plate bridge was determined using the experimental results and compared to a composite concrete deck and steel girder system.

6.2 Conclusions

6.2.1 Static Test Panel

The testing objectives for each series of testing were achieved. The local strains and deflections were investigated using two elastic load cases on a full scale sandwich plate bridge deck panel. The same test specimen was loaded to 1156 kN (260 kips) and still exhibited linear-elastic behavior. The experiential results are in reasonable agreement with the finite element analyses predictions provided by Intelligent Engineering.

6.2.2 Longitudinal Bridge Deck Joint – Fatigue Test

All the welds in the longitudinal weld group can be classified as at least a fatigue detail E. The stresses measured on the welds are less than the corresponding stresses from the AASHTO (1998) standard S-N Curve for fatigue detail E indicating the weld is of good quality. The square butt weld controls the ultimate strength of the weld group because the square butt weld has a smaller effective throat.

6.2.3 Half Scale Continuous Bridge Deck Test

Load Case C1

The sandwich plate deck exhibited almost full composite action with the steel girders for Load Case C1. The neutral axis was found to be above the center of the steel girder indicating composite action is present. The measured deflections and strains had good agreement with the finite element analysis predictions.

Load Case C2

For the most part, the results from the experimental testing and finite element analysis are in good agreement. The deflections measured on the South side of the half scale bridge and underneath Girder 1 are within reasonable agreement to the predicted deflection. A rigid body rotation that could not be accounted for, possibly caused a discrepancy between the measured and predicted strains, and the rigid body rotation also possibly raised the location of the neutral axis of Girder 1. Full composite action was not observed on Girder 1 for Load Case C2. A change in the strain occurred at the interface between the sandwich plate deck and the steel girders indicating some slip occurred.

Load Case C3

The measured and predicted deflections and strains were in reasonable agreement for Load Case C3. The predicted strains from the finite element analysis do not match the measured strains through the depth of the test specimen. The slip critical connections between the bent plate and the girder flange were not designed for a cantilever span and some slip under maximum loading occurred. The neutral axis location for Load Case C3 was lower than for Load Case C1, indicating less composite action is present for Load Case C3 than Load Case C1.

Load Case C4

The measured and predicted deflections are not in good agreement for Load Case C4. The measured and predicted strains are not in good agreement for the strains measured along Joint 3. A possible explanation of the discrepancy in the strains is that the weld surface was not level before the strain gage was applied. The strains measured on the half scale test specimen longitudinal weld group indicate yielding will not occur under service loads and the measured strains reaffirm the idea that the butt weld is the critical detail in the weld group.

6.2.4 Shear Lag and Effective Width

The effective width determined from the *AISC Specification* (1999) is the same as the experimental effective width, and the effective width from the *AASHTO Specification* (1998), determined from an equivalent concrete deck, is smaller than the experimental effective width. The neutral axis location determined from strain gage measurement is in good agreement with the neutral axis back calculated from the experimental effective width. The effective width was determined to be the full physical width for the half scale simple span bridge.

6.3 Suggestions for Future Research

Additional testing is required to verify the findings of this study. The ultimate load of a sandwich plate panel needs to be determined. Also, the method of failure should be determined. The analyses should include any yielding of the steel top and bottom plates, debonding of the elastomer core and steel plates, and any yielding of the steel cross stringers.

Fatigue testing should be conducted on the half scale simple span bridge to verify the S-N Curve that was developed using smaller connection test specimens. Also, fatigue testing the half scale bridge would provide insight on any problems related to the slip-critical bolts slipping under fatigue loading.

Further, a field bridge should be constructed and monitored to determine the effects of repeated fatigue loading on a full scale bridge. Strain gages should be located on the cross stringers to observe if any bending occurs under loading. Also, strain gages should be placed through the depth of the cross section to determine the percentage of composite action, and to evaluate any slip between the sandwich plate bridge deck and steel girders. The field connection between two bridge deck panels should also be investigated to determine the effects of localized tension on the weld.

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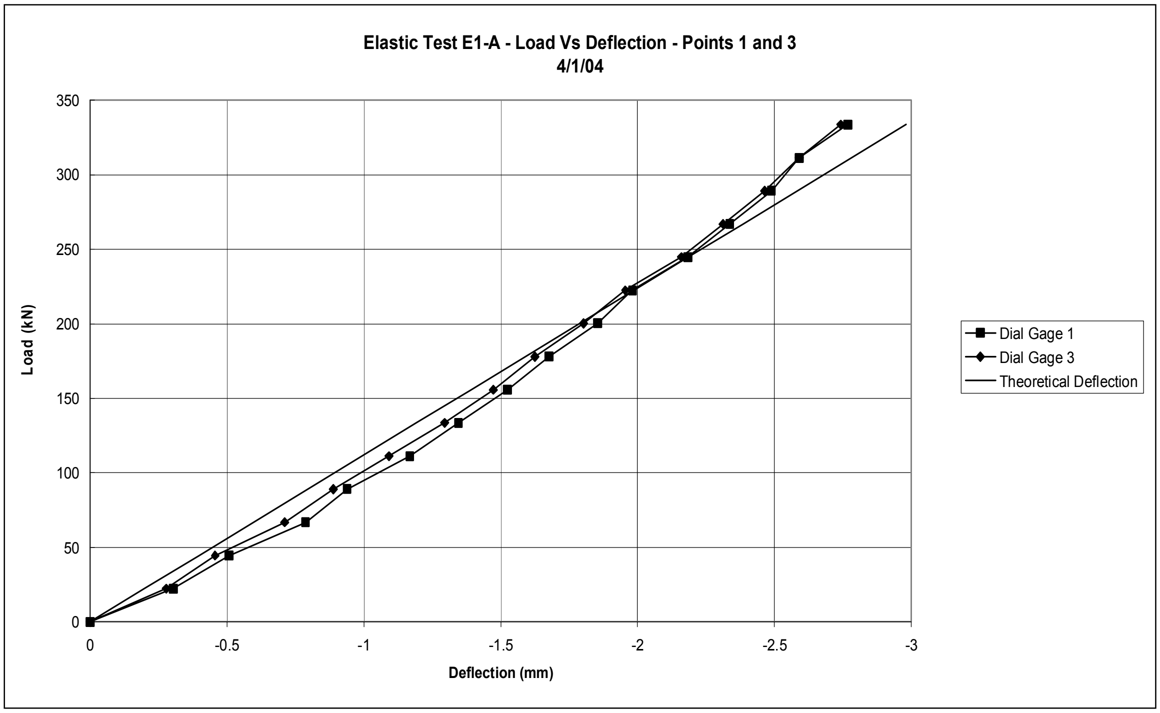
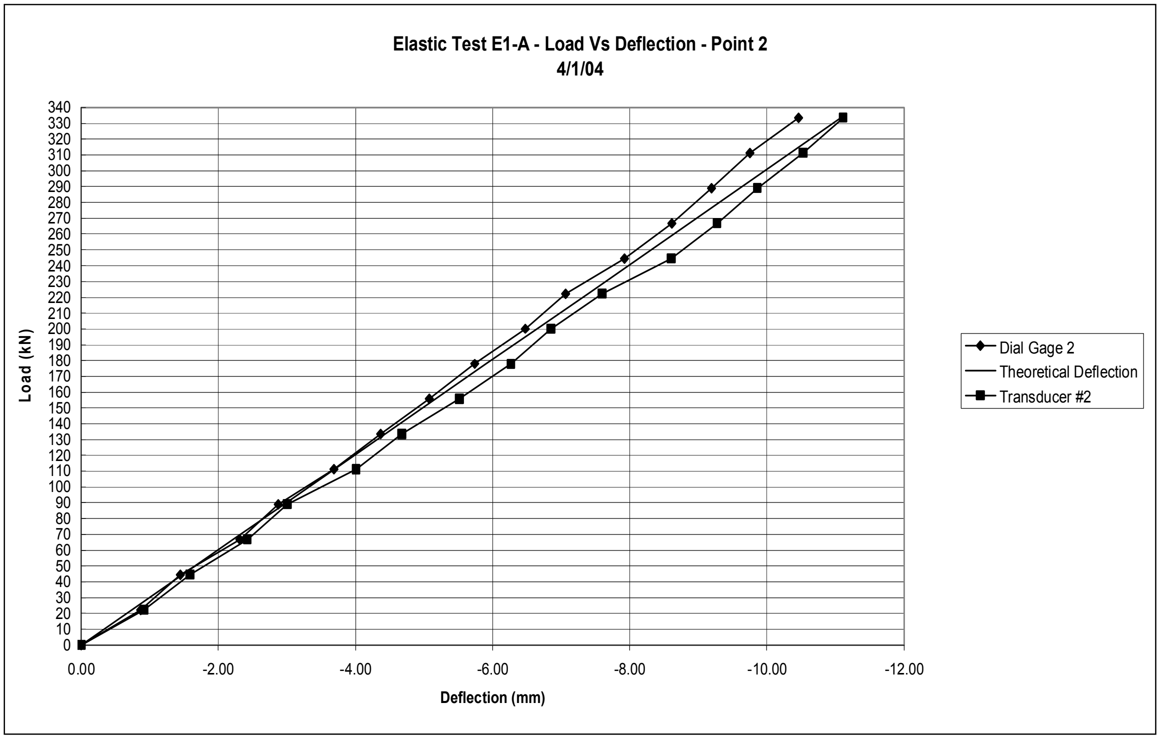
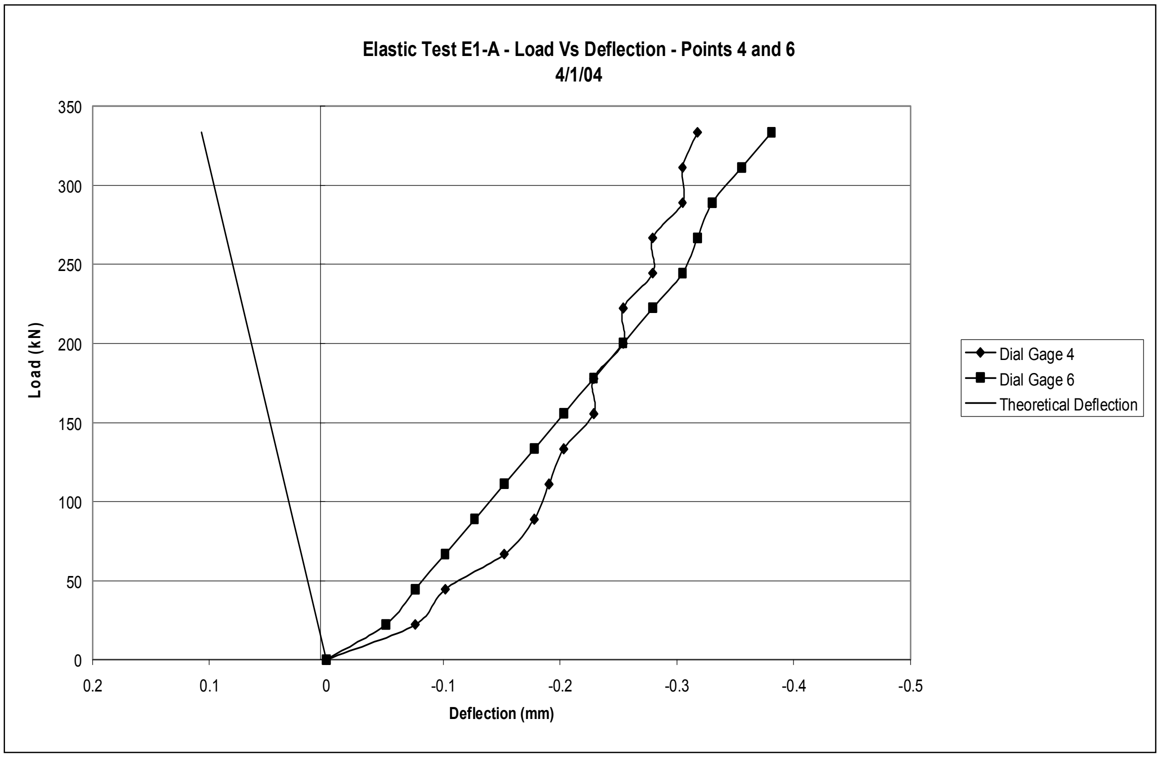
APPENDIX A:
EXPERIMENTAL TEST PLOTS FOR STATIC PANEL TESTS

A.1 Elastic Test E1-A



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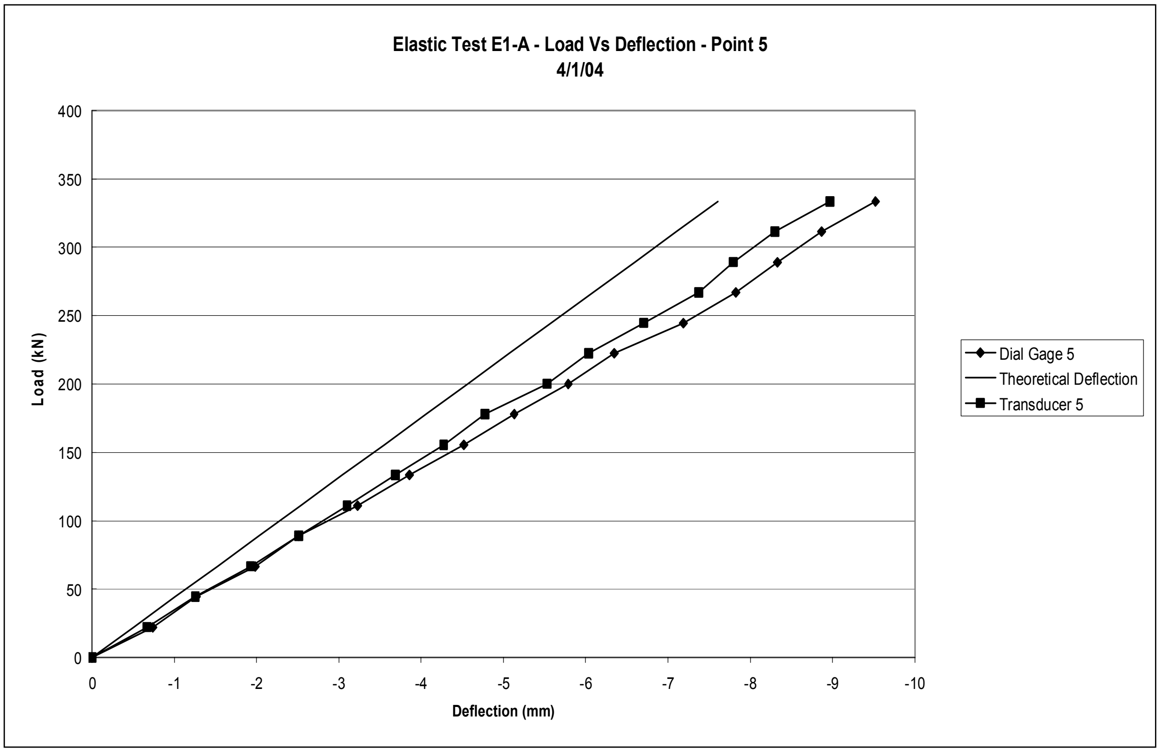
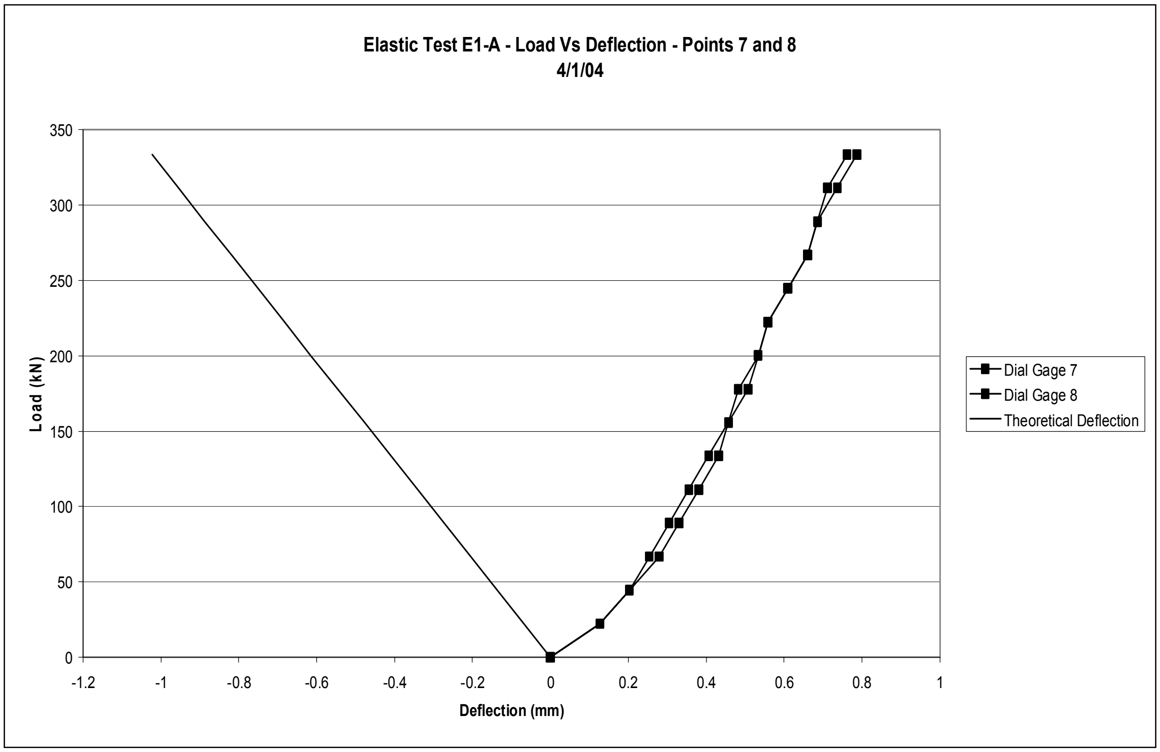
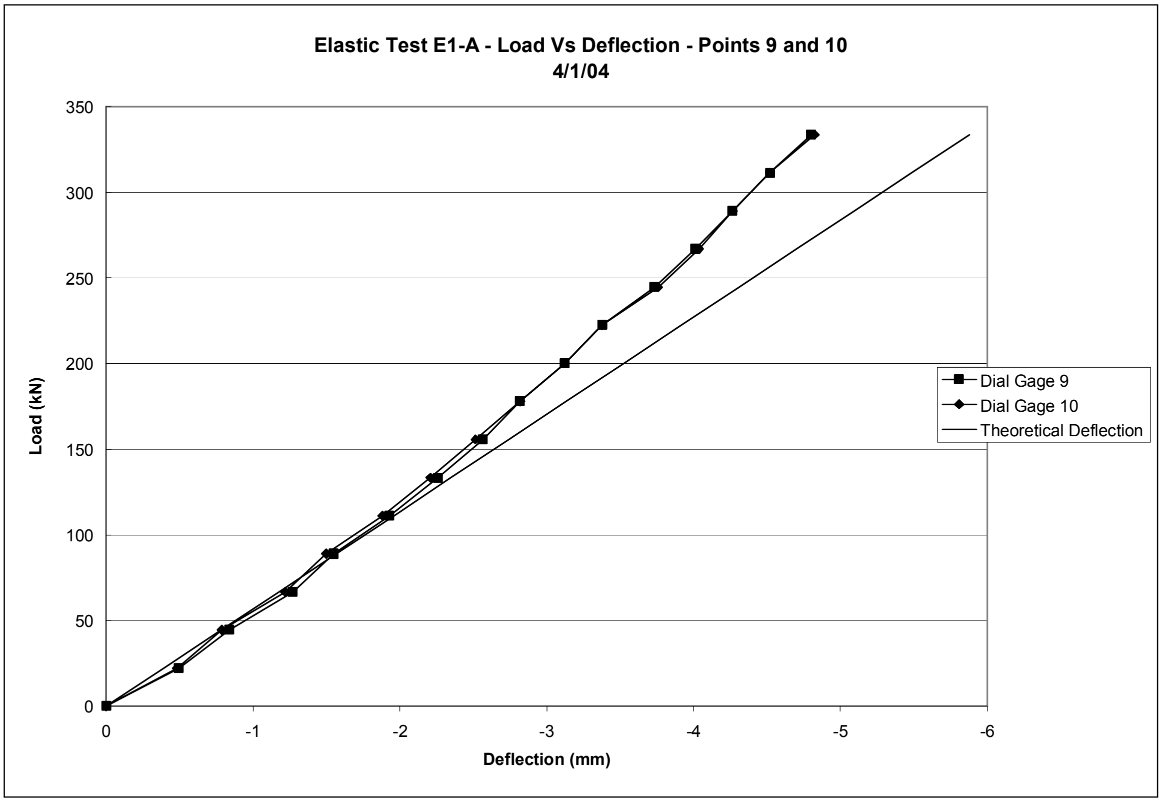
4/1/04
Load (kN)
350
300
250
200
150
100
50
0
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Deflection (mm)
Dial Gage 4
Dial Gage 6
Theoretical Deflection


Elastic Test E1-A - Load Vs Deflection - Point 5
4/1/04
Load (kN)
400
350
300
250
200
150
100
50
0
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
Deflection (mm)
Dial Gage 5
Theoretical Deflection
Transducer 5


Elastic Test E1-A - Load Vs Deflection - Points 7 and 8
4/1/04
Load (kN)
350
300
250
200
150
100
50
0
-1.2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Deflection (mm)
Dial Gage 7
Dial Gage 8
Theoretical Deflection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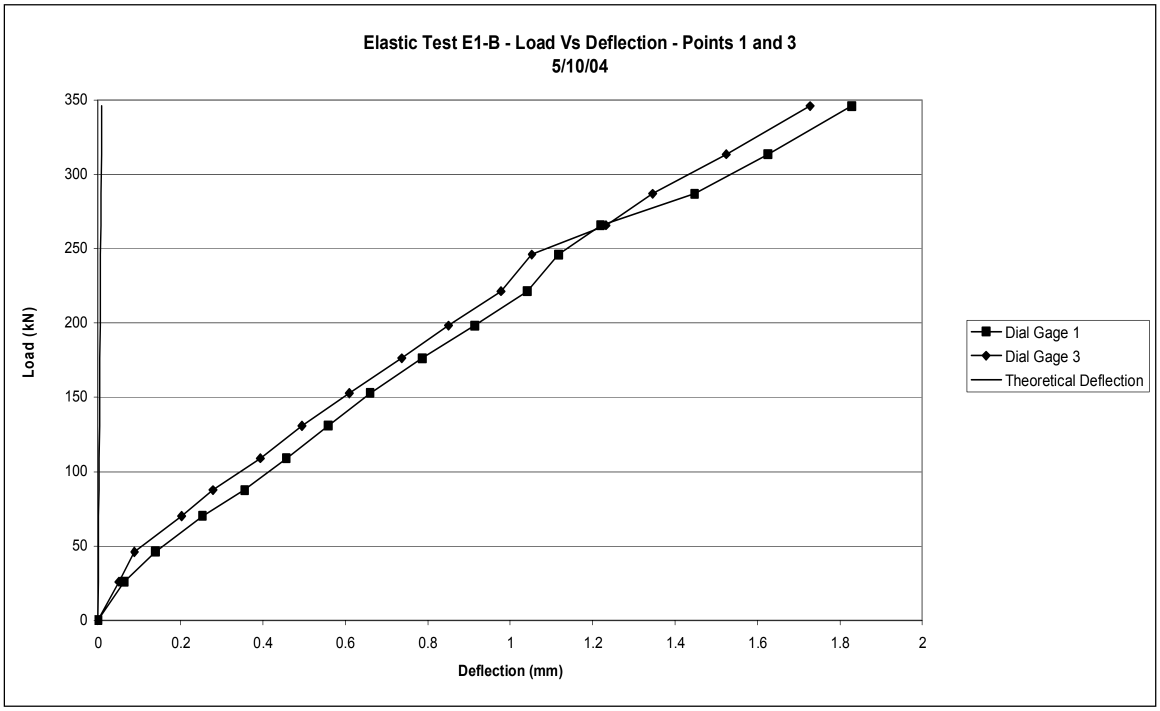
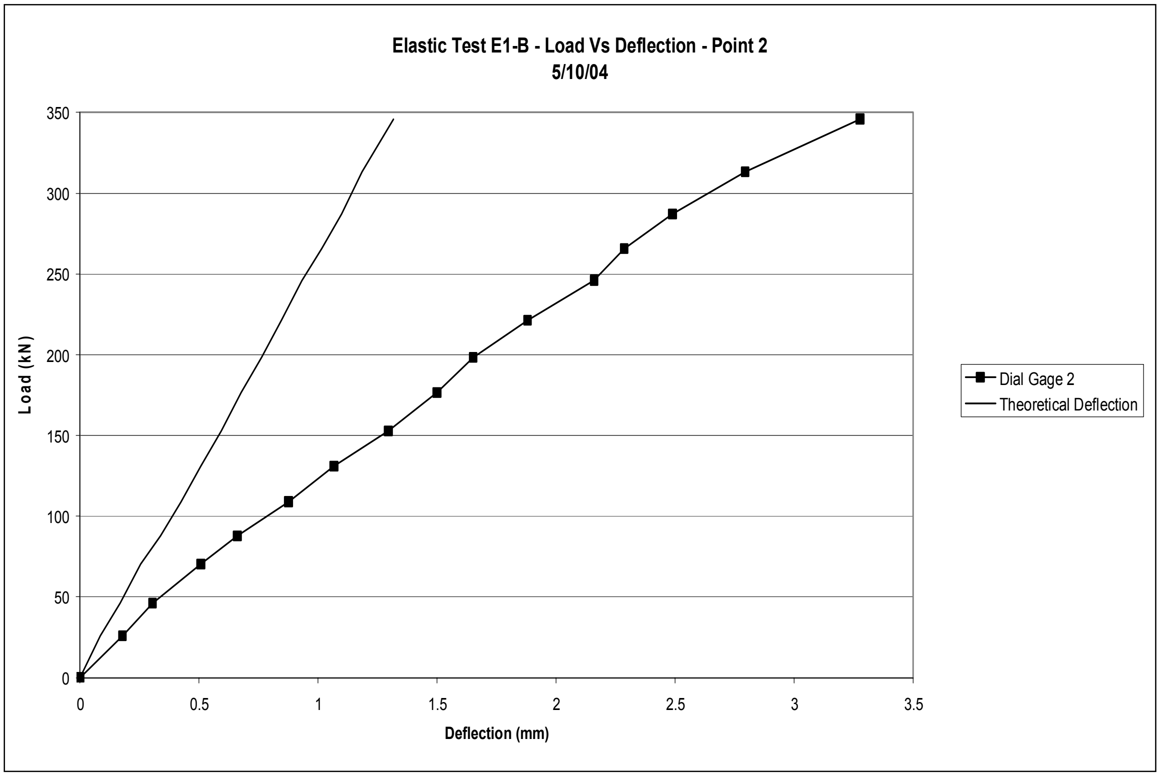
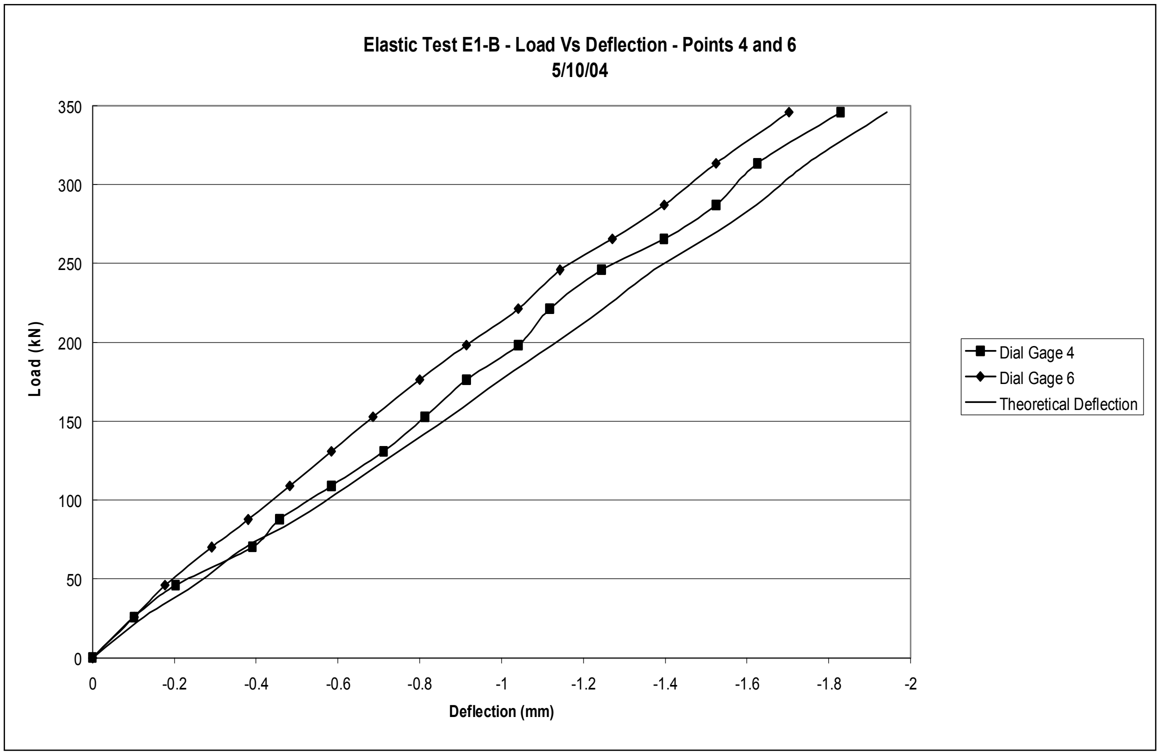
4/1/04
Load (kN)
350
300
250
200
150
100
50
0
0
-1
-2
-3
-4
-5
-6
Deflection (mm)
Dial Gage 9
Dial Gage 10
Theoretical Deflection

A.2 Elastic Test E1-B



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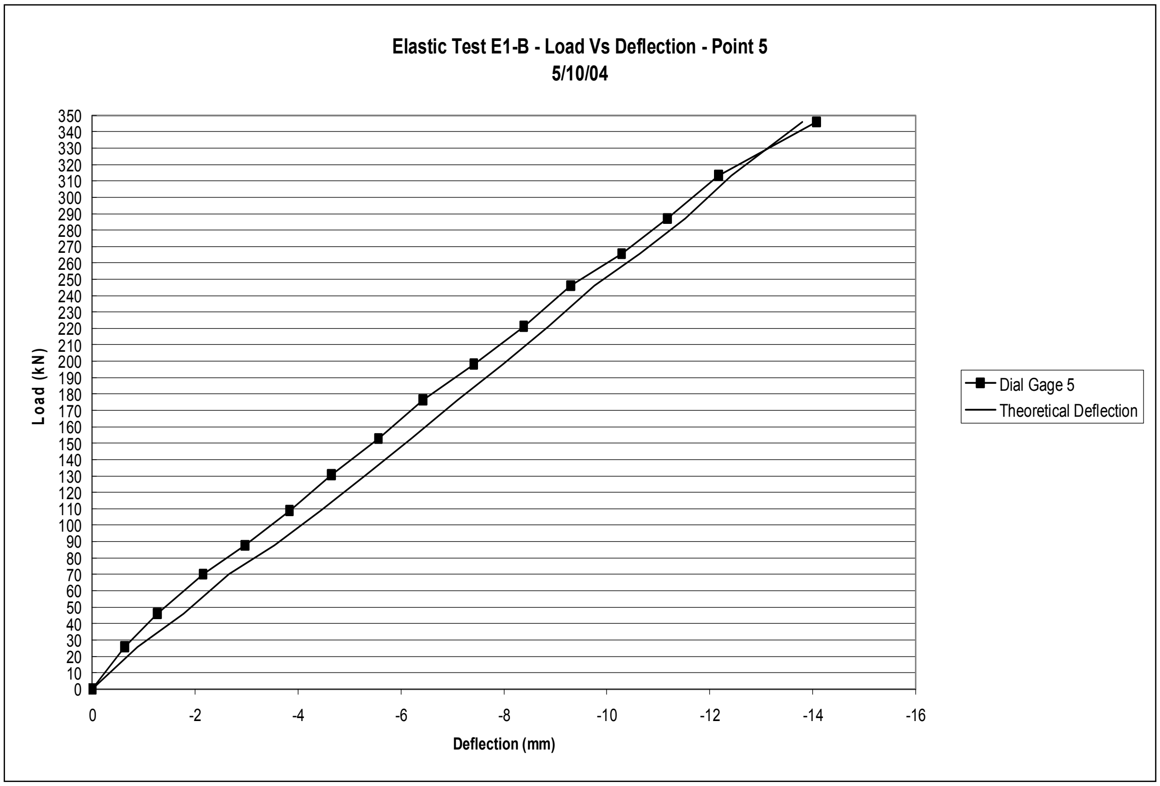
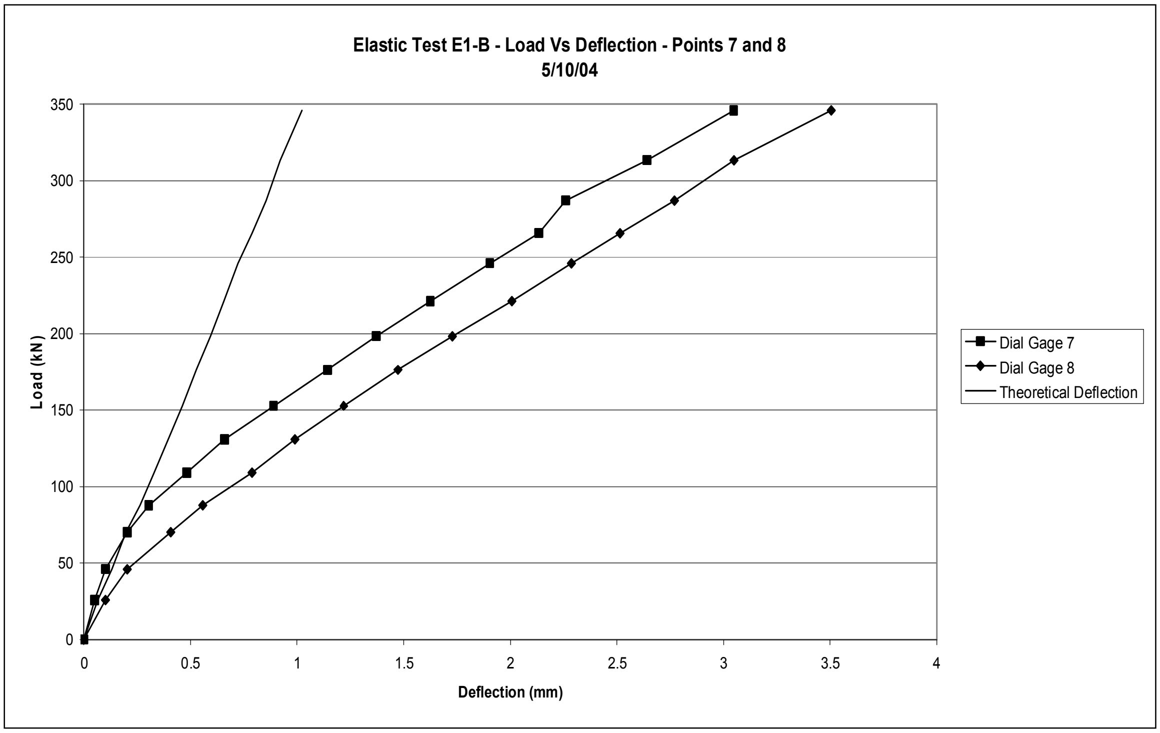
5/10/04
Load (kN)
350
300
250
200
150
100
50
0
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
Deflection (mm)
Dial Gage 4
Dial Gage 6
Theoretical Deflection


Elastic Test E1-B - Load Vs Deflection - Point 5
5/10/04
Load (kN)
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
-2
-4
-6
-8
-10
-12
-14
-16
Deflection (mm)
Dial Gage 5
Theoretical Deflection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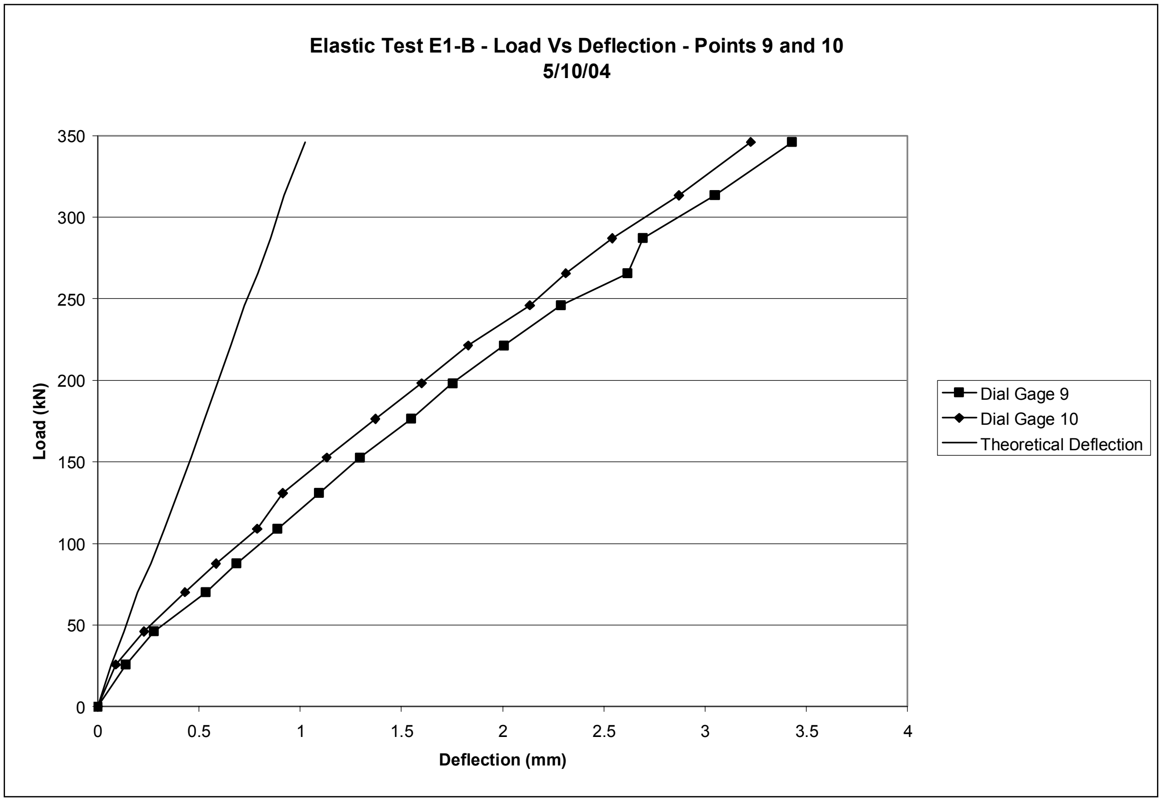
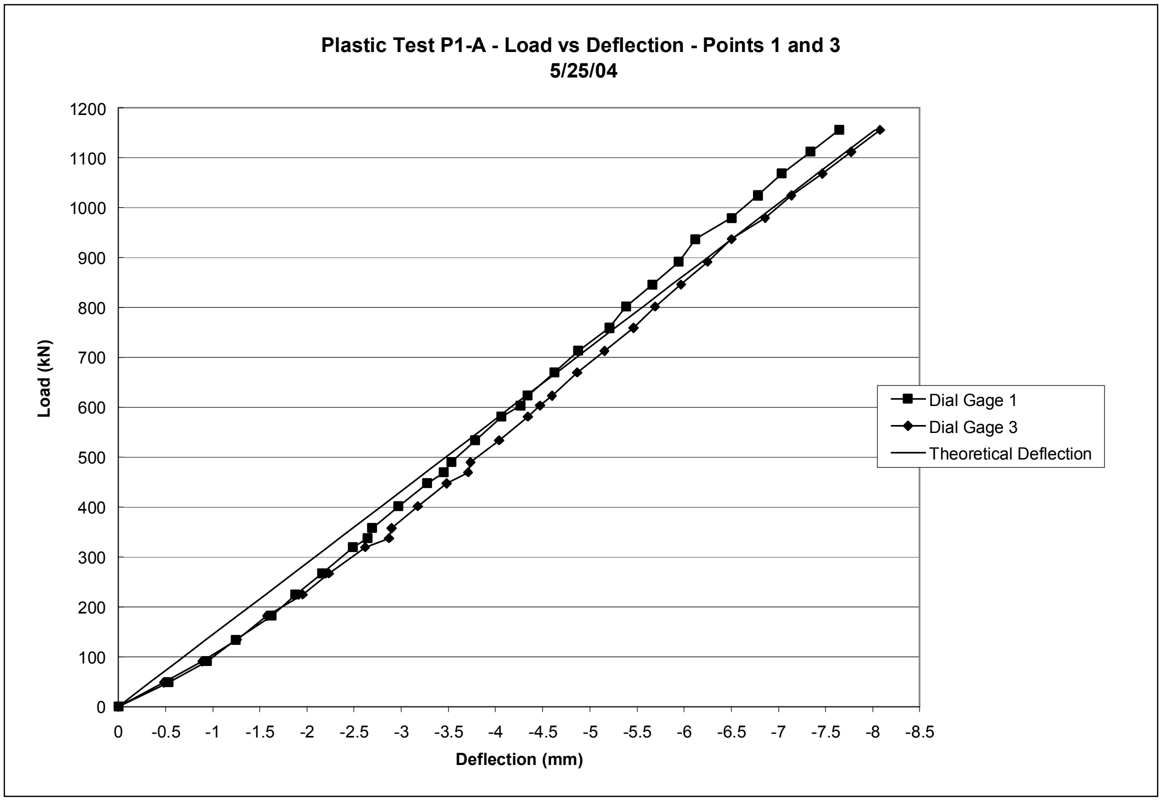
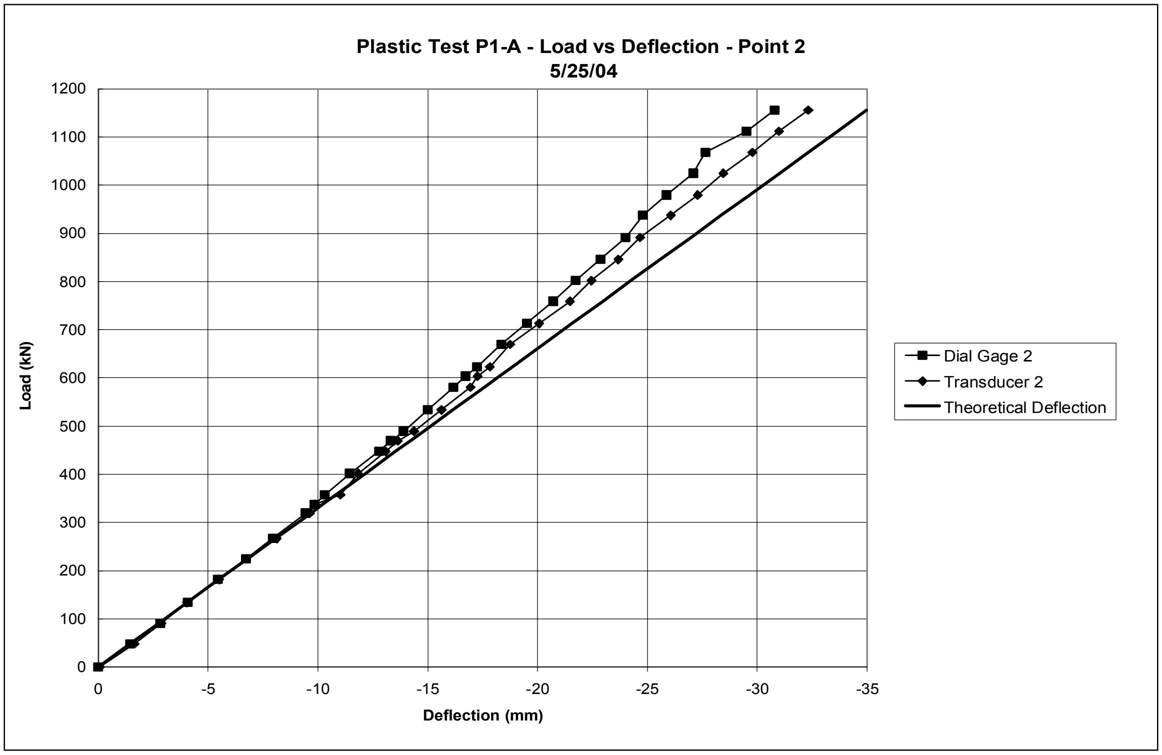
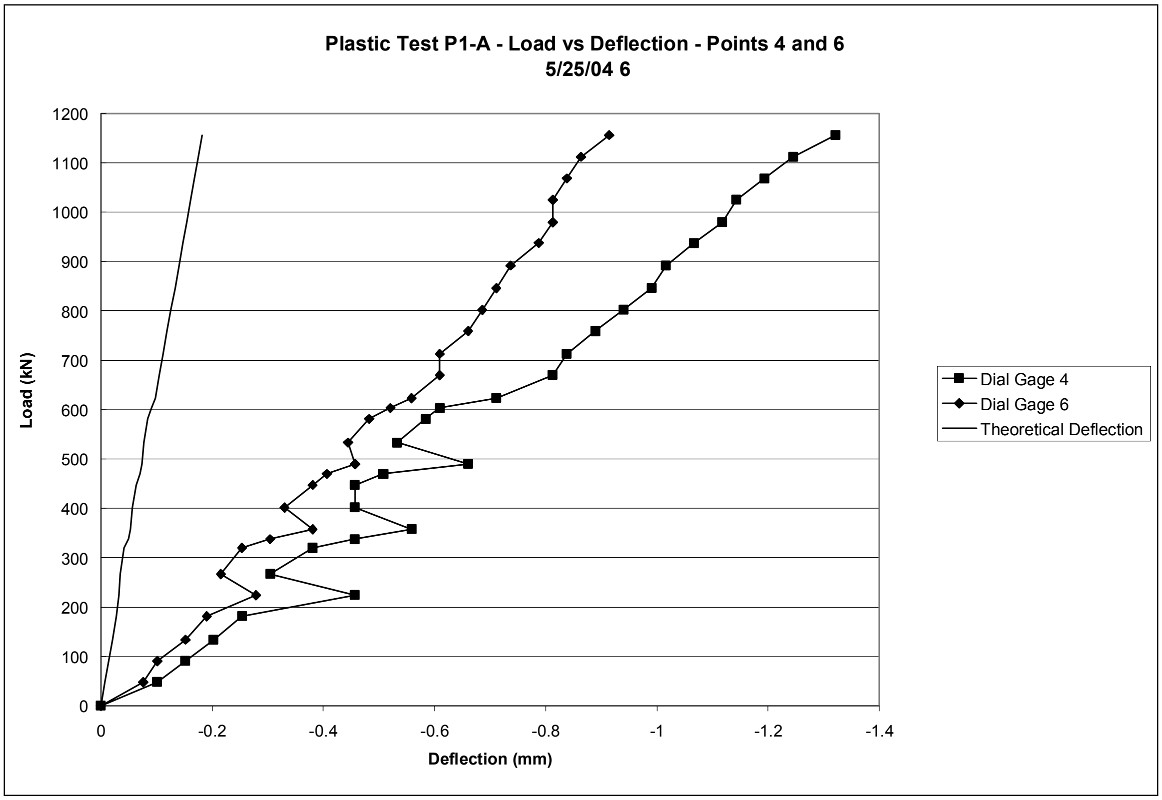
5/10/04
Load (kN)
Deflection (mm)
0
50
100
150
200
250
300
350
0
0.5
1
1.5
2
2.5
3
3.5
4
Dial Gage 7
Dial Gage 8
Theoretical Deflection

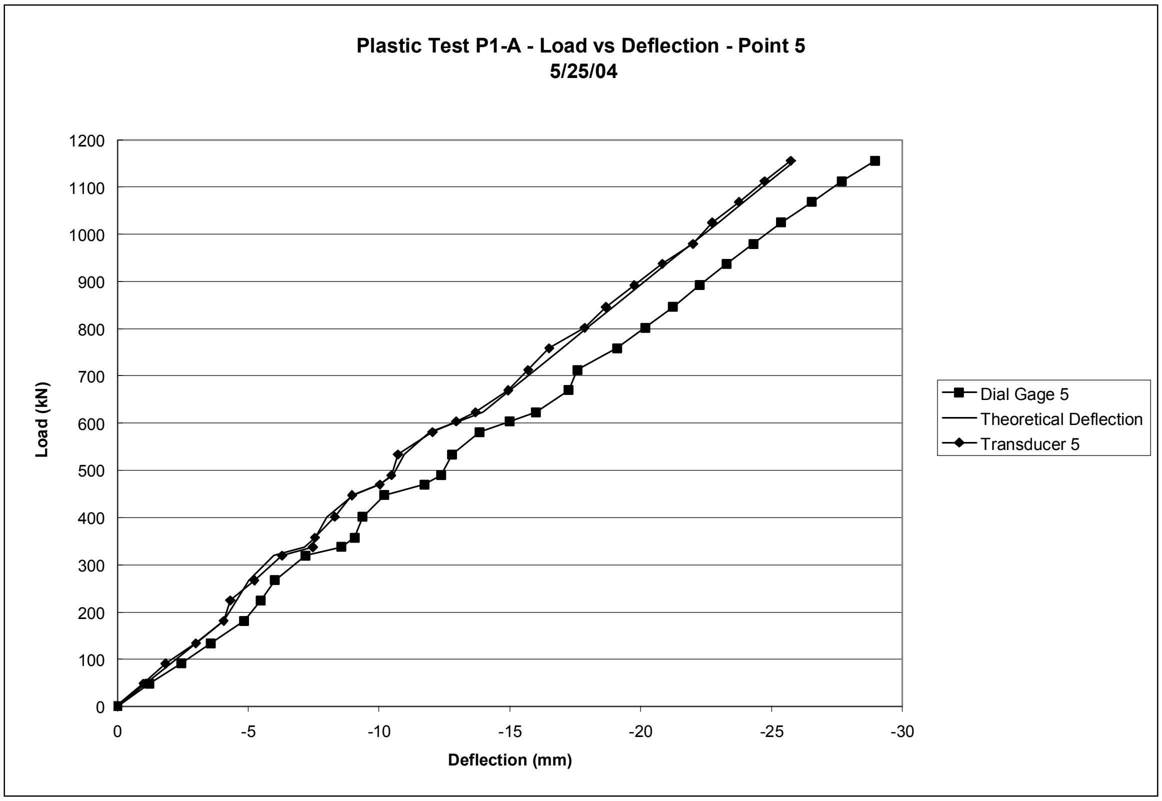

Elastic Test E1-B - Load Vs Deflection - Points 9 and 10
5/10/04
Load (kN)
Deflection (mm)
0
50
100
150
200
250
300
350
0
0.5
1
1.5
2
2.5
3
3.5
4
Dial Gage 9
Dial Gage 10
Theoretical Deflection

A.3 Plastic Test P1-A






Plastic Test P1-A - Load vs Deflection - Points 4 and 6
5/25/04 6
Load (kN)
Deflection (mm)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
Dial Gage 4
Dial Gage 6
Theoretical Deflection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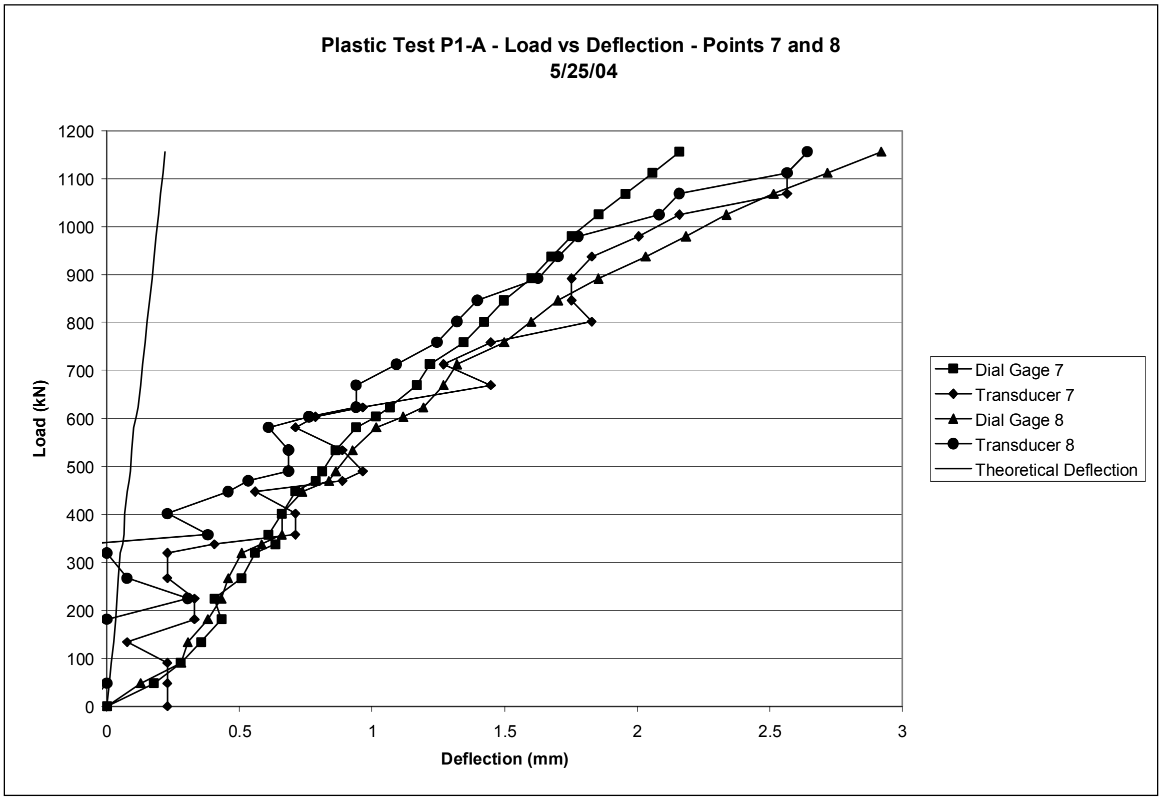
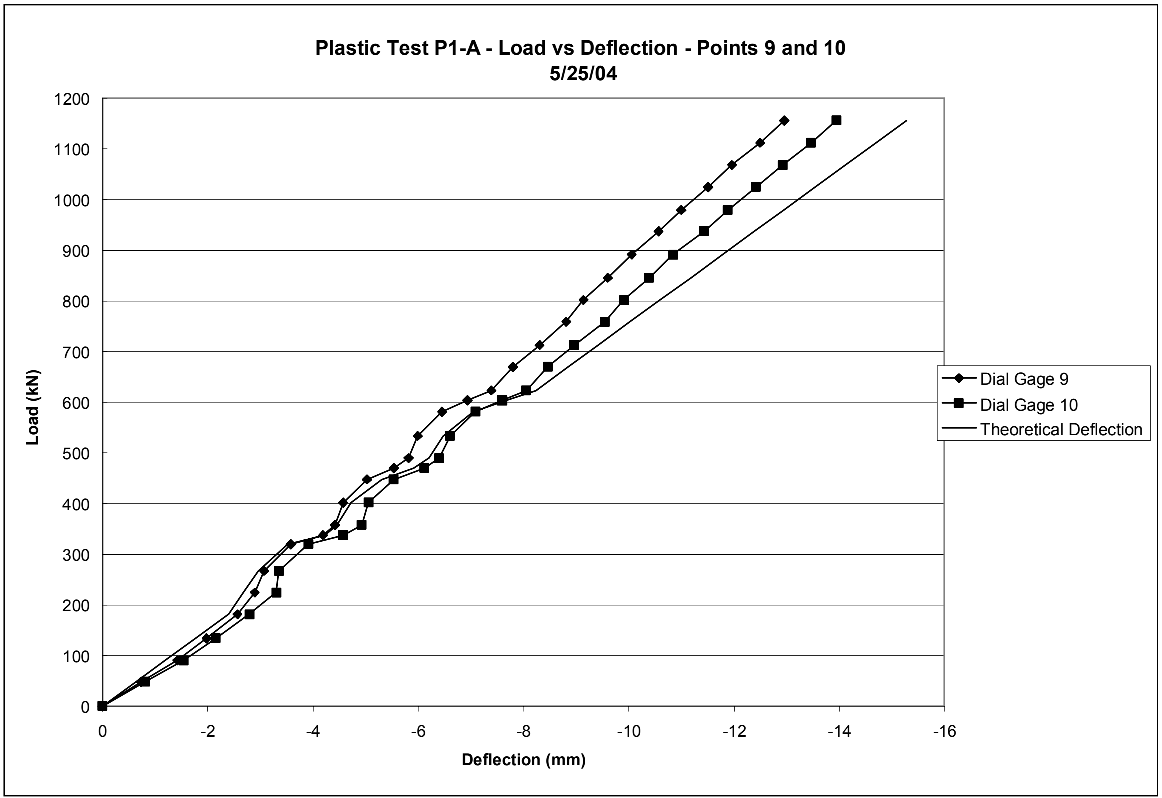
5/25/04
Load (kN)
Deflection (mm)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
-5
-10
-15
-20
-25
-30
Dial Gage 5
Theoretical Deflection
Transducer 5


Plastic Test P1-A - Load vs Deflection - Points 7 and 8
5/25/04
Load (kN)
Deflection (mm)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
0
0.5
1
1.5
2
2.5
3
Dial Gage 7
Transducer 7
Dial Gage 8
Transducer 8
Theoretical Deflection


Plastic Test P1-A - Load vs Deflection - Points 9 and 10
5/25/04
Load (kN)
Deflection (mm)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
0
-2
-4
-6
-8
-10
-12
-14
-16
Dial Gage 9
Dial Gage 10
Theoretical Deflection

APPENDIX B:
EXPERIMENTAL TEST DATA FOR JOINT FATIGUE TESTS

B.1 SPS Connections Tested to 10 Million Cycles

Static Test Number: 1		Date : 4/21/04	Number of Cycles: 1	
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4
0	0	0	0	0
-250	11	14	14	16
-500	23	30	27	31
-1000	35	47	41	48
-1500	46	63	53	64
-1750	57	79	66	80
-2000	68	97	78	98
-2250	78	112	89	113
-2500	89	126	101	127
-2750	98	142	112	144
-3000	109	157	124	158
-3250	119	172	135	174
-3525	129	185	145	189
Max Deflection: -0.045 in				

Static Test Number: 2		Date : 4/21/04	Number of Cycles: 10	
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4
0	0	0	0	0
-250	11	14	14	17
-500	23	31	28	34
-1000	34	45	41	50
-1500	45	62	53	64
-1750	57	78	66	81
-2000	68	93	79	95
-2250	78	108	90	112
-2500	89	124	101	126
-2750	99	138	112	142
-3000	109	153	124	158
-3250	118	167	134	172
-3525	128	182	145	188
Max Deflection: -0.045 in				

Static Test Number: 3		Date : 4/21/04	Number of Cycles: 100	
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4
-250	12	14	15	19
-500	23	30	29	35
-1000	35	48	42	52
-1500	46	63	55	67
-1750	58	80	68	84
-2000	69	94	79	100
-2250	79	109	91	116
-2500	89	124	103	131
-2750	100	141	114	145
-3000	110	155	125	160
-3250	120	172	136	175
-3525	130	185	146	189
Max Deflection: -0.045 in				

Static Test Number: 4		Date : 4/21/04	Number of Cycles: 1000	
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4
-250	13	17	16	18
-500	25	34	31	36
-1000	37	50	45	53
-1500	47	64	56	67
-1750	58	80	68	84
-2000	69	95	80	98
-2250	80	112	92	115
-2500	90	126	103	129
-2750	101	141	115	144
-3000	110	156	125	159
-3250	120	170	135	173
-3525	130	186	146	188
Max Deflection: -0.045 in				

Static Test Number: 5		Date : 4/22/04	Number of Cycles Completed: 10000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	14	18	15	18	-0.003	-0.003
-500	21	22	23	27	-0.006	-0.0062
-1000	31	38	35	43	-0.0099	-0.009
-1500	44	56	49	59	-0.013	-0.0115
-1750	55	68	58	72	-0.0155	-0.014
-2000	67	87	71	90	-0.02	-0.017
-2250	78	99	81	105	-0.0232	-0.0195
-2500	90	121	96	123	-0.0262	-0.022
-2750	101	136	108	140	-0.03	-0.025
-3000	108	144	114	148	-0.033	-0.028
-3250	119	160	126	165	-0.0363	-0.03
-3525	129	177	137	178	-0.039	-0.033
Max Deflection: -0.045 in						

Static Test Number: 6		Date : 4/23/04	Number of Cycles Completed: 50,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	14	16	17	20	-0.0035	-0.003
-500	20	24	26	30	-0.007	-0.006
-1000	29	39	37	44	-0.01	-0.009
-1500	43	57	52	63	-0.0135	-0.0115
-1750	52	71	62	77	-0.017	-0.014
-2000	64	89	75	95	-0.02	-0.017
-2250	74	104	85	109	-0.023	-0.019
-2500	89	123	101	127	-0.027	-0.022
-2750	96	134	109	139	-0.03	-0.0245
-3000	108	153	121	155	-0.033	-0.027
-3250	115	163	128	165	-0.036	-0.03
-3525	128	184	141	182	-0.039	-0.033
Max Deflection: -0.04365 in. from MTS						

Static Test Number: 7		Date : 4/24/04	Number of Cycles Completed: 100,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	13	19	14	21	-0.004	-0.003
-500	24	36	29	39	-0.007	-0.006
-1000	35	51	42	56	-0.01	-0.009
-1500	41	56	49	64	-0.0145	-0.0115
-1750	48	69	59	77	-0.017	-0.014
-2000	63	89	73	94	-0.02	-0.017
-2250	75	107	87	112	-0.023	-0.0205
-2500	87	124	98	130	-0.026	-0.022
-2750	93	136	108	142	-0.0295	-0.025
-3000	104	152	119	154	-0.032	-0.028
-3250	111	165	128	170	-0.035	-0.0305
-3525	128	188	145	188	-0.038	-0.033
Max Deflection: -0.04585 in. from MTS						

Static Test Number: 8		Date : 4/27/04	Number of Cycles Completed: 200,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	7	10	12	15	-0.0025	-0.0025
-500	18	26	26	31	-0.005	-0.005
-750	32	41	38	48	-0.0075	-0.0075
-1000	36	54	44	54	-0.01	-0.01
-1250	52	71	58	72	-0.013	-0.012
-1500	57	79	64	81	-0.016	-0.0145
-1750	66	92	75	95	-0.0185	-0.0165
-2000	75	107	84	109	-0.021	-0.019
-2250	82	120	92	122	-0.024	-0.021
-2500	97	137	106	139	-0.027	-0.0235
-2750	105	148	113	149	-0.03	-0.026
-3000	115	160	123	163	-0.032	-0.028
-3250	124	171	130	174	-0.035	-0.03
-3525	130	181	140	184	-0.0375	-0.033
Max Deflection: -0.04244 in. from MTS						

Static Test Number: 9		Date : 4/27/04	Number of Cycles Completed: 300,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	14	11	15	-0.003	-0.003
-500	17	25	22	30	-0.005	-0.005
-750	27	38	32	44	-0.008	-0.0075
-1000	37	52	43	58	-0.011	-0.01
-1250	46	66	53	72	-0.014	-0.012
-1500	56	79	63	86	-0.0175	-0.014
-1750	65	93	73	99	-0.019	-0.016
-2000	73	106	82	112	-0.022	-0.019
-2250	82	120	92	125	-0.025	-0.021
-2500	91	133	101	138	-0.028	-0.023
-2760	100	146	111	152	-0.031	-0.025
-3000	107	158	119	164	-0.033	-0.027
-3250	115	170	127	175	-0.036	-0.0295
-3500	123	182	135	187	-0.0385	-0.0315
Max Deflection: -0.04196 in. from MTS						

Static Test Number: 10		Date : 4/28/04	Number of Cycles Completed: 400,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	7	8	9	8	-0.004	-0.004
-500	19	25	23	25	-0.007	-0.006
-750	29	38	35	43	-0.01	-0.009
-1010	37	49	44	54	-0.013	-0.011
-1250	48	64	54	68	-0.015	-0.013
-1500	55	74	63	79	-0.018	-0.016
-1750	64	86	72	92	-0.021	-0.018
-2000	73	99	81	104	-0.0235	-0.02
-2250	84	115	91	119	-0.026	-0.0225
-2500	93	130	101	133	-0.029	-0.0255
-2760	101	141	109	145	-0.032	-0.027
-3000	107	158	119	164	-0.0345	-0.03
-3250	115	166	127	167	-0.037	-0.032
-3500	125	182	141	187	-0.0395	-0.034
Max Deflection: -0.04252 in. from MTS						

Static Test Number: 11		Date : 4/29/04	Number of Cycles Completed: 500,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	12	16	-0.005	-0.0045
-500	18	26	24	30	-0.008	-0.007
-750	28	39	35	44	-0.011	-0.01
-1000	37	53	46	58	-0.0135	-0.012
-1250	47	67	57	73	-0.016	-0.0145
-1500	57	80	66	87	-0.019	-0.017
-1750	66	94	77	100	-0.022	-0.0195
-2000	75	108	86	114	-0.025	-0.022
-2250	83	121	95	126	-0.027	-0.024
-2505	93	134	105	140	-0.03	-0.027
-2750	101	147	114	152	-0.033	-0.029
-3000	109	160	123	165	-0.035	-0.031
-3250	117	172	131	177	-0.038	-0.0335
-3500	125	185	140	189	-0.0405	-0.036
Max Deflection: -0.04300 in. from MTS						

Static Test Number: 12		Date : 4/29/04	Number of Cycles Completed: 600,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	6	8	6	9	-0.003	-0.002
-505	19	25	22	27	-0.006	-0.005
-750	27	34	31	39	-0.009	-0.007
-1000	36	46	41	53	-0.0115	-0.009
-1250	47	60	52	65	-0.014	-0.0115
-1500	57	80	66	87	-0.017	-0.0135
-1755	67	88	71	93	-0.02	-0.016
-2000	77	104	83	108	-0.023	-0.018
-2250	85	113	92	119	-0.0255	-0.0205
-2500	96	130	104	134	-0.028	-0.0225
-2750	102	143	114	144	-0.031	-0.025
-3000	113	156	123	159	-0.033	-0.027
-3255	118	165	129	168	-0.036	-0.029
-3500	126	176	136	179	-0.039	-0.031
Max Deflection: -0.04348 in. from MTS						

Static Test Number: 16	Date : 4/30/04	Number of Cycles Completed: 1,000,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	7	9	11	14	-0.0025	-0.0025
-500	15	19	22	27	-0.005	-0.005
-750	25	32	33	42	-0.008	-0.0075
-1000	34	46	44	56	-0.011	-0.01
-1250	44	60	56	71	-0.014	-0.0125
-1500	56	79	69	87	-0.0165	-0.015
-1750	62	88	75	98	-0.019	-0.017
-2005	71	97	83	109	-0.022	-0.0195
-2260	83	119	98	128	-0.0245	-0.0215
-2505	92	132	107	141	-0.027	-0.024
-2750	102	146	117	154	-0.0305	-0.026
-3000	107	156	125	164	-0.032	-0.028
-3250	117	171	133	177	-0.035	-0.0305
-3500	126	181	143	189	-0.0375	-0.033
Max Deflection: -0.04312 in. from MTS						

Static Test Number: 17	Date : 5/1/04	Number of Cycles Completed: 1,100,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	2	5	10	7	-0.003	-0.0025
-500	14	19	21	24	-0.0055	-0.005
-750	20	29	29	34	-0.0085	-0.0075
-1005	34	52	44	53	-0.011	-0.01
-1260	44	66	55	67	-0.014	-0.0125
-1500	54	80	65	81	-0.017	-0.015
-1750	62	92	74	93	-0.02	-0.017
-2000	69	101	81	103	-0.0225	-0.0195
-2255	81	120	93	120	-0.025	-0.022
-2500	88	130	102	132	-0.028	-0.024
-2750	92	138	108	143	-0.031	-0.0265
-3005	101	154	120	156	-0.0335	-0.029
-3250	113	170	130	169	-0.036	-0.031
-3500	119	180	138	176	-0.039	-0.033
Max Deflection: -0.04124 in. from MTS						

Static Test Number: 18	Date : 5/1/04	Number of Cycles Completed: 1,200,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-255	9	14	12	15	-0.0025	-0.0025
-505	20	25	21	28	-0.005	-0.005
-755	31	43	35	48	-0.008	-0.007
-1000	39	54	44	61	-0.01	-0.0095
-1250	49	68	54	75	-0.013	-0.0115
-1505	58	80	63	87	-0.016	-0.0135
-1750	64	90	70	97	-0.0185	-0.016
-2000	76	104	80	112	-0.021	-0.018
-2250	83	116	89	123	-0.0235	-0.02
-2505	89	131	99	136	-0.026	-0.0225
-2750	100	148	111	152	-0.029	-0.0245
-3005	107	153	115	158	-0.031	-0.0265
-3250	116	166	124	171	-0.034	-0.029
-3500	121	176	132	181	-0.036	-0.031
Max Deflection: -0.04112 in. from MTS						

Static Test Number: 19		Date : 5/2/04	Number of Cycles Completed: 1,300,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-255	3	0	4	2	-0.003	-0.002
-500	12	14	15	17	-0.005	-0.004
-755	25	33	29	38	-0.008	-0.0065
-1000	32	44	38	50	-0.011	-0.009
-1250	41	57	48	63	-0.014	-0.011
-1510	51	69	57	76	-0.017	-0.0135
-1750	58	81	66	90	-0.0195	-0.0155
-2000	69	98	77	106	-0.022	-0.018
-2250	76	107	84	116	-0.025	-0.02
-2505	88	125	97	132	-0.028	-0.022
-2750	92	133	103	142	-0.0305	-0.024
-3010	103	151	115	159	-0.033	-0.0265
-3250	111	160	121	168	-0.0355	-0.028
-3500	120	172	130	179	-0.038	-0.03
Max Deflection: -0.04108 in. from MTS						

Static Test Number: 20		Date : 5/2/04	Number of Cycles Completed: 1,400,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	7	9	9	11	-0.0025	-0.002
-510	16	21	21	25	-0.005	-0.004
-750	29	38	34	43	-0.008	-0.0065
-1000	34	45	39	53	-0.011	-0.009
-1255	44	60	53	67	-0.013	-0.011
-1500	53	74	63	81	-0.016	-0.013
-1750	61	85	72	93	-0.019	-0.015
-2000	71	100	82	108	-0.0215	-0.0175
-2250	77	110	89	118	-0.024	-0.0195
-2500	88	124	100	133	-0.027	-0.0215
-2755	99	142	112	150	-0.0295	-0.0235
-3000	108	157	122	164	-0.032	-0.026
-3250	115	166	129	174	-0.035	-0.028
-3500	125	183	140	189	-0.037	-0.03
Max Deflection: -0.04248in. from MTS						

Static Test Number: 21		Date : 5/3/04	Number of Cycles Completed: 1,500,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-255	9	13	12	15	-0.0025	-0.003
-500	18	26	23	29	-0.005	-0.005
-750	28	39	34	43	-0.008	-0.0075
-1000	38	52	45	58	-0.011	-0.01
-1250	47	65	54	71	-0.014	-0.012
-1505	56	79	64	85	-0.0165	-0.015
-1750	65	92	74	98	-0.019	-0.017
-2000	74	105	84	111	-0.022	-0.019
-2250	83	119	93	125	-0.025	-0.021
-2505	91	132	103	138	-0.0275	-0.0235
-2750	100	144	111	150	-0.03	-0.026
-3010	108	158	120	163	-0.033	-0.028
-3250	116	170	129	175	-0.035	-0.03
-3500	123	182	137	186	-0.038	-0.0325
Max Deflection: -0.04168 in. from MTS						

Static Test Number: 25		Date : 5/4/04	Number of Cycles Completed: 1,900,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	7	9	8	14	-0.0025	-0.0025
-500	19	26	24	33	-0.005	-0.005
-750	27	35	33	46	-0.0075	-0.0075
-1005	36	47	43	59	-0.011	-0.01
-1250	47	63	55	76	-0.014	-0.0125
-1500	56	78	66	90	-0.017	-0.015
-1750	67	94	78	106	-0.02	-0.017
-2000	76	106	85	118	-0.023	-0.02
-2250	85	118	95	130	-0.0255	-0.022
-2500	91	129	102	142	-0.028	-0.024
-2755	99	147	112	153	-0.031	-0.0265
-3000	106	158	120	164	-0.0335	-0.0285
-3255	116	171	129	176	-0.0365	-0.031
-3500	125	186	140	190	-0.039	-0.033
Max Deflection: -0.04276 in. from MTS						

Static Test Number: 26		Date : 5/4/04	Number of Cycles Completed: 2,000,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	12	12	13	-0.003	-0.0025
-500	15	20	21	23	-0.0055	-0.005
-750	29	37	35	43	-0.0085	-0.0075
-1000	38	50	46	58	-0.011	-0.01
-1250	48	64	57	72	-0.014	-0.012
-1505	55	74	64	83	-0.017	-0.0145
-1755	66	91	77	99	-0.0195	-0.017
-2000	75	104	86	112	-0.022	-0.019
-2250	85	118	95	126	-0.025	-0.021
-2500	91	127	103	135	-0.0275	-0.023
-2750	98	138	110	146	-0.03	-0.026
-3005	107	151	119	159	-0.033	-0.028
-3250	118	170	131	177	-0.0355	-0.03
-3500	124	179	138	185	-0.038	-0.032
Max Deflection: -0.04252 in. from MTS						

Static Test Number: 27		Date : 5/4/04	Number of Cycles Completed: 2,100,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-255	9	13	12	14	-0.003	-0.0025
-500	18	26	23	29	-0.006	-0.005
-750	29	40	35	44	-0.009	-0.007
-1000	38	53	45	57	-0.012	-0.0095
-1250	47	66	56	72	-0.015	-0.012
-1500	57	80	66	86	-0.0175	-0.014
-1750	66	93	75	98	-0.0205	-0.0165
-2005	74	107	85	113	-0.0235	-0.019
-2250	83	120	94	125	-0.026	-0.021
-2500	91	133	103	139	-0.029	-0.023
-2750	100	147	113	152	-0.032	-0.0255
-3005	108	159	121	165	-0.0345	-0.028
-3250	116	172	130	178	-0.0375	-0.03
-3500	124	184	138	189	-0.04	-0.032
Max Deflection: -0.04272 in. from MTS						

Static Test Number: 28		Date : 5/5/04	Number of Cycles Completed: 2,200,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	6	7	9	7	-0.0025	-0.002
-500	16	21	22	23	-0.005	-0.005
-750	28	40	37	42	-0.008	-0.007
-1000	38	53	48	57	-0.011	-0.01
-1255	48	66	59	70	-0.0135	-0.012
-1500	57	78	68	81	-0.016	-0.014
-1755	60	85	74	87	-0.019	-0.017
-2000	75	106	89	107	-0.022	-0.019
-2250	82	117	96	115	-0.0245	-0.021
-2500	90	128	104	128	-0.027	-0.023
-2750	97	139	112	137	-0.03	-0.0255
-3000	109	157	124	157	-0.0325	-0.028
-3250	117	170	132	168	-0.035	-0.03
-3500	123	178	137	183	-0.0375	-0.032
Max Deflection: -0.04256 in. from MTS						

Static Test Number: 29		Date : 5/5/04	Number of Cycles Completed: 2,300,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	7	9	10	12	-0.003	-0.003
-500	16	19	20	24	-0.006	-0.005
-750	24	28	30	34	-0.009	-0.008
-1000	34	42	42	49	-0.012	-0.01
-1250	43	54	52	61	-0.015	-0.0125
-1500	56	75	66	83	-0.018	-0.015
-1755	60	83	71	87	-0.021	-0.017
-2005	71	97	81	103	-0.024	-0.019
-2250	80	113	92	117	-0.027	-0.0215
-2510	91	129	103	132	-0.03	-0.0235
-2755	99	141	111	144	-0.0325	-0.026
-3000	107	154	120	159	-0.035	-0.028
-3250	117	170	132	174	-0.038	-0.03
-3500	125	181	140	185	-0.04	-0.0325
Max Deflection: -0.04276 in. from MTS						

Static Test Number: 30		Date : 5/5/04	Number of Cycles Completed: 2,400,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-255	10	13	13	15	-0.003	-0.0025
-510	20	26	25	29	-0.006	-0.005
-750	29	40	36	44	-0.009	-0.007
-1000	39	53	47	58	-0.012	-0.01
-1255	49	66	57	71	-0.015	-0.012
-1510	58	80	67	85	-0.018	-0.0145
-1750	67	93	77	98	-0.021	-0.017
-2005	76	107	87	111	-0.024	-0.019
-2250	85	119	95	124	-0.027	-0.021
-2500	95	134	105	139	-0.0295	-0.0235
-2750	102	146	114	150	-0.0325	-0.026
-3000	111	158	123	162	-0.035	-0.028
-3250	119	172	132	175	-0.038	-0.03
-3500	126	182	139	186	-0.041	-0.032
Max Deflection: -0.04232 in. from MTS						

Static Test Number: 31		Date : 5/6/04	Number of Cycles Completed: 2,500,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	10	14	13	16	-0.0025	-0.0025
-505	19	27	25	30	-0.0055	-0.005
-750	29	40	37	44	-0.008	-0.0075
-1000	36	49	45	54	-0.011	-0.01
-1255	46	64	55	68	-0.0135	-0.012
-1505	58	83	69	87	-0.016	-0.015
-1755	66	93	77	98	-0.019	-0.017
-2005	74	105	86	110	-0.022	-0.019
-2250	85	122	98	127	-0.024	-0.021
-2500	92	134	106	139	-0.027	-0.025
-2750	100	143	115	147	-0.03	-0.027
-3000	108	156	123	160	-0.0325	-0.0285
-3250	117	170	133	174	-0.035	-0.031
-3500	126	183	141	186	-0.0375	-0.033
Max Deflection: -0.04272 in. from MTS						

Static Test Number: 32		Date : 5/6/04	Number of Cycles Completed: 2,600,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	7	7	9	8	-0.003	-0.003
-500	16	20	17	23	-0.006	-0.005
-755	28	36	35	41	-0.009	-0.008
-1000	37	49	45	54	-0.0115	-0.01
-1255	48	67	58	72	-0.0145	-0.0125
-1500	54	72	62	77	-0.017	-0.015
-1750	65	91	75	95	-0.0195	-0.017
-2000	73	102	83	107	-0.022	-0.0195
-2250	82	115	93	122	-0.025	-0.022
-2500	90	126	100	131	-0.0275	-0.024
-2750	100	142	110	146	-0.03	-0.026
-3000	104	147	119	154	-0.033	-0.028
-3250	116	166	130	170	-0.035	-0.031
-3500	121	174	136	177	-0.038	-0.033
Max Deflection: -0.04256 in. from MTS						

Static Test Number: 33		Date : 5/6/04	Number of Cycles Completed: 2,700,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	7	7	9	8	-0.003	-0.002
-500	19	25	24	29	-0.006	-0.005
-750	29	38	36	43	-0.009	-0.007
-1005	39	52	48	58	-0.011	-0.01
-1250	48	64	57	72	-0.014	-0.012
-1500	57	78	68	85	-0.017	-0.014
-1750	67	92	78	99	-0.02	-0.0165
-2000	75	104	87	111	-0.023	-0.019
-2250	84	118	97	124	-0.026	-0.021
-2505	93	131	106	137	-0.0285	-0.023
-2750	102	145	115	150	-0.031	-0.0255
-3000	111	157	123	163	-0.034	-0.028
-3250	119	171	132	176	-0.037	-0.03
-3500	127	183	141	188	-0.039	-0.032
Max Deflection: -0.04276 in. from MTS						

Static Test Number: 34		Date : 5/7/04	Number of Cycles Completed: 2,800,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	0	-5	0	1	-0.0025	-0.0025
-505	13	14	15	20	-0.0055	-0.005
-750	25	31	30	38	-0.008	-0.008
-1000	34	45	41	51	-0.011	-0.01
-1250	37	49	44	57	-0.014	-0.012
-1505	50	68	58	76	-0.017	-0.0145
-1750	58	82	68	89	-0.0195	-0.017
-2010	67	97	78	102	-0.0225	-0.0195
-2250	78	115	88	117	-0.025	-0.0215
-2500	82	122	92	126	-0.0275	-0.024
-2750	95	142	108	145	-0.0305	-0.026
-3000	98	145	110	152	-0.033	-0.0275
-3250	107	160	120	164	-0.0355	-0.031
-3500	119	176	131	180	-0.038	-0.033
Max Deflection: -0.04272 in. from MTS						

Static Test Number: 35		Date : 5/8/04	Number of Cycles Completed: 3,000,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	12	9	12	-0.003	-0.003
-505	22	28	24	30	-0.006	-0.0055
-750	28	37	28	45	-0.0085	-0.008
-1000	40	55	54	63	-0.011	-0.0105
-1250	49	68	64	74	-0.015	-0.013
-1505	58	79	69	87	-0.017	-0.015
-1750	66	90	81	104	-0.02	-0.017
-2000	78	107	96	121	-0.0225	-0.019
-2230	84	118	103	135	-0.025	-0.022
-2500	95	133	116	152	-0.028	-0.024
-2750	107	151	137	171	-0.031	-0.0265
-3000	113	160	142	181	-0.033	-0.029
-3250	120	171	148	194	-0.036	-0.031
-3500	131	190	170	214	-0.0385	-0.033
Max Deflection: -0.04476 in. from MTS						

Notes: The Strain gages on specimen 3 and 4 fatigued at 2,900,000. Either the glue or soldering failed. New gages were installed after 3,000,000 cycles.

Static Test Number: 36		Date : 5/9/04	Number of Cycles Completed: 3,100,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	4	6	0	9	-0.0025	-0.0025
-500	15	21	17	25	-0.0055	-0.005
-750	27	37	33	43	-0.008	-0.007
-1000	35	49	41	56	-0.011	-0.01
-1250	47	67	60	77	-0.015	-0.012
-1500	54	77	62	88	-0.017	-0.014
-1755	62	91	74	107	-0.02	-0.017
-2005	71	103	84	121	-0.023	-0.019
-2250	80	117	97	136	-0.0255	-0.021
-2500	87	128	102	149	-0.028	-0.023
-2750	94	141	112	162	-0.031	-0.025
-3000	108	160	133	182	-0.0335	-0.027
-3250	113	169	137	191	-0.036	-0.0295
-3500	123	185	155	209	-0.039	-0.032
Max Deflection: -0.04336 in. from MTS						

Static Test Number: 37		Date : 5/9/04	Number of Cycles Completed: 3,200,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	14	16	-0.002	-0.003
-505	19	26	26	31	-0.006	-0.055
-750	27	38	36	44	-0.009	-0.008
-1000	37	53	47	61	-0.011	-0.01
-1250	47	67	58	77	-0.0145	-0.0125
1505	57	80	68	92	-0.017	-0.015
-1755	67	95	83	110	-0.02	-0.017
-2000	75	107	95	122	-0.023	-0.019
-2250	84	120	105	138	-0.026	-0.0215
-2500	94	136	117	155	-0.0285	-0.024
-2750	102	148	127	168	-0.031	-0.026
-3000	110	160	135	182	-0.034	-0.028
-3250	118	172	144	196	-0.037	-0.03
-3500	123	180	145	203	-0.039	-0.0325
Max Deflection: -0.04308 in. from MTS						

Static Test Number: 38		Date : 5/10/04	Number of Cycles Completed: 3,300,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	10	13	12	15	-0.003	-0.0025
-505	20	27	26	32	-0.006	-0.005
-750	29	40	38	48	-0.0085	-0.007
-1000	39	53	50	63	-0.0115	-0.01
-1250	47	66	61	79	-0.0145	-0.012
-1500	57	80	72	94	-0.017	-0.014
-1750	66	93	83	109	-0.02	-0.016
-2005	75	106	94	124	-0.023	-0.0185
-2250	84	120	104	139	-0.0255	-0.021
-2505	92	133	114	153	-0.0275	-0.023
-2750	101	146	125	168	-0.031	-0.025
-3000	108	158	134	181	-0.034	-0.027
-3250	117	171	144	195	-0.0365	-0.029
-3500	125	182	154	208	-0.039	-0.0315
Max Deflection: -0.04228 in. from MTS						

Static Test Number: 39		Date : 5/10/04	Number of Cycles Completed: 3,400,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	11	15	16	17	-0.003	-0.002
-505	20	28	29	32	-0.006	-0.0045
-750	26	38	33	53	-0.0085	-0.007
-1000	38	54	50	73	-0.011	-0.009
-1250	46	67	60	87	-0.014	-0.011
-1505	56	80	71	102	-0.017	-0.0135
-1755	64	92	81	116	-0.02	-0.016
-2000	75	107	96	133	-0.0225	-0.018
-2250	82	119	104	146	-0.025	-0.02
-2505	89	131	112	160	-0.028	-0.022
-2750	102	148	130	178	-0.031	-0.0245
-3000	112	162	143	193	-0.033	-0.0265
-3250	117	171	146	203	-0.036	-0.0285
-3500	127	185	161	218	-0.038	-0.031
Max Deflection: -0.04204 in. from MTS						

Static Test Number: 40		Date : 5/10/04	Number of Cycles Completed: 3,500,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	7	10	3	9	-0.0025	-0.002
-500	19	25	22	29	-0.005	-0.004
-750	26	34	25	39	-0.008	-0.0065
-1000	37	51	45	59	-0.011	-0.009
-1250	45	62	52	72	-0.014	-0.011
-1510	56	77	67	89	-0.017	-0.013
-1750	66	92	82	106	-0.019	-0.015
-2005	74	104	89	119	-0.022	-0.0175
-2255	81	115	96	131	-0.025	-0.0195
-2505	90	129	105	145	-0.0275	-0.022
-2750	99	142	116	160	-0.03	-0.024
-3000	108	156	128	174	-0.0325	-0.026
-3250	115	168	136	188	-0.035	-0.028
-3500	121	176	140	196	-0.038	-0.03
Max Deflection: -0.04216 in. from MTS						

Static Test Number: 41		Date : 5/11/04	Number of Cycles Completed: 3,600,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	10	14	14	16	-0.002	-0.0025
-500	19	27	26	32	-0.005	-0.005
-750	29	41	39	48	-0.008	-0.0075
-1000	38	54	50	64	-0.011	-0.01
-1250	47	67	62	79	-0.014	-0.012
-1500	57	81	72	95	-0.017	-0.0145
-1755	65	94	84	110	-0.0195	-0.017
-2005	74	108	95	125	-0.022	-0.019
-2255	83	120	104	139	-0.025	-0.021
-2505	91	134	116	154	-0.028	-0.0235
-2750	99	146	125	168	-0.03	-0.026
-3000	108	159	135	183	-0.033	-0.028
-3250	116	171	144	196	-0.0355	-0.03
-3500	123	184	154	208	-0.038	-0.0325
Max Deflection: -0.04224 in. from MTS						

Static Test Number: 42		Date : 5/11/04	Number of Cycles Completed: 3,700,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	8	12	12	15	-0.003	-0.003
-500	17	25	25	31	-0.0055	-0.005
-750	25	37	35	46	-0.008	-0.0075
-1000	31	46	41	57	-0.011	-0.01
-1250	42	61	55	74	-0.014	-0.0125
-1500	52	76	68	90	-0.0165	-0.015
-1750	59	88	76	102	-0.0195	-0.017
-2000	72	105	94	122	-0.022	-0.019
-2250	79	116	101	134	-0.025	-0.0215
-2500	88	130	110	149	-0.0275	-0.024
-2750	94	140	115	160	-0.03	-0.026
-3000	104	156	131	179	-0.033	-0.028
-3250	111	167	137	190	-0.035	-0.0305
-3500	122	182	152	208	-0.038	-0.033
Max Deflection: -0.04212 in. from MTS						

Static Test Number: 43		Date : 5/11/04	Number of Cycles Completed: 3,800,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	10	14	13	17	-0.002	-0.0025
-500	19	27	25	32	-0.0055	-0.005
-750	29	41	37	48	-0.008	-0.0075
-1000	39	54	48	63	-0.011	-0.01
-1250	48	67	59	79	-0.014	-0.012
-1510	57	81	71	94	-0.017	-0.015
-1750	66	94	81	109	-0.019	-0.017
-2000	74	108	91	123	-0.022	-0.019
-2250	83	120	101	138	-0.025	-0.0215
-2500	92	133	112	153	-0.0275	-0.024
-2750	101	147	122	167	-0.03	-0.026
-3000	109	159	132	181	-0.033	-0.0285
-3250	117	172	141	194	-0.036	-0.031
-3500	124	184	150	205	-0.038	-0.033
Max Deflection: -0.04220 in. from MTS						

Static Test Number: 44		Date : 5/12/04	Number of Cycles Completed: 3,900,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	10	14	13	15	-0.002	-0.003
-500	19	27	26	31	-0.005	-0.005
-750	29	40	37	47	-0.008	-0.0075
-1000	38	53	49	62	-0.011	-0.01
-1250	47	66	60	78	-0.0135	-0.012
-1500	57	80	71	93	-0.016	-0.014
-1750	65	93	82	108	-0.019	-0.0165
-2000	74	107	93	123	-0.022	-0.019
-2250	83	120	104	138	-0.025	-0.021
-2500	91	133	114	152	-0.027	-0.023
-2750	100	146	124	167	-0.03	-0.025
-3005	108	159	134	181	-0.033	-0.0275
-3250	116	171	143	194	-0.035	-0.03
-3500	123	183	152	206	-0.038	-0.032
Max Deflection: -0.04176 in. from MTS						

Static Test Number: 45		Date : 5/12/04	Number of Cycles Completed: 4,000,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	10	14	14	17	-0.003	-0.0025
-500	19	27	26	33	-0.0055	-0.005
-750	29	40	38	48	-0.008	-0.007
-1000	38	53	49	64	-0.011	-0.0095
-1250	47	67	61	79	-0.014	-0.012
-1500	56	80	71	94	-0.0165	-0.014
-1750	65	94	82	109	-0.019	-0.016
-2000	74	107	93	124	-0.022	-0.018
-2250	82	119	103	138	-0.025	-0.02
-2500	91	133	113	153	-0.0275	-0.022
-2750	99	145	123	167	-0.03	-0.024
-3000	107	158	133	181	-0.033	-0.0265
-3250	116	171	143	195	-0.0355	-0.029
-3500	123	182	151	206	-0.038	-0.031
Max Deflection: -0.04040 in. from MTS						

Static Test Number: 46		Date : 5/12/04	Number of Cycles Completed: 4,100,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	10	14	13	16	-0.0025	-0.0025
-500	17	24	19	28	-0.0055	-0.005
-750	27	37	31	43	-0.008	-0.0075
-1000	35	48	37	56	-0.011	-0.01
-1255	46	64	54	75	-0.014	-0.012
-1500	55	77	65	90	-0.016	-0.0145
-1750	62	89	74	103	-0.019	-0.017
-2000	71	102	85	118	-0.022	-0.019
-2250	81	117	99	135	-0.024	-0.021
-2500	89	129	107	148	-0.027	-0.0235
-2750	97	141	116	161	-0.03	-0.026
-3000	106	155	127	177	-0.032	-0.028
-3250	115	169	139	192	-0.035	-0.0305
-3500	123	180	148	204	-0.038	-0.033
Max Deflection: -0.04204 in. from MTS						

Static Test Number: 47		Date : 5/12/04	Number of Cycles Completed: 4,200,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	11	15	-0.002	-0.003
-500	18	26	22	31	-0.005	-0.004
-750	28	39	33	46	-0.008	-0.0065
-1000	37	53	46	62	-0.011	-0.009
-1250	47	67	56	77	-0.014	-0.011
-1500	55	80	67	92	-0.016	-0.013
-1750	64	92	77	107	-0.019	-0.0155
-2000	73	106	88	122	-0.022	-0.018
-2250	82	118	98	136	-0.0245	-0.02
-2500	90	132	108	150	-0.027	-0.022
-2750	99	145	118	165	-0.03	-0.024
-3000	107	157	128	178	-0.032	-0.0265
-3250	116	170	138	192	-0.035	-0.029
-3500	123	181	145	202	-0.037	-0.031
Max Deflection: -0.04168 in. from MTS						

Static Test Number: 48		Date : 5/13/04	Number of Cycles Completed: 4,300,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-255	9	12	13	15	-0.003	-0.002
-500	17	25	22	29	-0.005	-0.004
-750	27	38	33	46	-0.008	-0.0065
-1000	36	52	47	62	-0.011	-0.009
-1255	46	65	60	78	-0.014	-0.011
-1500	54	78	71	93	-0.0165	-0.0135
-1755	60	90	77	105	-0.019	-0.016
-2000	72	105	89	122	-0.022	-0.018
-2250	81	119	101	137	-0.025	-0.02
-2500	91	133	116	155	-0.0275	-0.0225
-2750	97	143	115	165	-0.03	-0.025
-3000	108	159	136	183	-0.0325	-0.027
-3250	112	167	133	190	-0.035	-0.029
-3500	121	181	149	206	-0.038	-0.031
Max Deflection: -0.04224 in. from MTS						

Static Test Number: 49		Date : 5/13/04	Number of Cycles Completed: 4,400,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	8	12	9	14	-0.003	-0.002
-500	19	26	21	30	-0.0055	-0.004
-750	27	38	28	44	-0.008	-0.0065
-1000	37	51	40	59	-0.011	-0.009
-1250	45	64	47	74	-0.0135	-0.011
-1500	55	77	56	90	-0.016	-0.0135
-1750	64	91	67	104	-0.019	-0.016
-2000	72	103	73	118	-0.0215	-0.018
-2250	81	116	87	133	-0.024	-0.02
-2500	91	132	103	150	-0.027	-0.0225
-2750	101	145	116	166	-0.0295	-0.025
-3000	107	156	119	177	-0.032	-0.027
-3250	113	165	118	185	-0.0345	-0.029
-3500	123	180	138	202	-0.037	-0.031
Max Deflection: -0.04172 in. from MTS						

Static Test Number: 50		Date : 5/13/04	Number of Cycles Completed: 4,500,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	11	16	-0.002	-0.002
-500	18	27	23	32	-0.005	-0.004
-750	28	40	35	48	-0.0075	-0.0065
-1000	37	53	47	63	-0.01	-0.009
-1250	46	67	59	79	-0.0125	-0.011
-1500	56	81	69	94	-0.016	-0.014
-1750	64	94	79	108	-0.018	-0.016
-2000	73	107	90	123	-0.021	-0.018
-2250	82	120	101	138	-0.023	-0.0205
-2500	90	133	111	152	-0.026	-0.023
-2750	98	145	121	166	-0.028	-0.025
-3000	107	159	131	180	-0.031	-0.027
-3250	115	171	140	194	-0.033	-0.0295
-3500	122	182	149	206	-0.0355	-0.0315
Max Deflection: -0.04176 in. from MTS						

Static Test Number: 51		Date : 5/14/04	Number of Cycles Completed: 4,600,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	5	11	2	10	-0.003	-0.002
-500	16	26	19	26	-0.006	-0.0045
-750	26	38	29	40	-0.009	-0.007
-1000	35	53	41	58	-0.012	-0.0095
-1250	46	64	48	75	-0.015	-0.012
-1500	56	77	62	88	-0.018	-0.014
-1750	64	92	73	106	-0.021	-0.0165
-2000	73	107	90	121	-0.024	-0.019
-2250	80	118	95	131	-0.0265	-0.021
-2500	89	131	104	147	-0.0295	-0.023
-2750	99	145	116	163	-0.032	-0.0255
-3000	105	156	121	173	-0.035	-0.028
-3250	113	169	133	187	-0.0375	-0.03
-3500	119	179	138	197	-0.04	-0.032
Max Deflection: -0.04212 in. from MTS						

Static Test Number: 52 | Date : 5/14/04 | Number of Cycles Completed: 4,700,000

Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	5	9	0	8	-0.0025	-0.002
-500	16	23	19	26	-0.0055	-0.0045
-750	26	36	28	41	-0.008	-0.007
-1000	35	49	40	56	-0.011	-0.009
-1250	46	65	55	74	-0.014	-0.0115
-1500	53	75	59	85	-0.0165	-0.014
-1750	63	90	75	104	-0.019	-0.016
-2000	73	103	88	119	-0.022	-0.018
-2250	80	116	96	131	-0.0245	-0.0205
-2500	89	129	107	147	-0.027	-0.023
-2750	96	141	115	158	-0.03	-0.025
-3000	105	154	127	174	-0.032	-0.027
-3250	113	166	135	187	-0.0345	-0.029
-3500	119	175	141	198	-0.037	-0.0315

Max Deflection: -0.04216 in. from MTS

Static Test Number: 53 | Date : 5/14/04 | Number of Cycles Completed: 4,800,000

Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	11	15	-0.0025	-0.002
-500	19	25	24	30	-0.005	-0.004
-750	29	39	36	46	-0.008	-0.0065
-1000	38	52	48	61	-0.011	-0.009
-1250	47	65	58	76	-0.0135	-0.011
-1500	56	78	69	91	-0.016	-0.0135
-1750	65	92	80	107	-0.019	-0.016
-2000	73	105	90	121	-0.021	-0.018
-2250	82	118	100	136	-0.024	-0.02
-2500	90	131	110	150	-0.027	-0.0225
-2750	99	144	121	165	-0.03	-0.025
-3000	107	157	131	179	-0.032	-0.027
-3250	115	169	140	192	-0.0345	-0.029
-3500	123	180	148	203	-0.037	-0.031

Max Deflection: -0.04172 in. from MTS

Static Test Number: 54 | Date : 5/15/04 | Number of Cycles Completed: 4,900,000

Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	7	11	8	12	-0.0025	-0.002
-500	16	22	18	25	-0.005	-0.0045
-750	27	37	33	45	-0.008	-0.007
-1000	36	51	47	61	-0.011	-0.009
-1250	46	64	59	76	-0.014	-0.0115
-1500	55	78	68	91	-0.017	-0.014
-1750	64	92	82	107	-0.0195	-0.016
-2000	68	100	84	117	-0.022	-0.018
-2250	78	115	98	135	-0.025	-0.02
-2500	88	131	112	152	-0.0275	-0.022
-2750	95	141	114	163	-0.03	-0.0245
-3000	103	154	124	177	-0.033	-0.0265
-3250	112	166	136	191	-0.035	-0.029
-3500	120	180	148	206	-0.0375	-0.031

Max Deflection: -0.04208 in. from MTS

Static Test Number: 55	Date : 5/15/04	Number of Cycles Completed: 5,000,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	8	10	7	13	-0.0025	-0.002
-500	15	21	16	27	-0.0055	-0.004
-750	26	35	28	44	-0.0085	-0.007
-1000	36	49	42	61	-0.011	-0.009
-1250	44	60	46	73	-0.014	-0.011
-1500	56	76	59	91	-0.017	-0.013
-1750	66	91	73	109	-0.02	-0.0155
-2000	74	104	84	123	-0.0225	-0.0175
-2250	82	117	93	137	-0.025	-0.02
-2500	91	129	103	152	-0.028	-0.022
-2750	100	142	113	166	-0.031	-0.024
-3000	107	154	118	178	-0.0335	-0.026
-3250	115	166	129	192	-0.036	-0.028
-3500	121	176	136	202	-0.0385	-0.03
Max Deflection: -0.04192 in. from MTS						

Static Test Number: 56	Date : 5/15/04	Number of Cycles Completed: 5,100,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	11	15	-0.0025	-0.002
-500	19	26	23	31	-0.006	-0.0045
-750	28	39	35	46	-0.0085	-0.007
-1000	38	52	46	61	-0.0115	-0.009
-1250	47	65	57	77	-0.014	-0.0115
-1500	56	78	68	92	-0.017	-0.014
-1750	65	92	79	107	-0.02	-0.016
-2000	73	105	89	122	-0.023	-0.0185
-2250	82	119	101	137	-0.026	-0.021
-2500	90	131	110	151	-0.0285	-0.023
-2750	99	144	120	165	-0.031	-0.025
-3000	107	157	129	179	-0.034	-0.028
-3250	115	170	139	192	-0.0365	-0.03
-3500	123	181	148	205	-0.039	-0.032
Max Deflection: -0.04152 in. from MTS						

Static Test Number: 57	Date : 5/16/04	Number of Cycles Completed: 5,200,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	8	12	10	14	-0.002	-0.002
-500	16	23	17	27	-0.005	-0.005
-750	24	35	24	39	-0.0075	-0.007
-1000	35	50	41	60	-0.0105	-0.0095
-1250	45	61	46	72	-0.013	-0.012
-1500	55	76	60	89	-0.016	-0.014
-1750	64	90	75	106	-0.019	-0.0165
-2000	72	102	84	120	-0.022	-0.019
-2250	79	113	90	131	-0.0245	-0.021
-2500	89	130	109	152	-0.027	-0.0235
-2750	96	140	111	160	-0.03	-0.026
-3000	106	156	129	179	-0.0325	-0.028
-3250	114	167	136	191	-0.035	-0.03
-3500	119	177	140	201	-0.0375	-0.0325
Max Deflection: -0.04212 in. from MTS						

Static Test Number: 58		Date : 5/16/04	Number of Cycles Completed: 5,300,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	8	11	9	14	-0.003	-0.002
-500	17	25	18	29	-0.006	-0.004
-750	28	38	30	46	-0.009	-0.0065
-1000	36	51	43	60	-0.0115	-0.009
-1250	46	65	56	77	-0.014	-0.011
-1500	56	79	68	93	-0.017	-0.013
-1750	64	92	77	107	-0.02	-0.015
-2000	73	106	89	123	-0.023	-0.0175
-2250	82	119	99	138	-0.0255	-0.02
-2500	90	131	105	151	-0.0285	-0.022
-2750	97	142	129	168	-0.031	-0.024
-3000	105	155	134	179	-0.034	-0.026
-3250	113	168	143	193	-0.036	-0.028
-3500	121	179	150	204	-0.039	-0.03
Max Deflection: -0.04200 in. from MTS						

Static Test Number: 59		Date : 5/16/04	Number of Cycles Completed: 5,400,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	8	12	11	15	-0.0025	-0.002
-500	17	24	23	30	-0.005	-0.0045
-750	27	38	35	45	-0.008	-0.007
-1000	37	52	48	62	-0.011	-0.0095
-1250	45	64	57	76	-0.0135	-0.0115
-1500	55	78	69	92	-0.016	-0.014
-1750	63	90	79	105	-0.018	-0.016
-2000	72	103	89	120	-0.022	-0.018
-2250	80	116	99	134	-0.0245	-0.0205
-2500	89	129	110	149	-0.027	-0.023
-2750	98	142	120	163	-0.03	-0.025
-3000	106	156	130	178	-0.0325	-0.027
-3250	114	169	139	191	-0.035	-0.029
-3500	123	183	150	206	-0.0375	-0.031
Max Deflection: -0.04148 in. from MTS						

Static Test Number: 60		Date : 5/17/04	Number of Cycles Completed: 5,500,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	8	12	11	15	-0.002	-0.0025
-500	17	24	23	30	-0.005	-0.005
-750	27	38	35	45	-0.008	-0.007
-1000	37	52	48	62	-0.011	-0.0095
-1250	45	64	57	76	-0.0135	-0.012
-1500	55	78	69	92	-0.016	-0.014
-1750	63	90	79	105	-0.019	-0.016
-2000	72	103	89	120	-0.022	-0.019
-2250	80	116	99	134	-0.0245	-0.021
-2500	89	129	110	149	-0.027	-0.023
-2750	98	142	120	163	-0.03	-0.025
-3000	106	156	130	178	-0.0325	-0.027
-3250	114	169	139	191	-0.035	-0.029
-3500	123	183	150	206	-0.038	-0.032
Max Deflection: -0.04232 in. from MTS						

Static Test Number: 61		Date : 5/17/04	Number of Cycles Completed: 5,600,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	6	7	9	12	-0.003	-0.002
-500	17	23	23	29	-0.0055	-0.005
-750	26	34	34	43	-0.008	-0.007
-1000	38	49	46	59	-0.011	-0.009
-1250	47	63	58	74	-0.014	-0.0115
-1500	53	71	64	84	-0.0165	-0.0135
-1750	65	89	79	102	-0.019	-0.016
-2000	72	99	87	115	-0.022	-0.018
-2250	79	108	96	126	-0.025	-0.0205
-2500	87	120	106	140	-0.027	-0.0225
-2750	96	134	117	155	-0.03	-0.025
-3000	104	149	127	168	-0.033	-0.027
-3250	111	159	135	182	-0.035	-0.029
-3500	119	173	146	194	-0.038	-0.031
Max Deflection: -0.04192 in. from MTS						

Static Test Number: 62		Date : 5/17/04	Number of Cycles Completed: 5,700,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	8	12	12	15	-0.002	-0.002
-500	17	25	23	30	-0.005	-0.004
-750	29	41	37	49	-0.008	-0.007
-1000	38	53	48	63	-0.011	-0.009
-1250	47	67	59	79	-0.0135	-0.011
-1500	57	81	70	94	-0.0165	-0.014
-1750	65	94	81	109	-0.019	-0.016
-2000	74	108	92	124	-0.022	-0.018
-2250	83	120	102	139	-0.025	-0.0205
-2500	91	133	112	153	-0.0275	-0.0225
-2750	99	145	121	167	-0.03	-0.025
-3000	107	158	131	181	-0.033	-0.027
-3250	116	171	141	195	-0.0355	-0.029
-3500	122	182	149	207	-0.038	-0.0315
Max Deflection: -0.04192 in. from MTS						

Static Test Number: 63		Date : 5/18/04	Number of Cycles Completed: 5,800,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	8	12	12	15	-0.0025	-0.002
-500	14	18	18	23	-0.005	-0.0045
-750	25	34	33	43	-0.008	-0.007
-1000	37	51	47	62	-0.011	-0.0095
-1250	46	64	57	77	-0.0135	-0.012
-1500	53	74	67	91	-0.016	-0.014
-1750	61	86	77	105	-0.019	-0.0165
-2000	70	99	88	120	-0.022	-0.0185
-2250	81	116	99	137	-0.0245	-0.021
-2500	85	121	102	144	-0.027	-0.023
-2750	98	142	119	166	-0.03	-0.0255
-3000	106	154	129	179	-0.032	-0.0275
-3250	112	162	137	189	-0.035	-0.03
-3500	119	175	146	202	-0.038	-0.032
Max Deflection: -0.04196 in. from MTS						

Static Test Number: 64		Date : 5/18/04	Number of Cycles Completed: 5,900,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	11	12	15	-0.0025	-0.002
-500	15	19	21	27	-0.0055	-0.0045
-750	24	31	32	42	-0.0083	-0.007
-1000	33	44	43	57	-0.011	-0.009
-1250	44	59	55	74	-0.014	-0.012
-1500	52	71	66	87	-0.017	-0.014
-1750	63	87	79	105	-0.0197	-0.0165
-2000	69	97	86	116	-0.0223	-0.0185
-2250	81	113	100	134	-0.025	-0.021
-2500	88	125	110	148	-0.028	-0.023
-2750	97	137	119	161	-0.0304	-0.025
-3000	104	150	129	176	-0.033	-0.0275
-3250	113	162	139	190	-0.035	-0.0295
-3500	123	178	152	207	-0.038	-0.032
Max Deflection: -0.04240 in. from MTS						

Static Test Number: 65		Date : 5/18/04	Number of Cycles Completed: 6,000,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	10	13	13	16	-0.0025	-0.002
-500	18	26	25	31	-0.0055	-0.0045
-750	29	40	36	47	-0.008	-0.007
-1000	38	52	47	61	-0.011	-0.009
-1250	47	66	59	77	-0.014	-0.0115
-1500	56	79	69	92	-0.017	-0.0135
-1750	65	91	80	107	-0.02	-0.016
-2000	74	105	90	122	-0.022	-0.018
-2250	82	118	100	136	-0.025	-0.02
-2500	91	132	111	151	-0.028	-0.022
-2750	100	144	121	165	-0.031	-0.0245
-3000	108	157	132	180	-0.033	-0.027
-3250	116	170	141	193	-0.036	-0.029
-3500	124	183	150	206	-0.039	-0.031
Max Deflection: -0.04192 in. from MTS						

Static Test Number: 66		Date : 5/19/04	Number of Cycles Completed: 6,100,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	5	5	6	10	-0.003	-0.002
-500	16	20	21	29	-0.0055	-0.0045
-750	26	33	33	45	-0.008	-0.007
-1000	35	45	44	60	-0.011	-0.009
-1250	47	64	58	79	-0.014	-0.011
-1500	52	71	64	89	-0.017	-0.014
-1750	60	83	75	104	-0.02	-0.016
-2000	71	100	87	120	-0.023	-0.018
-2250	80	116	100	138	-0.026	-0.02
-2500	87	127	108	152	-0.0285	-0.022
-2750	94	138	115	164	-0.031	-0.0245
-3000	107	158	133	183	-0.034	-0.0265
-3250	112	166	138	194	-0.037	-0.029
-3500	119	175	144	203	-0.04	-0.031
Max Deflection: -0.04236 in. from MTS						

Static Test Number: 67		Date : 5/19/04	Number of Cycles Completed: 6,200,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	7	10	11	14	-0.003	-0.002
-500	15	20	21	28	-0.0055	-0.004
-750	25	34	34	44	-0.008	-0.0065
-1000	33	45	44	58	-0.011	-0.009
-1250	44	61	57	75	-0.014	-0.0115
-1500	52	72	66	88	-0.017	-0.014
-1750	62	87	78	104	-0.02	-0.016
-2000	73	103	91	121	-0.0228	-0.018
-2250	79	113	99	133	-0.0251	-0.0205
-2500	89	127	110	148	-0.0281	-0.023
-2750	99	142	121	164	-0.031	-0.025
-3000	107	154	131	177	-0.0335	-0.027
-3250	115	166	140	191	-0.036	-0.029
-3500	120	173	145	200	-0.039	-0.0315
Max Deflection: -0.04216 in. from MTS						

Static Test Number: 68		Date : 5/19/04	Number of Cycles Completed: 6,300,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	11	15	-0.002	-0.002
-500	18	26	23	31	-0.005	-0.005
-750	28	39	35	46	-0.008	-0.007
-1000	38	52	47	62	-0.011	-0.01
-1250	47	66	58	77	-0.014	-0.012
-1500	56	78	68	92	-0.017	-0.0145
-1750	64	92	79	107	-0.02	-0.0165
-2000	73	105	89	121	-0.023	-0.019
-2250	83	119	101	137	-0.026	-0.021
-2500	91	132	111	152	-0.029	-0.0235
-2750	100	145	121	166	-0.032	-0.026
-3000	108	157	131	179	-0.0345	-0.028
-3250	116	170	140	193	-0.037	-0.03
-3500	123	182	149	205	-0.04	-0.032
Max Deflection: -0.04196 in. from MTS						

Static Test Number: 69		Date : 5/20/04	Number of Cycles Completed: 6,400,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	8	10	10	13	-0.003	-0.002
-500	15	17	17	22	-0.0055	-0.005
-750	24	30	29	38	-0.0085	-0.007
-1000	34	45	42	55	-0.0115	-0.0095
-1250	44	58	54	71	-0.0145	-0.012
-1500	51	67	61	82	-0.017	-0.014
-1750	63	86	77	103	-0.02	-0.0165
-2000	70	96	83	114	-0.023	-0.019
-2250	81	113	98	133	-0.026	-0.021
-2500	86	123	104	141	-0.0285	-0.023
-2750	96	138	116	157	-0.031	-0.025
-3000	104	150	126	171	-0.034	-0.0275
-3250	110	160	133	182	-0.0365	-0.03
-3500	118	173	143	195	-0.039	-0.032
Max Deflection: -0.04236 in. from MTS						

Static Test Number: 70		Date : 5/20/04	Number of Cycles Completed: 6,500,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	7	11	8	12	-0.003	-0.002
-500	16	23	20	27	-0.006	-0.004
-750	26	37	32	43	-0.009	-0.007
-1000	39	55	48	63	-0.0118	-0.009
-1250	42	57	50	68	-0.0144	-0.011
-1500	57	81	69	93	-0.0172	-0.0135
-1750	66	92	79	106	-0.0201	-0.016
-2000	72	101	86	117	-0.023	-0.018
-2250	81	115	97	132	-0.026	-0.0205
-2500	93	133	111	151	-0.0288	-0.023
-2750	101	144	120	164	-0.0314	-0.025
-3000	107	154	127	174	-0.034	-0.027
-3250	116	169	138	189	-0.037	-0.029
-3500	122	177	144	198	-0.039	-0.031
Max Deflection: -0.04204 in. from MTS						

Static Test Number: 71		Date : 5/20/04	Number of Cycles Completed: 6,600,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	8	13	11	15	-0.002	-0.002
-500	18	25	23	31	-0.0055	-0.004
-750	28	38	34	46	-0.008	-0.0065
-1000	38	53	47	62	-0.011	-0.009
-1250	46	64	56	76	-0.014	-0.011
-1500	56	78	67	92	-0.017	-0.013
-1750	64	90	77	105	-0.02	-0.0155
-2000	73	104	88	121	-0.0225	-0.018
-2250	82	118	99	135	-0.025	-0.02
-2500	91	131	109	150	-0.028	-0.022
-2750	99	143	118	164	-0.0305	-0.0245
-3000	107	156	129	178	-0.033	-0.027
-3250	115	169	138	191	-0.0355	-0.029
-3500	122	180	146	202	-0.038	-0.031
Max Deflection: -0.04184 in. from MTS						

Static Test Number: 72		Date : 5/21/04	Number of Cycles Completed: 6,700,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	6	8	8	12	-0.002	-0.002
-500	14	19	17	25	-0.005	-0.0045
-750	28	39	35	46	-0.008	-0.007
-1000	34	48	42	58	-0.011	-0.009
-1250	46	65	56	75	-0.014	-0.0115
-1500	53	75	64	86	-0.017	-0.014
-1750	65	94	80	106	-0.0195	-0.016
-2000	74	107	89	121	-0.022	-0.0185
-2250	80	115	97	131	-0.025	-0.0205
-2500	90	130	107	148	-0.028	-0.023
-2750	98	142	116	162	-0.031	-0.025
-3000	107	158	129	178	-0.0335	-0.0275
-3250	115	170	137	191	-0.036	-0.0295
-3500	122	180	145	202	-0.0385	-0.032
Max Deflection: -0.04260 in. from MTS						

Static Test Number: 73		Date : 5/21/04	Number of Cycles Completed: 6,800,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	12	11	14	-0.003	-0.002
-500	18	24	22	29	-0.006	-0.004
-750	27	36	33	44	-0.009	-0.007
-1000	38	52	46	61	-0.0115	-0.009
-1250	48	65	57	76	-0.014	-0.011
-1500	56	77	66	90	-0.017	-0.0135
-1750	66	91	78	106	-0.02	-0.016
-2000	75	104	89	120	-0.023	-0.018
-2250	81	112	96	131	-0.0255	-0.0205
-2500	90	125	105	145	-0.028	-0.0225
-2750	99	141	117	160	-0.031	-0.025
-3000	108	155	127	175	-0.033	-0.027
-3250	116	165	134	187	-0.036	-0.029
-3500	125	180	147	202	-0.0385	-0.031
Max Deflection: -0.04208 in. from MTS						

Static Test Number: 74		Date : 5/22/04	Number of Cycles Completed: 6,900,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	10	13	13	16	-0.002	-0.002
-500	18	23	23	27	-0.005	-0.005
-750	29	38	38	46	-0.008	-0.007
-1000	39	52	49	61	-0.011	-0.0095
-1250	49	67	63	77	-0.014	-0.012
-1500	58	80	73	91	-0.017	-0.014
-1750	68	94	84	107	-0.02	-0.016
-2000	75	104	92	119	-0.023	-0.019
-2250	85	118	104	135	-0.0255	-0.021
-2500	95	133	116	151	-0.0285	-0.023
-2750	103	147	126	166	-0.0315	-0.0255
-3000	111	157	134	178	-0.034	-0.028
-3250	119	173	145	194	-0.037	-0.03
-3500	126	182	152	203	-0.04	-0.032
Max Deflection: -0.04328 in. from MTS						

Static Test Number: 75		Date : 5/22/04	Number of Cycles Completed: 7,000,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	7	10	9	13	-0.003	-0.002
-500	16	22	19	28	-0.006	-0.0045
-750	28	40	35	47	-0.009	-0.007
-1000	38	52	46	61	-0.0115	-0.0095
-1250	45	63	53	75	-0.015	-0.012
-1500	54	76	64	89	-0.0175	-0.0145
-1750	64	92	77	106	-0.02	-0.017
-2000	74	107	89	122	-0.023	-0.019
-2250	79	114	94	131	-0.026	-0.021
-2500	89	132	103	147	-0.0285	-0.0235
-2750	97	144	112	160	-0.031	-0.026
-3000	106	158	122	176	-0.034	-0.028
-3250	116	173	135	192	-0.037	-0.03
-3500	123	182	143	202	-0.039	-0.032
Max Deflection: -0.04220 in. from MTS						

Static Test Number: 76		Date : 5/23/04	Number of Cycles Completed: 7,100,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	7	9	9	13	-0.002	-0.002
-500	17	24	22	29	-0.0055	-0.004
-750	26	36	32	44	-0.0085	-0.006
-1000	37	50	44	60	-0.0115	-0.009
-1250	47	66	57	77	-0.014	-0.011
-1500	56	78	68	92	-0.017	-0.013
-1750	64	90	78	106	-0.02	-0.015
-2000	73	104	89	121	-0.023	-0.0175
-2250	82	116	99	135	-0.026	-0.02
-2500	92	131	110	150	-0.029	-0.022
-2750	101	148	119	164	-0.0315	-0.024
-3000	108	158	130	178	-0.034	-0.026
-3250	115	168	137	189	-0.037	-0.0285
-3500	122	181	146	202	-0.0395	-0.0305
Max Deflection: -0.04232 in. from MTS						

Static Test Number: 77		Date : 5/23/04	Number of Cycles Completed: 7,200,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	12	15	-0.0025	-0.002
-500	18	26	23	31	-0.0055	-0.004
-750	28	40	35	47	-0.0085	-0.007
-1000	37	53	46	62	-0.0115	-0.009
-1250	46	66	56	76	-0.014	-0.011
-1500	55	79	67	91	-0.017	-0.0135
-1750	64	93	78	106	-0.02	-0.016
-2000	73	106	88	121	-0.023	-0.018
-2250	81	118	98	135	-0.026	-0.02
-2500	89	131	108	149	-0.029	-0.022
-2750	98	144	118	163	-0.032	-0.0245
-3000	106	157	127	177	-0.034	-0.027
-3250	114	170	136	190	-0.037	-0.029
-3500	121	181	146	202	-0.0395	-0.031
Max Deflection: -0.04212 in. from MTS						

Static Test Number: 78		Date : 5/24/04	Number of Cycles Completed: 7,300,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	12	15	-0.0025	-0.002
-500	16	23	20	29	-0.005	-0.005
-750	26	36	32	44	-0.008	-0.007
-1000	36	50	44	60	-0.011	-0.009
-1250	44	60	52	73	-0.014	-0.012
-1500	56	79	68	92	-0.017	-0.014
-1750	62	89	75	104	-0.02	-0.016
-2000	72	104	86	120	-0.022	-0.0185
-2250	81	117	96	134	-0.025	-0.021
-2500	88	128	106	147	-0.028	-0.023
-2750	97	141	116	161	-0.031	-0.025
-3000	107	156	127	177	-0.0335	-0.027
-3250	115	169	136	191	-0.036	-0.0295
-3500	122	179	144	203	-0.039	-0.032
Max Deflection: -0.04268 in. from MTS						

Static Test Number: 79		Date : 5/24/04	Number of Cycles Completed: 7,400,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	10	13	12	15	-0.002	-0.002
-500	19	26	25	32	-0.005	-0.004
-750	29	39	36	47	-0.008	-0.0065
-1000	38	53	47	62	-0.011	-0.009
-1250	48	66	58	77	-0.014	-0.011
-1500	57	80	69	92	-0.0165	-0.013
-1750	65	92	79	107	-0.0195	-0.0155
-2000	75	105	89	120	-0.022	-0.018
-2250	83	119	100	135	-0.025	-0.02
-2500	92	131	109	149	-0.028	-0.022
-2750	100	144	120	163	-0.0305	-0.024
-3000	108	157	129	177	-0.033	-0.026
-3250	116	170	138	189	-0.036	-0.028
-3500	124	181	148	202	-0.0385	-0.0305
Max Deflection: -0.04240 in. from MTS						

Static Test Number: 80		Date : 5/24/04	Number of Cycles Completed: 7,500,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	11	13	12	17	-0.002	-0.002
-500	20	27	25	33	-0.0045	-0.0045
-750	30	40	36	49	-0.007	-0.007
-1000	39	54	47	63	-0.01	-0.009
-1250	48	66	58	78	-0.013	-0.011
-1500	58	80	69	93	-0.0155	-0.0135
-1750	66	93	80	107	-0.018	-0.016
-2000	75	106	89	122	-0.021	-0.018
-2250	83	119	100	136	-0.024	-0.02
-2500	92	132	110	152	-0.027	-0.022
-2750	101	146	120	165	-0.029	-0.024
-3000	108	158	130	178	-0.032	-0.0265
-3250	116	170	138	191	-0.034	-0.0285
-3500	124	181	147	202	-0.037	-0.0305
Max Deflection: -0.04200 in. from MTS						

Static Test Number: 81		Date : 5/25/04	Number of Cycles Completed: 7,600,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	10	13	12	16	-0.002	-0.002
-500	18	26	23	31	-0.005	-0.0045
-750	28	38	36	46	-0.008	-0.007
-1000	37	52	46	61	-0.011	-0.009
-1250	47	64	57	76	-0.014	-0.0115
-1500	56	78	67	90	-0.017	-0.014
-1750	64	91	78	105	-0.02	-0.016
-2000	74	105	88	120	-0.023	-0.018
-2250	83	118	99	134	-0.026	-0.0205
-2500	90	130	109	148	-0.029	-0.023
-2750	99	144	118	162	-0.032	-0.025
-3000	107	155	128	176	-0.034	-0.027
-3250	114	168	137	189	-0.037	-0.029
-3500	122	179	146	201	-0.0395	-0.031
Max Deflection: -0.04200 in. from MTS						

Static Test Number: 82		Date : 5/25/04	Number of Cycles Completed: 7,700,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	12	15	-0.003	-0.002
-500	19	27	25	32	-0.006	-0.0045
-750	28	39	36	46	-0.009	-0.007
-1000	38	53	47	61	-0.012	-0.009
-1250	47	66	58	76	-0.015	-0.0115
-1500	57	79	69	91	-0.018	-0.014
-1750	65	92	80	106	-0.021	-0.016
-2000	74	105	90	120	-0.024	-0.018
-2250	83	119	100	134	-0.027	-0.0205
-2500	92	132	110	149	-0.03	-0.023
-2750	100	145	120	163	-0.033	-0.025
-3000	108	157	130	176	-0.036	-0.027
-3250	116	169	139	189	-0.038	-0.029
-3500	124	181	148	202	-0.041	-0.031
Max Deflection: -0.04280 in. from MTS						

Static Test Number: 83		Date : 5/25/04	Number of Cycles Completed: 7,800,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	12	15	-0.0025	-0.002
-500	18	27	23	31	-0.0055	-0.004
-750	28	39	35	46	-0.0085	-0.007
-1000	37	53	46	61	-0.0115	-0.009
-1250	47	66	57	77	-0.0145	-0.011
-1500	57	80	67	92	-0.0175	-0.013
-1750	64	92	77	106	-0.02	-0.015
-2000	74	105	87	120	-0.023	-0.018
-2250	82	118	98	134	-0.026	-0.02
-2500	90	131	108	149	-0.029	-0.022
-2750	99	144	117	162	-0.031	-0.024
-3000	107	156	127	175	-0.034	-0.026
-3250	114	169	136	188	-0.0365	-0.028
-3500	122	181	145	201	-0.039	-0.0305
Max Deflection: -0.04192 in. from MTS						

Static Test Number: 84		Date : 5/26/04	Number of Cycles Completed: 7,900,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	10	12	12	15	-0.0025	-0.002
-500	19	26	25	31	-0.005	-0.004
-750	29	39	36	47	-0.0085	-0.0065
-1000	38	53	47	61	-0.011	-0.009
-1250	48	66	59	77	-0.014	-0.011
-1500	57	79	69	91	-0.017	-0.013
-1750	66	92	80	107	-0.02	-0.015
-2000	75	105	89	120	-0.023	-0.0175
-2250	83	118	100	134	-0.0255	-0.0195
-2500	92	131	110	149	-0.028	-0.0215
-2750	100	143	119	162	-0.031	-0.023
-3000	107	155	129	176	-0.0335	-0.0255
-3250	116	169	138	189	-0.036	-0.0275
-3500	123	180	147	202	-0.039	-0.0295
Max Deflection: -0.04216 in. from MTS						

Static Test Number: 85		Date : 5/26/04	Number of Cycles Completed: 8,000,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	8	12	12	15	-0.003	-0.002
-500	17	24	22	30	-0.0055	-0.005
-750	27	36	33	44	-0.0085	-0.007
-1000	35	47	42	57	-0.011	-0.01
-1250	45	62	54	74	-0.014	-0.012
-1500	56	77	67	90	-0.017	-0.014
-1750	65	92	79	106	-0.02	-0.0165
-2000	73	103	88	120	-0.023	-0.019
-2250	82	117	98	134	-0.0255	-0.021
-2500	90	130	109	149	-0.028	-0.023
-2750	97	140	116	161	-0.031	-0.025
-3000	106	154	126	176	-0.034	-0.028
-3250	115	169	137	191	-0.036	-0.031
-3500	122	180	146	203	-0.039	-0.032
Max Deflection: -0.04292 in. from MTS						

Static Test Number: 86		Date : 5/26/04	Number of Cycles Completed: 8,100,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	12	16	-0.003	-0.002
-500	19	27	24	32	-0.0055	-0.005
-750	29	40	35	47	-0.0085	-0.007
-1000	38	53	47	63	-0.011	-0.01
-1250	47	66	58	77	-0.014	-0.012
-1500	57	80	68	93	-0.017	-0.014
-1750	65	93	79	107	-0.02	-0.0165
-2000	74	106	90	122	-0.023	-0.019
-2250	83	119	100	136	-0.0255	-0.021
-2500	91	132	110	151	-0.028	-0.023
-2750	99	144	119	164	-0.031	-0.025
-3000	107	158	129	178	-0.034	-0.028
-3250	115	170	138	191	-0.036	-0.03
-3500	123	182	148	204	-0.039	-0.032
Max Deflection: -0.04292 in. from MTS						

Static Test Number: 87		Date : 5/27/04	Number of Cycles Completed: 8,200,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	12	16	-0.0025	-0.002
-500	18	27	23	31	-0.006	-0.0045
-750	29	42	37	48	-0.009	-0.007
-1000	39	55	49	64	-0.0115	-0.009
-1250	47	68	58	78	-0.0145	-0.011
-1500	57	81	69	94	-0.017	-0.013
-1750	64	93	78	107	-0.02	-0.015
-2000	74	107	90	123	-0.023	-0.0175
-2250	83	121	102	138	-0.0255	-0.02
-2500	91	133	110	151	-0.0285	-0.022
-2750	99	146	119	166	-0.031	-0.024
-3000	108	159	130	180	-0.034	-0.026
-3250	114	170	137	191	-0.036	-0.028
-3500	122	183	147	204	-0.039	-0.03
Max Deflection: -0.04292 in. from MTS						

Static Test Number: 88		Date : 5/27/04	Number of Cycles Completed: 8,300,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	11	14	12	16	-0.0030	-0.0020
-500	20	28	23	32	-0.0055	-0.0040
-750	30	42	35	47	-0.0085	-0.0060
-1000	40	56	45	62	-0.0115	-0.0080
-1250	50	69	56	77	-0.0145	-0.0100
-1500	59	83	66	91	-0.0170	-0.0115
-1750	68	96	76	106	-0.0200	-0.0135
-2000	77	109	86	120	-0.0230	-0.0155
-2250	85	123	96	133	-0.0255	-0.0170
-2500	95	136	107	148	-0.0285	-0.0190
-2750	103	149	115	161	-0.0310	-0.0210
-3000	111	161	124	174	-0.0340	-0.0230
-3250	119	174	133	186	-0.0360	-0.0250
-3500	127	186	141	198	-0.0390	-0.0270
Max Deflection: -0.04220 in. from MTS						

Static Test Number: 89		Date : 5/27/04	Number of Cycles Completed: 8,400,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	10	15	13	18	-0.0030	-0.0025
-500	20	29	24	34	-0.0060	-0.0045
-750	29	42	36	50	-0.0090	-0.0065
-1000	39	56	47	65	-0.0115	-0.0085
-1250	49	70	57	81	-0.0140	-0.1050
-1500	58	84	68	95	-0.0170	-0.0125
-1750	67	97	78	110	-0.0200	-0.0140
-2000	75	110	88	124	-0.0220	-0.0160
-2250	84	124	98	139	-0.0250	-0.0180
-2500	92	136	108	153	-0.0280	-0.0200
-2750	101	149	118	167	-0.0310	-0.0220
-3000	108	162	126	180	-0.0330	-0.0240
-3250	116	175	136	193	-0.0360	-0.0260
-3500	123	186	145	206	-0.0390	-0.0280
Max Deflection: -0.04140 in. from MTS						

Static Test Number: 90		Date : 5/28/04	Number of Cycles Completed: 8,500,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	11	16	12	20	-0.0025	-0.0020
-500	15	24	17	33	-0.0055	-0.0050
-750	29	40	34	51	-0.0085	-0.0070
-1000	38	54	45	66	-0.0110	-0.0090
-1250	47	67	55	81	-0.0140	-0.0110
-1500	53	76	61	93	-0.0170	-0.0130
-1750	65	93	76	110	-0.0200	-0.0155
-2000	74	107	87	124	-0.0225	-0.0175
-2250	83	120	97	138	-0.0250	-0.0200
-2500	91	133	106	153	-0.0280	-0.0220
-2750	99	145	116	166	-0.0310	-0.0240
-3000	107	158	124	179	-0.0330	-0.0260
-3250	116	172	136	193	-0.0360	-0.0280
-3500	123	182	143	205	-0.0385	-0.0300
Max Deflection: -0.04164 in. from MTS						

Static Test Number: 91		Date : 5/29/04	Number of Cycles Completed: 8,600,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	11	16	12	20	-0.0030	-0.0025
-500	15	24	17	33	-0.0060	-0.0050
-750	29	40	34	51	-0.0090	-0.0070
-1000	38	54	45	66	-0.0120	-0.0090
-1250	47	67	55	81	-0.0150	-0.0110
-1500	53	76	61	93	-0.0180	-0.0135
-1750	65	93	76	110	-0.0210	-0.0155
-2000	74	107	87	124	-0.0240	-0.0180
-2250	83	120	97	138	-0.0270	-0.0200
-2500	91	133	106	153	-0.0300	-0.0220
-2750	99	145	116	166	-0.0325	-0.0240
-3000	107	158	124	179	-0.0355	-0.0265
-3250	116	172	136	193	-0.0380	-0.0285
-3500	123	182	143	205	-0.0410	-0.0310
Max Deflection: -0.04212 in. from MTS						

Static Test Number: 92		Date : 5/30/04	Number of Cycles Completed: 8,700,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	14	18	22	19	-0.0030	-0.0025
-500	15	24	28	31	-0.0060	-0.0050
-750	25	38	39	46	-0.0085	-0.0070
-1000	36	53	53	62	-0.0110	-0.0050
-1250	42	63	61	76	-0.0140	-0.0120
-1500	55	80	74	92	-0.0170	-0.0140
-1750	66	94	86	108	-0.0200	-0.0160
-2000	71	104	94	121	-0.0230	-0.0185
-2250	81	119	105	136	-0.0255	-0.0205
-2500	90	134	116	151	-0.0280	-0.0230
-2750	97	145	124	163	-0.0310	-0.0250
-3000	107	160	136	178	-0.0340	-0.0270
-3250	111	169	141	189	-0.0360	-0.0295
-3500	119	182	151	202	-0.0395	-0.0315
Max Deflection: -0.04232 in. from MTS						

Static Test Number: 93		Date : 5/30/04	Number of Cycles Completed: 8,800,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	10	14	13	16	-0.0030	-0.0025
-500	15	23	21	30	-0.0055	-0.0050
-750	24	35	31	44	-0.0080	-0.0070
-1000	33	48	42	59	-0.0110	-0.0095
-1250	41	60	51	72	-0.0140	-0.0120
-1500	50	74	62	87	-0.0170	-0.0140
-1750	59	87	72	102	-0.0200	-0.0165
-2000	69	101	84	117	-0.0220	-0.0190
-2250	77	114	93	130	-0.0250	-0.0210
-2500	88	130	105	146	-0.0280	-0.0230
-2750	93	140	112	157	-0.0305	-0.0250
-3000	103	155	124	172	-0.0330	-0.0275
-3250	112	167	133	185	-0.0360	-0.0295
-3500	116	176	139	196	-0.0385	-0.0320
Max Deflection: -0.04172 in. from MTS						

Static Test Number: 94		Date : 5/30/04	Number of Cycles Completed: 8,900,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	14	12	16	-0.0030	-0.0030
-500	18	26	23	31	-0.0060	-0.0050
-750	29	40	35	47	-0.0090	-0.0050
-1000	37	53	46	62	-0.0120	-0.0100
-1250	47	67	57	77	-0.0150	-0.0120
-1500	56	79	67	92	-0.0175	-0.0140
-1750	64	93	77	106	-0.0205	-0.0170
-2000	73	106	87	121	-0.0230	-0.0190
-2250	81	118	97	135	-0.0260	-0.0210
-2500	90	131	107	149	-0.0290	-0.0230
-2750	98	144	117	162	-0.0315	-0.0255
-3000	106	157	126	176	-0.0340	-0.0275
-3250	114	170	136	189	-0.0370	-0.0300
-3500	122	182	145	201	-0.0390	-0.0320
Max Deflection: -0.04160 in. from MTS						

Static Test Number: 95		Date : 5/31/04	Number of Cycles Completed: 9,000,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	8	11	9	15	-0.0025	-0.0025
-500	15	23	19	30	-0.0050	-0.0050
-750	24	35	30	44	-0.0080	-0.0070
-1000	34	49	42	61	-0.0110	-0.0095
-1250	42	62	51	75	-0.0140	-0.0120
-1500	52	76	63	90	-0.0160	-0.0140
-1750	61	90	74	105	-0.0190	-0.0160
-2000	70	103	84	119	-0.0220	-0.0185
-2250	80	117	93	134	-0.0245	-0.0210
-2500	88	130	103	148	-0.0270	-0.0230
-2750	96	143	112	162	-0.0295	-0.0250
-3000	104	156	122	176	-0.0320	-0.0275
-3250	115	170	135	191	-0.0345	-0.0295
-3500	122	182	143	204	-0.0370	-0.0320
Max Deflection: -0.04228 in. from MTS						

Static Test Number: 96		Date : 5/31/04	Number of Cycles Completed: 9,100,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	7	10	9	14	-0.0025	-0.0020
-500	17	24	21	30	-0.0055	-0.0040
-750	27	38	34	46	-0.0085	-0.0060
-1000	34	48	42	59	-0.0115	-0.0080
-1250	43	62	53	74	-0.0145	-0.0100
-1500	55	77	66	90	-0.0170	-0.0120
-1750	62	89	75	103	-0.0200	-0.0140
-2000	71	102	85	118	-0.0230	-0.0160
-2250	81	117	97	133	-0.0260	-0.0180
-2500	89	128	106	146	-0.0290	-0.0200
-2750	95	140	114	159	-0.0320	-0.0220
-3000	106	156	126	174	-0.0345	-0.0240
-3250	115	169	136	188	-0.0370	-0.0260
-3500	123	183	146	201	-0.0400	-0.0280
Max Deflection: -0.04208 in. from MTS						

Static Test Number: 97		Date : 5/31/04	Number of Cycles Completed: 9,200,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	10	14	12	16	-0.0030	-0.0020
-500	19	27	24	31	-0.0060	-0.0040
-750	29	40	35	47	-0.0090	-0.0060
-1000	38	53	47	62	-0.0120	-0.0080
-1250	48	67	57	77	-0.0150	-0.0105
-1500	57	81	68	92	-0.0180	-0.0125
-1750	66	94	79	107	-0.0210	-0.0150
-2000	74	107	89	121	-0.0240	-0.0170
-2250	83	120	99	135	-0.0270	-0.0190
-2500	91	133	108	149	-0.0300	-0.0210
-2750	99	145	119	163	-0.0330	-0.0230
-3000	108	159	128	177	-0.0360	-0.0250
-3250	116	171	137	190	-0.0380	-0.0270
-3500	123	183	146	202	-0.0410	-0.0290
Max Deflection: -0.04168 in. from MTS						

Static Test Number: 98		Date : 6/1/04	Number of Cycles Completed: 9,300,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	12	16	-0.0030	-0.0025
-500	14	22	19	29	-0.0055	-0.0045
-750	20	31	27	42	-0.0080	-0.0070
-1000	34	49	43	60	-0.0011	-0.0090
-1250	37	56	47	72	-0.0135	-0.0110
-1500	53	77	65	91	-0.0160	-0.0130
-1750	59	88	73	104	-0.0190	-0.0150
-2000	68	101	83	118	-0.0210	-0.0175
-2250	79	117	96	134	-0.0240	-0.0195
-2500	87	128	104	147	-0.0260	-0.0220
-2750	92	139	111	160	-0.0290	-0.0240
-3000	102	154	123	175	-0.0320	-0.0260
-3250	111	168	133	189	-0.0345	-0.0280
-3500	121	182	144	203	-0.0370	-0.0300
Max Deflection: -0.04180 in. from MTS						

Static Test Number: 99		Date : 6/1/04	Number of Cycles Completed: 9,400,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	12	11	15	-0.0030	-0.0025
-500	14	22	19	29	-0.0060	-0.0050
-750	24	35	31	44	-0.0090	-0.0070
-1000	37	52	45	61	-0.0115	-0.0095
-1250	43	61	52	74	-0.0140	-0.0120
-1500	56	78	67	91	-0.0170	-0.0140
-1750	61	88	74	103	-0.0200	-0.0160
-2000	73	104	87	119	-0.0225	-0.0190
-2250	79	115	95	132	-0.0250	-0.0210
-2500	90	130	107	148	-0.0280	-0.0230
-2750	100	144	118	162	-0.0305	-0.0250
-3000	106	156	126	175	-0.0335	-0.0280
-3250	113	167	135	188	-0.0360	-0.0300
-3500	119	177	142	200	-0.0380	-0.0320
Max Deflection: -0.04208 in. from MTS						

Static Test Number: 100		Date : 6/1/04	Number of Cycles Completed: 9,500,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	12	15	-0.0030	-0.0030
-500	18	26	23	31	-0.0055	-0.0050
-750	28	39	34	47	-0.0080	-0.0070
-1000	38	53	46	62	-0.0110	-0.0100
-1250	47	66	56	77	-0.0140	-0.0120
-1500	56	80	67	92	-0.0170	-0.0150
-1750	64	92	77	107	-0.0200	-0.0170
-2000	73	106	88	122	-0.0230	-0.0190
-2250	81	119	97	135	-0.0250	-0.0215
-2500	90	132	107	150	-0.0280	-0.0240
-2750	98	145	118	164	-0.0310	-0.0260
-3000	106	157	126	178	-0.0330	-0.0285
-3250	114	171	136	191	-0.0360	-0.0310
-3500	122	183	145	204	-0.0385	-0.0330
Max Deflection: -0.04176 in. from MTS						

Static Test Number: 101		Date : 6/2/04	Number of Cycles Completed: 9,600,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	11	15	14	17	-0.0030	-0.0020
-500	17	26	22	31	-0.0060	-0.0045
-750	24	36	30	45	-0.0085	-0.0070
-1000	35	51	43	61	-0.0115	-0.0090
-1250	47	68	58	78	-0.0145	-0.0110
-1500	54	79	66	91	-0.0170	-0.0130
-1750	61	90	74	104	-0.0200	-0.0150
-2000	72	105	86	119	-0.0230	-0.0170
-2250	77	115	93	131	-0.0250	-0.0190
-2500	87	128	103	145	-0.0280	-0.0210
-2750	97	142	116	159	-0.0310	-0.0230
-3000	101	153	122	172	-0.0330	-0.0250
-3250	111	166	133	186	-0.0360	-0.0270
-3500	120	182	145	202	-0.0390	-0.0300
Max Deflection: -0.04028 in. from MTS						

Static Test Number: 102		Date : 6/2/04	Number of Cycles Completed: 9,700,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	12	11	13	-0.0020	-0.0020
-500	13	20	16	26	-0.0050	-0.0045
-750	23	34	27	41	-0.0080	-0.0070
-1000	35	50	42	58	-0.0110	-0.0090
-1250	42	61	50	71	-0.0135	-0.0110
-1500	50	74	60	85	-0.0160	-0.0130
-1750	59	87	71	100	-0.0190	-0.0150
-2000	68	101	81	115	-0.0220	-0.0175
-2250	77	115	93	129	-0.0250	-0.0195
-2500	83	126	100	141	-0.0270	-0.0215
-2750	91	138	109	154	-0.0300	-0.0235
-3000	99	150	117	167	-0.0325	-0.0255
-3250	105	161	126	180	-0.0350	-0.0275
-3500	116	176	138	194	-0.0375	-0.0295
Max Deflection: -0.04035 in. from MTS						

Static Test Number: 103		Date : 6/3/04	Number of Cycles Completed: 9,800,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	8	13	10	15	-0.0030	-0.0020
-500	15	24	18	29	-0.0060	-0.0040
-750	26	38	31	44	-0.0085	-0.0060
-1000	33	50	39	57	-0.0110	-0.0080
-1250	42	63	50	73	-0.0140	-0.0100
-1500	50	75	60	87	-0.0170	-0.0120
-1750	60	90	72	102	-0.0200	-0.0145
-2000	70	104	84	117	-0.0255	-0.0170
-2250	78	116	92	131	-0.0250	-0.0190
-2500	83	126	99	143	-0.0280	-0.0210
-2750	91	139	108	157	-0.0300	-0.0230
-3000	99	151	117	170	-0.0330	-0.0250
-3250	107	164	128	183	-0.0350	-0.0270
-3500	116	177	138	196	-0.0380	-0.0290
Max Deflection: -0.04076 in. from MTS						

Static Test Number: 104		Date : 6/3/04	Number of Cycles Completed: 9,900,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	11	15	-0.0020	-0.0025
-500	17	25	22	30	-0.0050	-0.0045
-750	27	39	33	45	-0.0080	-0.0070
-1000	37	53	44	60	-0.0110	-0.0090
-1250	44	64	53	74	-0.0140	-0.0110
-1500	53	78	64	88	-0.0170	-0.0130
-1750	61	90	73	102	-0.0195	-0.0150
-2000	69	103	83	116	-0.0225	-0.0180
-2250	78	116	93	130	-0.0255	-0.0200
-2500	83	126	99	143	-0.0285	-0.0220
-2750	94	141	112	157	-0.0310	-0.0240
-3000	102	154	121	170	-0.0340	-0.0265
-3250	107	164	128	182	-0.0360	-0.0285
-3500	117	178	139	196	-0.0390	-0.0305
Max Deflection: -0.04032 in. from MTS						

Static Test Number: 105		Date : 6/4/04	Number of Cycles Completed: 10,000,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Dial Gage 1	Dial Gage 2
-250	9	13	10	14	-0.0030	-0.0020
-500	15	23	18	28	-0.0060	-0.0050
-750	25	37	30	44	-0.0090	-0.0070
-1000	35	52	41	59	-0.0120	-0.0090
-1250	43	64	50	73	-0.0150	-0.0110
-1500	49	74	57	86	-0.0170	-0.0130
-1750	58	88	68	101	-0.0200	-0.0150
-2000	67	101	78	115	-0.0230	-0.0170
-2250	76	116	90	130	-0.0260	-0.0195
-2500	82	126	97	143	-0.0290	-0.0215
-2750	93	142	111	158	-0.0310	-0.0235
-3000	109	164	130	177	-0.0340	-0.0260
-3250	117	176	139	189	-0.0365	-0.0280
-3500	124	187	146	202	-0.0390	-0.0300
Max Deflection: -0.04100 in. from MTS						

B.2 SPS Connections Tested to 5 Million Cycles

Static Test Number: 1		Date : 6/29/04	Number of Cycles Completed: 1			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	31	14	12	12	29	-0.005
-500	64	33	27	27	62	-0.01
-750	94	50	41	40	90	-0.0145
-1000	125	70	56	56	120	-0.019
-1250	153	82	68	67	147	-0.024
-1500	183	102	83	83	175	-0.0285
-1750	208	118	97	97	200	-0.033
-2000	235	135	111	111	225	-0.037
-2250	258	150	124	124	247	-0.042
-2500	279	164	136	137	267	-0.045
-2750	301	180	149	152	289	-0.0495
-3000	321	195	162	165	307	-0.053
-3250	341	207	174	177	327	-0.0575
Max Deflection: -0.06260 in from MTS						

Static Test Number: 2		Date : 6/29/04	Number of Cycles Completed: 10			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	34	21	16	16	31	-0.005
-500	64	34	28	28	60	-0.0095
-750	95	51	42	42	90	-0.014
-1000	127	70	56	56	120	-0.019
-1250	156	86	70	70	148	-0.0235
-1500	186	105	86	85	177	-0.028
-1750	212	122	99	100	202	-0.032
-2000	238	136	111	113	228	-0.037
-2250	261	154	126	127	249	-0.0405
-2500	283	166	138	139	270	-0.045
-2750	305	182	151	153	291	-0.049
-3000	325	197	163	166	310	-0.052
-3250	346	212	177	180	329	-0.057
Max Deflection: -0.06204 in from MTS						

Static Test Number: 3		Date : 6/29/04	Number of Cycles Completed: 100			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	33	17	13	14	31	-0.005
-500	65	35	28	29	62	-0.01
-750	96	51	41	41	92	-0.015
-1000	127	69	56	56	121	-0.019
-1250	156	86	70	70	149	-0.024
-1500	186	103	84	84	178	-0.0285
-1750	213	119	97	98	204	-0.0325
-2000	239	137	111	113	229	-0.037
-2250	262	153	125	127	251	-0.041
-2500	284	165	135	137	271	-0.045
-2750	307	184	150	154	293	-0.049
-3000	326	195	162	165	311	-0.053
-3250	345	207	174	177	329	-0.057
Max Deflection: -0.06196 in from MTS						

Static Test Number: 4		Date : 6/29/04	Number of Cycles Completed: 1000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	31	16	13	13	30	-0.004
-500	65	35	28	29	62	-0.0095
-750	93	46	38	39	89	-0.014
-1000	128	72	57	59	123	-0.019
-1250	156	87	70	71	150	-0.023
-1500	187	105	85	87	180	-0.028
-1750	215	119	98	100	207	-0.032
-2000	242	137	112	115	232	-0.036
-2250	268	154	126	129	257	-0.041
-2500	290	166	137	140	278	-0.045
-2750	313	183	150	154	300	-0.049
-3000	336	201	165	170	322	-0.053
-3250	355	213	176	182	340	-0.056
Max Deflection: -0.06184 in from MTS						

Static Test Number: 5		Date : 6/29/04	Number of Cycles Completed: 10,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	31	14	12	12	30	-0.005
-500	63	31	25	25	60	-0.0095
-750	95	49	40	40	91	-0.014
-1000	128	67	54	55	123	-0.019
-1250	155	82	66	67	148	-0.023
-1500	185	101	82	84	178	-0.028
-1750	214	119	96	99	206	-0.032
-2000	242	134	109	112	232	-0.037
-2250	265	148	121	124	255	-0.041
-2500	292	166	136	139	280	-0.045
-2750	311	180	148	152	298	-0.049
-3000	333	193	160	164	319	-0.053
-3250	353	209	173	179	338	-0.057
Max Deflection: -0.06148 in from MTS						

Static Test Number: 6		Date : 6/29/04	Number of Cycles Completed: 50,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	31	13	12	13	30	-0.005
-500	61	28	25	26	59	-0.01
-750	93	44	38	40	89	-0.0145
-1000	123	64	54	56	118	-0.019
-1250	155	86	70	74	149	-0.0235
-1500	186	106	86	90	179	-0.028
-1750	215	118	98	102	207	-0.033
-2000	241	135	112	117	232	-0.0375
-2250	266	151	126	131	255	-0.042
-2500	290	167	139	145	278	-0.046
-2750	313	184	153	159	300	-0.05
-3000	331	194	163	169	317	-0.0535
-3250	351	211	177	185	336	-0.057
Max Deflection: -0.06248 in from MTS						

Static Test Number: 7		Date : 6/29/04	Number of Cycles Completed: 100,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	34	22	17	18	33	-0.0045
-500	67	41	32	34	65	-0.01
-750	100	61	48	50	97	-0.014
-1000	127	75	60	63	122	-0.019
-1250	157	92	73	77	151	-0.023
-1500	186	111	89	93	180	-0.0275
-1750	214	125	101	106	206	-0.032
-2000	242	145	116	122	233	-0.036
-2250	267	160	130	136	256	-0.0405
-2500	287	172	141	147	276	-0.044
-2750	312	191	157	164	299	-0.048
-3000	331	203	167	174	317	-0.052
-3250	351	218	181	188	336	-0.056
Max Deflection: -0.06172 in from MTS						

Static Test Number: 8		Date : 6/29/04	Number of Cycles Completed: 150,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	18	15	16	31	-0.005
-500	63	36	29	31	61	-0.01
-750	93	53	42	45	90	-0.015
-1000	125	72	57	61	120	-0.02
-1250	155	89	72	75	149	-0.025
-1500	184	107	86	91	178	-0.0295
-1750	212	123	100	105	204	-0.034
-2000	238	139	113	119	230	-0.039
-2250	262	154	126	132	252	-0.0435
-2500	285	169	140	146	274	-0.048
-2750	307	184	152	159	295	-0.053
-3000	328	199	165	172	316	-0.057
-3250	346	211	178	185	332	-0.0605
Max Deflection: -0.06168 in from MTS						

Static Test Number: 9		Date : 6/30/04	Number of Cycles Completed: 200,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	18	15	15	30	-0.004
-500	66	38	30	32	63	-0.009
-750	96	55	44	46	92	-0.0135
-1000	126	73	58	61	121	-0.018
-1250	157	91	72	76	150	-0.023
-1500	186	107	87	90	179	-0.027
-1750	215	124	100	104	207	-0.032
-2000	241	139	113	118	231	-0.036
-2250	264	155	127	132	254	-0.04
-2500	287	170	140	145	276	-0.044
-2750	310	185	153	158	297	-0.0485
-3000	331	200	166	171	316	-0.052
-3250	349	213	178	183	334	-0.056
Max Deflection: -0.06184 in from MTS						

Static Test Number: 10		Date : 6/30/04	Number of Cycles Completed: 300,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	16	13	15	31	-0.005
-500	64	36	28	31	61	-0.0095
-750	96	55	43	47	93	-0.014
-1000	129	75	59	63	124	-0.019
-1250	157	88	71	75	151	-0.023
-1500	189	110	87	92	181	-0.028
-1750	217	125	101	105	209	-0.032
-2000	245	137	112	117	236	-0.037
-2250	268	153	126	130	258	-0.0405
-2500	291	167	138	143	280	-0.0445
-2750	314	183	151	156	302	-0.049
-3000	335	197	163	169	321	-0.0525
-3250	353	210	176	181	339	-0.056
Max Deflection: -0.06216 in from MTS						

Notes: The static test for 250,000 cycles was omitted due to time constraints.

Static Test Number: 11		Date : 6/30/04	Number of Cycles Completed: 350,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	35	23	18	19	33	-0.005
-500	66	39	31	33	63	-0.01
-750	98	55	45	48	93	-0.014
-1000	129	73	59	63	123	-0.0185
-1250	159	92	74	79	153	-0.023
-1500	189	110	88	93	181	-0.027
-1750	218	126	103	107	209	-0.0315
-2000	245	143	116	122	235	-0.0355
-2250	267	155	127	133	257	-0.039
-2500	291	171	141	146	279	-0.0435
-2750	312	185	153	159	299	-0.048
-3000	334	203	168	174	320	-0.052
-3250	352	216	180	186	338	-0.056
Max Deflection: -0.06232 in from MTS						

Static Test Number: 12		Date : 6/30/04	Number of Cycles Completed: 400,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	30	12	11	11	29	-0.005
-500	62	34	27	29	60	-0.01
-750	95	53	42	45	92	-0.015
-1000	125	67	54	57	120	-0.0195
-1250	154	84	68	71	148	-0.024
-1500	184	101	82	86	177	-0.0295
-1750	215	122	99	103	207	-0.034
-2000	240	137	111	116	231	-0.038
-2250	262	148	122	126	252	-0.042
-2500	286	165	136	141	276	-0.046
-2750	309	179	149	154	296	-0.0505
-3000	328	191	160	165	315	-0.0545
-3250	349	213	178	184	335	-0.058
Max Deflection: -0.06180 in from MTS						

Static Test Number: 13		Date : 6/30/04	Number of Cycles Completed: 450,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	33	22	17	17	31	-0.005
-500	65	40	31	33	62	-0.0095
-750	95	54	43	46	91	-0.014
-1000	127	75	60	63	121	-0.0185
-1250	157	92	74	77	150	-0.023
-1500	186	107	87	91	179	-0.0275
-1750	215	126	102	106	206	-0.0325
-2000	241	141	115	119	231	-0.036
-2250	264	154	126	132	254	-0.04
-2500	289	170	142	147	278	-0.0445
-2750	312	189	156	162	299	-0.0485
-3000	330	200	167	172	316	-0.052
-3250	350	215	181	186	335	-0.057
Max Deflection: -0.06196 in from MTS						

Static Test Number: 14		Date : 7/1/04	Number of Cycles Completed: 500,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	33	19	15	16	32	-0.004
-500	64	37	29	31	61	-0.009
-750	96	55	44	47	93	-0.014
-1000	128	74	59	62	123	-0.018
-1250	159	92	73	77	153	-0.023
-1500	187	108	87	90	180	-0.027
-1750	217	125	102	105	209	-0.0315
-2000	243	141	115	119	234	-0.035
-2250	267	156	127	132	257	-0.039
-2500	291	172	142	146	280	-0.0435
-2750	312	185	154	158	300	-0.047
-3000	334	201	168	172	321	-0.051
-3250	352	213	179	184	337	-0.055
Max Deflection: -0.06212 in from MTS						

Static Test Number: 15		Date : 7/1/04	Number of Cycles Completed: 600,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	33	19	15	17	32	-0.005
-500	65	35	28	31	63	-0.01
-750	97	53	42	46	94	-0.015
-1000	129	70	57	60	124	-0.0195
-1250	157	85	69	73	151	-0.024
-1500	189	108	87	91	182	-0.0285
-1750	217	121	98	103	209	-0.0335
-2000	247	140	114	119	239	-0.038
-2250	270	153	125	131	261	-0.042
-2500	297	175	143	149	286	-0.047
-2750	318	188	155	160	306	-0.0505
-3000	336	197	163	169	323	-0.055
-3250	356	214	179	185	343	-0.059
Max Deflection: -0.06180 in from MTS						

Notes: The static test for 550,000 cycles was omitted due to time constraints.

Static Test Number: 16	Date : 7/1/04	Number of Cycles Completed: 650,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	31	13	12	11	30	-0.004
-500	64	34	27	28	61	-0.0095
-750	98	53	43	45	94	-0.014
-1000	130	73	58	61	124	-0.018
-1250	160	88	71	73	152	-0.023
-1500	192	107	86	89	184	-0.028
-1750	222	127	102	106	213	-0.032
-2000	248	142	114	119	238	-0.036
-2250	272	154	125	129	261	-0.04
-2500	297	174	142	146	285	-0.044
-2750	317	186	153	157	304	-0.048
-3000	340	202	166	170	326	-0.052
-3250	358	214	178	182	343	-0.056
Max Deflection: -0.06216 in from MTS						

Static Test Number: 17	Date : 7/1/04	Number of Cycles Completed: 700,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	33	19	15	16	32	-0.005
-500	65	38	30	31	62	-0.01
-750	97	56	43	47	92	-0.0145
-1000	127	74	58	61	122	-0.019
-1250	157	92	72	76	150	-0.0235
-1500	189	110	87	91	180	-0.028
-1750	219	126	101	106	211	-0.033
-2000	245	142	115	119	236	-0.037
-2250	269	158	128	132	260	-0.041
-2500	295	173	141	145	282	-0.045
-2750	316	188	154	158	304	-0.049
-3000	337	203	167	171	323	-0.053
-3250	355	215	179	184	341	-0.057
Max Deflection: -0.06280 in from MTS						

Static Test Number: 18	Date : 7/1/04	Number of Cycles Completed: 750,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	14	12	13	31	-0.005
-500	65	27	24	26	62	-0.01
-750	95	50	41	43	90	-0.015
-1000	127	68	55	58	121	-0.02
-1250	155	80	67	70	148	-0.025
-1500	187	100	83	87	179	-0.029
-1750	215	117	97	101	206	-0.0335
-2000	243	132	110	115	232	-0.038
-2250	266	147	123	127	255	-0.042
-2500	288	161	135	140	276	-0.046
-2750	316	175	148	153	304	-0.0505
-3000	332	193	163	168	317	-0.0545
-3250	348	203	173	178	333	-0.058
Max Deflection: -0.06212 in from MTS						

Static Test Number: 19	Date : 7/1/04	Number of Cycles Completed: 800,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	18	15	16	31	-0.005
-500	67	38	30	32	64	-0.0095
-750	97	56	45	47	93	-0.014
-1000	128	73	58	61	122	-0.019
-1250	158	91	73	76	151	-0.023
-1500	189	110	89	92	182	-0.028
-1750	216	125	101	105	208	-0.032
-2000	243	141	115	118	234	-0.0365
-2250	269	157	129	133	259	-0.041
-2500	291	171	141	145	279	-0.045
-2750	312	185	154	158	299	-0.049
-3000	333	200	167	171	319	-0.053
-3250	351	212	179	183	336	-0.057
Max Deflection: -0.06208 in from MTS						

Static Test Number: 20		Date : 7/2/04	Number of Cycles Completed: 900,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	34	21	17	17	33	-0.004
-500	64	36	29	30	62	-0.009
-750	95	51	41	43	91	-0.013
-1000	128	71	57	60	123	-0.018
-1250	157	90	72	75	151	-0.022
-1500	187	108	87	90	180	-0.0265
-1750	219	127	102	106	211	-0.031
-2000	244	141	114	118	235	-0.035
-2250	271	158	128	133	261	-0.0395
-2500	293	171	140	145	281	-0.0435
-2750	316	187	155	159	304	-0.048
-3000	335	200	165	170	322	-0.052
-3250	354	213	178	183	340	-0.056
Max Deflection: -0.06224 in from MTS						

Notes: The static test for 850,000 cycles was omitted due to time constraints.

Static Test Number: 21		Date : 7/2/04	Number of Cycles Completed: 950,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	31	9	9	10	29	-0.005
-500	65	33	27	29	62	-0.011
-750	96	48	40	42	92	-0.016
-1000	127	63	53	55	121	-0.02
-1250	160	87	71	74	153	-0.025
-1500	190	102	83	87	182	-0.03
-1750	222	123	100	104	213	-0.035
-2000	248	135	111	115	239	-0.039
-2250	273	150	124	128	262	-0.043
-2500	297	166	137	141	285	-0.0475
-2750	321	182	151	155	308	-0.0515
-3000	340	198	165	169	326	-0.055
-3250	359	211	179	183	341	-0.059
Max Deflection: -0.06292 in from MTS						

Static Test Number: 22		Date : 7/2/04	Number of Cycles Completed: 1,000,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	33	18	14	15	32	-0.005
-500	66	35	29	30	63	-0.01
-750	97	56	44	49	94	-0.014
-1000	131	75	62	66	126	-0.019
-1250	160	88	73	78	154	-0.024
-1500	191	105	88	92	184	-0.0285
-1750	217	122	102	106	211	-0.032
-2000	246	139	116	119	239	-0.037
-2250	271	156	130	134	262	-0.041
-2500	295	171	145	149	284	-0.045
-2750	318	183	156	161	305	-0.05
-3000	337	195	168	174	324	-0.053
-3250	354	213	181	186	340	-0.0565
Max Deflection: -0.06212 in from MTS						

Notes: Test will continue until Specimen Failure

Static Test Number: 23		Date : 7/10/04	Number of Cycles Completed: 1,000,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	33	18	14	15	31	-0.004
-500	64	35	28	30	61	-0.009
-750	93	52	41	44	90	-0.013
-1000	123	72	57	60	118	-0.018
-1250	153	89	71	75	147	-0.0225
-1500	179	102	83	87	172	-0.027
-1750	206	120	97	101	198	-0.031
-2000	232	135	110	115	222	-0.0355
-2250	255	153	124	129	245	-0.039
-2500	278	167	137	142	266	-0.0435
-2750	301	185	152	156	289	-0.047
-3000	317	194	163	167	304	-0.051
-3250	335	205	174	178	321	-0.055
Max Deflection: -0.06276 in from MTS						

Notes: This Static Test was ran to check the set up/instrumentation and the effects on the panel after sitting idle for one week.

Static Test Number: 24		Date : 7/10/04	Number of Cycles Completed: 1,100,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	31	14	13	14	29	-0.005
-500	62	33	27	29	59	-0.009
-750	93	49	41	44	89	-0.014
-1000	124	68	56	59	119	-0.019
-1250	153	85	70	73	146	-0.023
-1500	181	102	84	88	174	-0.028
-1750	209	118	97	102	201	-0.033
-2000	236	135	111	116	227	-0.037
-2250	260	153	126	130	250	-0.041
-2500	282	168	138	143	271	-0.045
-2750	303	184	151	157	291	-0.049
-3000	322	194	163	168	309	-0.053
-3250	340	207	175	180	326	-0.057
Max Deflection: -0.06208 in from MTS						

Static Test Number: 25		Date : 7/11/04	Number of Cycles Completed: 1,200,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	33	19	15	16	32	-0.005
-500	63	30	26	28	60	-0.01
-750	95	49	41	43	91	-0.014
-1000	128	71	57	60	122	-0.02
-1250	158	88	71	74	151	-0.025
-1500	186	100	83	86	179	-0.03
-1750	215	119	97	102	207	-0.034
-2000	244	136	111	116	235	-0.039
-2250	269	152	124	129	259	-0.043
-2500	293	166	137	141	281	-0.047
-2750	316	182	150	154	304	-0.051
-3000	337	198	164	168	324	-0.055
-3250	355	210	175	179	341	-0.059
Max Deflection: -0.06248 in from MTS						

Static Test Number: 26		Date : 7/11/04	Number of Cycles Completed: 1,300,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	31	16	14	14	30	-0.005
-500	63	36	29	30	61	-0.01
-750	92	52	42	44	89	-0.014
-1000	124	73	57	60	119	-0.019
-1250	154	90	71	75	148	-0.0235
-1500	185	107	86	90	178	-0.029
-1750	212	124	99	104	204	-0.033
-2000	239	140	113	118	230	-0.037
-2250	263	153	125	130	252	-0.0415
-2500	289	175	142	147	278	-0.046
-2750	309	188	153	158	297	-0.05
-3000	329	203	166	171	316	-0.054
-3250	347	216	178	184	333	-0.058
Max Deflection: -0.06232 in from MTS						

Static Test Number: 27		Date : 7/12/04	Number of Cycles Completed: 1,400,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	19	15	16	31	-0.005
-500	63	37	29	31	61	-0.009
-750	95	55	43	46	91	-0.014
-1000	124	73	57	60	119	-0.019
-1250	156	91	72	76	150	-0.024
-1500	185	108	86	90	178	-0.028
-1750	212	124	99	103	205	-0.0325
-2000	240	141	113	118	232	-0.037
-2250	266	157	127	132	256	-0.041
-2500	287	171	139	144	277	-0.045
-2750	309	187	152	157	298	-0.049
-3000	330	201	164	170	317	-0.053
-3250	348	214	177	182	335	-0.057
Max Deflection: -0.06180 in from MTS						

Static Test Number: 28		Date : 7/12/04	Number of Cycles Completed: 1,500,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	30	11	10	11	29	-0.005
-500	66	33	27	29	63	-0.0105
-750	95	51	41	43	91	-0.015
-1000	127	68	55	58	123	-0.02
-1250	158	88	70	74	152	-0.0245
-1500	188	105	84	88	181	-0.029
-1750	216	121	97	101	208	-0.033
-2000	243	136	110	115	234	-0.038
-2250	268	150	122	127	258	-0.042
-2500	291	166	135	140	280	-0.046
-2750	314	184	149	154	302	-0.05
-3000	335	196	161	166	322	-0.054
-3250	353	208	173	177	339	-0.057
Max Deflection: -0.06248 in from MTS						

Static Test Number: 29		Date : 7/12/04	Number of Cycles Completed: 1,600,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	33	18	14	15	31	-0.005
-500	66	37	29	31	63	-0.01
-750	95	53	42	45	91	-0.014
-1000	127	73	57	60	121	-0.019
-1250	156	89	71	75	150	-0.024
-1500	188	109	86	90	181	-0.029
-1750	216	127	100	105	208	-0.033
-2000	244	142	114	119	234	-0.037
-2250	267	156	126	131	257	-0.041
-2500	291	171	139	144	280	-0.046
-2750	312	185	151	156	299	-0.05
-3000	331	200	164	170	318	-0.053
-3250	350	213	176	181	335	-0.057
Max Deflection: -0.06216 in from MTS						

Static Test Number: 30		Date : 7/12/04	Number of Cycles Completed: 1,700,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	19	14	16	31	-0.0045
-500	65	38	29	33	63	-0.01
-750	96	56	43	48	92	-0.0145
-1000	126	75	57	62	122	-0.0195
-1250	156	92	71	76	150	-0.024
-1500	185	108	85	90	179	-0.029
-1750	212	125	99	104	206	-0.033
-2000	241	143	113	119	232	-0.037
-2250	264	158	126	132	255	-0.041
-2500	287	173	139	146	277	-0.046
-2750	310	188	153	159	299	-0.0495
-3000	329	202	164	171	316	-0.053
-3250	347	215	177	184	334	-0.057
Max Deflection: -0.06200 in from MTS						

Static Test Number: 31		Date : 7/13/04	Number of Cycles Completed: 1,800,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	15	13	15	31	-0.005
-500	64	33	27	30	61	-0.01
-750	95	52	42	45	91	-0.0145
-1000	125	71	56	60	121	-0.02
-1250	155	87	70	74	150	-0.024
-1500	185	105	84	88	179	-0.028
-1750	214	123	99	103	207	-0.033
-2000	240	135	110	115	232	-0.037
-2250	265	150	123	128	256	-0.0415
-2500	288	165	136	140	277	-0.045
-2750	312	183	150	155	300	-0.049
-3000	332	200	164	168	320	-0.0535
-3250	350	207	173	177	336	-0.056
Max Deflection: -0.06200 in from MTS						

Static Test Number: 32		Date : 7/13/04	Number of Cycles Completed: 1,900,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	20	15	17	32	-0.005
-500	65	38	30	33	64	-0.0105
-750	95	53	42	46	92	-0.015
-1000	128	72	57	62	124	-0.02
-1250	158	91	73	77	152	-0.0245
-1500	187	106	85	90	180	-0.029
-1750	213	122	98	103	206	-0.03354
-2000	243	141	115	119	234	-0.0375
-2250	265	154	125	130	255	-0.0415
-2500	290	172	140	144	279	-0.046
-2750	312	187	153	158	300	-0.05
-3000	331	200	164	169	318	-0.0535
-3250	349	211	176	181	334	-0.0565
Max Deflection: -0.06192 in from MTS						

Static Test Number: 33		Date : 7/13/04	Number of Cycles Completed: 2,000,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	19	15	15	31	-0.005
-500	62	37	29	30	60	-0.01
-750	96	56	44	46	92	-0.015
-1000	126	73	58	60	120	-0.02
-1250	156	91	72	75	150	-0.024
-1500	188	109	87	90	181	-0.029
-1750	214	124	100	103	206	-0.034
-2000	240	141	113	118	231	-0.0375
-2250	263	157	127	131	253	-0.041
-2500	288	174	141	145	277	-0.0455
-2750	310	189	155	158	298	-0.0505
-3000	328	202	166	170	315	-0.053
-3250	346	215	179	183	333	-0.0565
Max Deflection: -0.06192 in from MTS						

Static Test Number: 34		Date : 7/14/04	Number of Cycles Completed: 2,100,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	19	14	15	30	-0.005
-500	62	33	26	26	58	-0.01
-750	96	55	43	42	91	-0.015
-1000	127	73	57	56	122	-0.02
-1250	154	86	69	67	148	-0.024
-1500	187	107	85	82	180	-0.029
-1750	214	121	97	93	205	-0.0335
-2000	240	136	110	105	231	-0.0375
-2250	266	155	124	118	256	-0.042
-2500	290	171	138	130	279	-0.046
-2750	312	185	149	141	300	-0.05
-3000	331	196	161	151	318	-0.0535
-3250	350	210	172	162	335	-0.057
Max Deflection: -0.06224 in from MTS						

Notes: Strain Gage 4 was replaced. The terminal strip was intact and therefore, reused.

Static Test Number: 35		Date : 7/14/04	Number of Cycles Completed: 2,200,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	17	13	12	29	-0.005
-500	62	29	24	23	58	-0.01
-750	94	49	39	37	88	-0.015
-1000	126	68	55	51	119	-0.02
-1250	154	85	68	63	147	-0.024
-1500	186	102	81	76	178	-0.029
-1750	213	118	94	88	203	-0.033
-2000	240	136	108	102	230	-0.038
-2250	265	152	122	114	254	-0.042
-2500	287	168	134	125	275	-0.046
-2750	311	182	148	137	297	-0.05
-3000	330	195	159	148	315	-0.0535
-3250	347	208	171	158	331	-0.057
Max Deflection: -0.06236 in from MTS						

Static Test Number: 36		Date : 7/14/04	Number of Cycles Completed: 2,300,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	19	15	14	31	-0.005
-500	65	37	29	28	62	-0.01
-750	95	55	43	41	91	-0.0145
-1000	128	74	57	55	122	-0.0195
-1250	157	91	71	68	151	-0.024
-1500	187	109	85	82	180	-0.0285
-1750	215	125	98	94	207	-0.033
-2000	243	142	112	106	233	-0.037
-2250	266	157	125	118	256	-0.041
-2500	289	172	137	130	278	-0.045
-2750	310	188	150	141	298	-0.049
-3000	330	201	163	153	317	-0.0525
-3250	349	214	175	164	334	-0.056
Max Deflection: -0.06220 in from MTS						

Static Test Number: 37		Date : 7/15/04	Number of Cycles Completed: 2,400,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	30	12	11	11	28	-0.005
-500	63	36	27	27	60	-0.01
-750	92	50	39	39	87	-0.015
-1000	125	73	55	54	120	-0.02
-1250	154	86	68	65	148	-0.0245
-1500	182	102	80	77	175	-0.0285
-1750	210	115	92	88	201	-0.033
-2000	240	137	108	103	230	-0.037
-2250	265	153	121	115	255	-0.042
-2500	290	172	135	128	280	-0.046
-2750	313	185	148	139	300	-0.05
-3000	334	199	160	151	320	-0.054
-3250	352	209	171	160	337	-0.058
Max Deflection: -0.06260 in from MTS						

Static Test Number: 38		Date : 7/15/04	Number of Cycles Completed: 2,500,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	19	13	15	30	-0.005
-500	64	37	28	28	61	-0.0105
-750	96	56	42	41	92	-0.0155
-1000	128	75	57	55	123	-0.02
-1250	158	93	71	68	152	-0.025
-1500	190	111	86	82	183	-0.0295
-1750	217	128	98	93	210	-0.0335
-2000	246	145	112	106	238	-0.038
-2250	272	160	125	118	261	-0.042
-2500	295	175	137	129	283	-0.046
-2750	316	189	150	140	305	-0.05
-3000	337	204	161	151	324	-0.054
-3250	357	217	174	162	343	-0.0575
Max Deflection: -0.06260 in from MTS						

Static Test Number: 39		Date : 7/16/04	Number of Cycles Completed: 2,600,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	17	14	13	31	-0.005
-500	66	39	30	29	64	-0.011
-750	98	58	44	42	94	-0.016
-1000	129	73	57	54	124	-0.021
-1250	159	92	71	68	153	-0.025
-1500	188	106	83	79	181	-0.03
-1750	219	128	99	93	211	-0.034
-2000	247	144	112	105	238	-0.0385
-2250	274	161	125	118	264	-0.0425
-2500	298	176	139	130	288	-0.0465
-2750	320	187	149	139	308	-0.051
-3000	342	205	163	152	329	-0.0545
-3250	360	215	174	161	346	-0.058
Max Deflection: -0.06248 in from MTS						

Static Test Number: 40	Date : 7/16/04	Number of Cycles Completed: 2,700,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	29	12	12	11	29	-0.0045
-500	62	33	26	26	60	-0.009
-750	93	50	41	39	90	-0.014
-1000	123	67	54	51	120	-0.0185
-1250	154	86	68	65	149	-0.023
-1500	184	102	82	77	178	-0.028
-1750	213	121	96	91	206	-0.032
-2000	241	136	109	102	233	-0.036
-2250	266	149	121	113	257	-0.0405
-2500	290	169	135	126	280	-0.044
-2750	311	182	147	137	300	-0.0485
-3000	331	196	160	148	319	-0.052
-3250	351	210	172	159	337	-0.055
Max Deflection: -0.06192 in from MTS						

Static Test Number: 41	Date : 7/17/04	Number of Cycles Completed: 2,800,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	12	12	11	31	-0.005
-500	66	32	27	26	63	-0.011
-750	96	50	40	38	93	-0.0155
-1000	130	73	56	54	125	-0.021
-1250	158	86	68	65	152	-0.025
-1500	190	103	83	78	182	-0.0295
-1750	219	121	96	91	211	-0.034
-2000	249	138	109	103	240	-0.0385
-2250	276	155	123	115	266	-0.043
-2500	302	174	137	129	291	-0.047
-2750	322	183	147	137	311	-0.0505
-3000	346	201	161	150	333	-0.055
-3250	363	211	171	159	349	-0.059
Max Deflection: -0.06392 in from MTS						

Static Test Number: 42	Date : 7/17/04	Number of Cycles Completed: 2,900,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	30	14	12	11	29	-0.005
-500	62	33	27	25	59	-0.0105
-750	93	48	39	37	89	-0.0155
-1000	125	71	55	52	119	-0.02
-1250	157	89	69	66	150	-0.025
-1500	187	105	82	78	180	-0.03
-1750	213	122	95	90	206	-0.0335
-2000	242	138	109	102	233	-0.038
-2250	267	155	122	115	257	-0.042
-2500	290	170	134	126	279	-0.0455
-2750	312	185	147	138	299	-0.0495
-3000	332	198	160	148	318	-0.053
-3250	350	210	171	159	335	-0.057
Max Deflection: -0.06208 in from MTS						

Static Test Number: 43	Date : 7/18/04	Number of Cycles Completed: 3,000,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	15	13	12	31	-0.0055
-500	65	34	27	26	63	-0.0105
-750	95	48	39	38	91	-0.015
-1000	126	65	53	51	121	-0.0205
-1250	157	81	67	63	151	-0.025
-1500	189	102	81	78	183	-0.0295
-1750	216	118	94	89	209	-0.034
-2000	247	139	110	104	238	-0.038
-2250	271	151	121	114	262	-0.042
-2500	295	167	133	125	284	-0.046
-2750	318	184	147	138	307	-0.05
-3000	337	195	158	148	326	-0.054
-3250	356	209	171	159	343	-0.0575
Max Deflection: -0.06248 in from MTS						

Static Test Number: 44		Date : 7/18/04	Number of Cycles Completed: 3,100,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	17	14	13	31	-0.005
-500	65	35	28	27	63	-0.01
-750	95	52	41	40	92	-0.015
-1000	127	69	55	53	123	-0.0195
-1250	156	85	68	65	150	-0.024
-1500	188	106	84	80	181	-0.0285
-1750	214	119	95	90	207	-0.033
-2000	241	137	109	103	232	-0.037
-2250	266	152	122	116	257	-0.041
-2500	288	168	134	127	278	-0.045
-2750	312	187	149	141	301	-0.049
-3000	331	198	160	151	318	-0.0535
-3250	349	209	171	161	335	-0.056
Max Deflection: -0.06200 in from MTS						

Static Test Number: 45		Date : 7/19/04	Number of Cycles Completed: 3,200,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	15	13	13	31	-0.005
-500	67	37	29	29	64	-0.01
-750	97	53	41	40	93	-0.015
-1000	127	70	55	53	122	-0.0195
-1250	157	87	69	66	152	-0.024
-1500	189	108	84	81	182	-0.0285
-1750	214	121	96	91	206	-0.033
-2000	242	138	110	104	233	-0.037
-2250	268	152	123	116	258	-0.041
-2500	291	167	134	127	280	-0.045
-2750	313	182	147	138	302	-0.049
-3000	334	198	161	151	321	-0.053
-3250	352	211	173	161	338	-0.0565
Max Deflection: -0.06256 in from MTS						

Static Test Number: 46		Date : 7/19/04	Number of Cycles Completed: 3,300,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	15	13	13	31	-0.005
-500	67	37	29	29	64	-0.01
-750	97	53	41	40	93	-0.015
-1000	127	70	55	53	122	-0.0195
-1250	157	87	69	66	152	-0.024
-1500	189	108	84	81	182	-0.029
-1750	214	121	96	91	206	-0.033
-2000	242	138	110	104	233	-0.037
-2250	268	152	123	116	258	-0.0415
-2500	291	167	134	127	280	-0.046
-2750	313	182	147	138	302	-0.0495
-3000	334	198	161	151	321	-0.053
-3250	352	211	173	161	338	-0.057
Max Deflection: -0.06200 in from MTS						

Static Test Number: 47		Date : 7/20/04	Number of Cycles Completed: 3,400,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	33	19	14	15	32	-0.005
-500	64	34	27	26	62	-0.01
-750	97	55	42	41	93	-0.015
-1000	125	67	54	51	121	-0.0195
-1250	156	88	68	66	151	-0.024
-1500	190	108	83	80	183	-0.029
-1750	217	122	95	91	209	-0.033
-2000	243	138	108	102	235	-0.037
-2250	269	154	121	115	261	-0.0415
-2500	296	174	137	129	286	-0.0455
-2750	317	188	148	140	305	-0.049
-3000	335	199	159	149	323	-0.053
-3250	352	209	170	158	339	-0.0565
Max Deflection: -0.06204 in from MTS						

Static Test Number: 48	Date : 7/20/04	Number of Cycles Completed: 3,500,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	31	14	12	12	30	-0.005
-500	65	36	28	27	62	-0.0105
-750	94	49	40	38	91	-0.015
-1000	127	70	55	53	123	-0.02
-1250	157	89	69	67	151	-0.024
-1500	187	106	83	79	180	-0.029
-1750	215	122	96	91	208	-0.033
-2000	243	141	110	104	235	-0.038
-2250	267	153	122	115	258	-0.042
-2500	291	170	135	127	281	-0.0455
-2750	311	181	146	137	300	-0.0495
-3000	334	201	161	150	321	-0.054
-3250	351	211	172	160	337	-0.057
Max Deflection: -0.06204 in from MTS						

Static Test Number: 49	Date : 7/20/04	Number of Cycles Completed: 3,600,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	34	20	15	16	32	-0.005
-500	64	38	29	29	61	-0.01
-750	97	57	44	43	93	-0.015
-1000	129	76	58	57	124	-0.02
-1250	159	93	72	69	152	-0.024
-1500	188	110	85	82	181	-0.029
-1750	216	126	98	94	208	-0.033
-2000	245	143	112	107	235	-0.038
-2250	269	160	126	119	259	-0.042
-2500	290	174	138	130	279	-0.046
-2750	312	189	150	142	300	-0.05
-3000	332	203	163	153	319	-0.0535
-3250	350	216	175	164	336	-0.057
Max Deflection: -0.06204 in from MTS						

Static Test Number: 50	Date : 7/21/04	Number of Cycles Completed: 3,700,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	30	9	10	10	30	-0.005
-500	63	30	26	25	61	-0.01
-750	95	51	40	41	92	-0.015
-1000	123	64	52	51	119	-0.019
-1250	155	81	66	64	149	-0.0235
-1500	186	100	80	78	180	-0.028
-1750	215	117	93	90	207	-0.032
-2000	243	132	107	102	235	-0.036
-2250	269	150	120	115	260	-0.04
-2500	292	165	132	126	281	-0.044
-2750	314	180	145	138	303	-0.048
-3000	334	193	157	149	322	-0.052
-3250	353	212	171	161	339	-0.055
Max Deflection: -0.06200 in from MTS						

Static Test Number: 51	Date : 7/21/04	Number of Cycles Completed: 3,800,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	28	9	9	9	28	-0.004
-500	61	26	23	23	59	-0.01
-750	94	51	40	39	90	-0.015
-1000	126	68	54	52	121	-0.0195
-1250	160	91	71	68	153	-0.0245
-1500	188	103	82	79	181	-0.029
-1750	219	126	99	94	211	-0.0335
-2000	248	144	113	107	239	-0.038
-2250	270	154	123	116	261	-0.042
-2500	293	168	135	128	283	-0.046
-2750	315	183	148	139	303	-0.05
-3000	334	197	161	151	322	-0.0535
-3250	353	216	174	163	338	-0.0565
Max Deflection: -0.06200 in from MTS						

Static Test Number: 52		Date : 7/21/04	Number of Cycles Completed: 3,900,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	34	20	15	16	32	-0.0045
-500	64	38	29	29	61	-0.0095
-750	97	57	44	43	93	-0.014
-1000	129	76	58	57	124	-0.019
-1250	159	93	72	69	152	-0.023
-1500	188	110	85	82	181	-0.028
-1750	216	126	98	94	208	-0.032
-2000	245	143	112	107	235	-0.0365
-2250	269	160	126	119	259	-0.0405
-2500	290	174	138	130	279	-0.0445
-2750	312	189	150	142	300	-0.049
-3000	332	203	163	153	319	-0.052
-3250	350	216	175	164	336	-0.056
Max Deflection: -0.06200 in from MTS						

Static Test Number: 53		Date : 7/22/04	Number of Cycles Completed: 4,000,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	30	9	10	10	30	-0.0045
-500	63	30	26	25	61	-0.0095
-750	95	51	40	41	92	-0.015
-1000	123	64	52	51	119	-0.019
-1250	155	81	66	64	149	-0.0235
-1500	186	100	80	78	180	-0.0275
-1750	215	117	93	90	207	-0.032
-2000	243	132	107	102	235	-0.036
-2250	269	150	120	115	260	-0.0405
-2500	292	165	132	126	281	-0.0445
-2750	314	180	145	138	303	-0.049
-3000	334	193	157	149	322	-0.053
-3250	353	212	171	161	339	-0.055
Max Deflection: -0.06204 in from MTS						

Static Test Number: 54		Date : 7/22/04	Number of Cycles Completed: 4,100,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	29	10	11	10	30	-0.055
-500	63	32	26	25	62	-0.011
-750	93	49	40	38	91	-0.0155
-1000	125	65	53	50	122	-0.0205
-1250	156	85	68	64	151	-0.025
-1500	186	103	82	77	180	-0.0295
-1750	219	123	97	91	210	-0.034
-2000	245	135	109	101	236	-0.038
-2250	271	152	122	113	261	-0.042
-2500	297	172	137	127	285	-0.0465
-2750	316	183	147	136	304	-0.05
-3000	336	197	160	147	323	-0.054
-3250	350	203	167	153	336	-0.057
Max Deflection: -0.06208 in from MTS						

Static Test Number: 55		Date : 7/22/04	Number of Cycles Completed: 4,200,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	34	19	15	15	33	-0.0045
-500	65	37	29	28	63	-0.01
-750	96	56	43	41	93	-0.014
-1000	127	74	56	55	123	-0.019
-1250	158	93	71	68	153	-0.0235
-1500	188	110	85	81	182	-0.028
-1750	218	127	98	94	211	-0.032
-2000	246	144	111	106	238	-0.036
-2250	271	159	124	118	262	-0.0405
-2500	293	173	136	129	283	-0.044
-2750	315	188	149	140	303	-0.048
-3000	335	201	161	151	322	-0.052
-3250	351	214	171	161	338	-0.055
Max Deflection: -0.06204 in from MTS						

Static Test Number: 56		Date : 7/23/04	Number of Cycles Completed: 4,300,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	16	13	12	31	-0.0045
-500	64	35	27	26	62	-0.01
-750	93	51	40	38	90	-0.014
-1000	128	72	55	53	123	-0.0195
-1250	155	84	66	62	149	-0.0235
-1500	186	104	81	77	180	-0.028
-1750	214	120	94	88	207	-0.032
-2000	242	136	107	100	234	-0.0365
-2250	267	151	119	112	258	-0.0405
-2500	292	170	134	125	282	-0.045
-2750	315	186	148	138	303	-0.049
-3000	333	196	157	146	320	-0.0525
-3250	349	208	168	156	335	-0.0555
Max Deflection: -0.06204 in from MTS						

Static Test Number: 57		Date : 7/23/04	Number of Cycles Completed: 4,400,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	26	11	8	7	25	-0.004
-500	59	31	24	22	57	-0.009
-750	88	46	36	33	85	-0.0135
-1000	118	64	50	47	114	-0.018
-1250	148	82	65	60	143	-0.0225
-1500	178	100	78	73	172	-0.027
-1750	202	114	91	85	195	-0.031
-2000	227	131	105	97	219	-0.035
-2250	249	145	116	108	239	-0.039
-2500	269	159	128	119	259	-0.043
-2750	290	173	140	130	279	-0.047
-3000	311	189	154	143	298	-0.0505
-3250	327	201	166	154	313	-0.054
Max Deflection: -0.06200 in from MTS						

Static Test Number: 58		Date : 7/23/04	Number of Cycles Completed: 4,500,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	32	18	15	14	31	-0.0045
-500	63	37	28	28	61	-0.009
-750	96	56	43	42	93	-0.014
-1000	127	74	57	55	122	-0.019
-1250	156	90	71	68	150	-0.023
-1500	190	110	86	83	183	-0.0275
-1750	214	124	98	93	207	-0.032
-2000	238	139	110	104	230	-0.036
-2250	263	156	124	118	253	-0.04
-2500	283	170	135	128	272	-0.0435
-2750	305	185	148	140	293	-0.0475
-3000	322	197	159	150	310	-0.051
-3250	338	209	170	159	324	-0.055
Max Deflection: -0.06200 in from MTS						

Static Test Number: 59		Date : 7/24/04	Number of Cycles Completed: 4,600,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	28	11	8	8	27	-0.0045
-500	60	28	21	21	57	-0.009
-750	91	48	37	35	88	-0.014
-1000	120	62	48	46	115	-0.0185
-1250	153	86	66	64	148	-0.023
-1500	184	102	79	76	177	-0.028
-1750	210	118	92	88	202	-0.032
-2000	234	133	105	100	225	-0.036
-2250	258	152	120	114	249	-0.04
-2500	277	162	129	122	266	-0.044
-2750	300	180	144	136	288	-0.0475
-3000	317	189	152	143	304	-0.051
-3250	333	203	165	155	319	-0.054
Max Deflection: -0.06200 in from MTS						

Static Test Number: 60		Date : 7/25/04	Number of Cycles Completed: 4,700,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	28	10	7	5	26	-0.0035
-500	59	28	21	19	56	-0.008
-750	90	44	34	31	85	-0.013
-1000	124	64	49	46	119	-0.018
-1250	154	83	64	60	147	-0.022
-1500	185	103	79	75	178	-0.027
-1750	212	119	92	87	204	-0.031
-2000	240	134	105	98	231	-0.035
-2250	264	152	119	112	254	-0.039
-2500	285	166	130	122	274	-0.043
-2750	308	181	143	134	295	-0.47
-3000	329	196	157	147	315	-0.0505
-3250	336	202	163	156	322	-0.053
Max Deflection: -0.06200 in from MTS						

Static Test Number: 61		Date : 7/25/04	Number of Cycles Completed: 4,800,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	30	12	9	8	29	-0.005
-500	63	35	26	26	61	-0.01
-750	90	47	36	34	87	-0.0145
-1000	123	69	54	52	119	-0.019
-1250	152	84	66	63	147	-0.023
-1500	179	96	75	71	173	-0.028
-1750	210	119	93	89	203	-0.032
-2000	236	137	108	103	227	-0.036
-2250	256	148	117	111	247	-0.04
-2500	283	169	135	128	272	-0.045
-2750	298	177	143	134	286	-0.048
-3000	319	192	156	146	306	-0.052
-3250	335	205	169	159	321	-0.055
Max Deflection: -0.06200 in from MTS						

Static Test Number: 62		Date : 7/26/04	Number of Cycles Completed: 4,900,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	34	19	15	14	33	-0.005
-500	66	38	29	28	63	-0.0095
-750	97	56	43	41	93	-0.014
-1000	127	74	56	54	122	-0.019
-1250	158	91	71	68	152	-0.0235
-1500	187	108	84	81	181	-0.028
-1750	216	125	98	93	209	-0.0325
-2000	242	141	111	105	233	-0.0365
-2250	265	157	125	118	256	-0.041
-2500	288	172	137	129	277	-0.0445
-2750	307	185	148	139	295	-0.048
-3000	328	200	161	151	315	-0.052
-3250	342	205	164	153	328	-0.055
Max Deflection: -0.06200 in from MTS						

Static Test Number: 63		Date : 7/26/04	Number of Cycles Completed: 5,000,000			
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Dial Gage 1
-250	31	16	12	12	30	-0.005
-500	61	32	24	23	60	-0.0095
-750	92	51	39	37	90	-0.014
-1000	124	71	55	53	120	-0.019
-1250	152	84	65	62	147	-0.023
-1500	183	101	78	74	177	-0.028
-1750	215	124	96	92	208	-0.032
-2000	240	138	109	103	232	-0.036
-2250	260	149	117	110	252	-0.04
-2500	285	167	132	124	276	-0.044
-2750	303	178	142	133	293	-0.048
-3000	328	198	158	148	316	-0.052
-3250	339	205	164	153	326	-0.055
Max Deflection: -0.06200 in from MTS						

B.3 SPS Connection Tested to 100,000 Cycles

Static Test Number: 1	Date : 7/30/04	Number of Cycles Completed: 1					
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Strain Gage #6	Dial Gage 1
1000	129	48	48	58	96	63	-0.02
2000	247	93	93	113	184	122	-0.038
3000	356	137	138	168	265	177	-0.055
4000	453	179	181	221	339	228	-0.071
5000	528	214	218	266	393	268	-0.085
6000	610	254	258	315	453	312	-0.098
7000	682	289	294	359	503	348	-0.1125
8000	752	323	329	403	550	383	-0.1265
9000	822	357	364	448	601	422	-0.14
10000	898	398	407	506	663	469	-0.155
11000	969	435	446	561	723	513	-0.17
12000	1027	468	481	606	770	549	-0.182
13000	1092	506	522	659	829	593	-0.198
Max Deflection: -0.22168 in from MTS							

Static Test Number: 2	Date : 7/30/04	Number of Cycles Completed: 10					
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Strain Gage #6	Dial Gage 1
1000	135	50	49	58	102	66	-0.021
2000	258	97	96	115	194	128	-0.0395
3000	380	148	145	175	287	191	-0.057
4000	483	188	186	225	365	242	-0.072
5000	586	230	228	277	442	295	-0.087
6000	682	271	270	329	515	345	-0.102
7000	770	312	311	380	582	393	-0.117
8000	842	347	347	424	636	433	-0.13
9000	915	383	385	470	690	474	-0.144
10000	978	419	420	515	736	512	-0.157
11000	1039	451	453	556	777	546	-0.171
12000	1092	481	484	596	814	575	-0.183
13000	1148	513	518	636	852	606	-0.197
Max Deflection: -0.22172 in from MTS							

Static Test Number: 3	Date : 7/30/04	Number of Cycles Completed: 100					
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Strain Gage #6	Dial Gage 1
1000	144	57	53	65	112	75	-0.022
2000	267	104	99	122	204	137	-0.0405
3000	382	150	145	177	292	196	-0.058
4000	495	197	191	233	376	254	-0.074
5000	604	241	234	286	458	309	-0.089
6000	701	282	276	338	532	360	-0.104
7000	790	324	318	390	600	409	-0.1195
8000	867	360	356	436	659	452	-0.133
9000	940	397	392	482	712	494	-0.1475
10000	1001	428	424	522	755	528	-0.16
11000	1063	463	459	566	798	563	-0.174
12000	1117	493	490	606	834	593	-0.187
13000	1160	518	517	639	863	618	-0.1985
Max Deflection: -0.22172 in from MTS							

Static Test Number: 4		Date : 7/30/04	Number of Cycles Completed: 1,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Strain Gage #6	Dial Gage 1
1000	141	54	51	61	109	73	-0.021
2000	279	108	102	123	212	142	-0.041
3000	392	153	146	177	298	200	-0.058
4000	508	201	193	233	386	259	-0.074
5000	619	247	237	289	470	315	-0.09
6000	710	287	277	339	542	366	-0.105
7000	800	329	320	391	612	416	-0.12
8000	878	365	357	437	671	460	-0.134
9000	950	400	392	481	724	500	-0.148
10000	1017	437	428	527	773	540	-0.1615
11000	1080	471	462	570	817	576	-0.1755
12000	1133	502	494	610	854	607	-0.1885
13000	1170	527	518	641	880	630	-0.1975
Max Deflection: -0.22172 in from MTS							

Static Test Number: 5		Date : 7/30/04	Number of Cycles Completed: 10,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Strain Gage #6	Dial Gage 1
1000	131	53	49	61	108	70	-0.022
2000	249	105	99	122	211	137	-0.041
3000	349	153	146	180	306	198	-0.058
4000	445	207	196	244	405	263	-0.076
5000	515	249	238	298	485	316	-0.091
6000	568	288	278	349	557	365	-0.0105
7000	617	329	319	400	626	415	-0.012
8000	658	368	358	450	687	461	-0.134
9000	696	406	396	499	745	505	-0.148
10000	729	441	432	547	797	545	-0.162
11000	753	473	464	589	840	578	-0.1755
12000	774	508	499	635	883	613	-0.189
13000	786	529	521	663	908	633	-0.198
Max Deflection: -0.22172 in from MTS							

Static Test Number: 6		Date : 7/30/04	Number of Cycles Completed: 50,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Strain Gage #6	Dial Gage 1
1000	119	57	53	68	115	74	-0.022
2000	221	113	106	142	231	146	-0.042
3000	310	164	155	211	336	210	-0.06
4000	389	211	201	276	433	269	-0.076
5000	454	256	245	341	523	326	-0.092
6000	505	298	288	405	604	378	-0.107
7000	549	336	328	462	677	426	-0.121
8000	590	377	369	524	751	476	-0.136
9000	624	415	408	582	817	520	-0.15
10000	650	449	442	635	873	559	-0.163
11000	673	484	479	691	928	597	-0.177
12000	687	516	512	742	975	629	-0.19
13000	694	531	527	766	998	644	-0.197
Max Deflection: -0.22172 in from MTS							

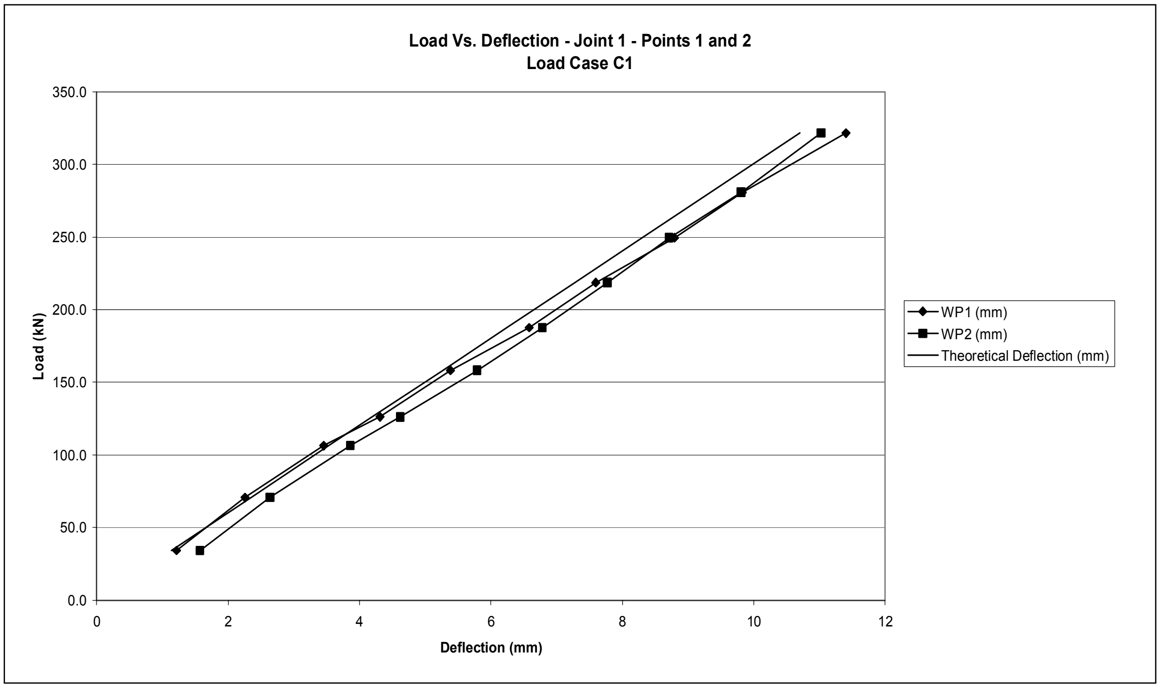
Notes: Strain Gage 1 is not loose from the weld surface. Also, a crack can not be seen around strain gage 1.

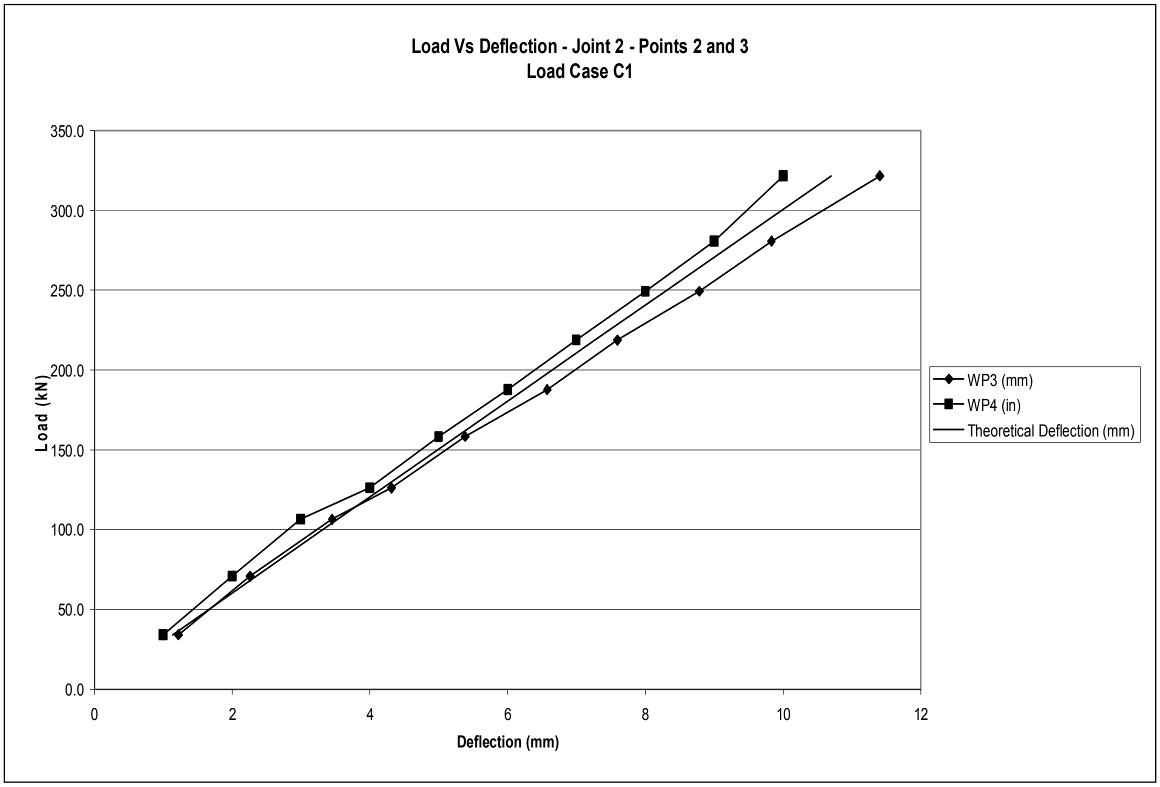
Static Test Number: 7		Date : 7/31/04	Number of Cycles Completed: 100,000				
Load (lbs)	Strain Gage #1	Strain Gage #2	Strain Gage #3	Strain Gage #4	Strain Gage #5	Strain Gage #6	Dial Gage 1
1000	89	62	28	Off Scale	77	115	-0.024
2000	181	124	57	Off Scale	155	225	-0.044
3000	265	180	83	Off Scale	225	334	-0.062
4000	340	235	105	Off Scale	286	446	-0.078
5000	414	296	126	Off Scale	342	580	-0.097
6000	470	352	143	Off Scale	386	714	-0.114
7000	508	404	158	Off Scale	418	839	-0.13
8000	538	454	174	Off Scale	446	960	-0.145
9000	565	505	188	Off Scale	473	1086	-0.161
10000	583	548	200	Off Scale	491	1195	-0.176
11000	596	592	211	Off Scale	507	1312	-0.191
12000	608	640	225	Off Scale	520	1411	-0.206
13000	615	687	235	Off Scale	528	1506	-0.2195
Max Deflection: -0.25160 in from MTS							

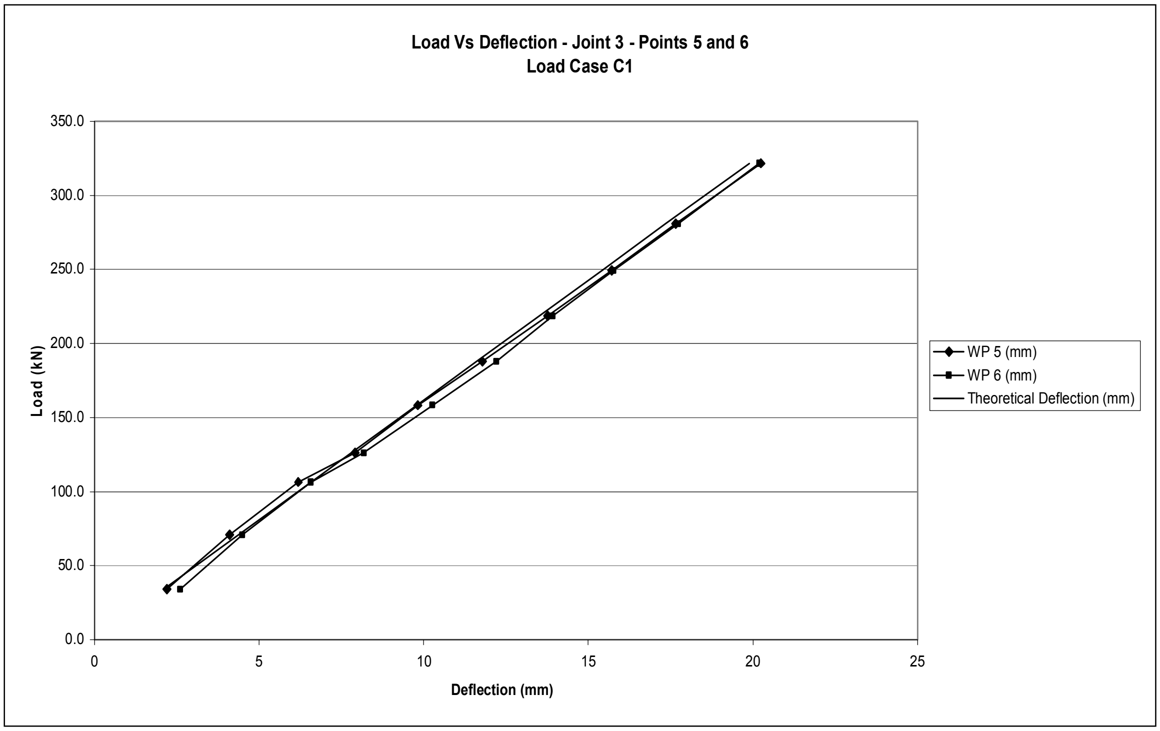
Notes: Visible Crack has developed along line of Strain gage 4. Crack begins at strain gage one and propagates until strain gage 6. Strain gage 4 is off scale due to the crack. Specimen 4 has failed.

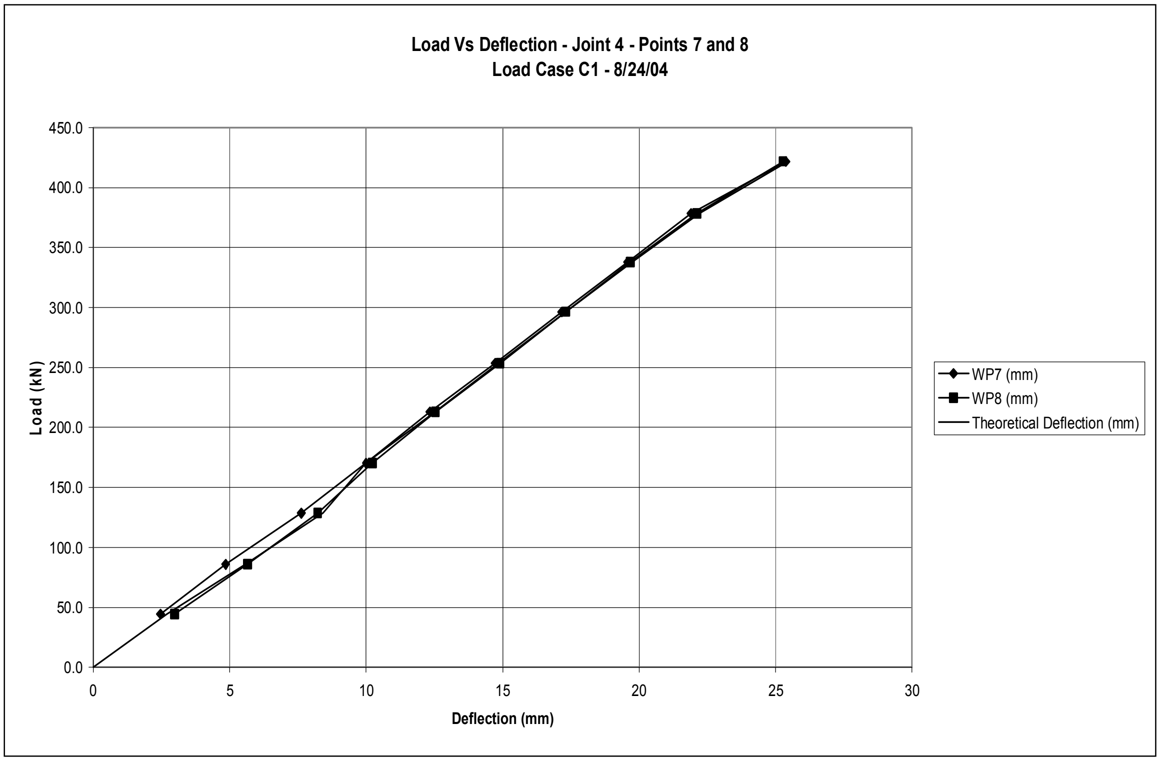
APPENDIX C:
EXPERIMENTAL TEST PLOTS FOR HALF SCALE SIMPLE SPAN BRIDGE TESTS

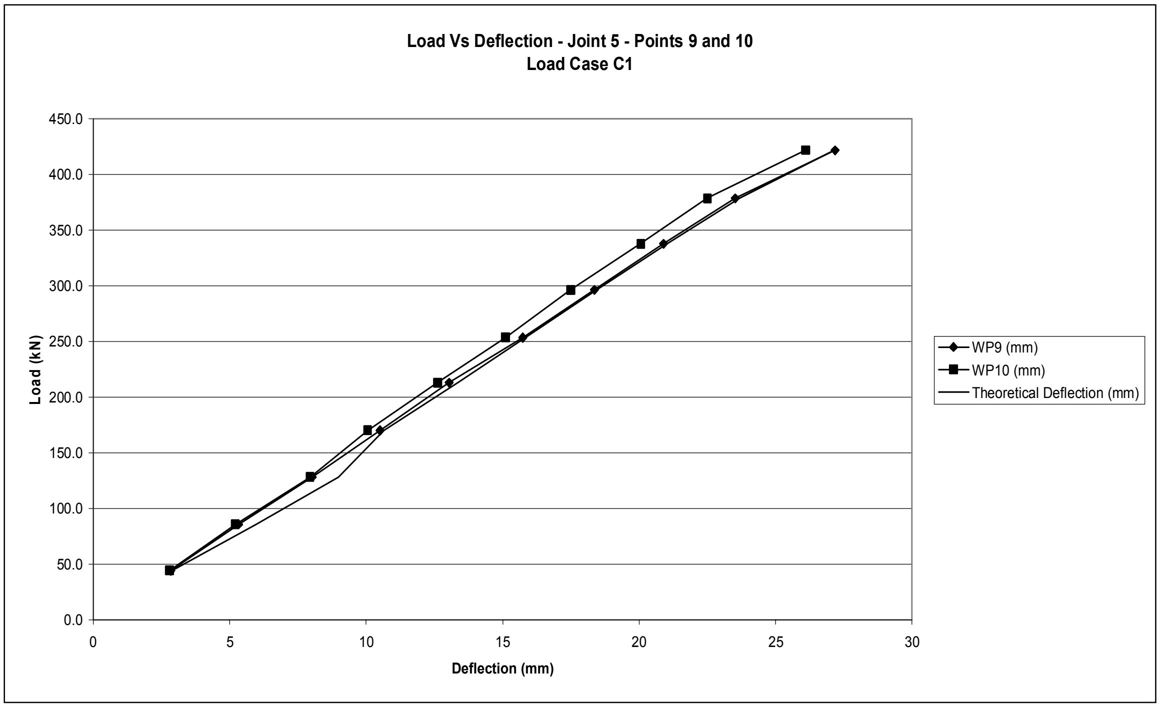
C.1 Load Case C1

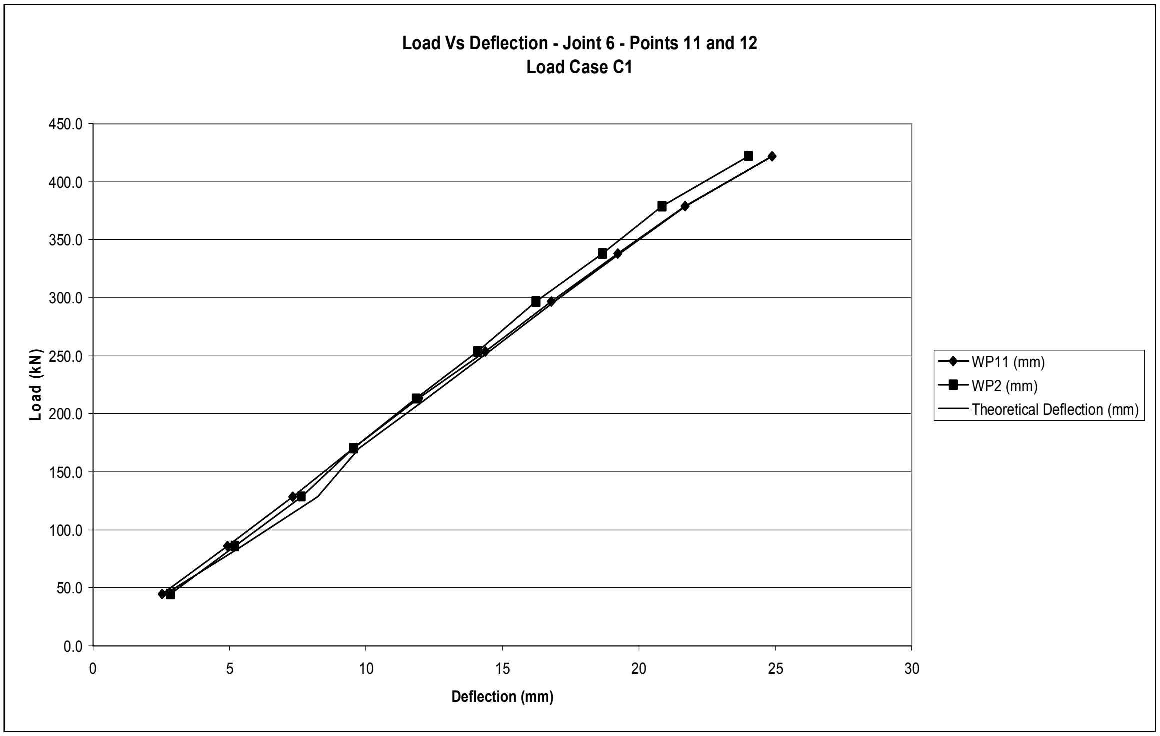


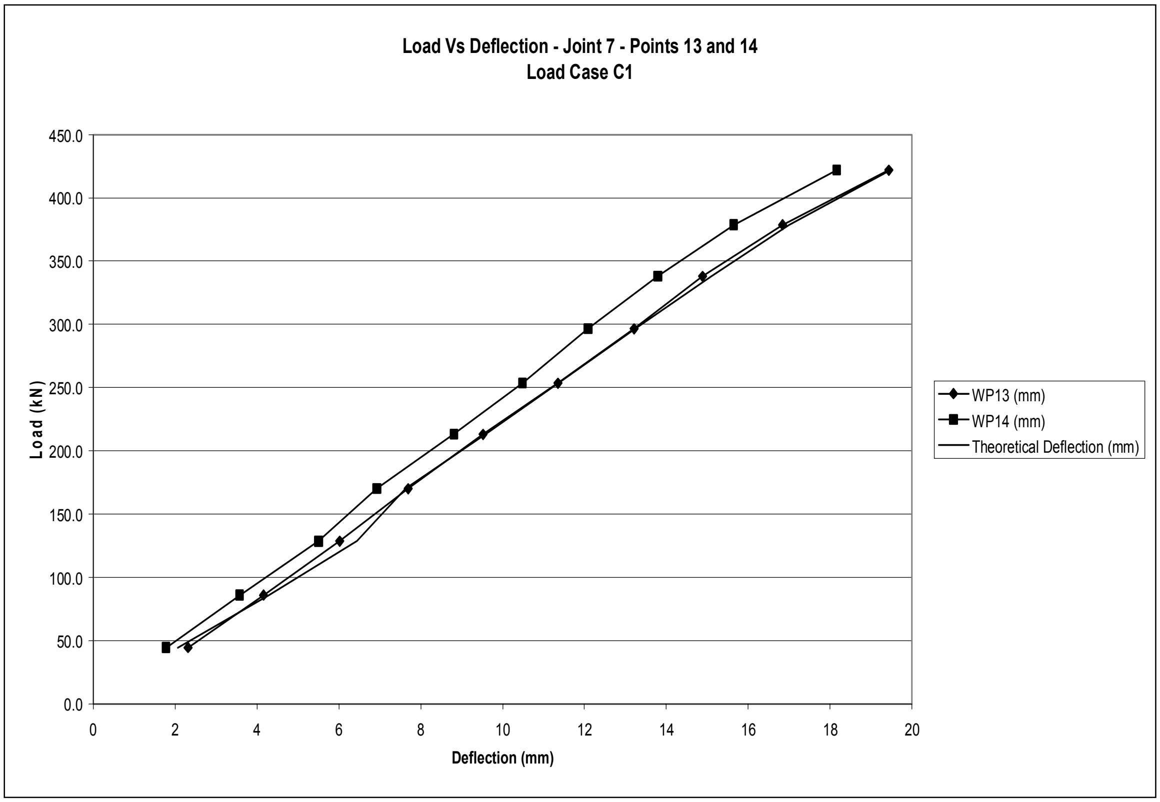



Load Vs Deflection - Joint 3 - Points 5 and 6
Load Case C1
Load (kN)
Deflection (mm)
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
0
5
10
15
20
25
WP 5 (mm)
WP 6 (mm)
Theoretical Deflection (mm)

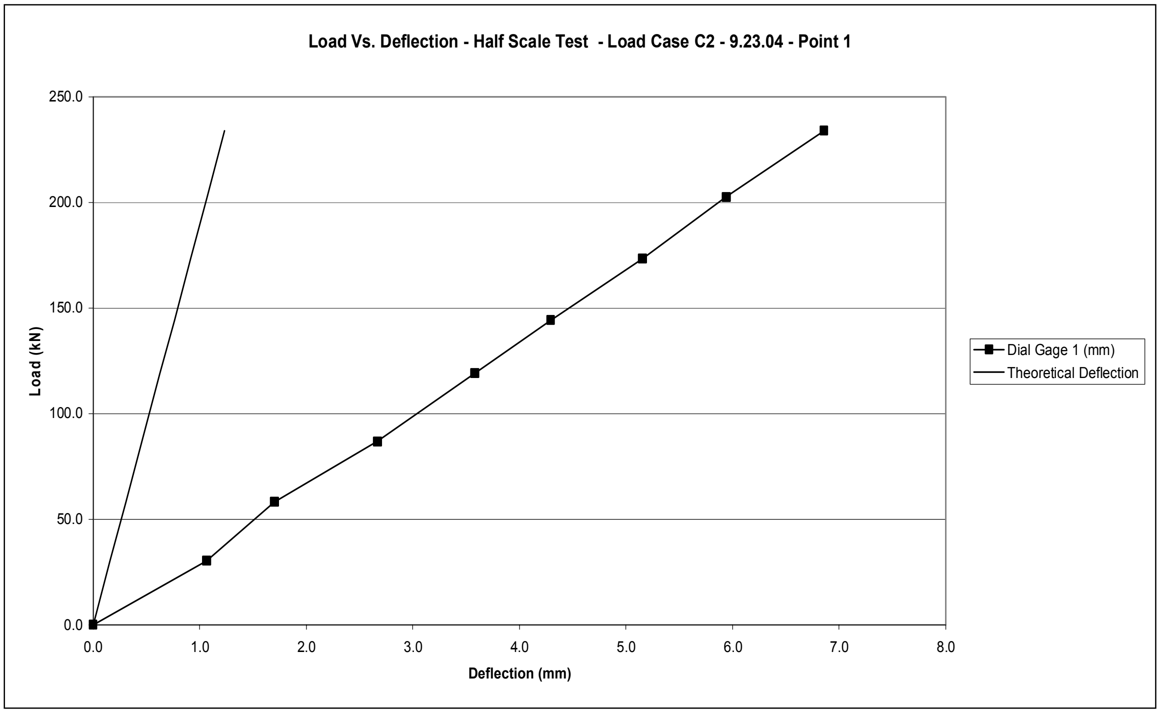

Load Vs Deflection - Joint 4 - Points 7 and 8
Load Case C1 - 8/24/04
Load (kN)
Deflection (mm)
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
0
5
10
15
20
25
30
WP7 (mm)
WP8 (mm)
Theoretical Deflection (mm)

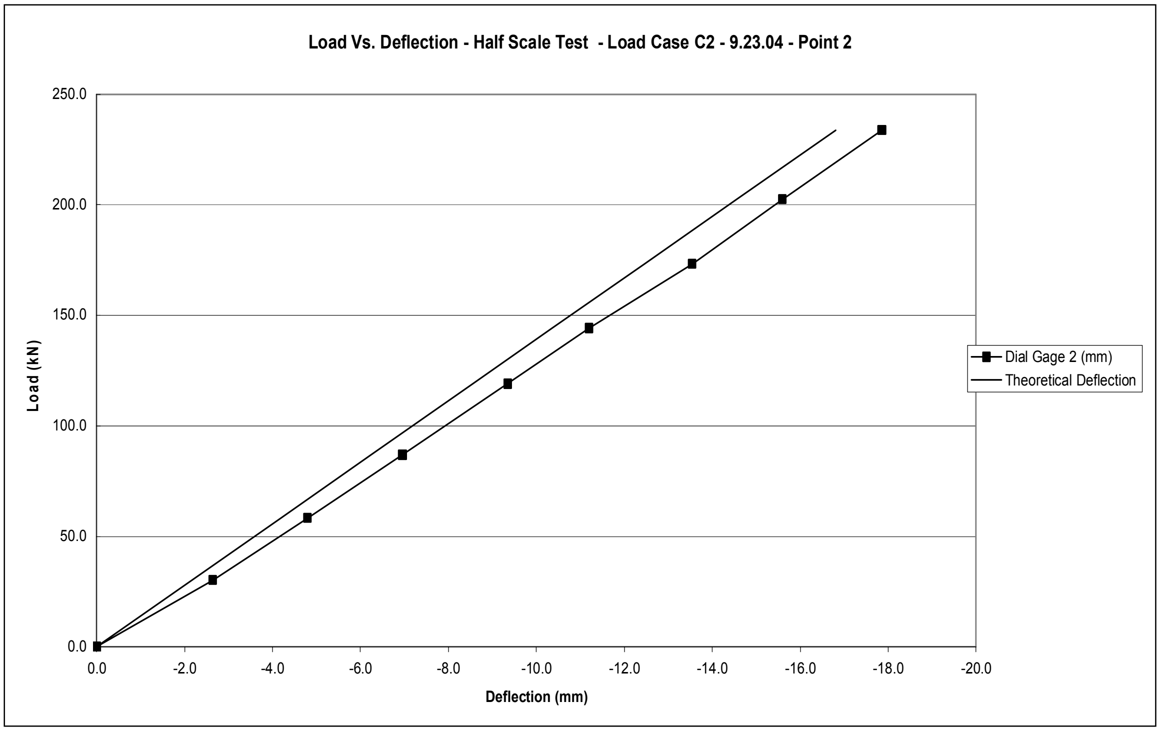

Load Vs Deflection - Joint 5 - Points 9 and 10
Load Case C1
Load (kN)
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0
5
10
15
20
25
30
Deflection (mm)
WP9 (mm)
WP10 (mm)
Theoretical Deflection (mm)

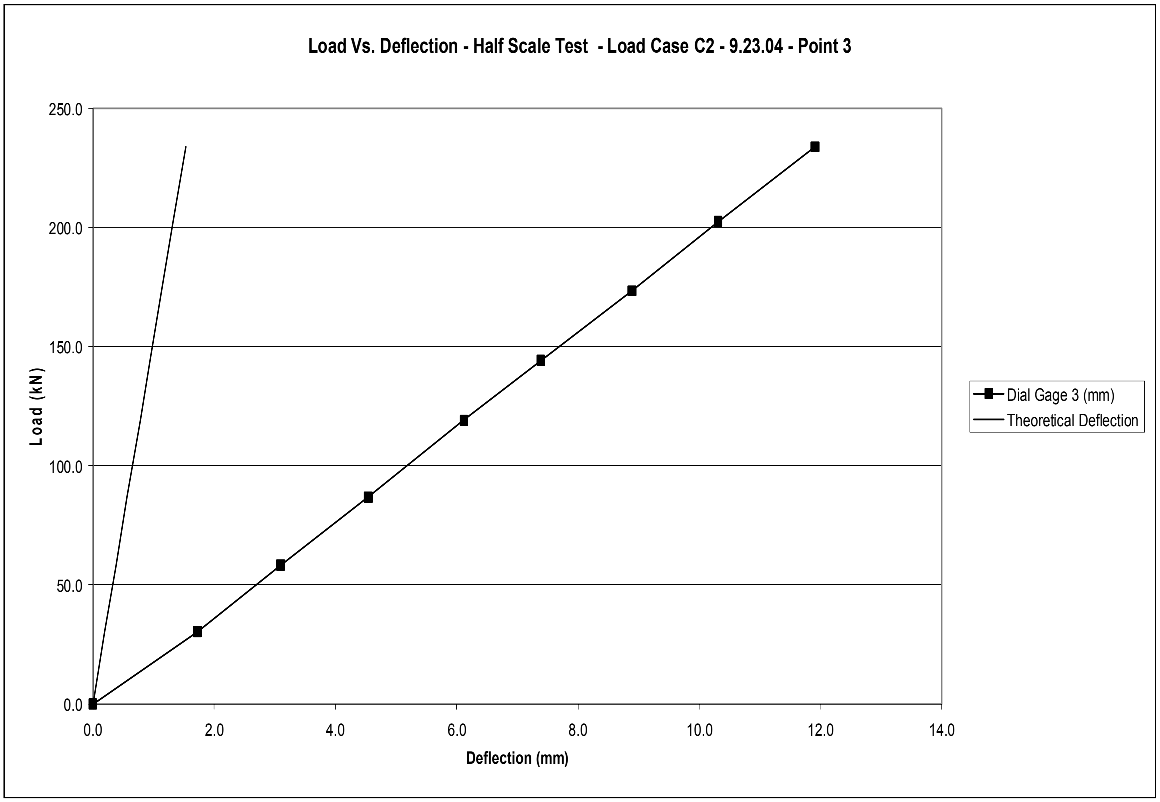

Load Vs Deflection - Joint 6 - Points 11 and 12
Load Case C1
Load (kN)
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0
5
10
15
20
25
30
Deflection (mm)
WP11 (mm)
WP2 (mm)
Theoretical Deflection (mm)

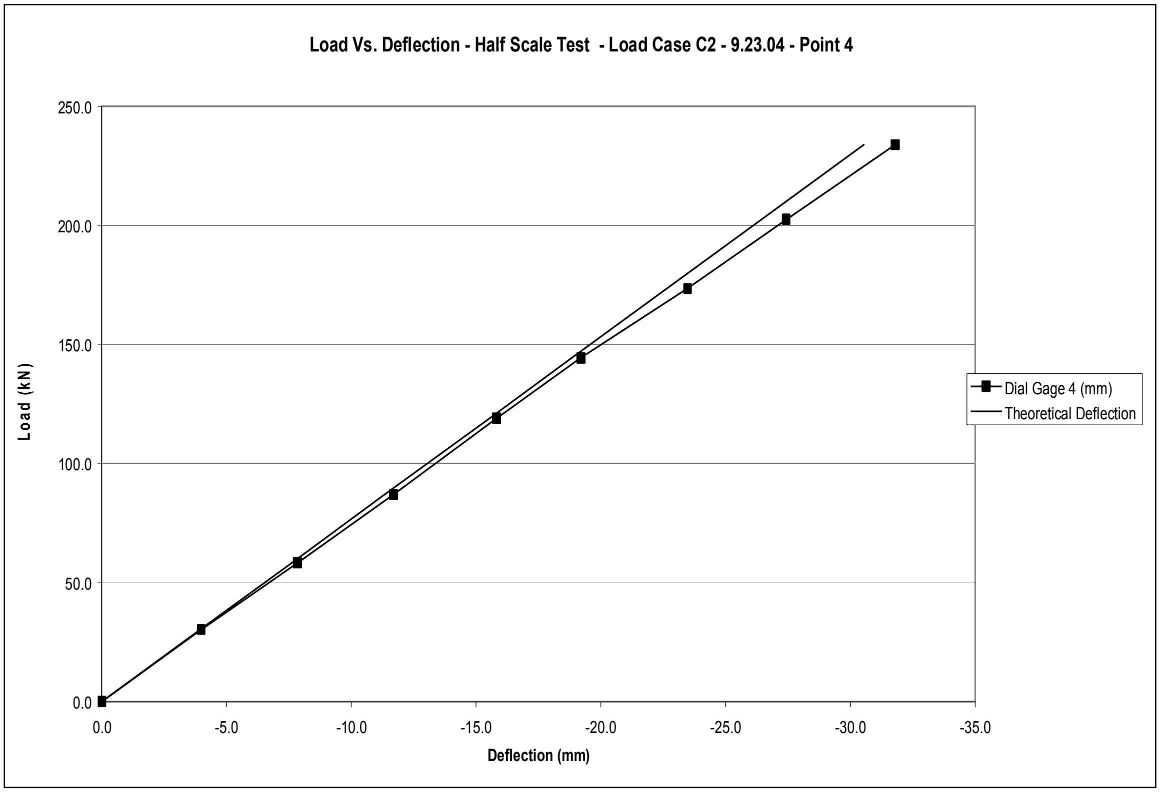

Load Vs Deflection - Joint 7 - Points 13 and 14
Load Case C1
Load (kN)
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
0
2
4
6
8
10
12
14
16
18
20
Deflection (mm)
WP13 (mm)
WP14 (mm)
Theoretical Deflection (mm)

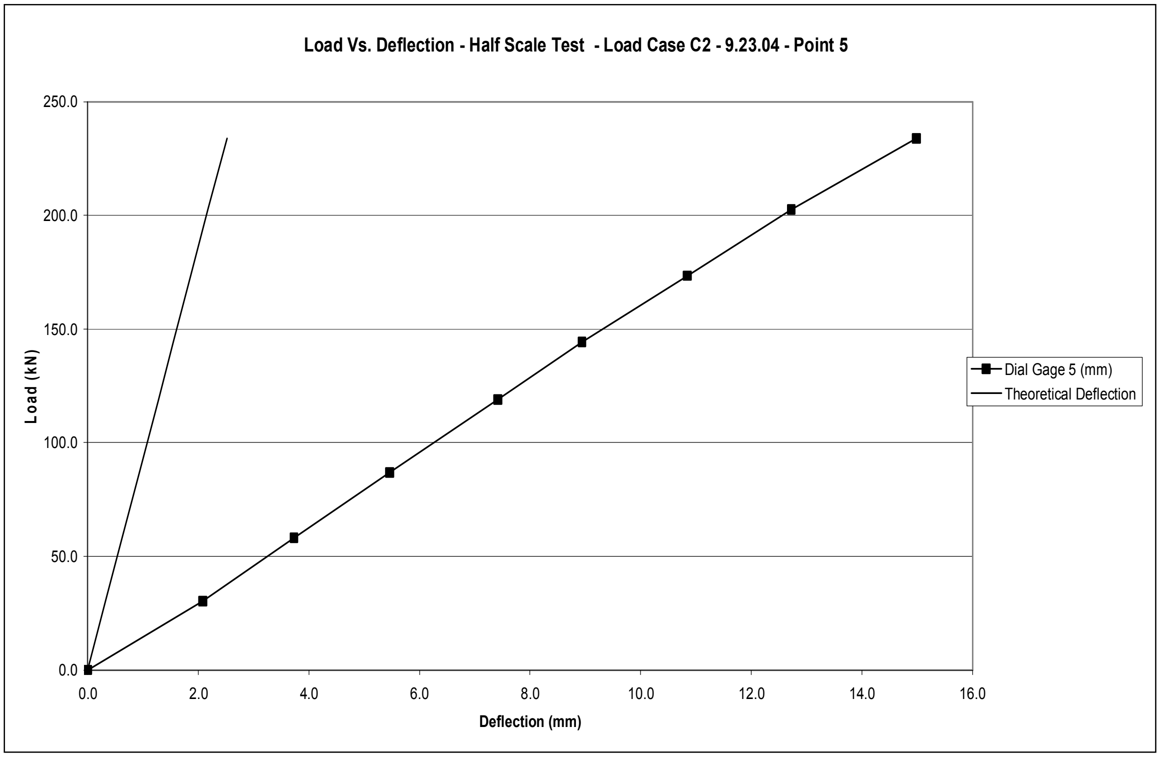
C.2 Load Case C2

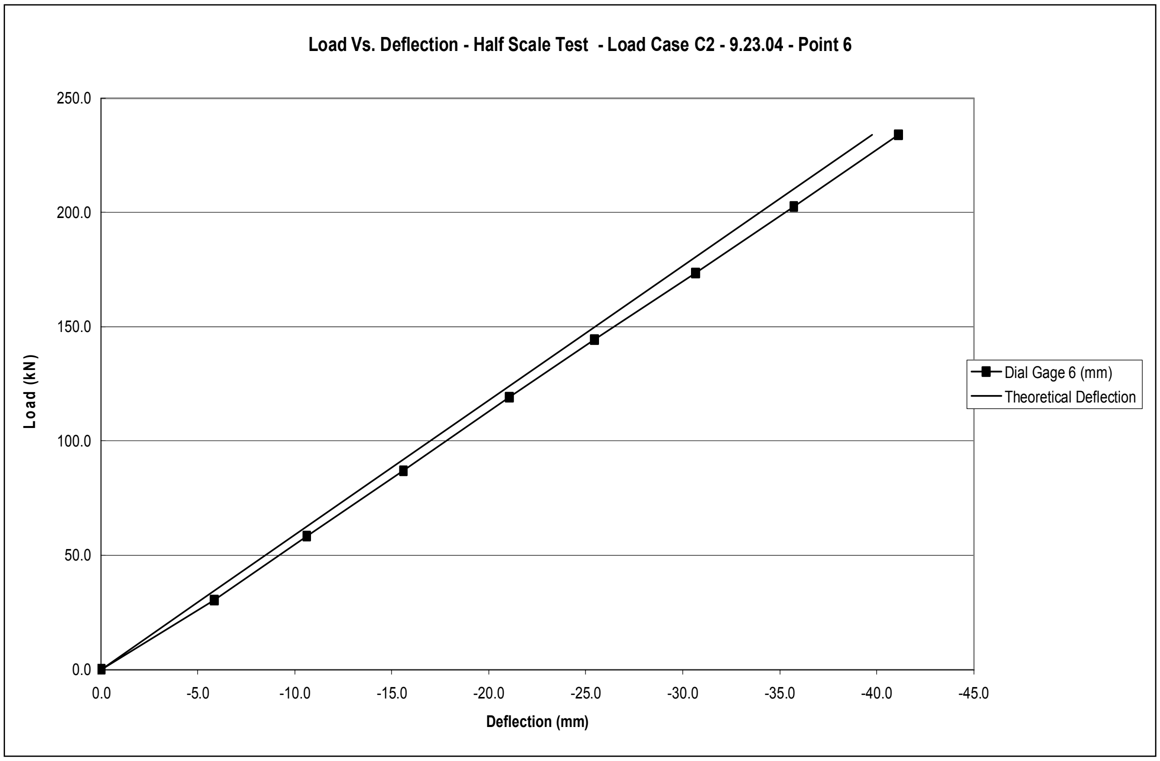


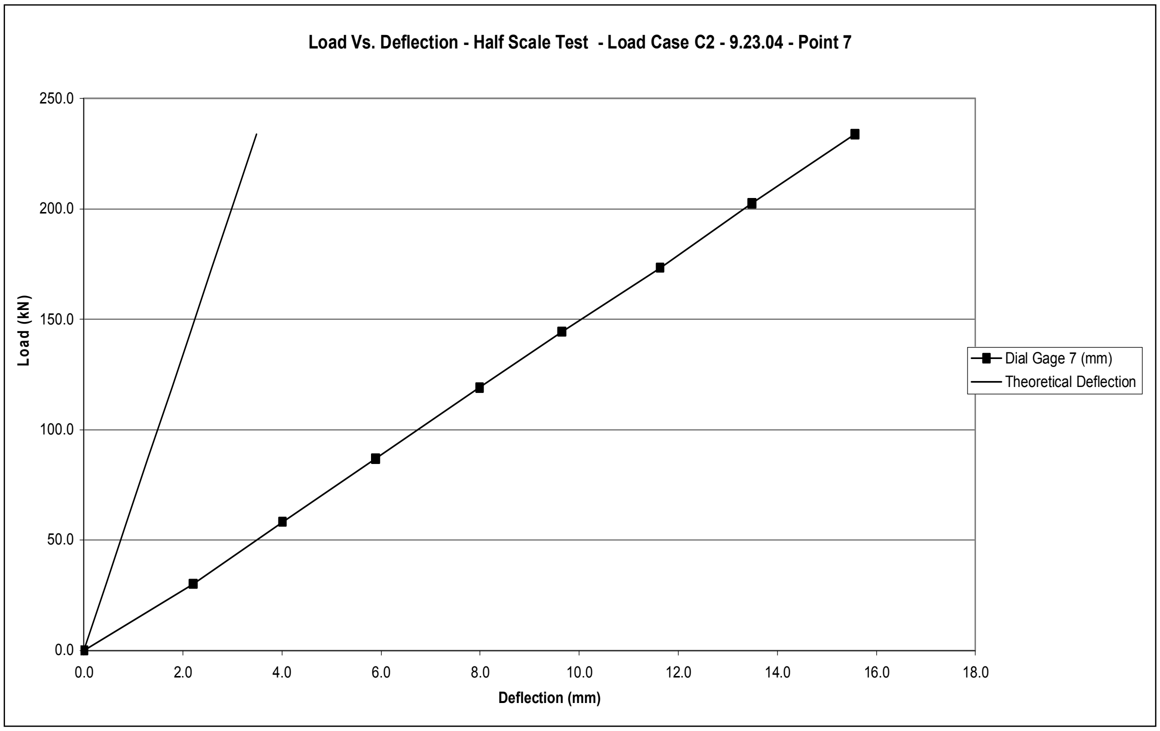


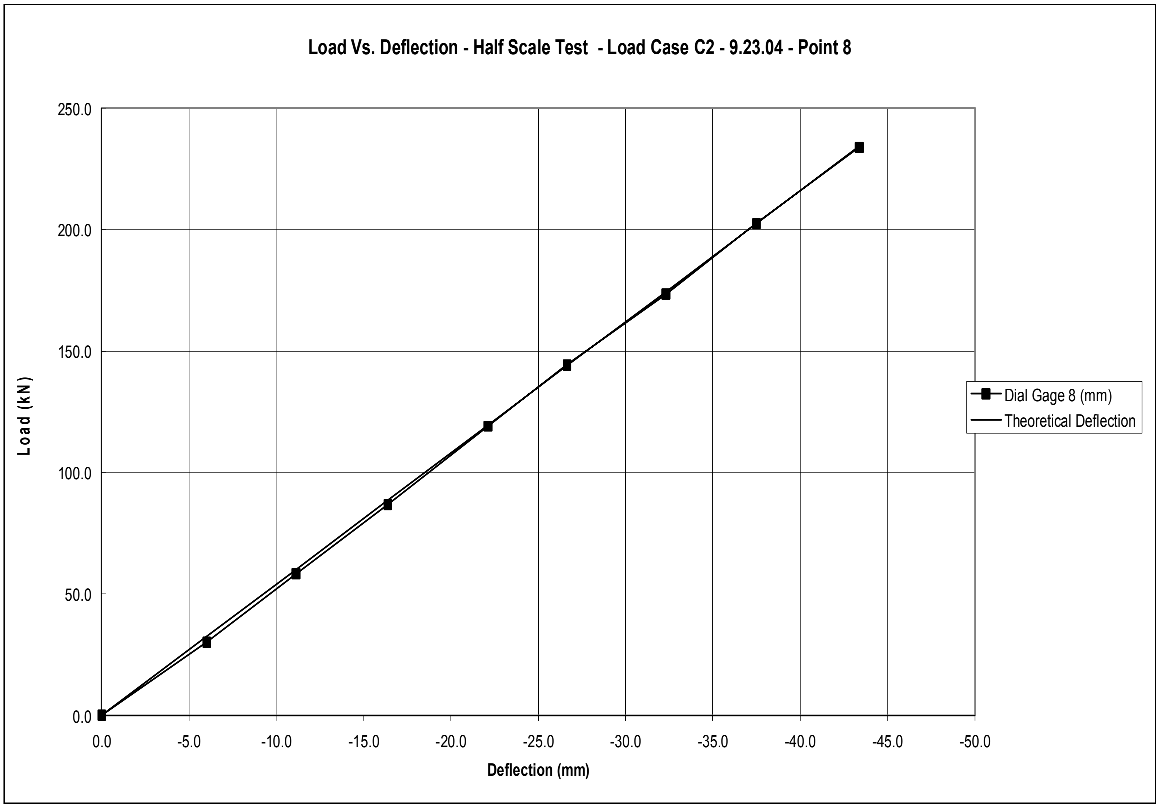

Load Vs. Deflection - Half Scale Test - Load Case C2 - 9.23.04 - Point 3

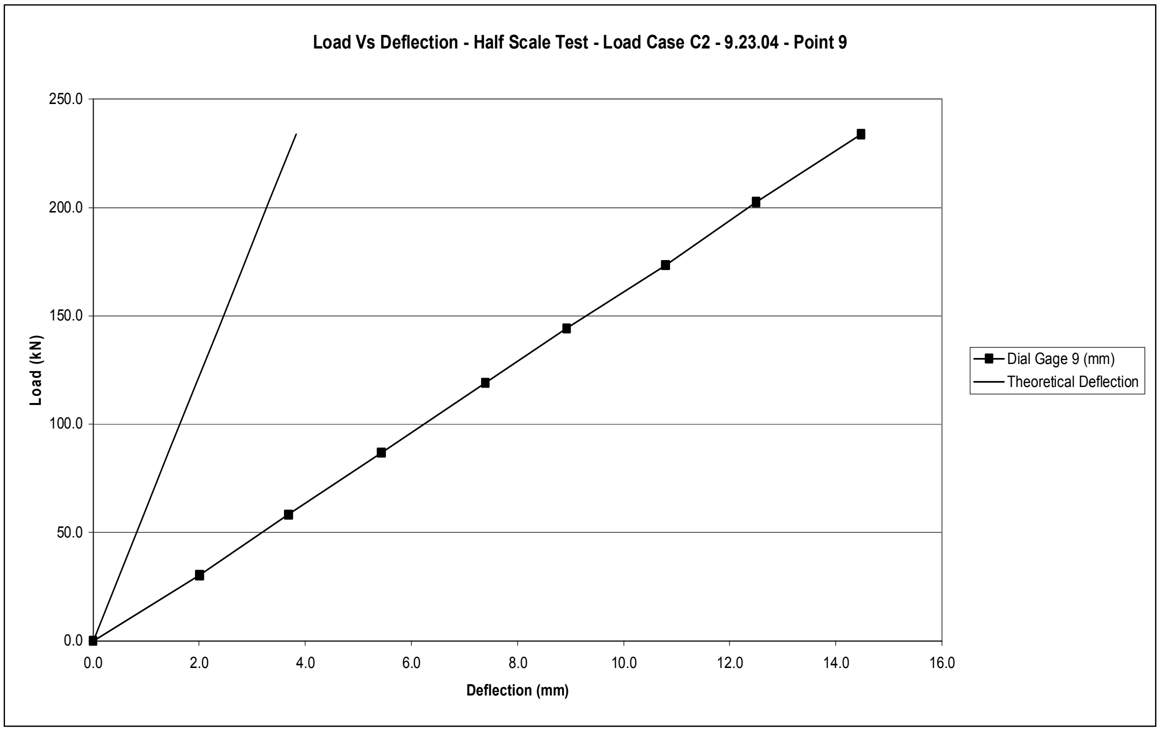

Load Vs. Deflection - Half Scale Test - Load Case C2 - 9.23.04 - Point 4

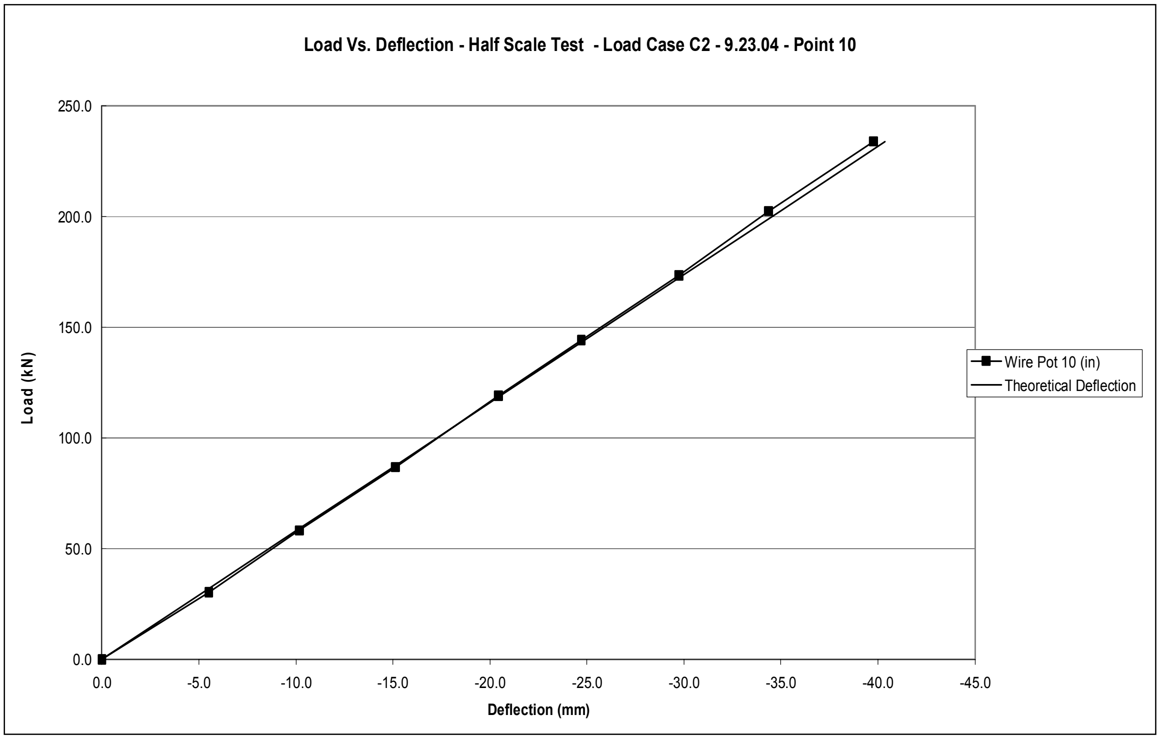

Load Vs. Deflection - Half Scale Test - Load Case C2 - 9.23.04 - Point 5
Load (kN)
250.0
200.0
150.0
100.0
50.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
Deflection (mm)
Dial Gage 5 (mm)
Theoretical Deflection

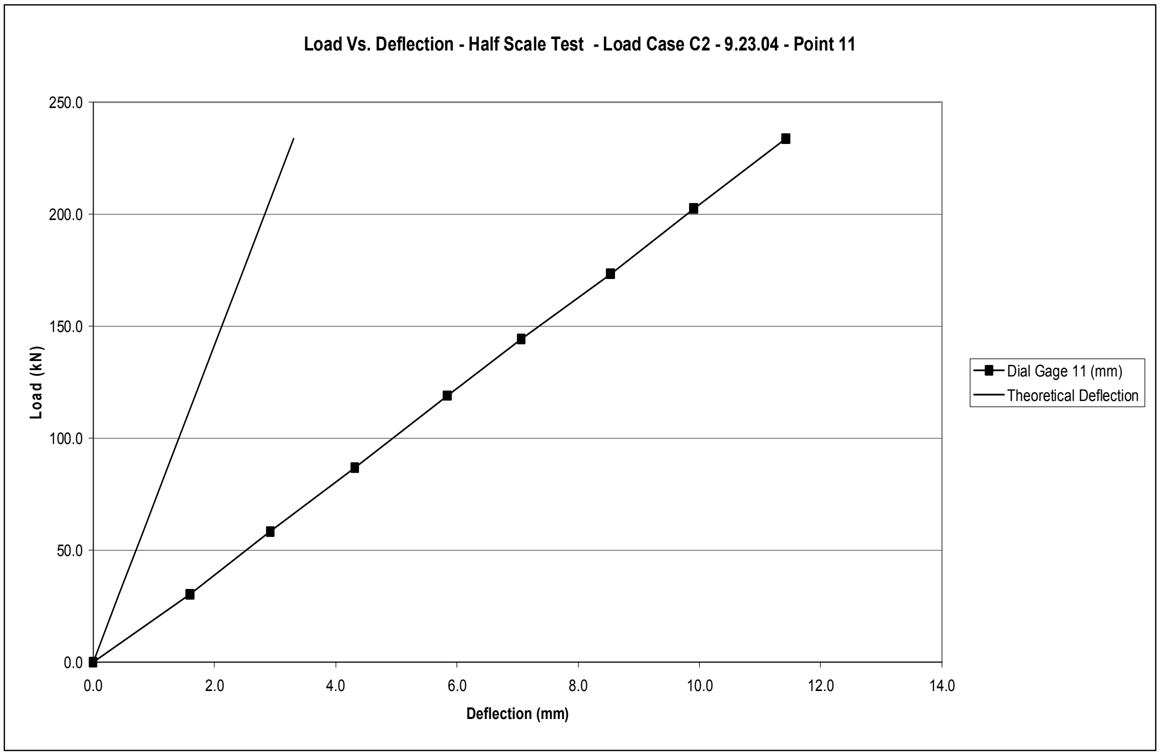

Load Vs. Deflection - Half Scale Test - Load Case C2 - 9.23.04 - Point 6
Load (kN)
250.0
200.0
150.0
100.0
50.0
0.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
Deflection (mm)
Dial Gage 6 (mm)
Theoretical Deflection


Load Vs. Deflection - Half Scale Test - Load Case C2 - 9.23.04 - Point 7
Load (kN)
250.0
200.0
150.0
100.0
50.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Deflection (mm)
Dial Gage 7 (mm)
Theoretical Deflection

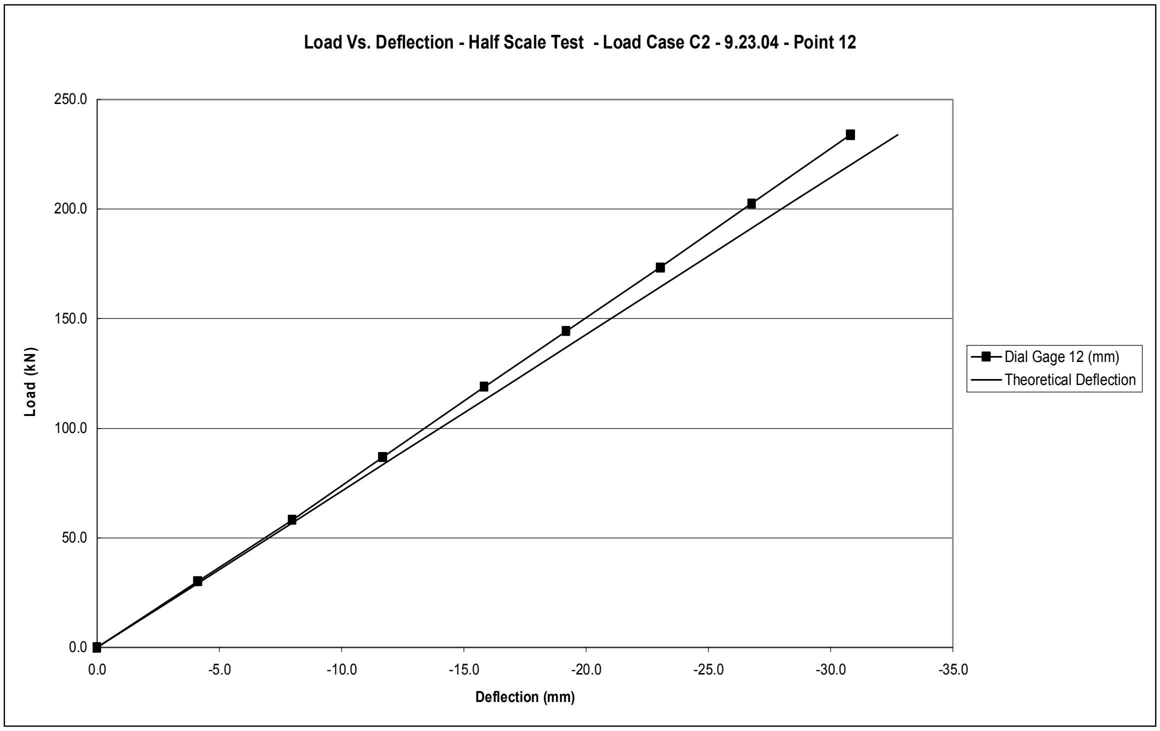

Load Vs. Deflection - Half Scale Test - Load Case C2 - 9.23.04 - Point 8
Load (kN)
250.0
200.0
150.0
100.0
50.0
0.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
Deflection (mm)
Dial Gage 8 (mm)
Theoretical Deflection


Load Vs Deflection - Half Scale Test - Load Case C2 - 9.23.04 - Point 9
Load (kN)
250.0
200.0
150.0
100.0
50.0
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
Deflection (mm)
Dial Gage 9 (mm)
Theoretical Deflection

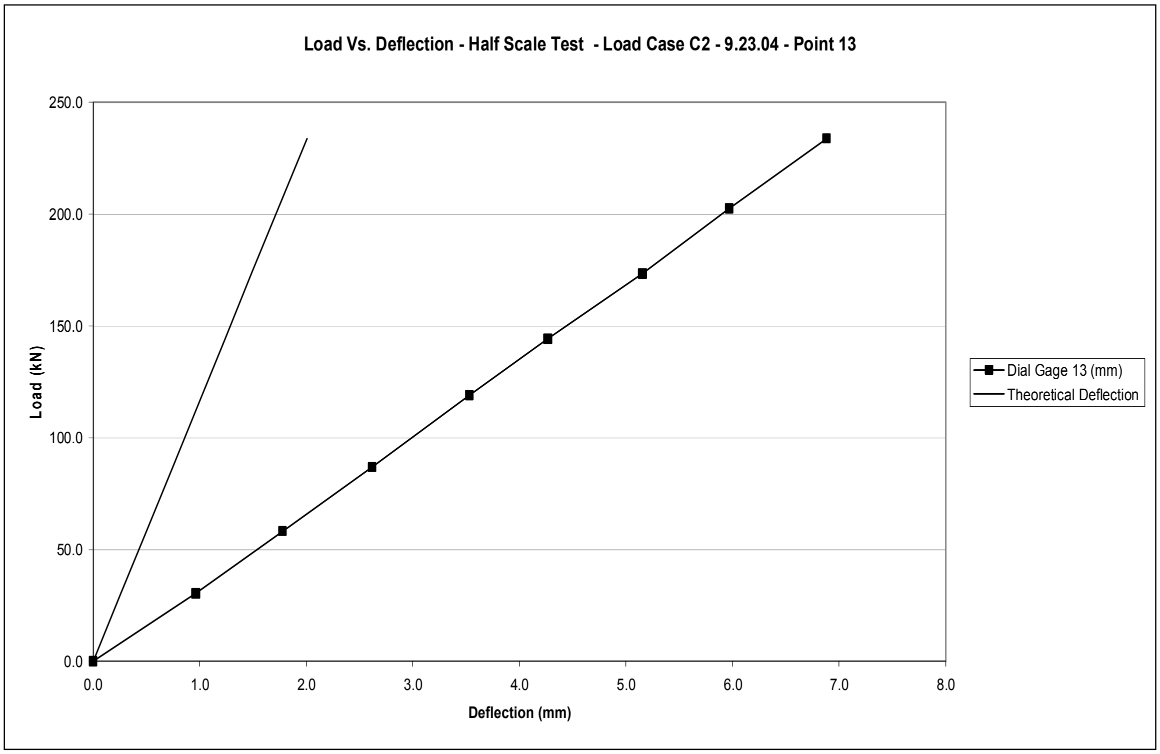

Load Vs. Deflection - Half Scale Test - Load Case C2 - 9.23.04 - Point 10
Load (kN)
250.0
200.0
150.0
100.0
50.0
0.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
Deflection (mm)
Wire Pot 10 (in)
Theoretical Deflection

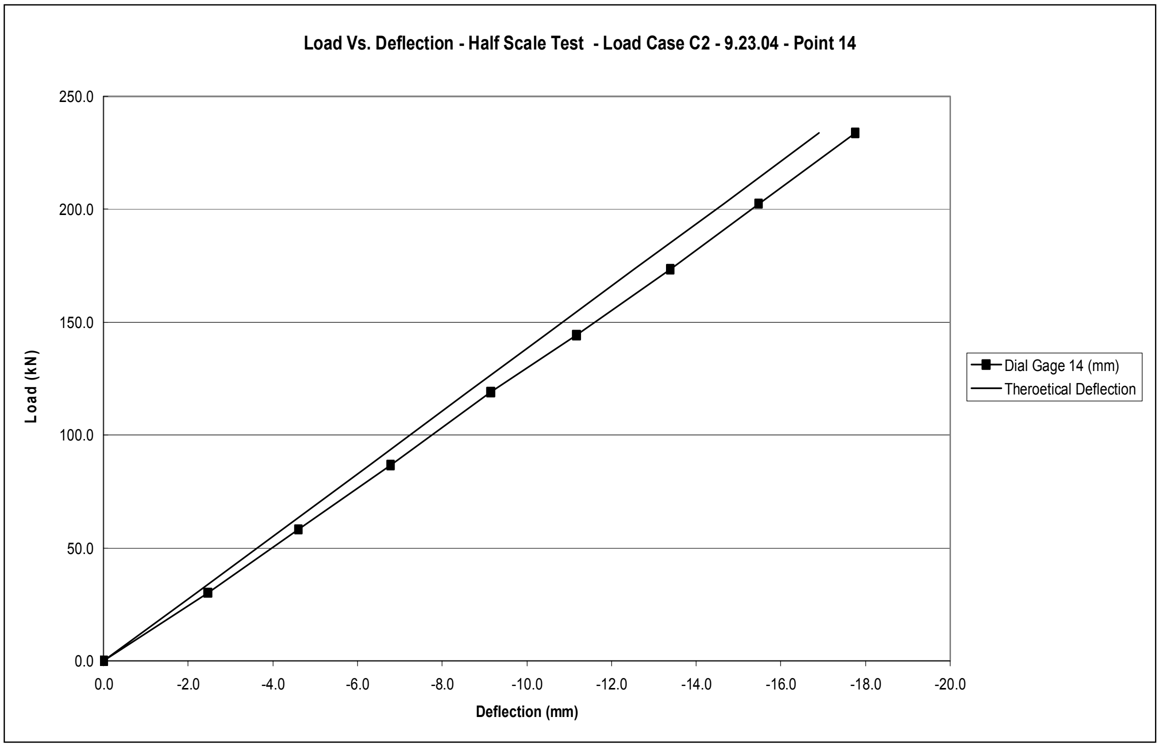


Load Vs. Deflection - Half Scale Test - Load Case C2 - 9.23.04 - Point 11

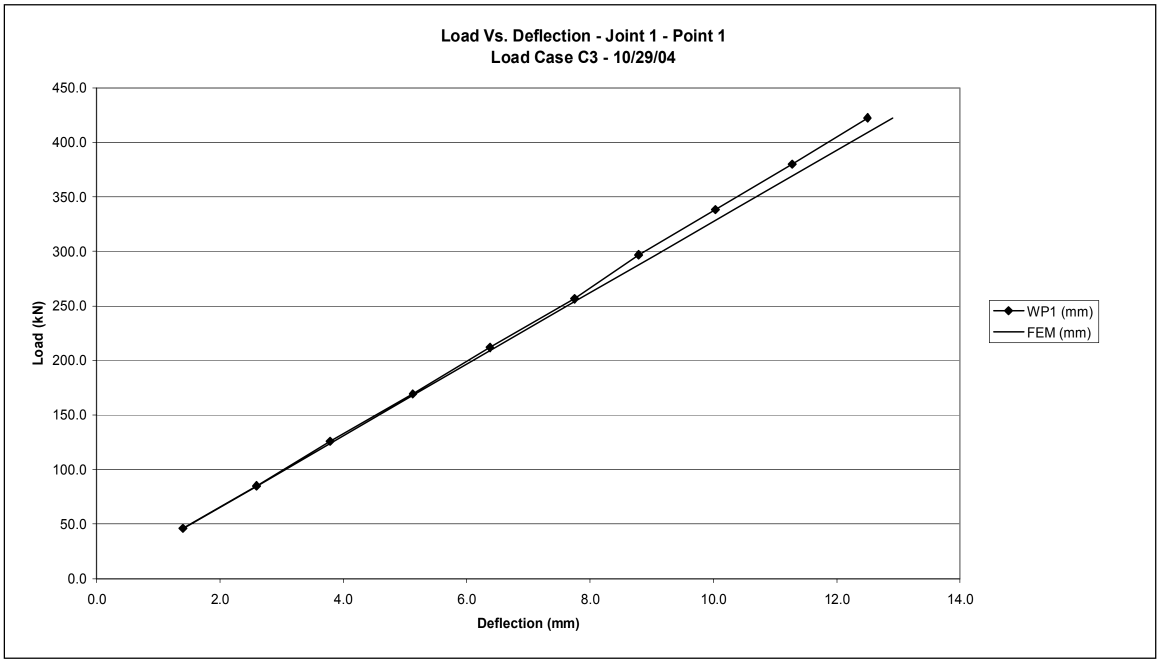


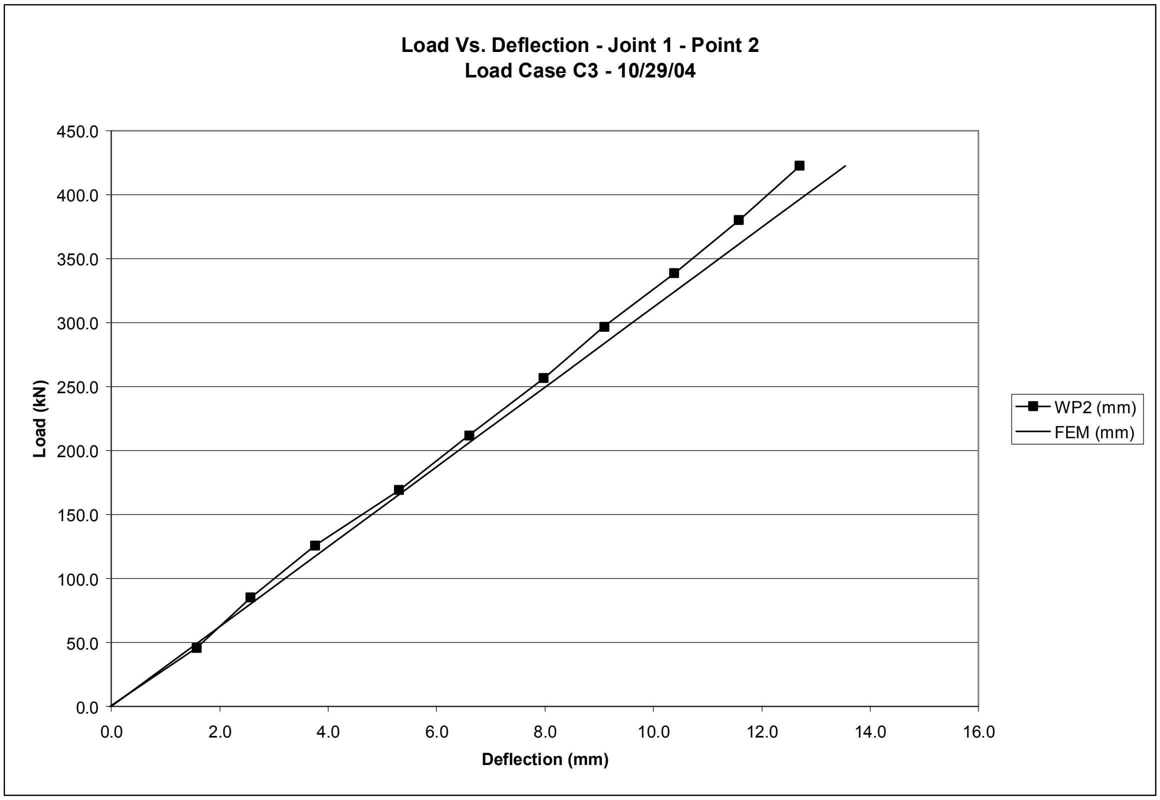
Load Vs. Deflection - Half Scale Test - Load Case C2 - 9.23.04 - Point 12

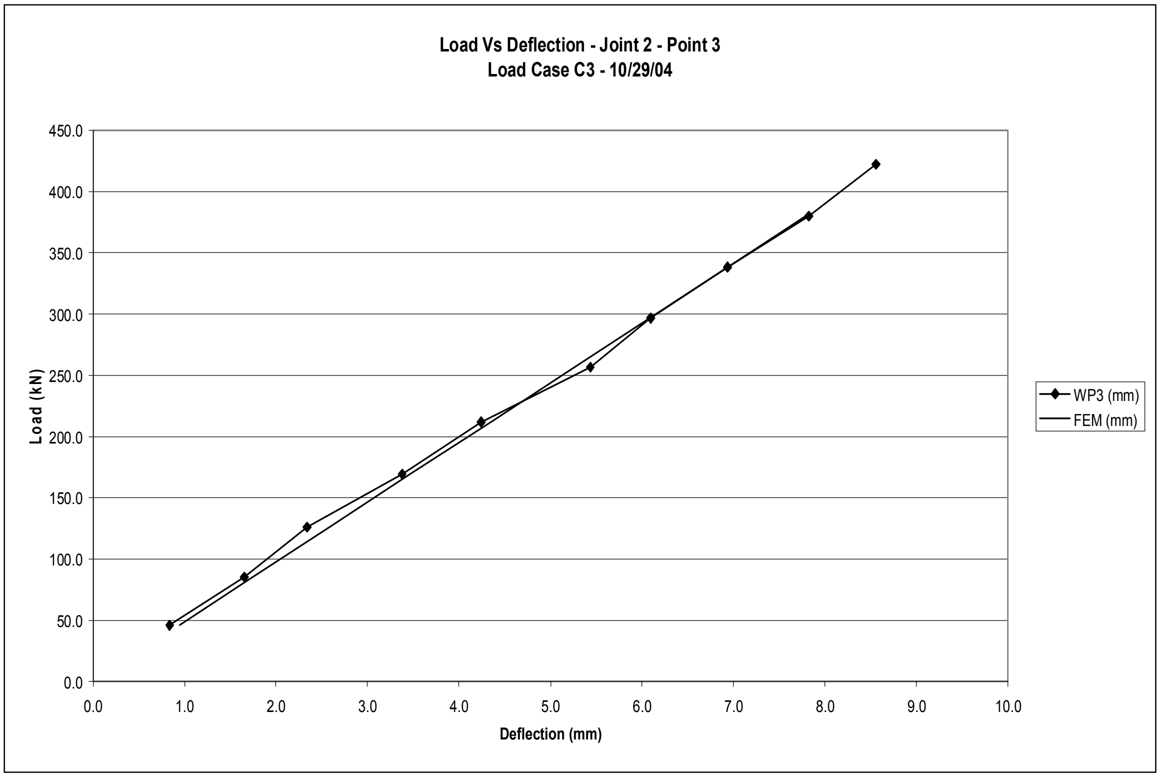

Load Vs. Deflection - Half Scale Test - Load Case C2 - 9.23.04 - Point 13
Load (kN)
250.0
200.0
150.0
100.0
50.0
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
Deflection (mm)
Dial Gage 13 (mm)
Theoretical Deflection

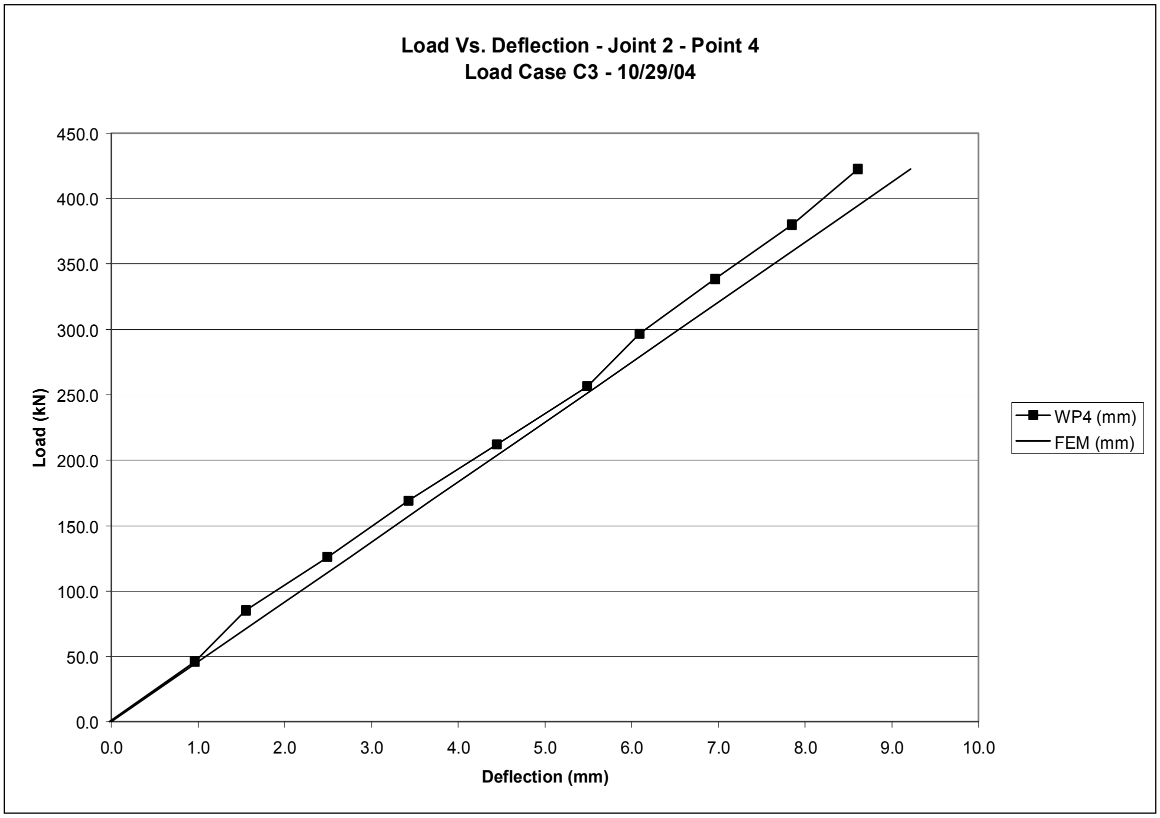

Load Vs. Deflection - Half Scale Test - Load Case C2 - 9.23.04 - Point 14
Load (kN)
250.0
200.0
150.0
100.0
50.0
0.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
-16.0
-18.0
-20.0
Deflection (mm)
Dial Gage 14 (mm)
Theroetical Deflection

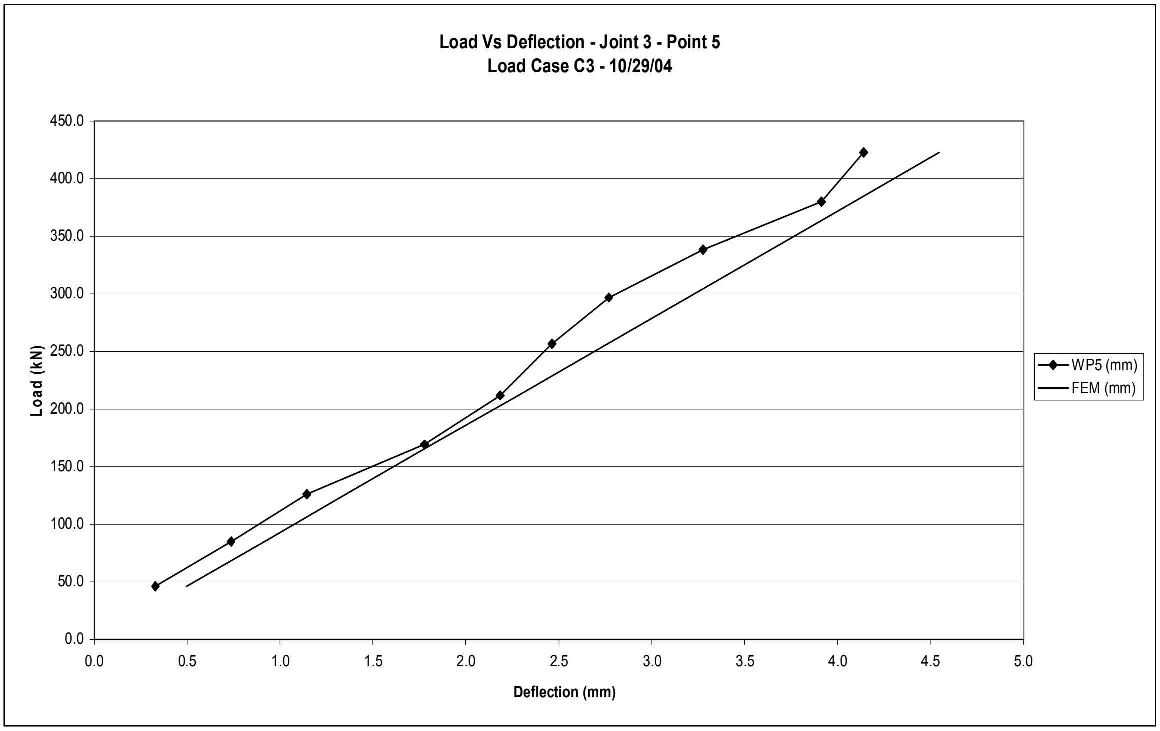
C.3 Load Case C3

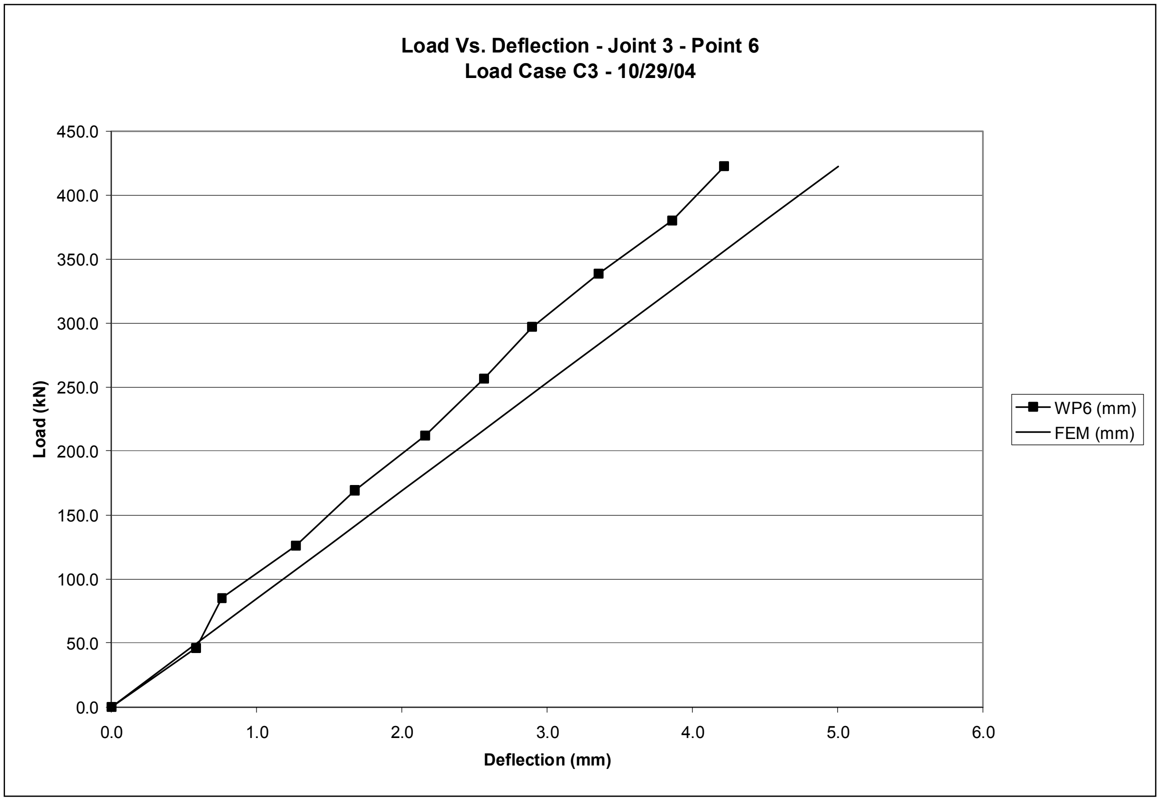


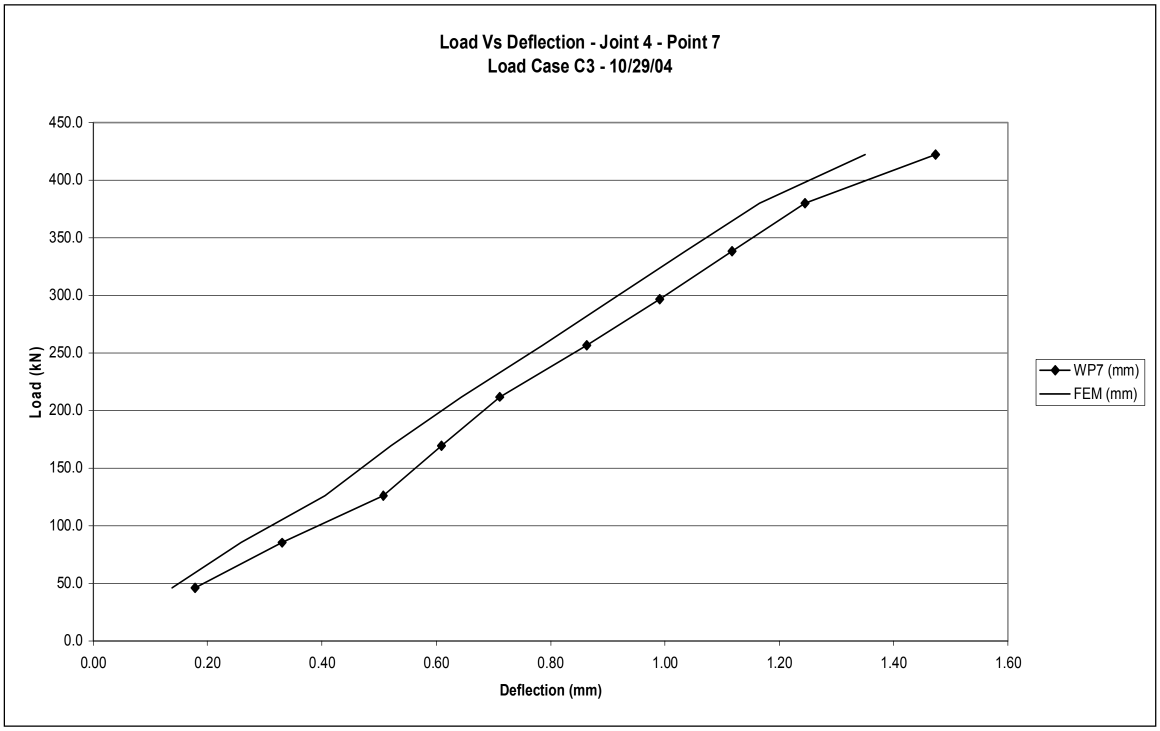


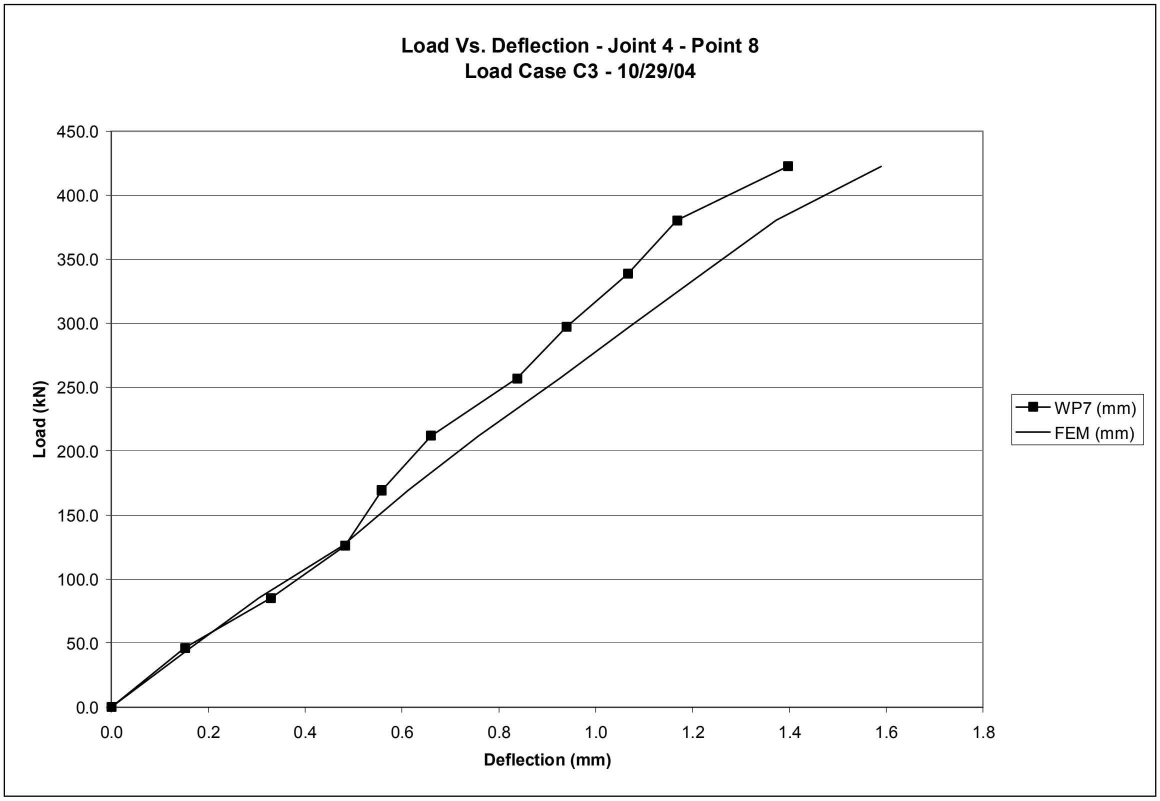

Load Vs Deflection - Joint 2 - Point 3
Load Case C3 - 10/29/04
Load (kN)
Deflection (mm)
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
WP3 (mm)
FEM (mm)

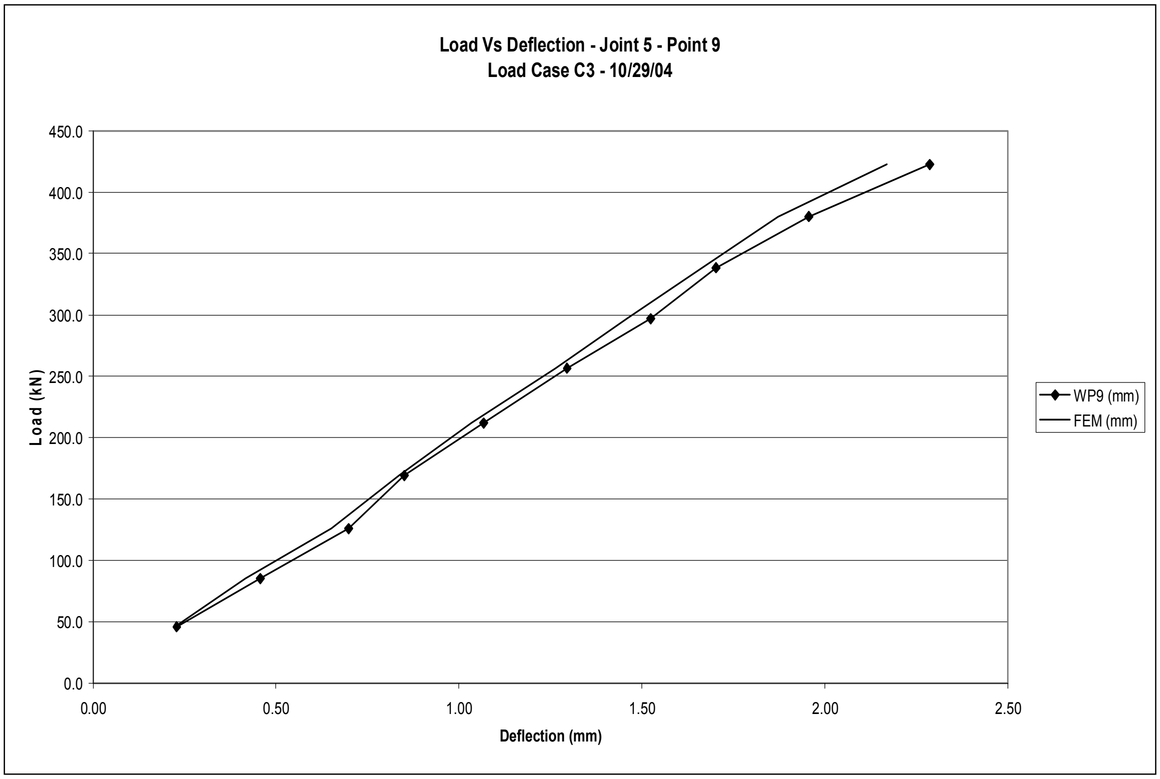

Load Vs. Deflection - Joint 2 - Point 4
Load Case C3 - 10/29/04
Load (kN)
Deflection (mm)
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
WP4 (mm)
FEM (mm)

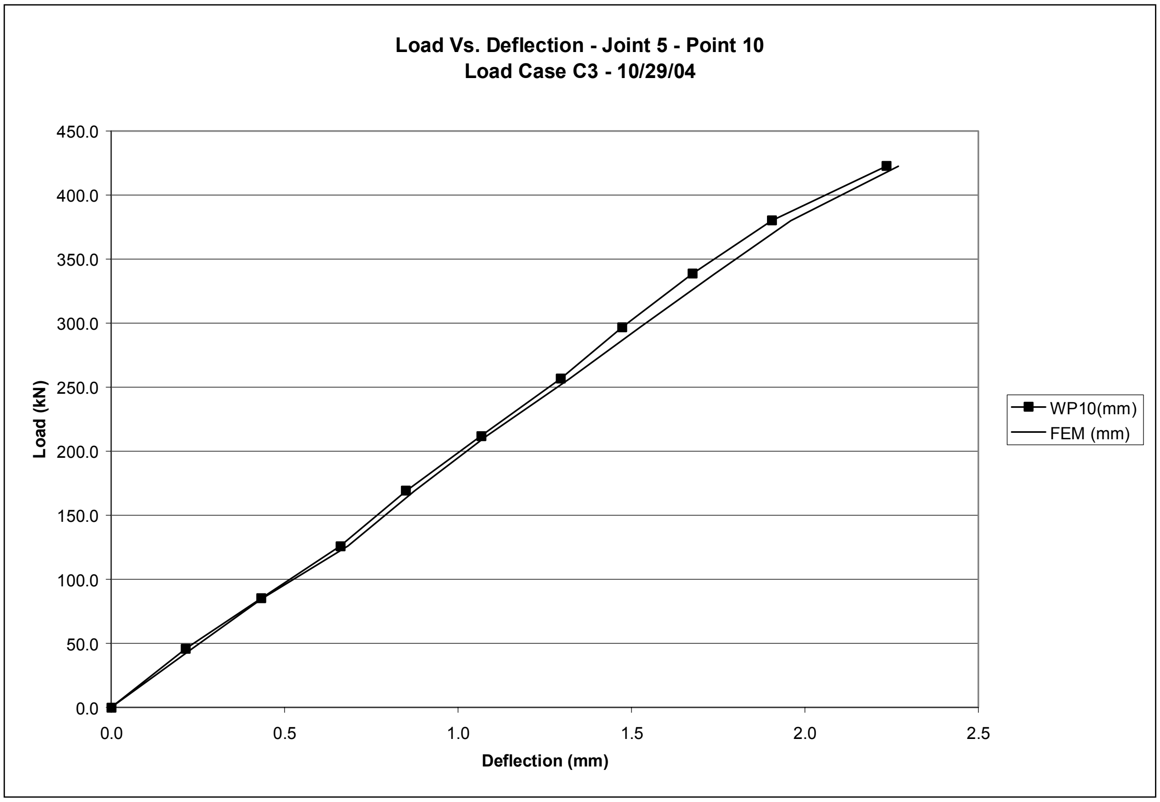

Load Vs Deflection - Joint 3 - Point 5
Load Case C3 - 10/29/04
Load (kN)
Deflection (mm)
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
WP5 (mm)
FEM (mm)

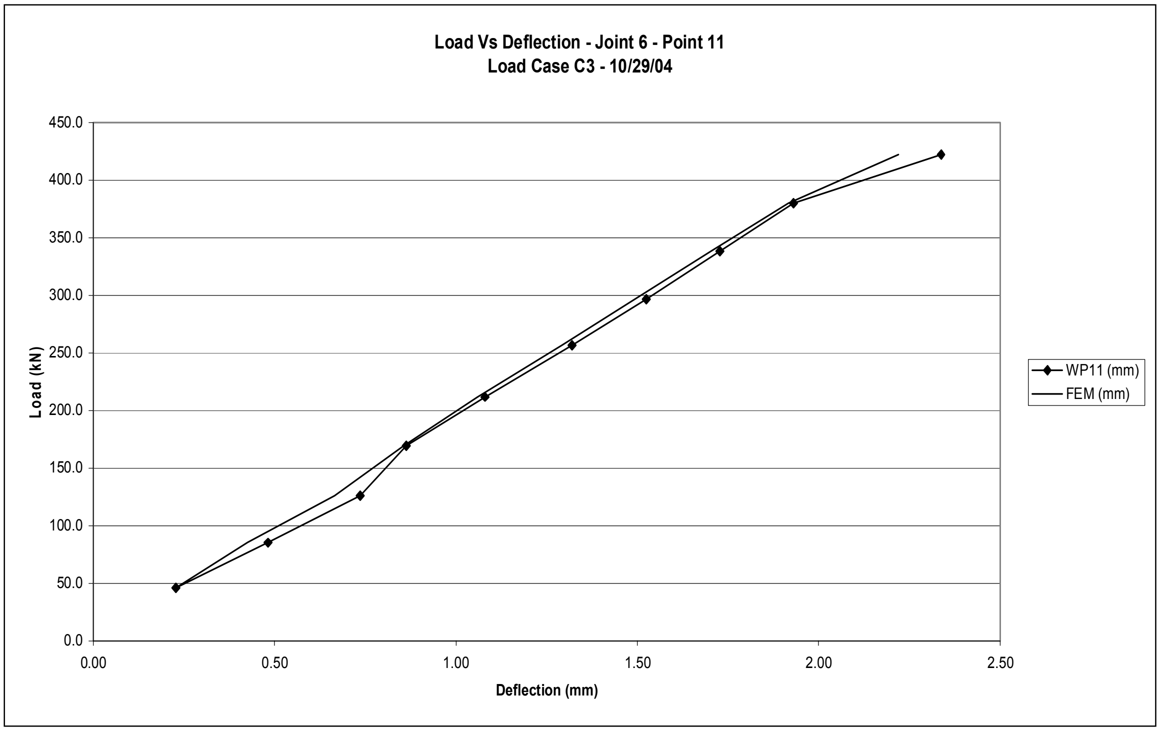

Load Vs. Deflection - Joint 3 - Point 6
Load Case C3 - 10/29/04
Load (kN)
Deflection (mm)
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
WP6 (mm)
FEM (mm)

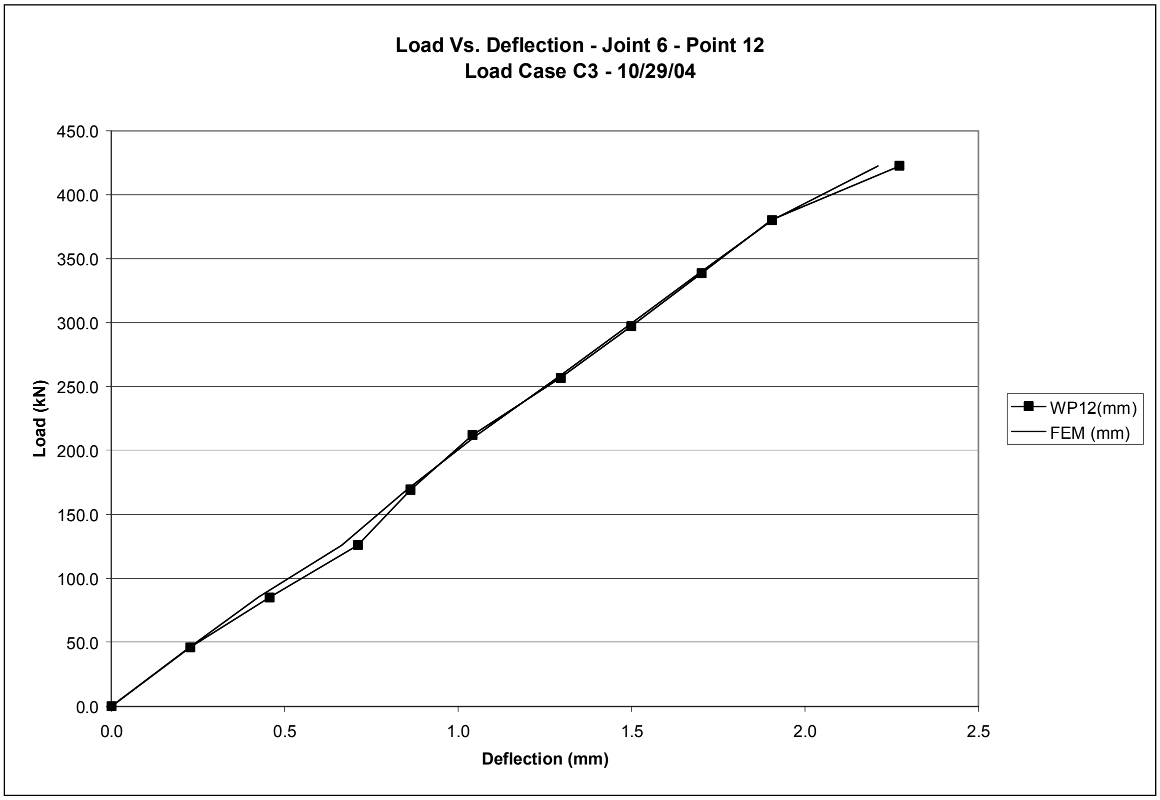

Load Vs Deflection - Joint 4 - Point 7
Load Case C3 - 10/29/04
Load (kN)
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
Deflection (mm)
WP7 (mm)
FEM (mm)

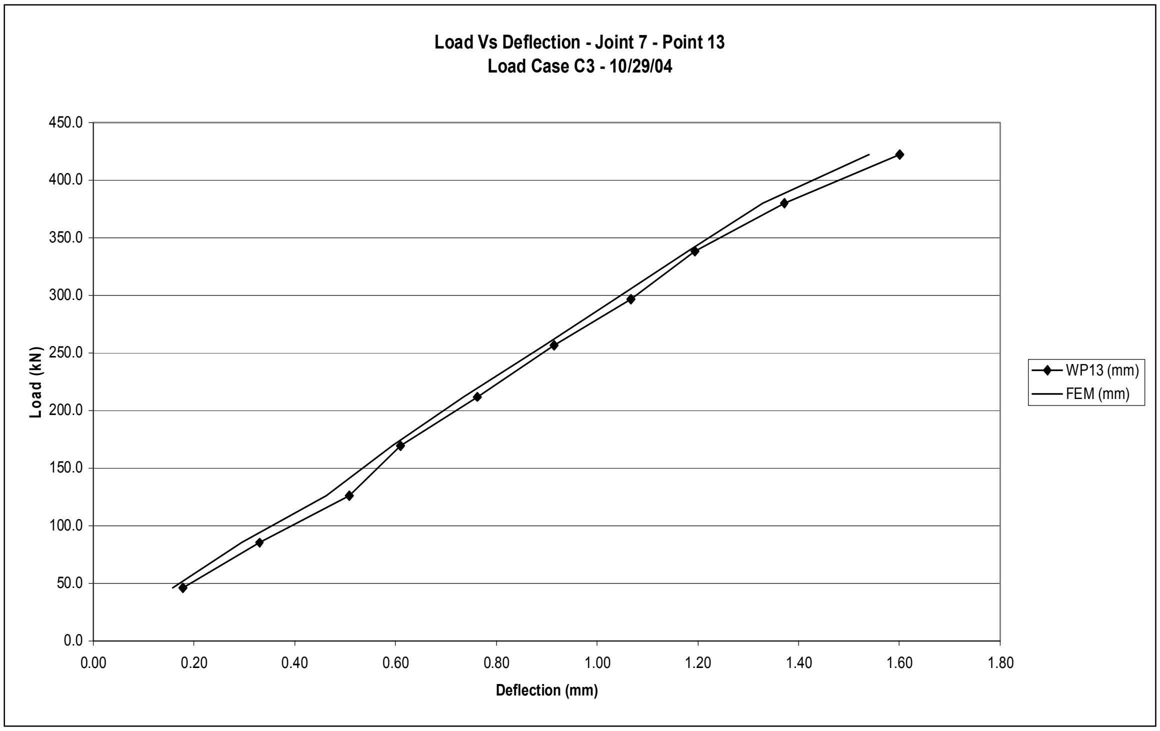

Load Vs. Deflection - Joint 4 - Point 8
Load Case C3 - 10/29/04
Load (kN)
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Deflection (mm)
WP7 (mm)
FEM (mm)

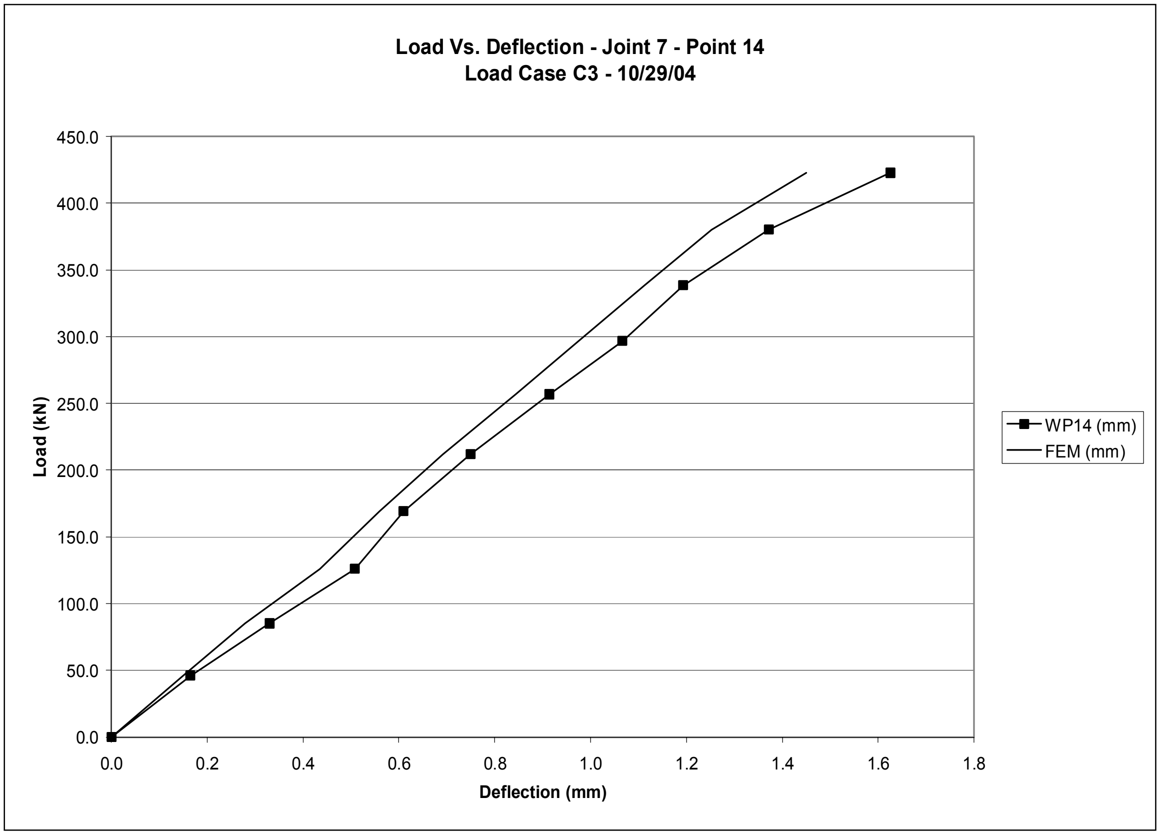

Load Vs Deflection - Joint 5 - Point 9
Load Case C3 - 10/29/04
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
Load (kN)
0.00
0.50
1.00
1.50
2.00
2.50
Deflection (mm)
WP9 (mm)
FEM (mm)


Load Vs. Deflection - Joint 5 - Point 10
Load Case C3 - 10/29/04
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
Load (kN)
0.0
0.5
1.0
1.5
2.0
2.5
Deflection (mm)
WP10(mm)
FEM (mm)

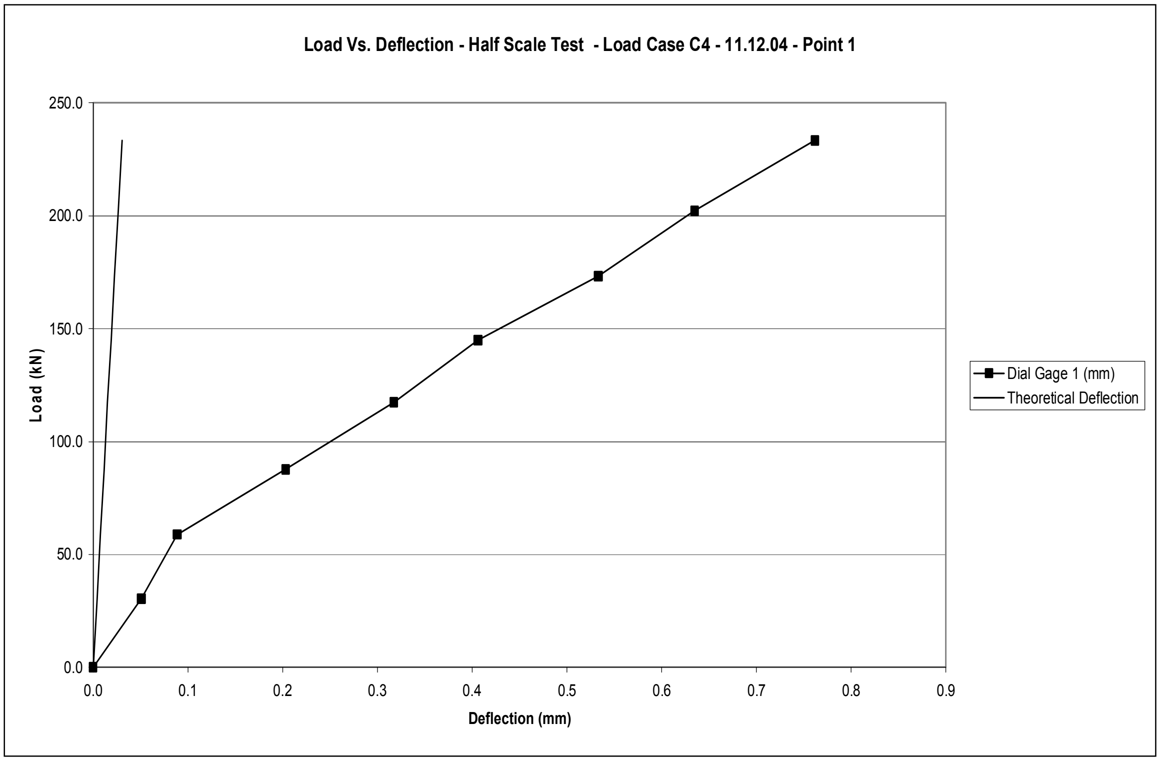

Load Vs Deflection - Joint 6 - Point 11
Load Case C3 - 10/29/04
Load (kN)
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0.00
0.50
1.00
1.50
2.00
2.50
Deflection (mm)
WP11 (mm)
FEM (mm)

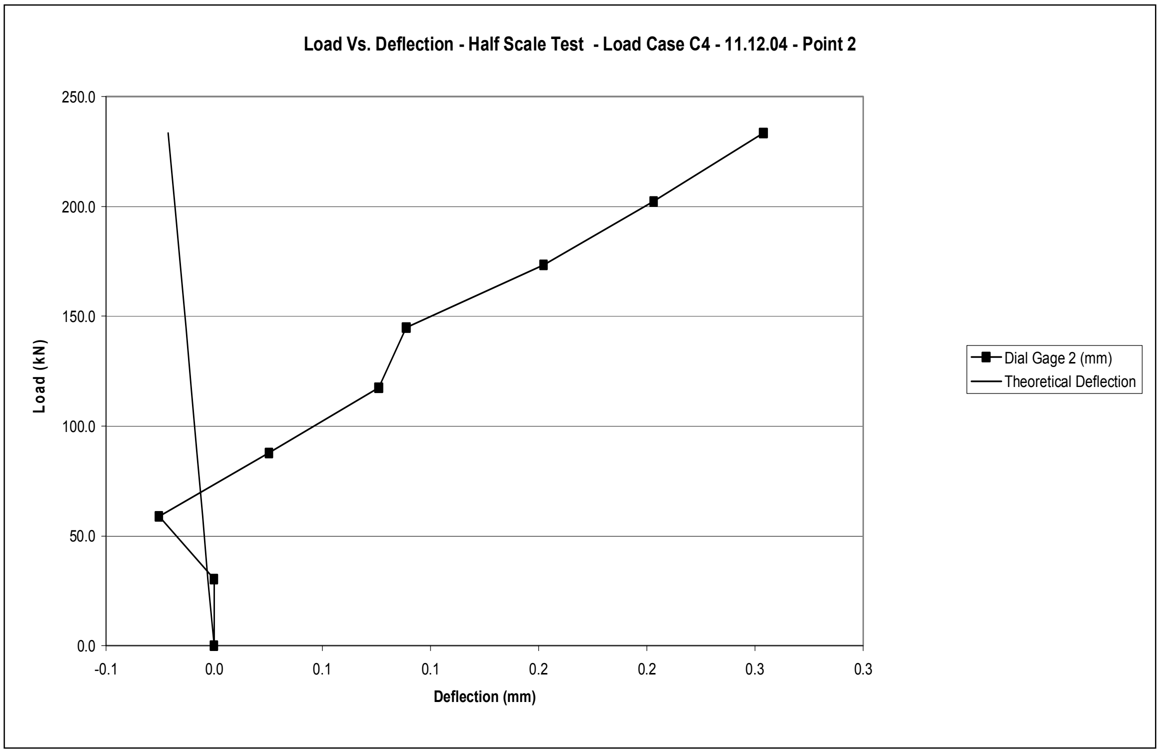

Load Vs. Deflection - Joint 6 - Point 12
Load Case C3 - 10/29/04
Load (kN)
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0.0
0.5
1.0
1.5
2.0
2.5
Deflection (mm)
WP12(mm)
FEM (mm)

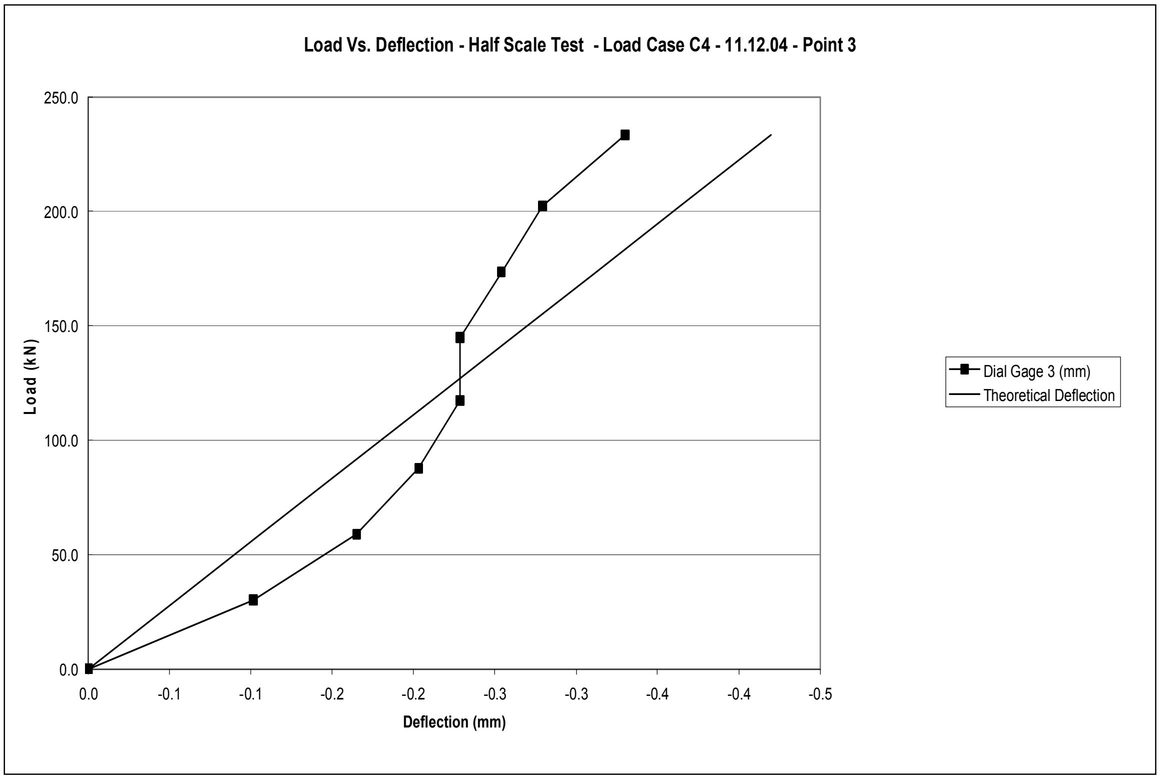

Load Vs Deflection - Joint 7 - Point 13
Load Case C3 - 10/29/04
Load (kN)
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
Deflection (mm)
WP13 (mm)
FEM (mm)

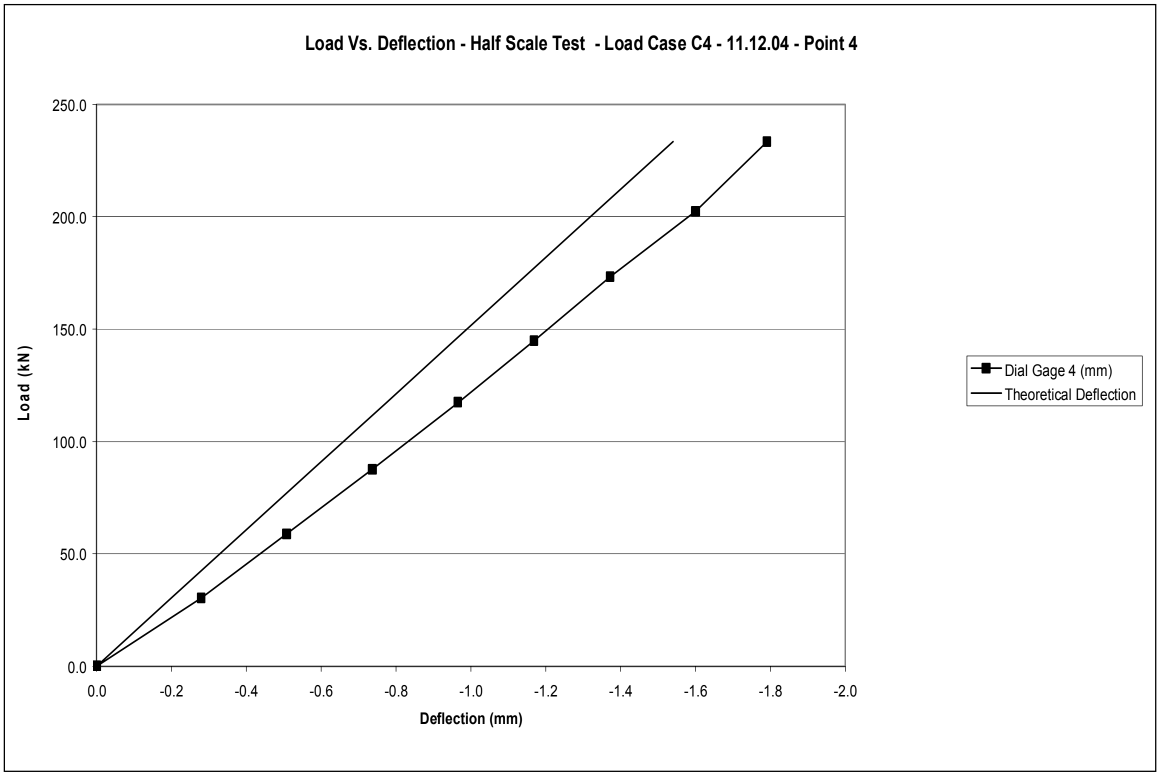

Load Vs. Deflection - Joint 7 - Point 14
Load Case C3 - 10/29/04
Load (kN)
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Deflection (mm)
WP14 (mm)
FEM (mm)

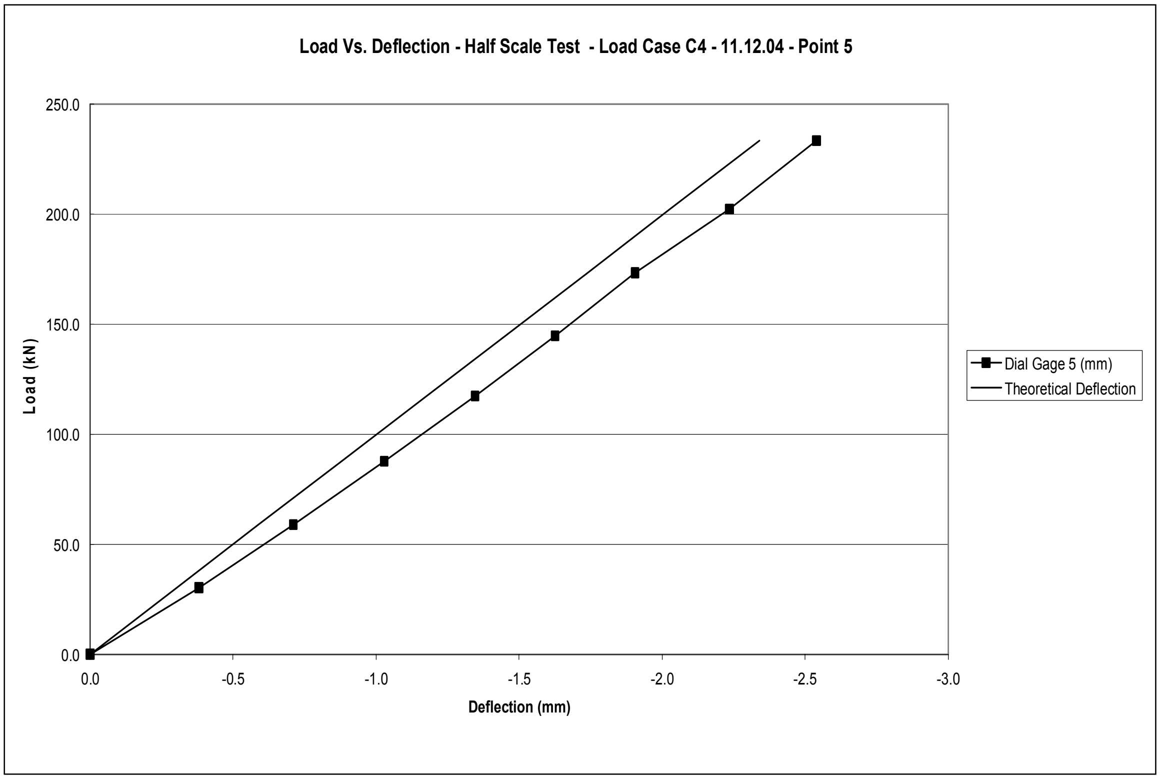
C.4 Load Case C4

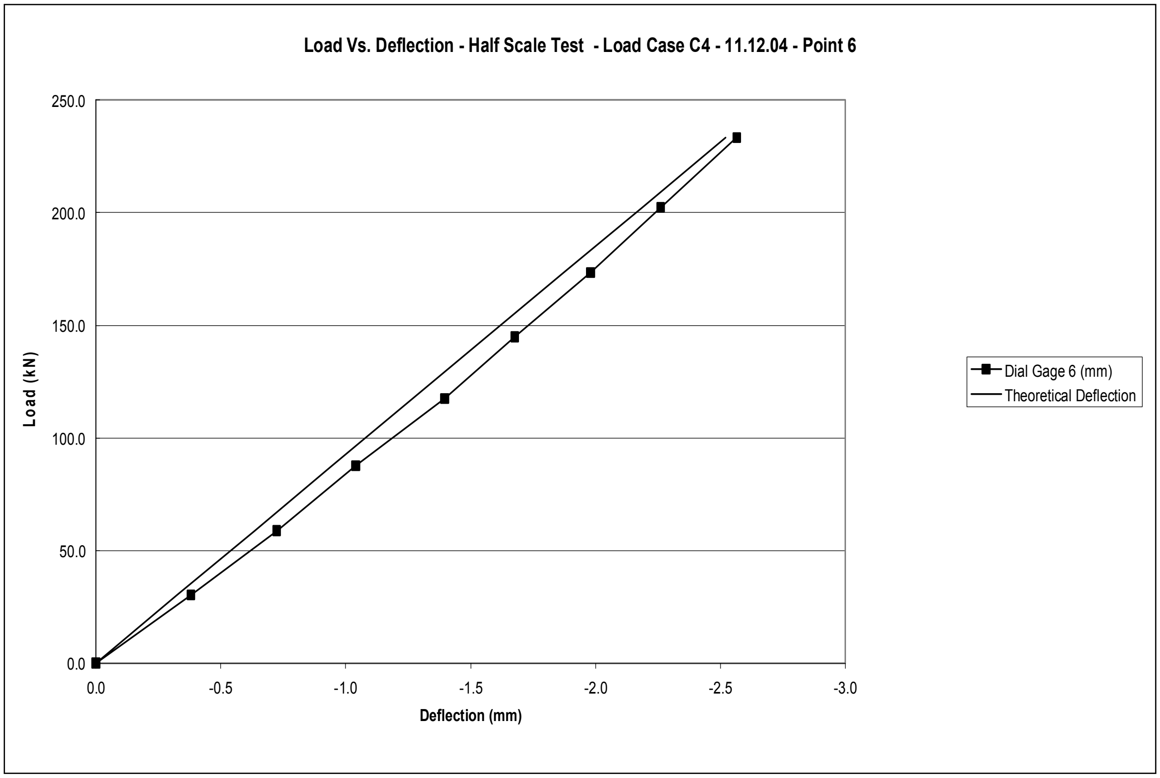


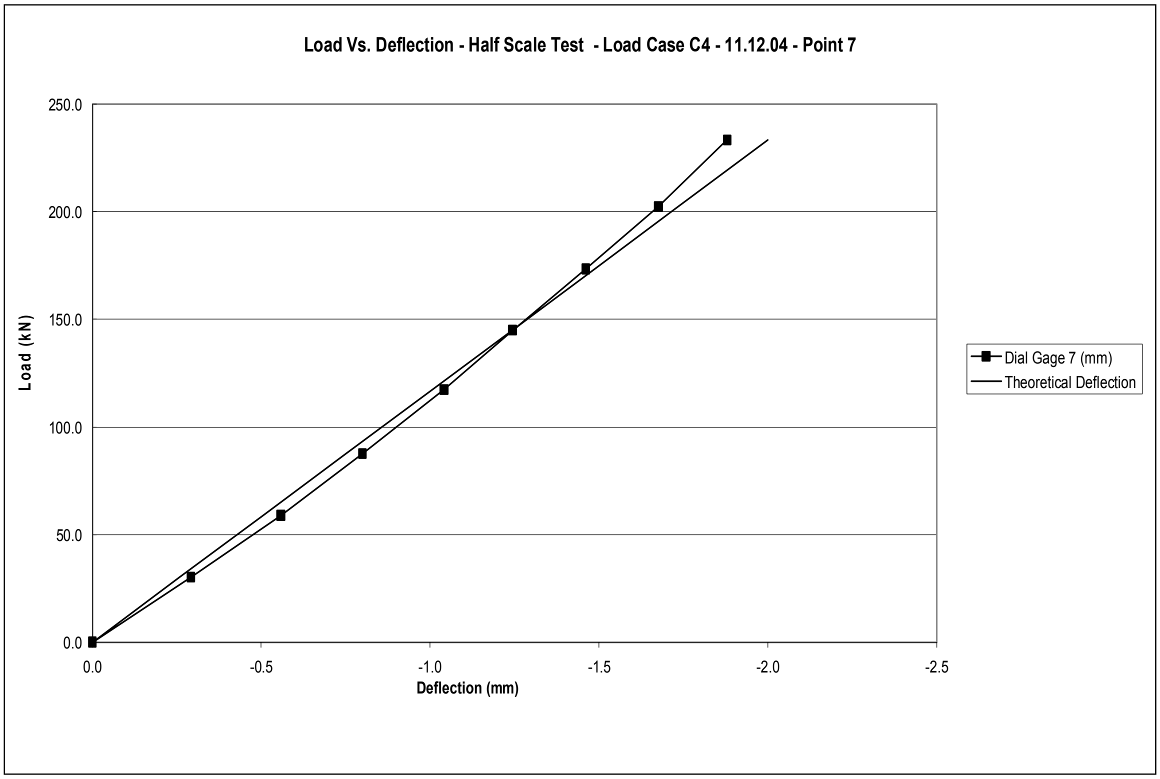


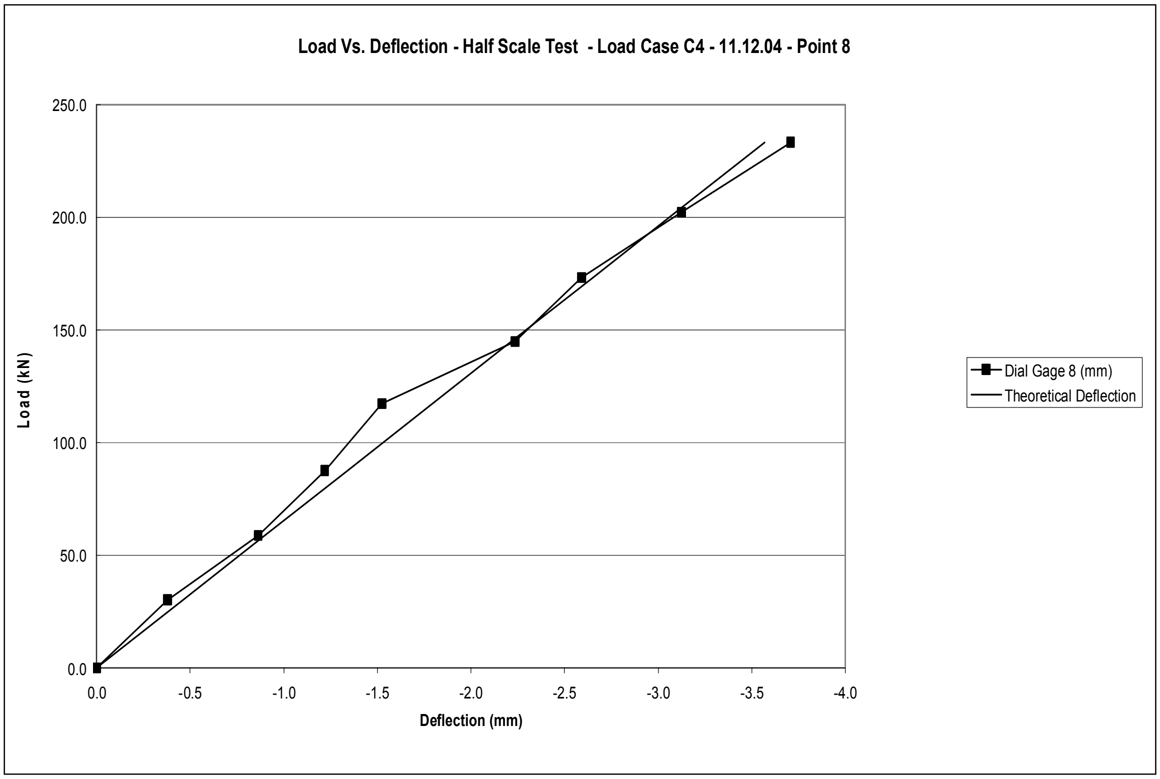

Load Vs. Deflection - Half Scale Test - Load Case C4 - 11.12.04 - Point 3
250.0
200.0
150.0
100.0
50.0
0.0
Load (kN)
0.0
-0.1
-0.1
-0.2
-0.2
-0.3
-0.3
-0.4
-0.4
-0.5
Deflection (mm)
Dial Gage 3 (mm)
Theoretical Deflection

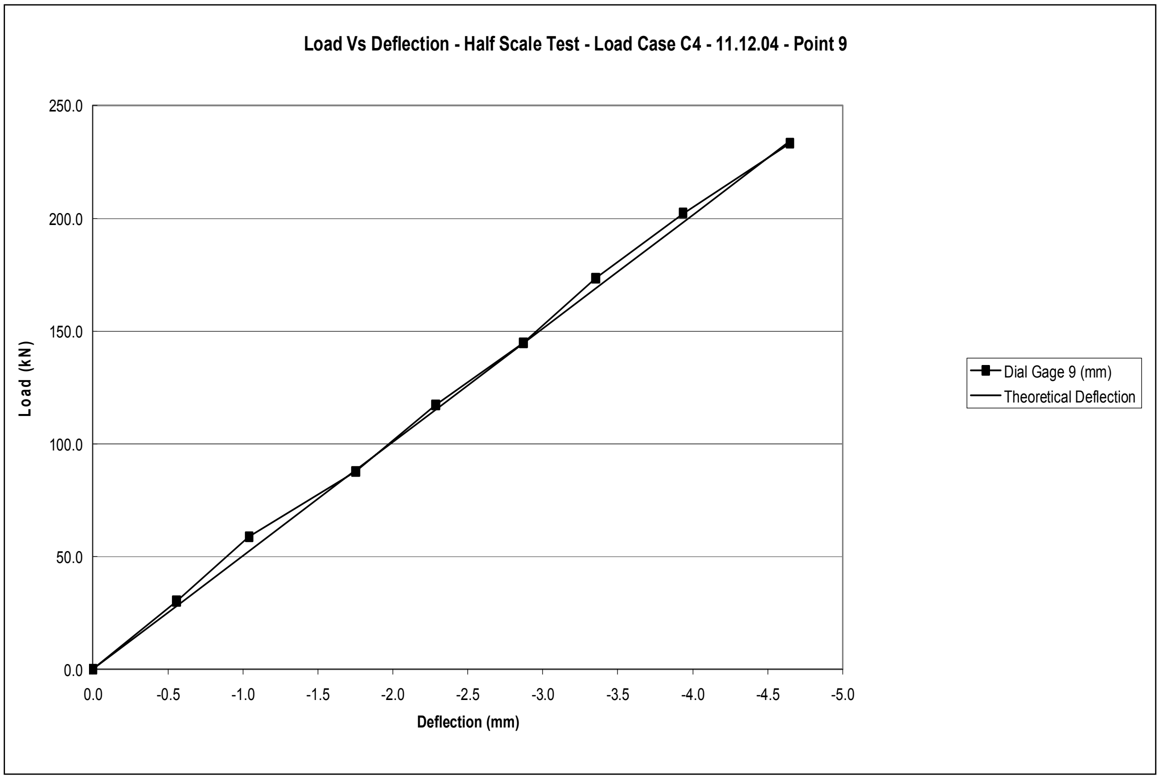

Load Vs. Deflection - Half Scale Test - Load Case C4 - 11.12.04 - Point 4
250.0
200.0
150.0
100.0
50.0
0.0
Load (kN)
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
-2.0
Deflection (mm)
Dial Gage 4 (mm)
Theoretical Deflection

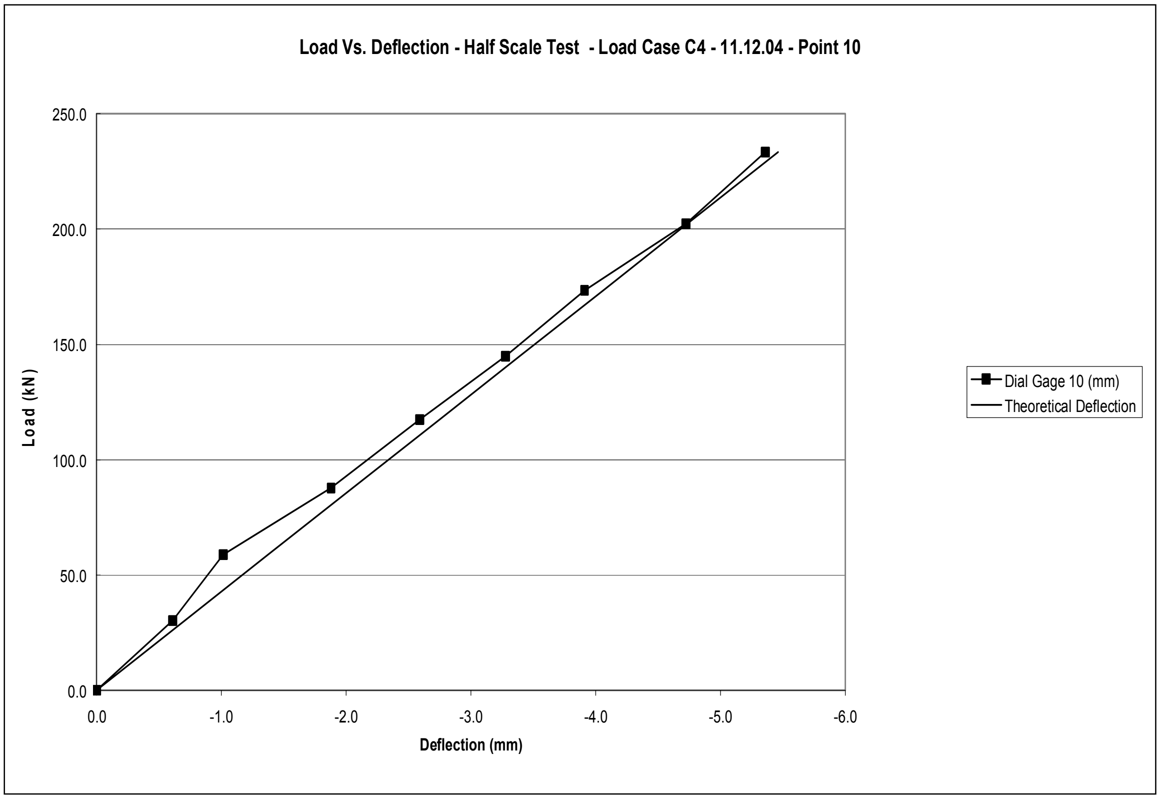

Load Vs. Deflection - Half Scale Test - Load Case C4 - 11.12.04 - Point 5
Load (kN)
250.0
200.0
150.0
100.0
50.0
0.0
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
Deflection (mm)
Dial Gage 5 (mm)
Theoretical Deflection

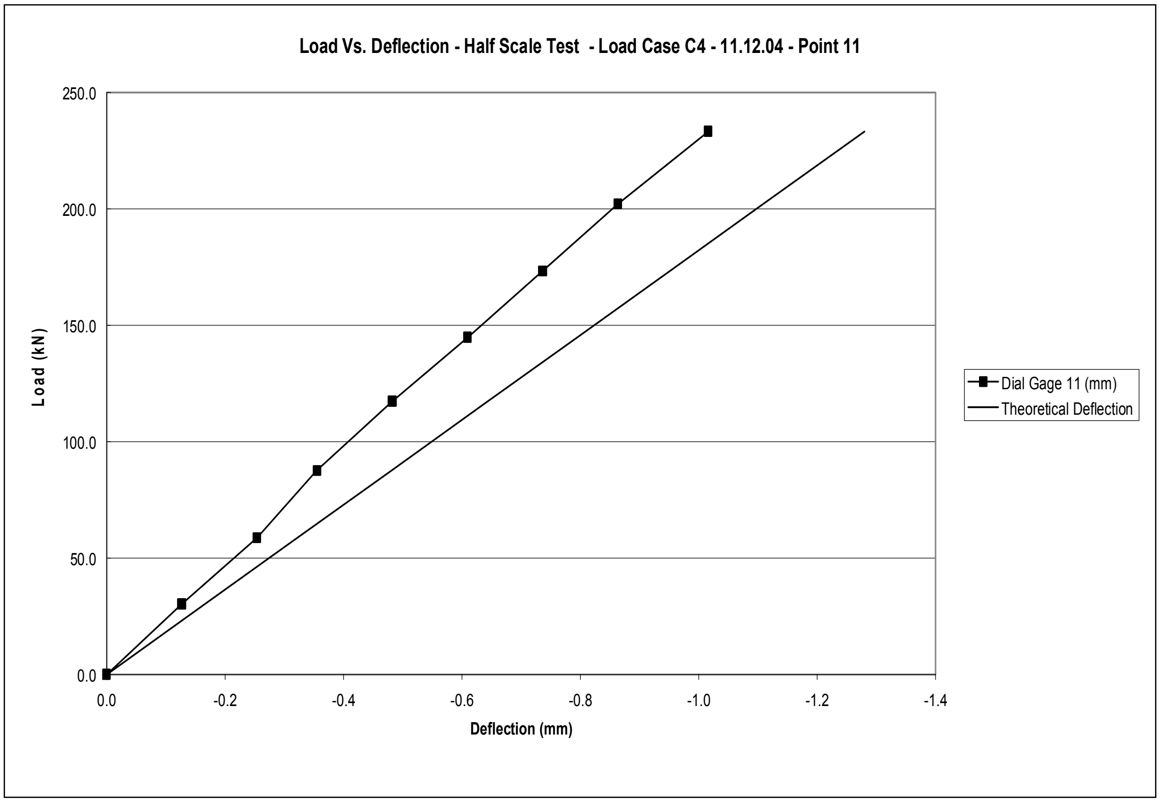

Load Vs. Deflection - Half Scale Test - Load Case C4 - 11.12.04 - Point 6
Load (kN)
250.0
200.0
150.0
100.0
50.0
0.0
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
Deflection (mm)
Dial Gage 6 (mm)
Theoretical Deflection

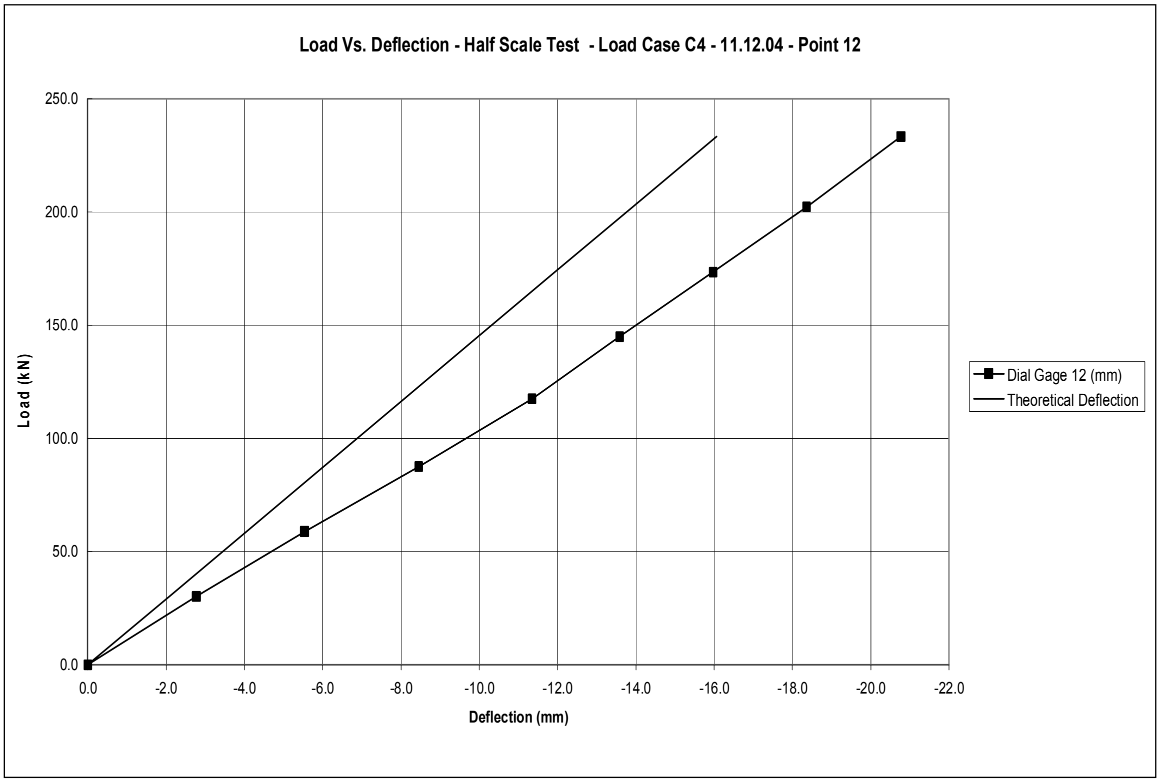

Load Vs. Deflection - Half Scale Test - Load Case C4 - 11.12.04 - Point 7
Load (kN)
250.0
200.0
150.0
100.0
50.0
0.0
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
Deflection (mm)
Dial Gage 7 (mm)
Theoretical Deflection

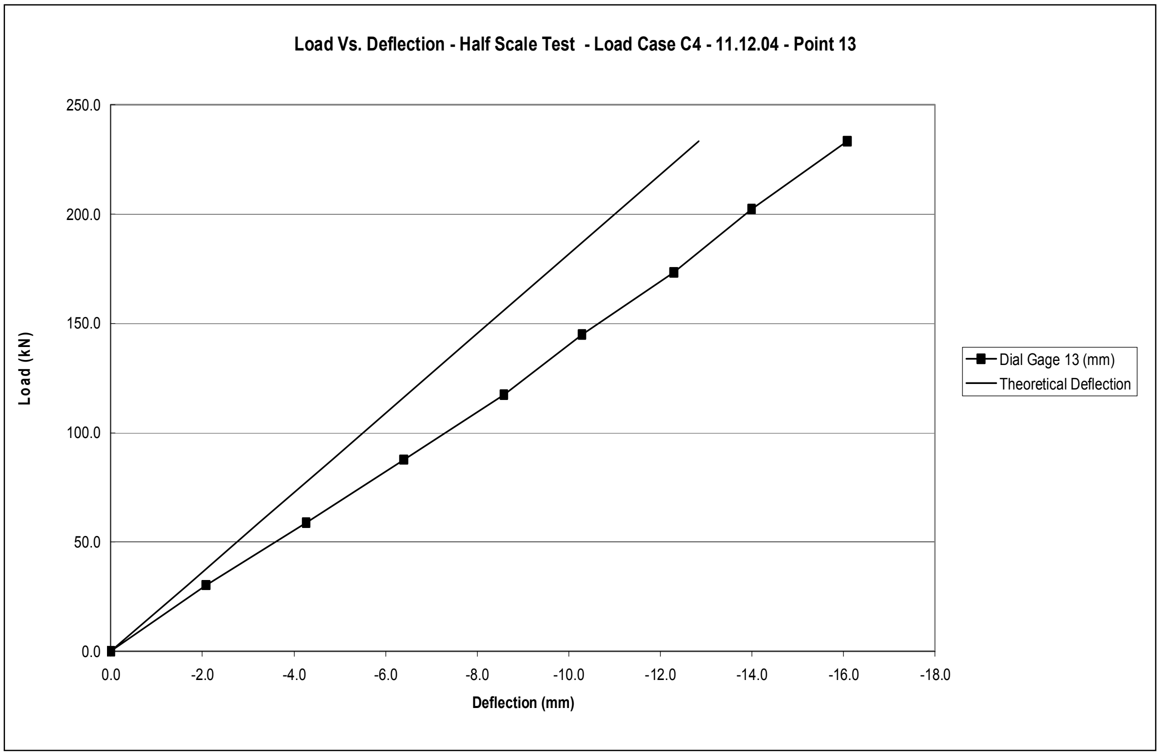

Load Vs. Deflection - Half Scale Test - Load Case C4 - 11.12.04 - Point 8
Load (kN)
250.0
200.0
150.0
100.0
50.0
0.0
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
Deflection (mm)
Dial Gage 8 (mm)
Theoretical Deflection


Load Vs Deflection - Half Scale Test - Load Case C4 - 11.12.04 - Point 9
Load (kN)
250.0
200.0
150.0
100.0
50.0
0.0
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
Deflection (mm)
Dial Gage 9 (mm)
Theoretical Deflection

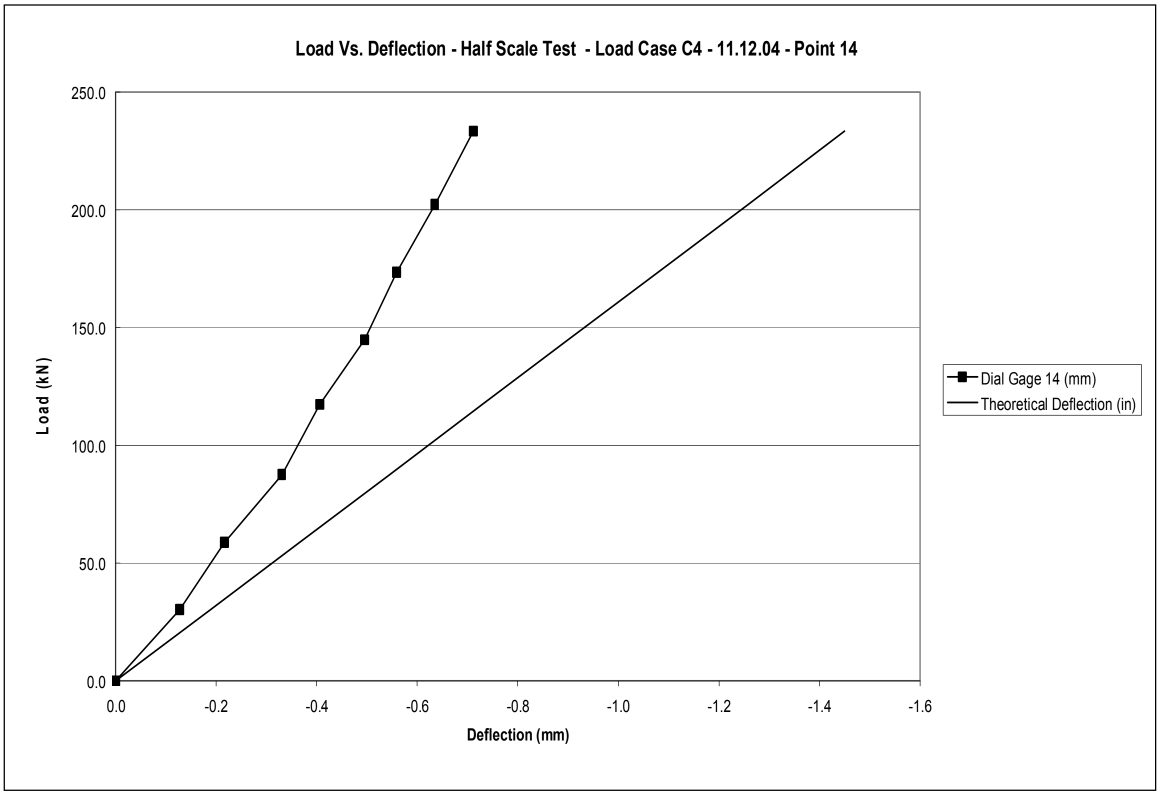

Load Vs. Deflection - Half Scale Test - Load Case C4 - 11.12.04 - Point 10
Load (kN)
250.0
200.0
150.0
100.0
50.0
0.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
Deflection (mm)
Dial Gage 10 (mm)
Theoretical Deflection


Load Vs. Deflection - Half Scale Test - Load Case C4 - 11.12.04 - Point 11
250.0
200.0
150.0
100.0
50.0
0.0
Load (kN)
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
Deflection (mm)
Dial Gage 11 (mm)
Theoretical Deflection

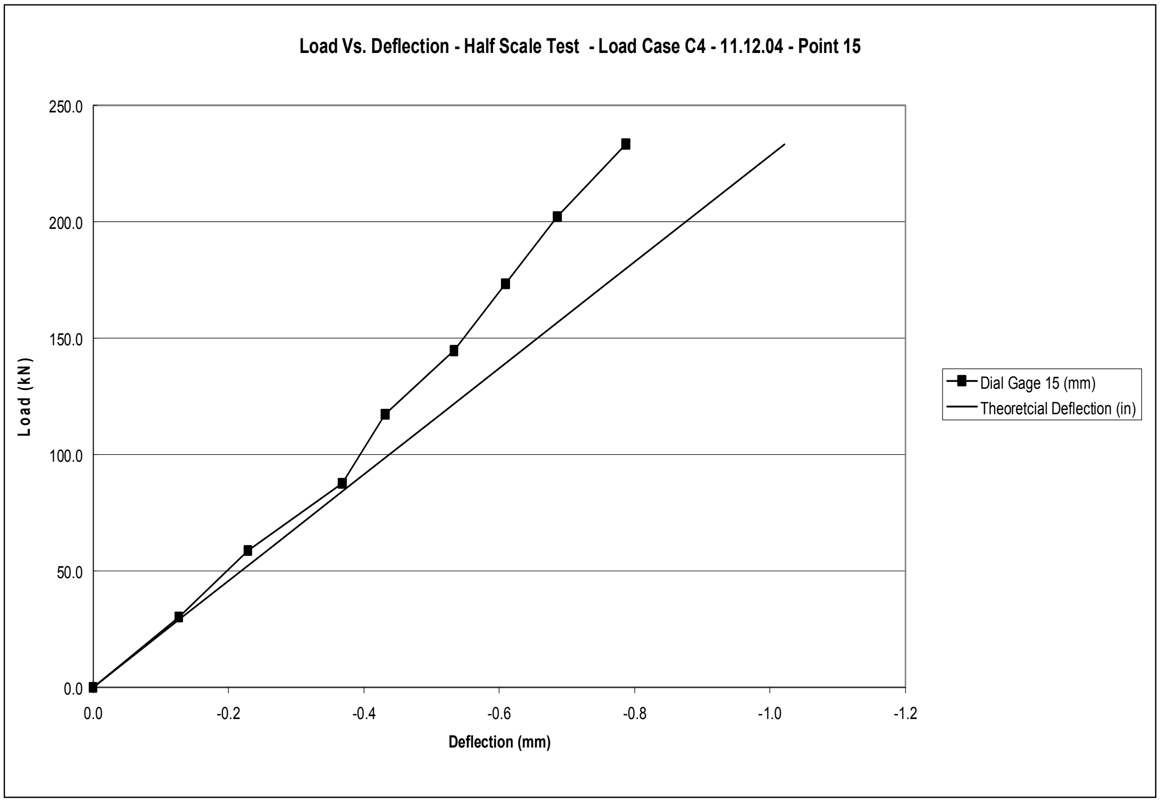

Load Vs. Deflection - Half Scale Test - Load Case C4 - 11.12.04 - Point 12
250.0
200.0
150.0
100.0
50.0
0.0
Load (kN)
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
-16.0
-18.0
-20.0
-22.0
Deflection (mm)
Dial Gage 12 (mm)
Theoretical Deflection



Load Vs. Deflection - Half Scale Test - Load Case C4 - 11.12.04 - Point 13



Load Vs. Deflection - Half Scale Test - Load Case C4 - 11.12.04 - Point 14


Load Vs. Deflection - Half Scale Test - Load Case C4 - 11.12.04 - Point 15
250.0
200.0
150.0
100.0
50.0
0.0
Load (kN)
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
Deflection (mm)
Dial Gage 15 (mm)
Theoretcial Deflection (in)

APPENDIX D:
EXPERIMENTAL DATA FROM TESTING OF HALF SCALE BRIDGE WITH NO WELDS

D.1 Test Setup

On June 16, 2004, a static test was conducted on the half scale specimen with the panels not welded together. The maximum applied load was 267 kN (60 kips). The centerline of the actuator was 19 mm (0.75 in.) to the left of the joint between panels 4 and 5. This was due to the location of the holes in the reaction floor. Therefore, the distance to the centerline of the left bearing pad was 781 mm (30.75 in.) from the joint, and the right bearing pad was 743 mm (29.25 in.) from the centerline of the joint. The total distance from the centerline of the left pad to the centerline of the right pad was 1524 mm (60 in.). Eight holes were drilled in the crosshead so that the actuator could be positioned directly above Girder 2. The test set up consisted of 3 displacement transducers, 1 load cell, 1 spreader beam, and the System 6000 data acquisition system. The transducers were positioned on the bottom flange of Girder 2. One transducer was located at the center of the joint between Panels 4 and 5, and the other two “string-type” potentiometers were orientated with the centerline of the bearing pad. The deflection of the girder alone and the total composite deflection were calculated and used to check the accuracy of the transducers readings. The deflection of the unwelded system should be more than the deflection of the total composite system, but less than the girder deflection alone. This was found to be the case. The maximum deflection at the center of Panels 4 and 5 was 32 mm (1.258 in.) under the maximum loading of 267 kN (60 kip). A seating load of 67 kN (15 kips) was applied to the specimen, and, after unloading and zeroing the instrumentation, the panel was loaded to 267 kN (60 kips). Figure D.1 is a photograph of the test specimen under maximum loading. Figure D.2 is a plot of load versus deflection beneath the centerline of Panels 4 and 5, and Figure D.3 is a plot of the deflections measured underneath Girder 2 below the load points. The average percent composite action for the test was 55%.

FIGURE D.1: TEST SPECIMEN UNDER MAXIMUM LOADING - UNWELDED PANEL TEST

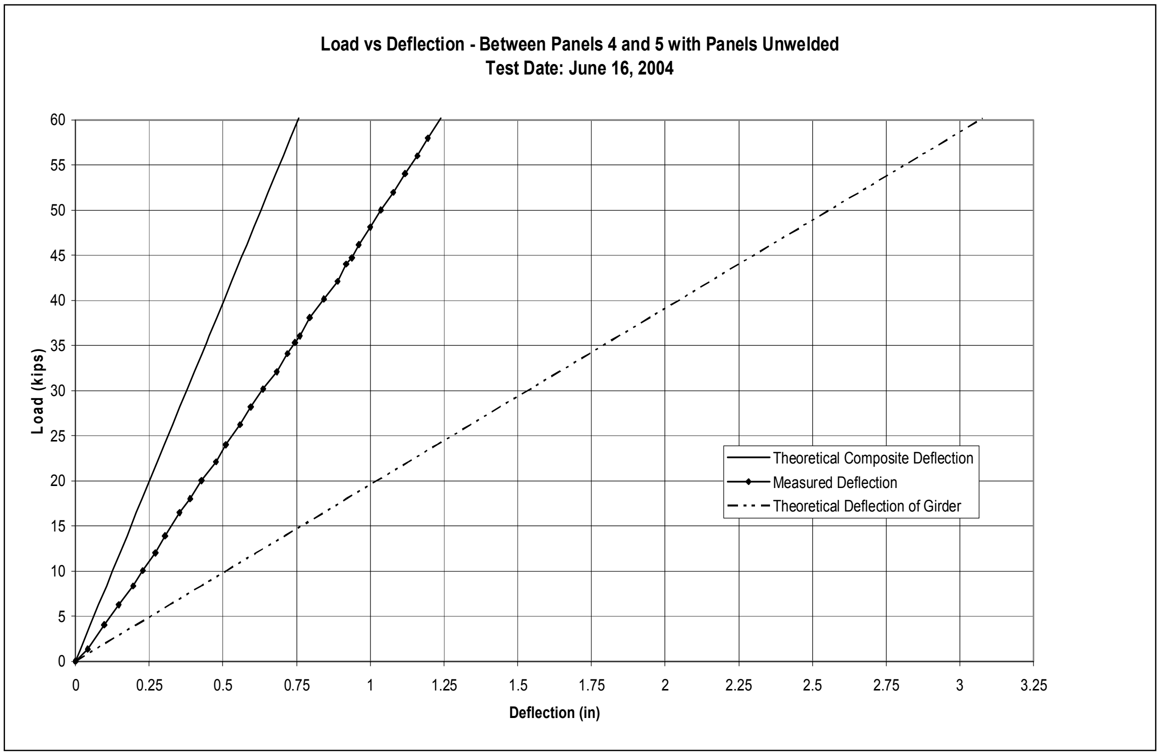


FIGURE D.2: LOAD VS DEFLECTION FOR THE JOINT BETWEEN PANELS 4 AND 5

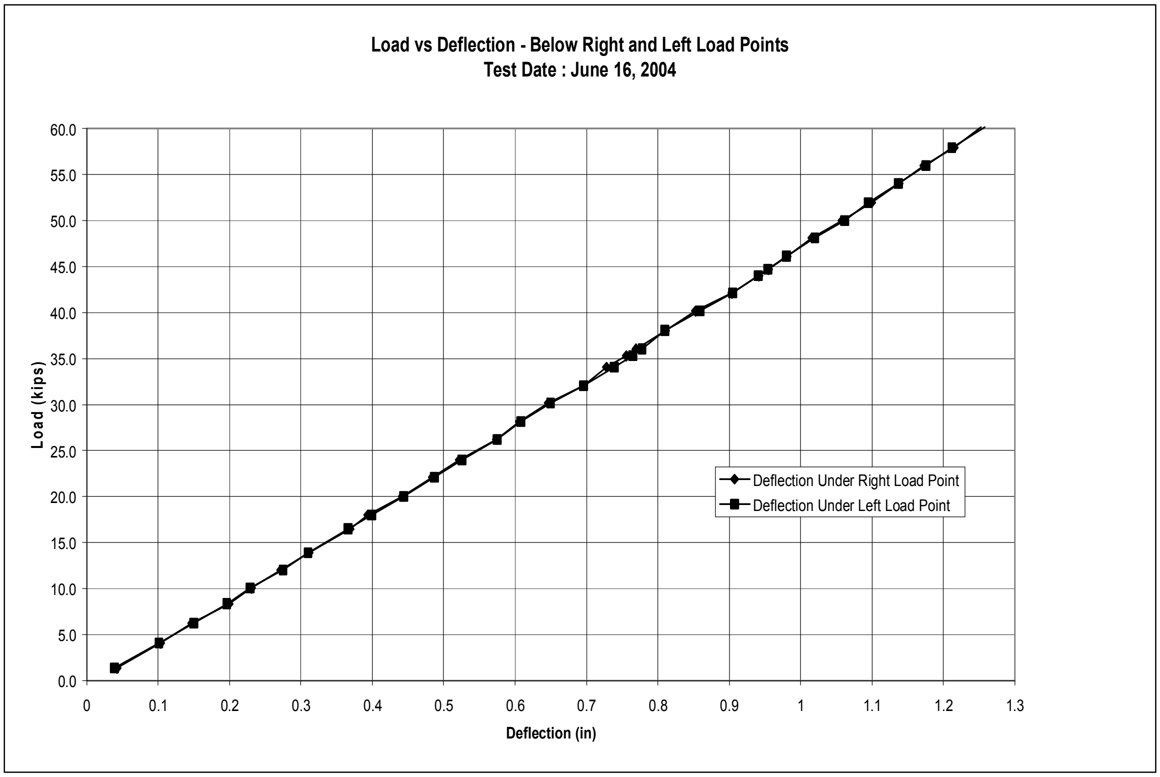


FIGURE D.3: LOAD VS DEFLECTION FOR THE TWO POINTS UNDERNEATH THE BEARING PAD

APPENDIX E:
CALCULATION OF FREQUENCY OF STATIC PANEL TEST SPECIMEN

E.1: Natural Frequency Determination

Determine natural frequency of static panel:

Calculate centroid based on cut through 3000 mm section (Section B-B on Test Panel Fabrication Drawings, File No: 2003-10-07 DEN03176001.dwg).

Modulus of Elastomer core is 750 MPa (109 ksi). Therefore, n = E_{steel}/E_{core} = 29000/1.35(109) = 197.

b_{tr} = 120 inches/197 =.6091inches.

Area of core when converted to steel is equal to (1.5 inches)(.6091 inches) =.913705 in^2.

	Area (in^2)	y_i (in)	Ay_i (in^3)	
Pd	1.25	0	0	x2
Pa	5.90625	7.785	45.98016	x2
Ph	30	13.875	416.25	x1
Elastomer	0.913705584	14.75	13.47716	x1
Pg	30	15.625	468.75	x1
Sum	75.22620558		990.4375	

$$\text{y bar} = \frac{Ay_i\ (in^3)}{\text{Area}\ (in^2)} = 13.16612 \quad \text{inches from bottom of angles}$$

Calculate I_{tr}:

	Area (in^2)	y_i (in)	Area *$(y_i\text{-}y_{bar})^2$ (in^4)	I (in^4)	Mult. By	I+A*(y-ybar)
	1.25	0	216.6834911	0.00651	x2	433.380003
Pa	5.90625	7.785	171.0242332	122.0933	x2	586.23499
Ph	30	13.875	15.07520124	0.15625	x1	15.2314512
Elastomer	0.913705584	14.75	2.292182671	0.17132	x1	2.46350247
Pg	30	15.625	181.3822942	0.15625	x1	181.538544
Sum						1218.84849

With Itr = 1218.8 in4, the frequency is calculated from:

$$fn := \frac{\pi}{2}\cdot {\frac{g\cdot Es\cdot Itr}{w\cdot\left(L^4\right)}}^{\frac{1}{2}}$$

(Eqn 1 from AISC Design Guide 11)

Panel weight = 10,000 lbs
Area of panel = 10 ft. x 30 ft = 300 ft^2
w = (10000lbs/300 ft^2)*10 ft = 333.3333lb/ft = 27.78 lb/in
g = 386 in^2/sec, Es = 29000ksi (29,000,000 psi), L= 30 ft (360 in)

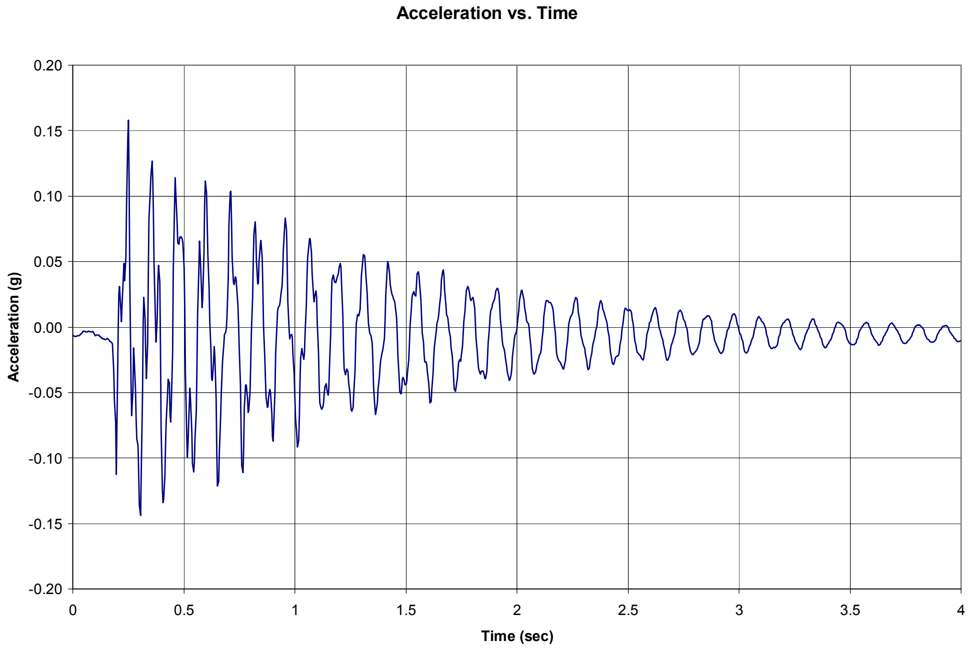
Using lbs and inches in Eqn 1:

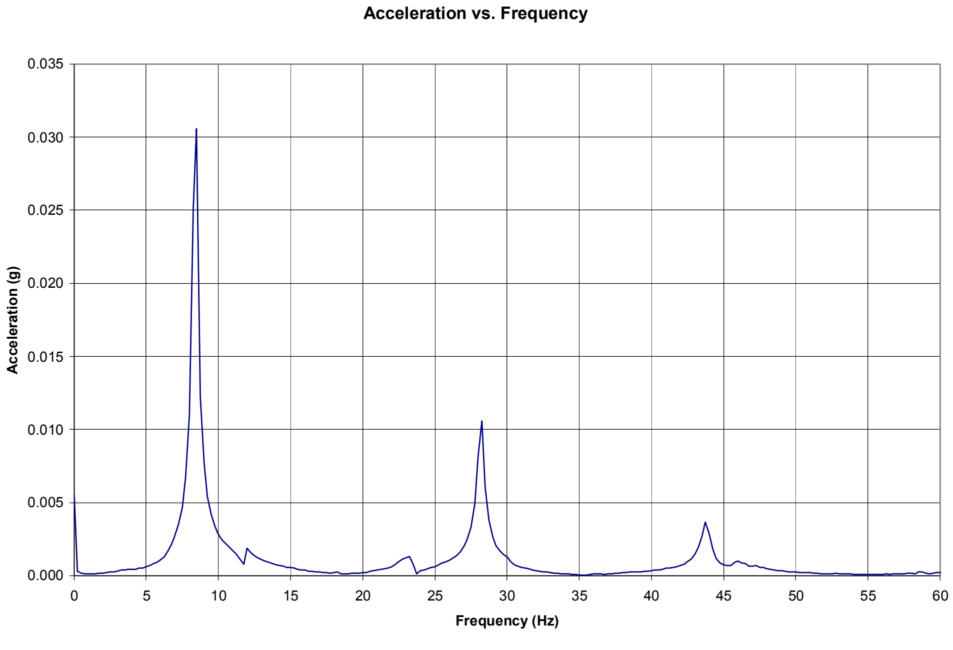
fn = 8.49 Hz

The measured frequency was 8.5 Hz.

APPENDIX F:
VIBRATION TESTING OF STATIC PANEL TEST SPECIMEN

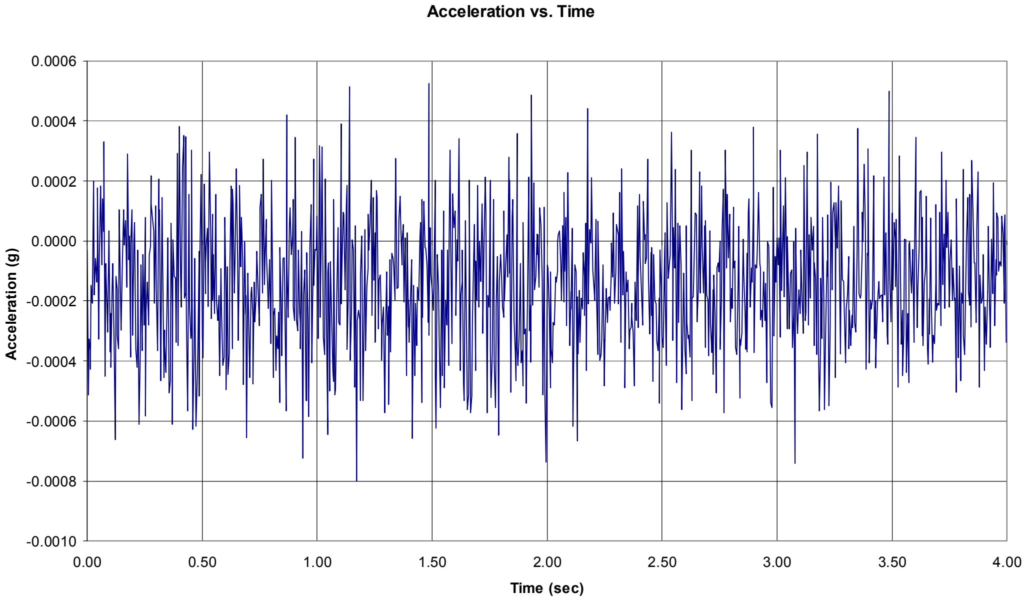
Record No. : 287-289
Building : Static Test Panel
Accelerometer Location : South Edge, Mid-span
Excitation : Onur – Knee Move at Mid Span at 168 BPM

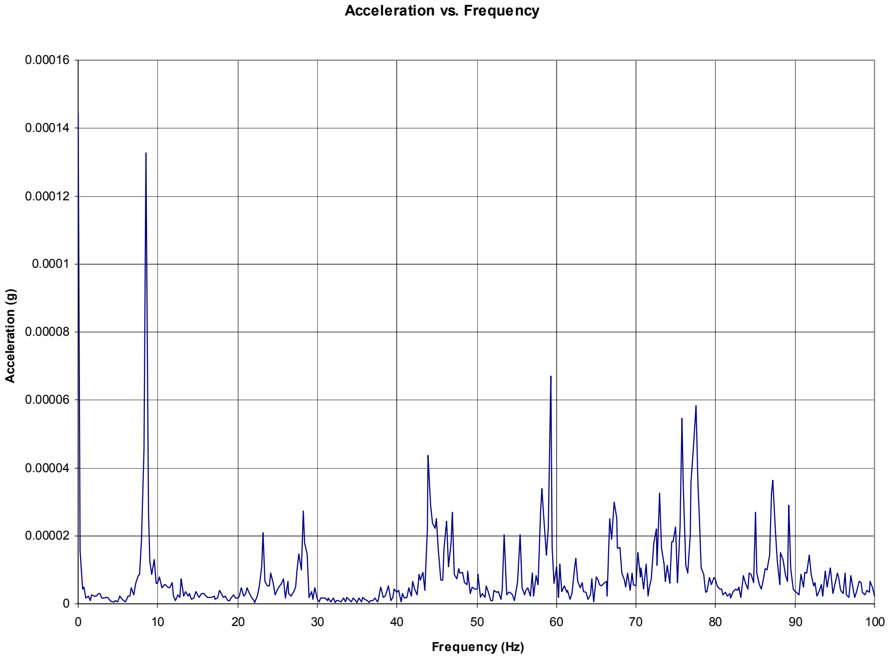




OVERALL	0.05031 g	
0-P:	0.250 s	15.780 %g
1ST:	8.50 Hz	3.057 %g
2ND:	28.25 Hz	1.060 %g
3RD:	43.75 Hz	0.368 %g

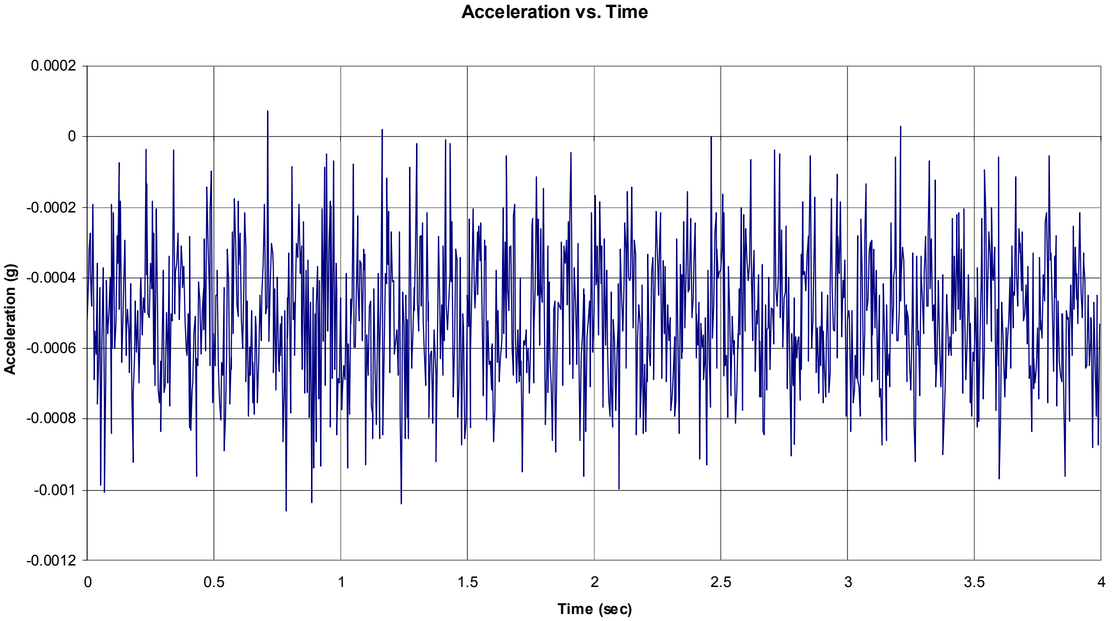
Record No. : 257-259
Building : Static Test Panel
Accelerometer Location : Center Line, Mid-span
Excitation : Ambient Case

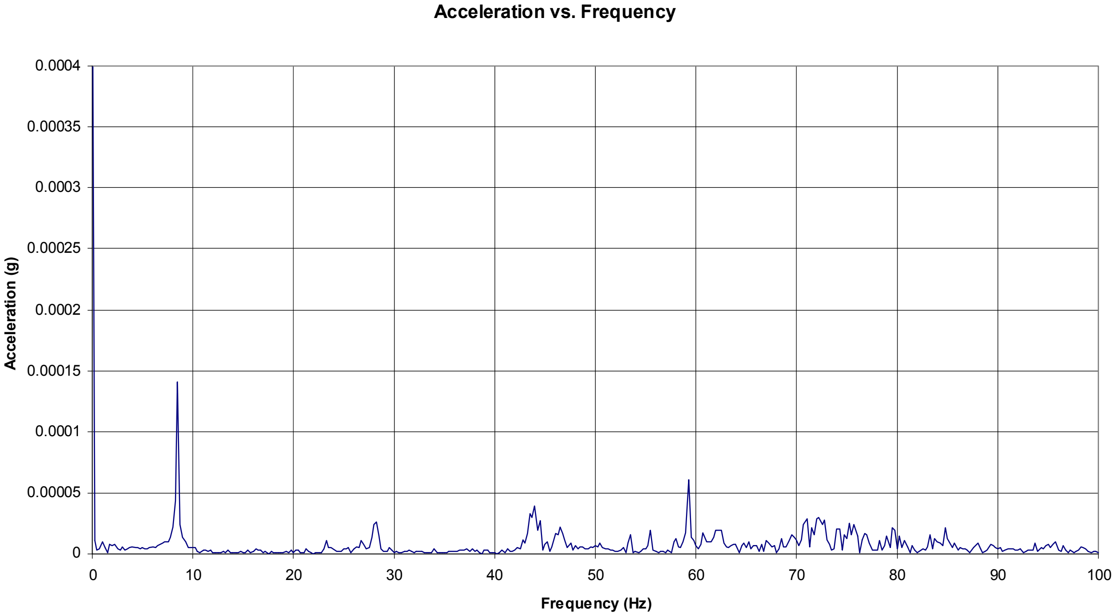




OVERALL	0.00034	g		
0-P:	1.484	s	0.052	%g
1ST:	8.50	Hz	0.013	%g
2ND:	59.25	Hz	0.007	%g
3RD:	77.50	Hz	0.006	%g

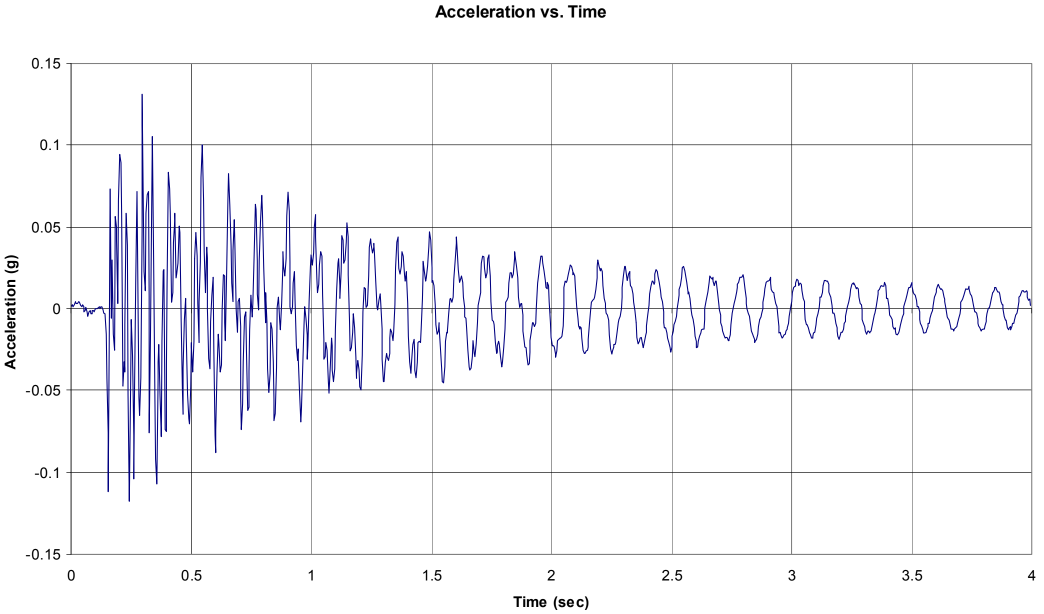
Record No. : 260-262
Building : Static Test Panel
Accelerometer Location : Center Line, Mid-span
Excitation : Ambient Case

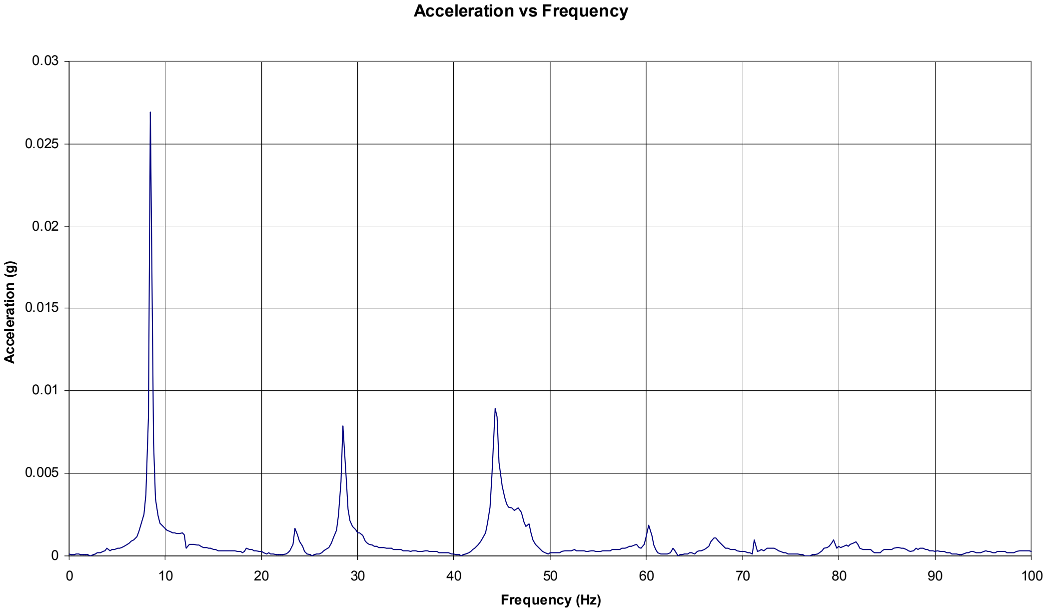




OVERALL	0.00076	g		
0-P:	0.715	s	0.007	%g
1ST:	8.50	Hz	0.014	%g
2ND:	59.25	Hz	0.006	%g
3RD:	44.00	Hz	0.004	%g

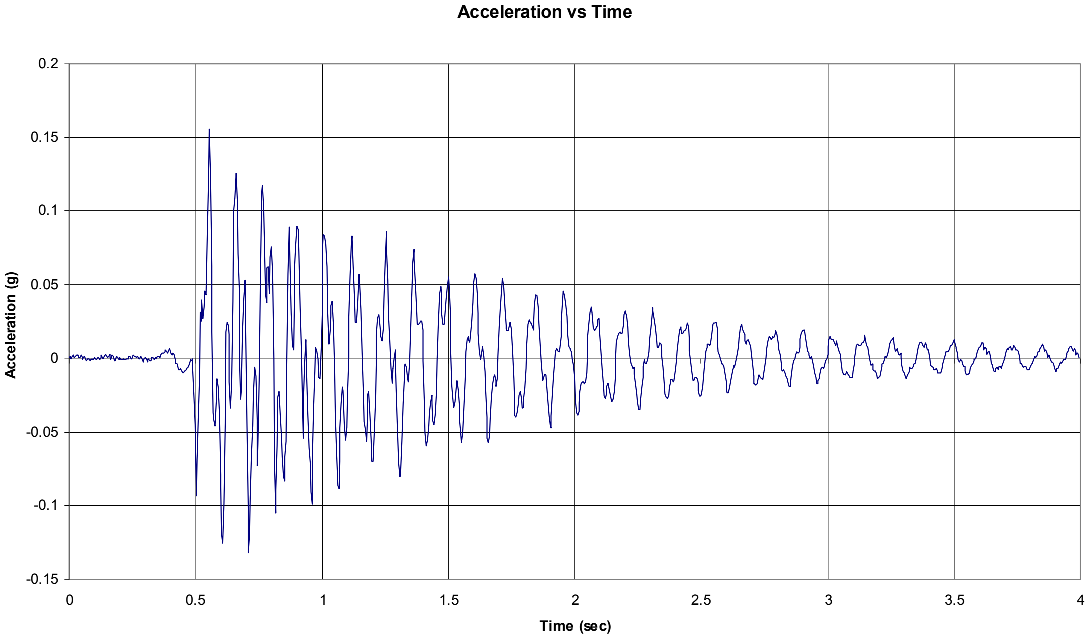
Record No. : 263-265
Building : Static Test Panel
Accelerometer Location : Center Line, Mid-span
Excitation : Onur - Heel Drop on North Edge, Mid-span

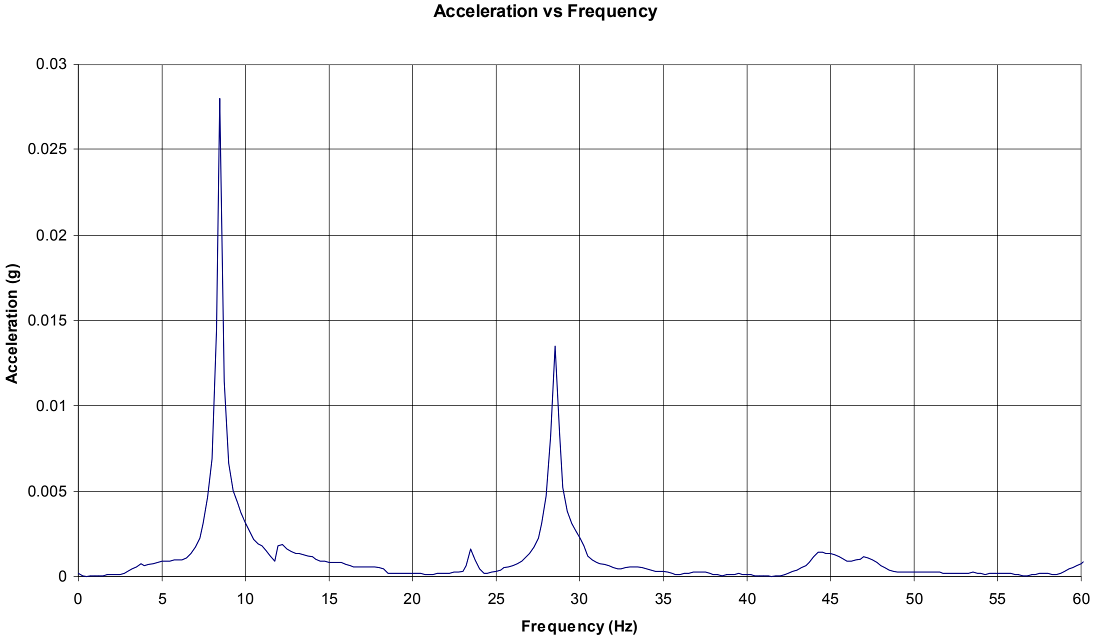




OVERALL	0.03795	g		
0-P:	0.297	s	13.100	%g
1ST:	8.50	Hz	2.689	%g
2ND:	44.25	Hz	0.895	%g
3RD:	28.50	Hz	0.791	%g

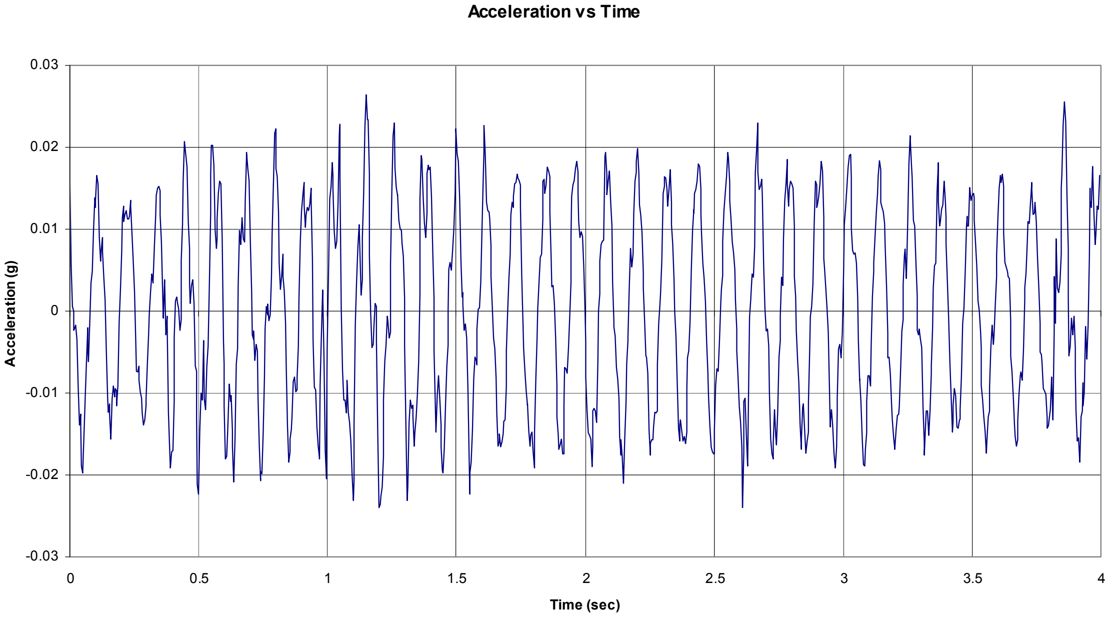
Record No. : 266-268
Building : Static Test Panel
Accelerometer Location : Center Line, Mid-span
Excitation : Onur - Heel Drop on South Edge, Mid-span

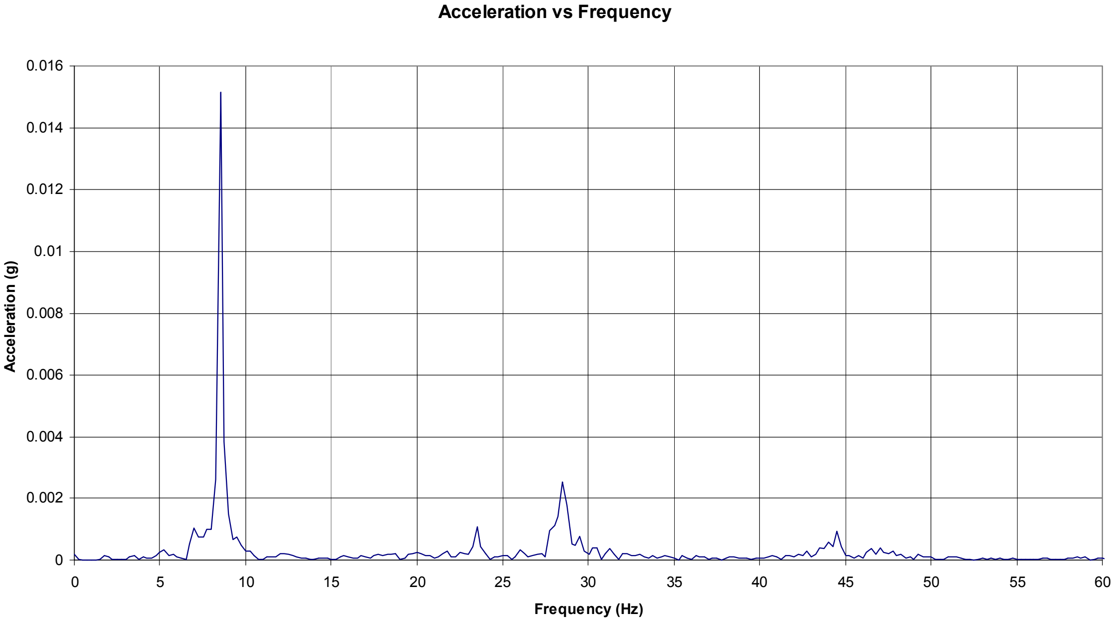




OVERALL	0.04324	g		
0-P:	0.555	s	15.550	%g
1ST:	8.50	Hz	2.800	%g
2ND:	28.50	Hz	1.353	%g
3RD:	12.25	Hz	0.185	%g

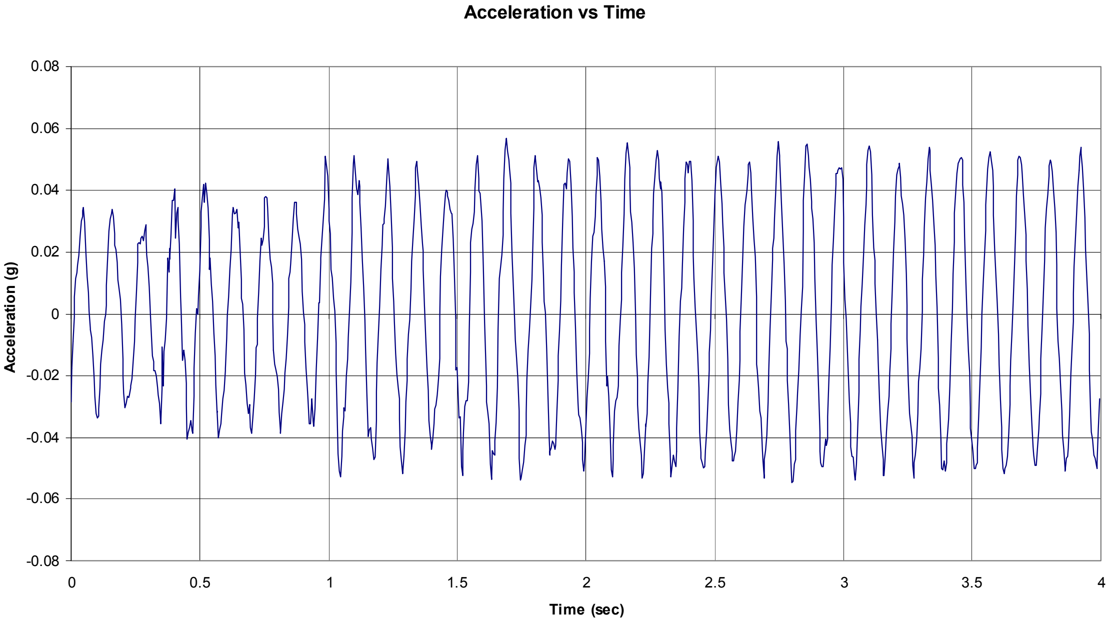
Record No. : 269-271
Building : Static Test Panel
Accelerometer Location : Center Line, Mid-span
Excitation : Onur - Walking on South Edge at 104 BPM

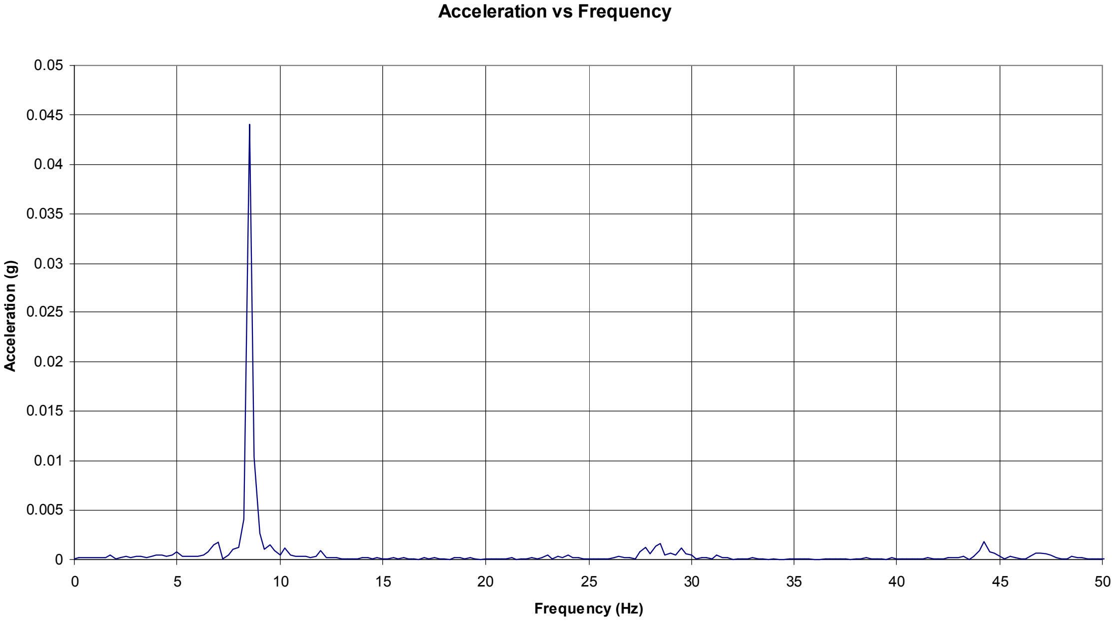




OVERALL	0.01686	g		
0-P:	1.148	s	2.646	%g
1ST:	8.50	Hz	1.514	%g
2ND:	28.50	Hz	0.252	%g
3RD:	23.50	Hz	0.107	%g

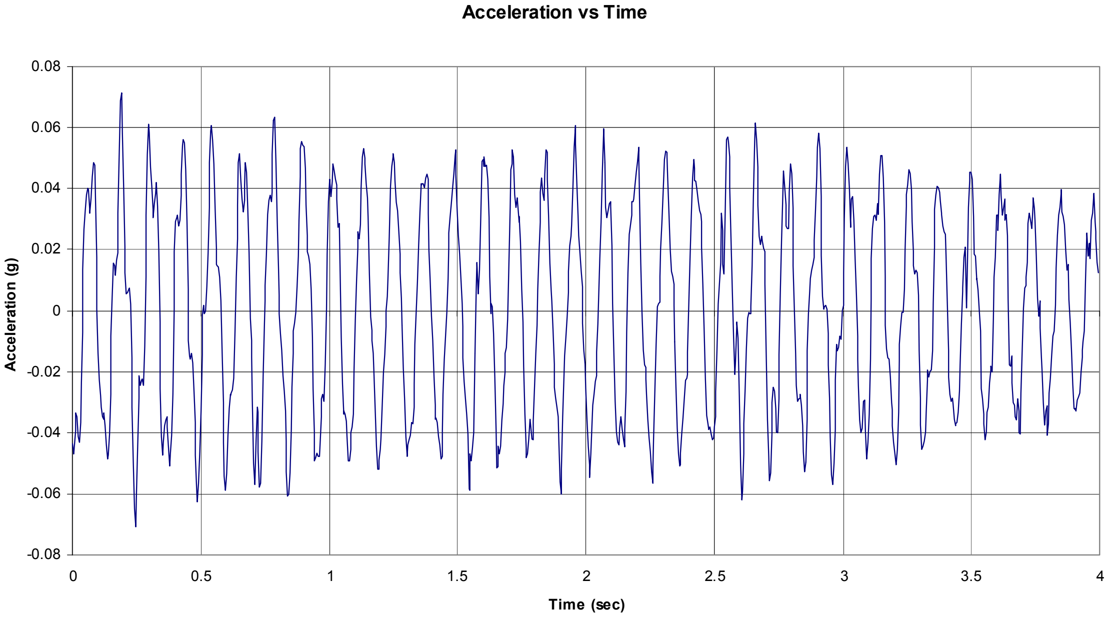
Record No. : 272-274
Building : Static Test Panel
Accelerometer Location : Center Line, Mid-span
Excitation : Onur - Walking on North Edge at 104 BPM

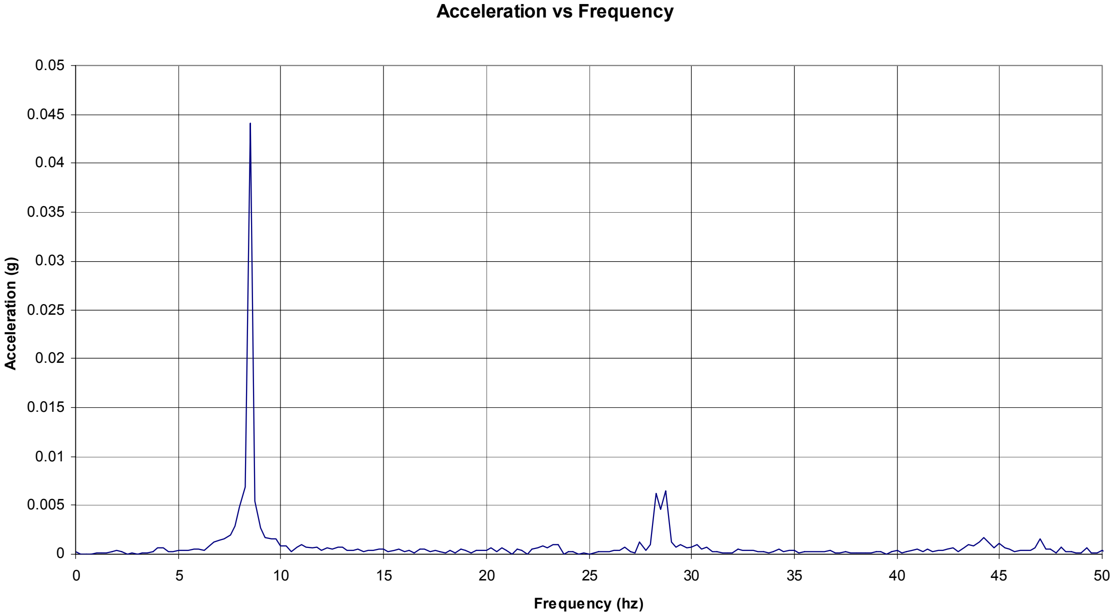




OVERALL	0.04606	g		
0-P:	1.691	s	5.698	%g
1ST:	8.50	Hz	4.410	%g
2ND:	44.25	Hz	0.187	%g
3RD:	7.00	Hz	0.178	%g

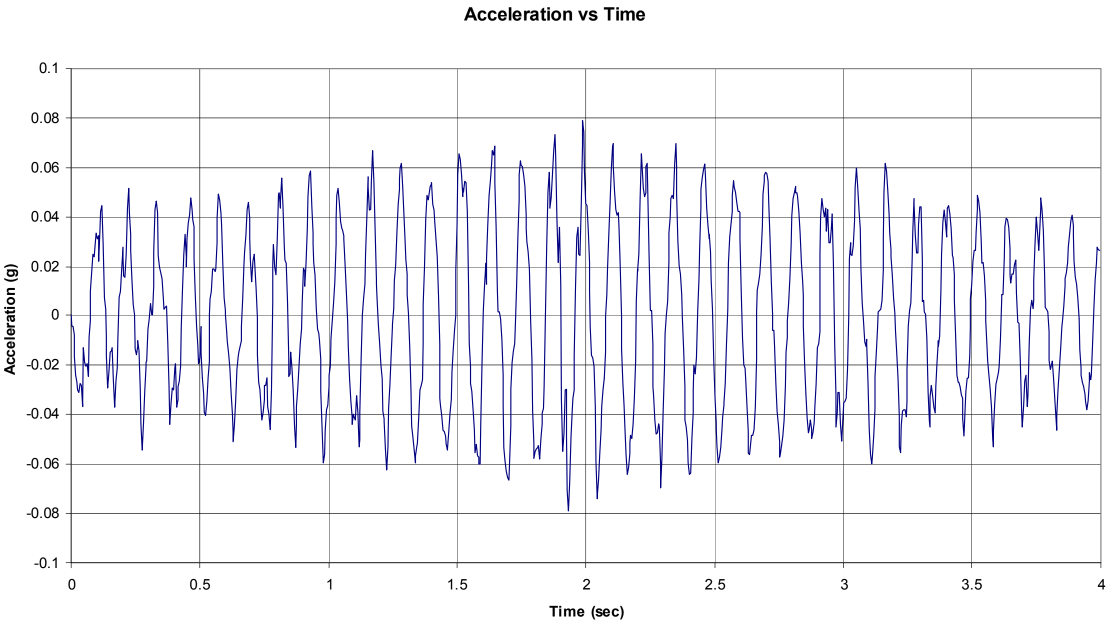
Record No. : 275-277
Building : Static Test Panel
Accelerometer Location : Center Line, Mid-span
Excitation : Onur - Walking on South Edge at 126 BPM

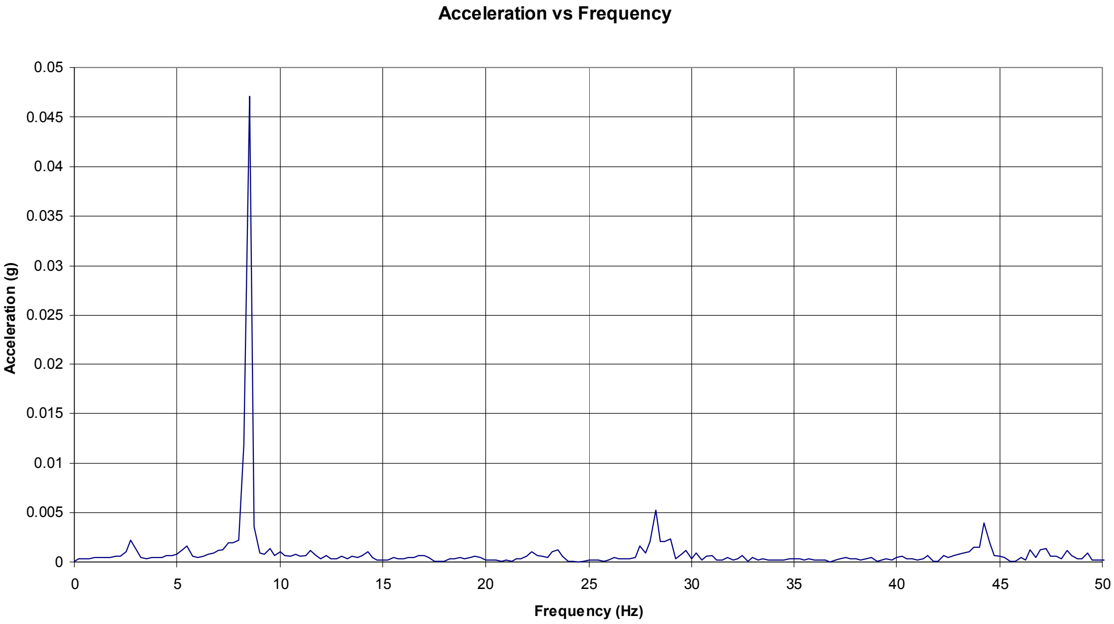




OVERALL	0.04718	g		
0-P:	0.191	s	7.158	%g
1ST:	8.50	Hz	4.407	%g
2ND:	28.75	Hz	0.642	%g
3RD:	28.25	Hz	0.619	%g

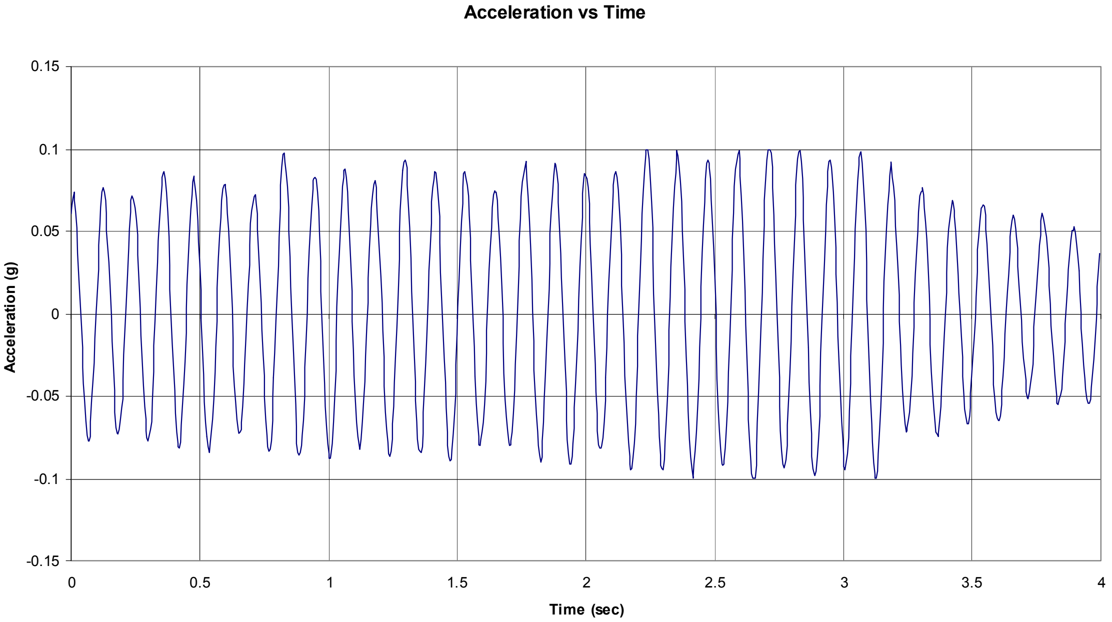
Record No. : 278-280
Building : Static Test Panel
Accelerometer Location : Center Line, Mid-span
Excitation : Onur - Running on South Edge at 168 BPM

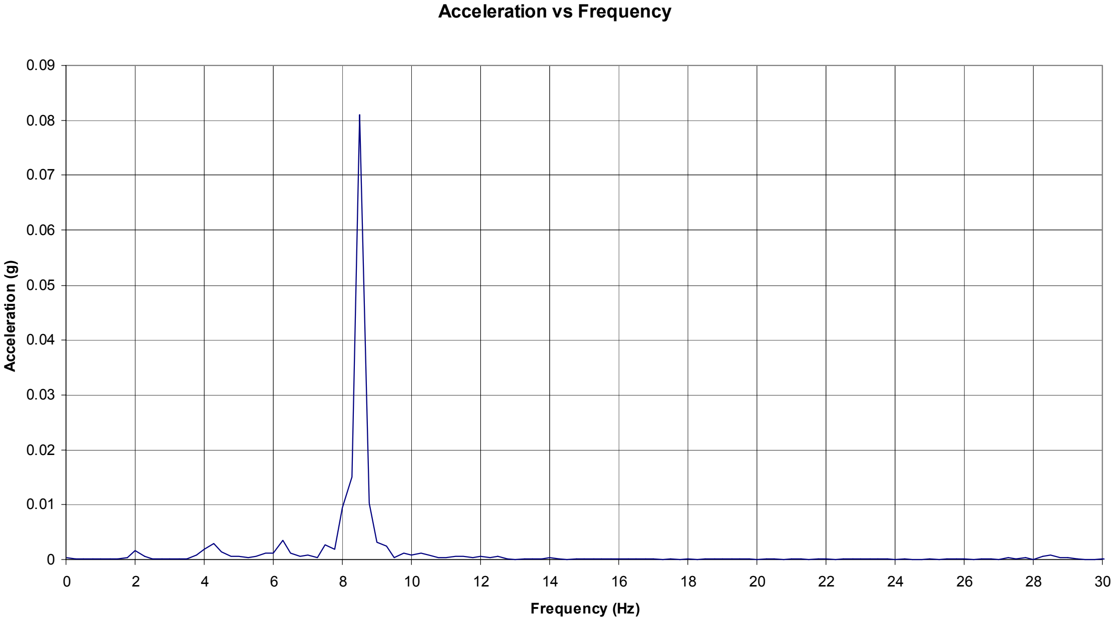




OVERALL	0.05036	g		
0-P:	1.988	s	7.900	%g
1ST:	8.50	Hz	4.707	%g
2ND:	28.25	Hz	0.526	%g
3RD:	44.25	Hz	0.394	%g

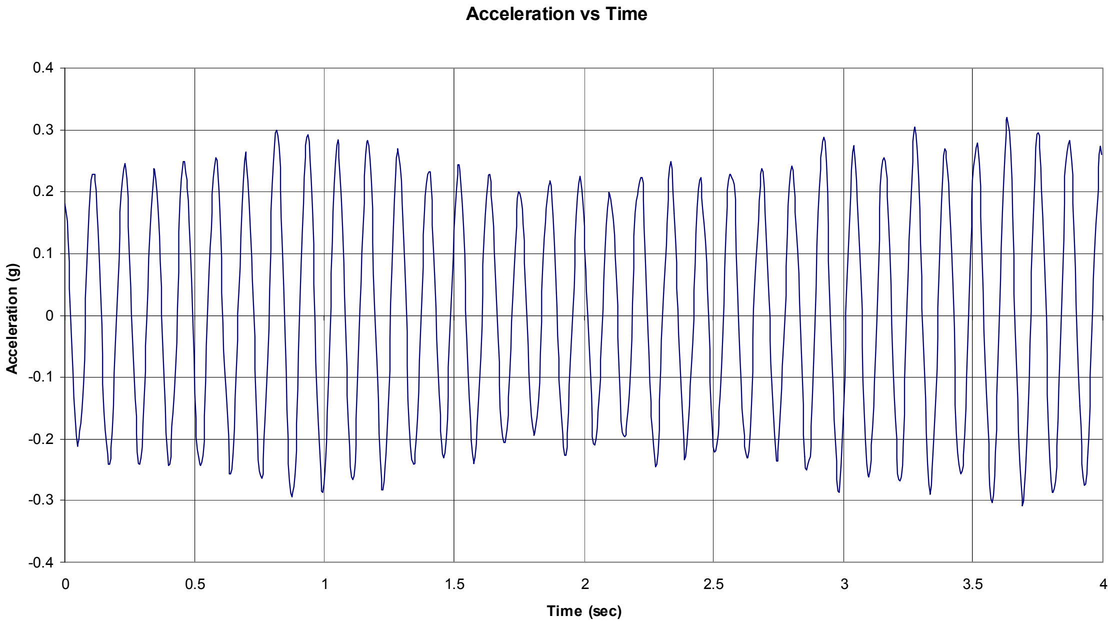
Record No. : 281-283
Building : Static Test Panel
Accelerometer Location : Center Line, Mid-span
Excitation : Onur – Knee Move on South Edge, Mid-span at 128 BPM

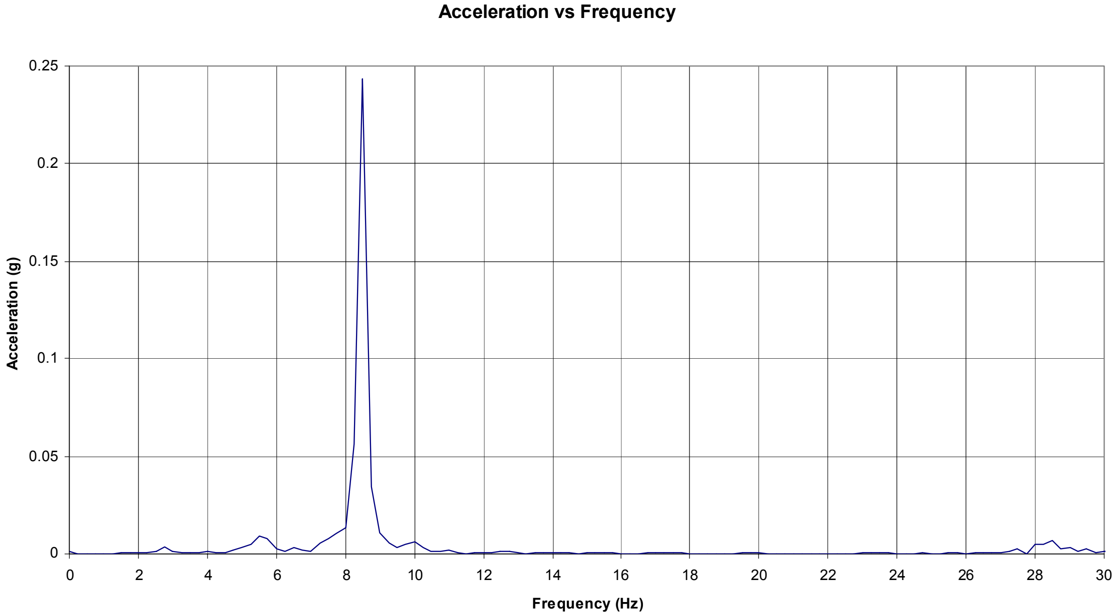




OVERALL	0.08394	g		
0-P:	2.234	s	10.000	%g
1ST:	8.50	Hz	8.090	%g
2ND:	6.25	Hz	0.360	%g
3RD:	4.25	Hz	0.288	%g

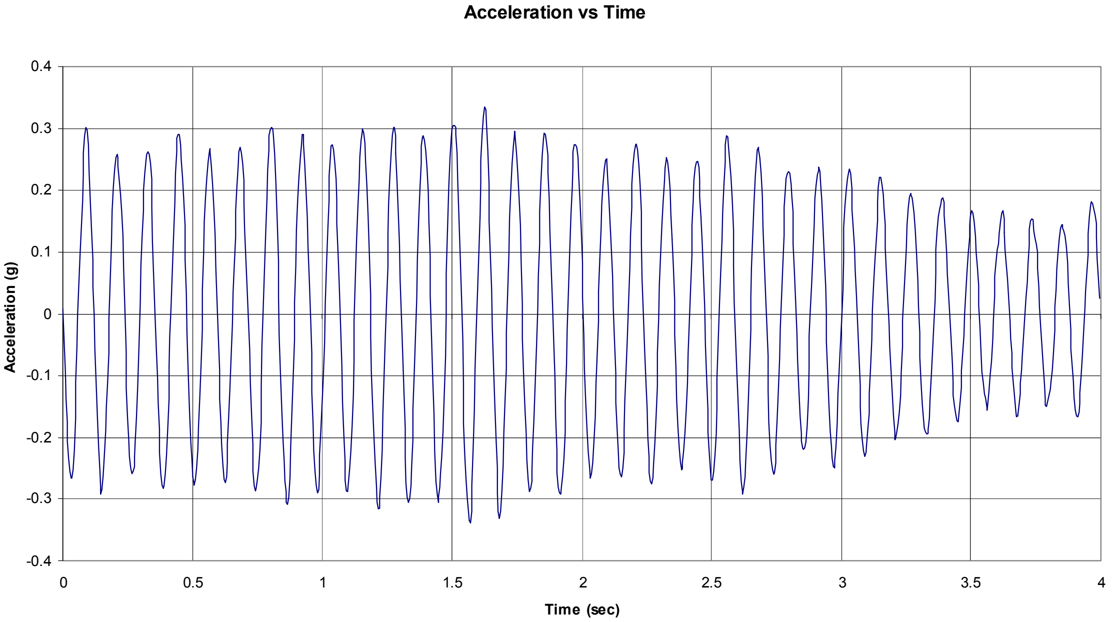
Record No. : 284-286
Building : Static Test Panel
Accelerometer Location : Center Line, Mid-span
Excitation : Onur – Knee Move on South Edge, Mid-span at 168 BPM

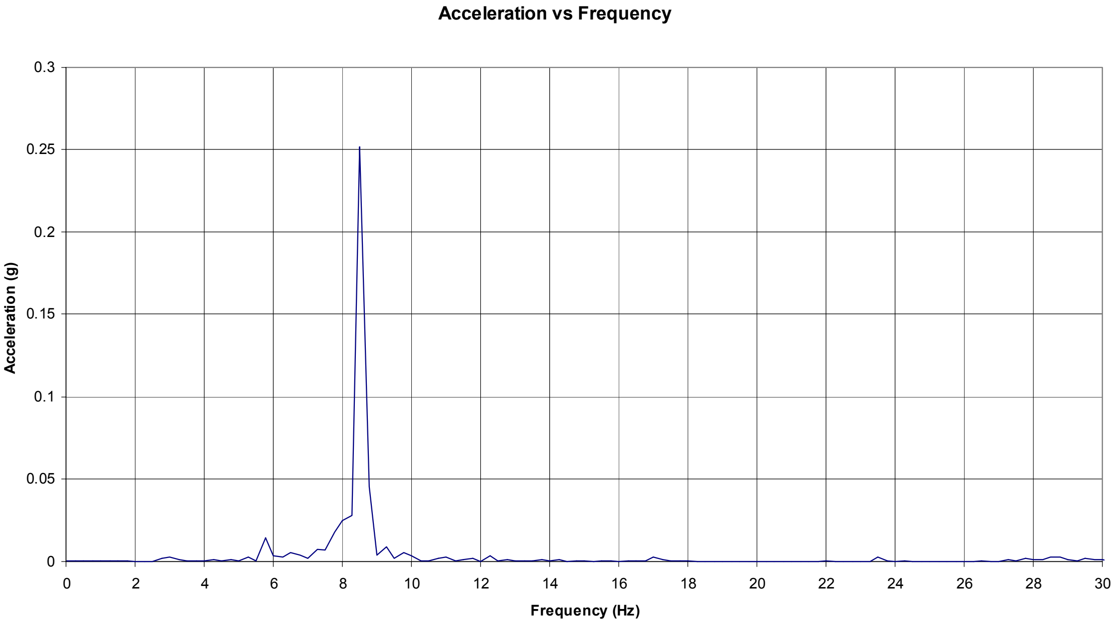




OVERALL	0.25400	g		
0-P:	3.633	s	32.030	%g
1ST:	8.50	Hz	24.340	%g
2ND:	5.50	Hz	0.874	%g
3RD:	28.50	Hz	0.630	%g

Record No. : 287-289
Building : Static Test Panel
Accelerometer Location : South Edge, Mid-span
Excitation : Onur – Knee Move at Mid Span at 168 BPM





OVERALL	0.26040	g		
0-P:	1.625	s	33.540	%g
1ST:	8.50	Hz	25.150	%g
2ND:	5.75	Hz	1.467	%g
3RD:	9.25	Hz	0.875	%g

VITA

James David Martin was born on January 3, 1980 in Knoxville, Tennessee to Jim and Linda Martin. In Spring of 2003, he received a Bachelor's of Science Degree in Civil Engineering from the University of Tennessee. After getting married on August 16, 2003, he began graduate studies at Virginia Polytechnic Institute and State University in pursuit of a Master's Degree in Civil Engineering. He will begin working for Walter P. Moore in Tampa, Florida in mid-April 2005.