Improving Bridge Load Rating Accuracy

By

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UTCA

University Transportation Center for Alabama

The University of Alabama, The University of Alabama at Birmingham, and
The University of Alabama in Huntsville

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UTCA Theme: Management and Safety of Transportation Systems

University Transportation Center for Alabama

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16. Abstract

   Nearly one-quarter of Alabama's bridges are deemed structurally deficient or functionally obsolete. An additional seven percent of Alabama's bridges were posted bridges in 2010. (Federal Highway Administration, 2011) Accurate bridge load rating can potentially reduce, and even remove, bridge postings throughout the state. Analytical structural bridge models were used to define new load ratings for ALDOT Bridges 005248, 005318, and 012296.

   With past methodology, Engineers' ratings tend to be inaccurate. This is due to the indefinite information in regards to actual traffic loading on bridges. This inaccuracy can lead to either over-estimates of bridge safety or excessive conservatism in repairs. Gaining further knowledge regarding the actual behavior of bridges with the help of analytical models can help reduce inaccuracy in calculations.

   The University Transportation Center for Alabama (UTCA) tasked The University of Alabama at Birmingham (UAB) to develop and verify analytical models from which accurate load rating could be obtained. ALDOT performed load testing and calculated ratings for bridges 005248 and 005318. The UAB team worked with ALDOT in gathering strain data for bridge 012296 via the Bridge Weigh-In-Motion (BWIM) technique. Bridge models for 005248 and 005318 proved capable of accurate load rating per data comparison as presented, and 012296 was load rated using Finite Element Modeling.

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Executive Summary

Nearly one-quarter of Alabama's bridges are deemed structurally deficient or functionally obsolete. An additional seven percent of Alabama's bridges were posted bridges in 2010. (Federal Highway Administration, 2011) Accurate bridge load rating can potentially reduce, and even remove, bridge postings throughout the state. Analytical structural bridge models were used to define new load ratings for ALDOT Bridges 005248, 005318, and 012296.

With past methodology, Engineers' ratings tend to be inaccurate. This is due to the indefinite information in regards to actual traffic loading on bridges. This inaccuracy can lead to over-estimates of bridge safety or on the contrary, excessive conservatism in repairs. Gaining further knowledge on the actual behavior of bridges with the help of analytical models can help reduce inaccuracy in calculations.

The University Transportation Center for Alabama (UTCA) tasked The University of Alabama at Birmingham (UAB) to develop and verify analytical models from which accurate load rating could be obtained. ALDOT performed load testing and calculated ratings for bridges 005248 and 005318. The UAB team worked with ALDOT in gathering strain data for bridge 012296 via the Bridge Weigh-In-Motion (BWIM) technique. Bridge models for 005248 and 005318 proved capable of accurate load rating per data comparison as presented, and 012296 was load rated using Finite Element Modeling.

Section 1 - Introduction

Field data provided was used to calibrate and modify structural models in SAP2000 for representation of actual bridge behavior. The resulting models for the three bridges considered were used for load rating. After appropriate calibration, they can also be used for permit load or overload stress predictions. Additionally, lateral load distribution can be predicted using the calibrated structural models.

In reality, bridges are rarely statically determinate. Complex behavior seen by the reinforced concrete slabs and beam-slab bridges prevents traditional beam analysis and load distribution factoring approaches from accuracy. Geometry and secondary stiffening effects mainly control the behavior of bridges under traffic load. Skew and beam spacing-to-span length ratios largely influence load distribution along the bridge.(Yost, Schulz, & Commander, 2005) End restraints greatly influence the moment seen by the bridge girders, and these restraints will be controlled to mirror actual bridge behavior.

There were three bridges modeled and analyzed for this project. The first bridge modeled was ALDOT Bridge 005248, which crosses the Tallapoosa River and connects SR-49 in Dadeville, AL. The second bridge, ALDOT Bridge 005318 connects State Road 145 and spans the Waxahatchee Creek in Shelby County, AL. The last bridge studied was Bridge 012296, located near the I-459 and SR-150 interchange (Exit 10) in Birmingham, AL. Each bridge was modeled and modified as mentioned above, and the results were recorded.

1.1 Objective

The objective of this report is to prove that finite element analysis software, such as

SAP2000, can be used to model bridges in the state of Alabama for load rating purposes.

ALDOT currently uses software such as BRUFEM and VIRTIS to determine load-rating

factors for bridges. Load rating values for bridges 005248 and 005318 have been

provided along with calculation for comparison with those obtained through finite

element analysis software. Once the load rating values calculated from results in

SAP2000 are deemed accurate, one can safely assume that the load rating values for

Bridge 012296 are precise. ALDOT will then have evidence that other bridges

throughout the state can be modeled and calibrated providing an economical means for

load rating and permitting. UTCA wishes to use the findings in this report to verify that

analytical models can be used as a more accurate load rating technique, potentially

reducing or removing bridge postings in Alabama.

1.2 Report Organization

The report has been organized in a manner to effectively guide the reader through the

load rating process and findings for each bridge. First, load rating methodology and

concepts are explained. Then each bridge model is presented with calibration results

versus experimental data provided by ALDOT. All moments and strains obtained through

SAP2000 are provided in conjunction with the experimental values via graphical

representation. After appropriate calibration evidence is delivered, load-rating values are

calculated and compared with ALDOT's results.

1.3 Task Description

1.3.1 Task 1 – Data Examination

Visual examination of experimental data (via BWIM and ALDOT) is the first step in qualitative assessment of the structure. Strain data values provide the engineer with a feel for member cross-section definition and response behavior. Other preliminary tasks include noting the peak strain values and girder member properties. With this information, a reasonable initial model can be formed with appropriate parameters and boundary conditions. This step is imperative for an initial evaluation of the structure's performance and crucial for effective completion of model calibration.

1.3.2 Task 2 – Generate Bridge Model

The finite element analysis program used was SAP2000. Computers and Structures, Inc. provides SAP as a means for structural design and analysis for a variety of buildings, bridges, and other structures. Distribution factors when loading the bridge will not be used in bridge calibration, because the models represent existing structures. The use of distribution factors is reasonable in design, because they provide safety measures for all conditions.(American Association of State Highway and Transportation Officials, 1996) Since the bridges are existing structures, more sophisticated loading measures were used to result in more accurate bridge behavior and load rating factors.

1.3.3 Task 3 – Verification with Experimental Data

Experimental data was gathered from two sources: BWIM data performed by UAB and ALDOT provided values. Values obtained from the SAP model are to be compared with this experimental data to provide visual and statistical information.

1.3.4 Task 4 – Application of Rating Loads

After appropriate calibration of bridge models with experimental data, wheel loads for HS20-44 trucks are applied to the model. Results from loading the model are used to compute the Rating Factors. An accurate model will provide the engineer with accurate bridge response behavior when standard design loads, rating vehicles, or permit loads are applied to the structure. The developed structural model will be used for the following:

- Providing a more accurate structural model

- Be used for load rating and permitting

- Prediction of Lateral Load Distribution

- Enabling of funds to target truly unsafe bridges

- Prove beneficial to maintenance efforts and bridge design

An illustrative process of the approach for bridge modeling and assessment has been provided below.
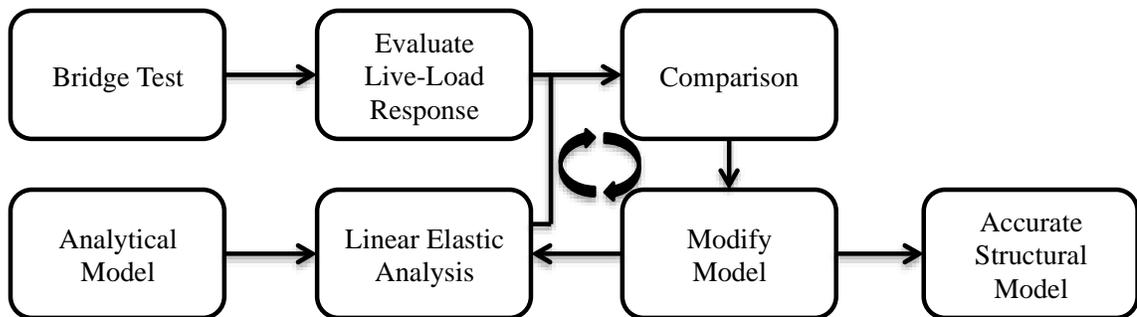
Figure 1: Illustration of Integrated Approach to Project Tasks

Section 2 – Load Rating Methodology

Load rating was determined using the Standard AASHTO "HS" loading method in accordance with the 17th Edition (2002) of Standard Specifications for Highway Bridges. Lane loading was performed using an AASHTO HS20-44 truck in conformance with AASHTO Specifications. The axle loads were distributed into two point loads representing the left and right tires, respectively. The position of the resultant load of two load cases was determined. This resultant load was placed in the center of the bridge, and each lane was loaded accordingly.

The first load case evaluated included only the resultant of one truck per lane. The resultant position of two trucks spaced two feet apart was calculated and placed in the center of the bridge for the second load case. The load case that produced the maximum moment was regarded as controlling for load rating. Each bridge was loaded to result in the largest moment experienced by any girder. This moment was then used in accordance with the AASHTO Standard Specification for load rating. Both Allowable Stress Rating and Load Factor Rating were performed.

AASHTO rating truck HS20-44 axle loads and resultant forces have been included. Provided clearance dimensions for the truck were also used for determination of load positions in the model. All figures representing these locations are included below the following explanation of rating levels and methods.

2.1 Rating Levels

Each highway bridge is to be rated at two separate levels. These levels are distinguishable as the Inventory Rating Level (IRL) and the Operating Rating Level (ORL). The Inventory level replicates existing conditions of the bridge, such as material and section deterioration. However, IRL corresponds with initial design level of stresses, and this allows for comparison with capacity for new structures. This provides a live load deemed safe for the existing bridge for future awareness when additional loads are considered. The ORL generally describes a live load that can be considered a maximum permissible load for the bridge to experience. Allowing the bridge to experience this maximum permissible load indefinitely can significantly shorten the life of the bridge.(American Association of State Highway and Transportation Officials, 2011)

2.2 Rating Methods

Two rating methods were considered in the report. These include the Allowable Stress Rating (ASR) and the Load Factor Rating (LFR). Although similar, these two rating methods have significant differences in purpose. The ASR method, also known as the working stress method utilizes actual loads on the members to determine the maximum stresses experienced by each member. These stresses must not surpass the member allowable stress after application of a safety factor. The LFR method uses different factors that are applied to account for uncertainty in load calculations. The rating is performed to ensure that the factored loading does not exceed the strength of the member.
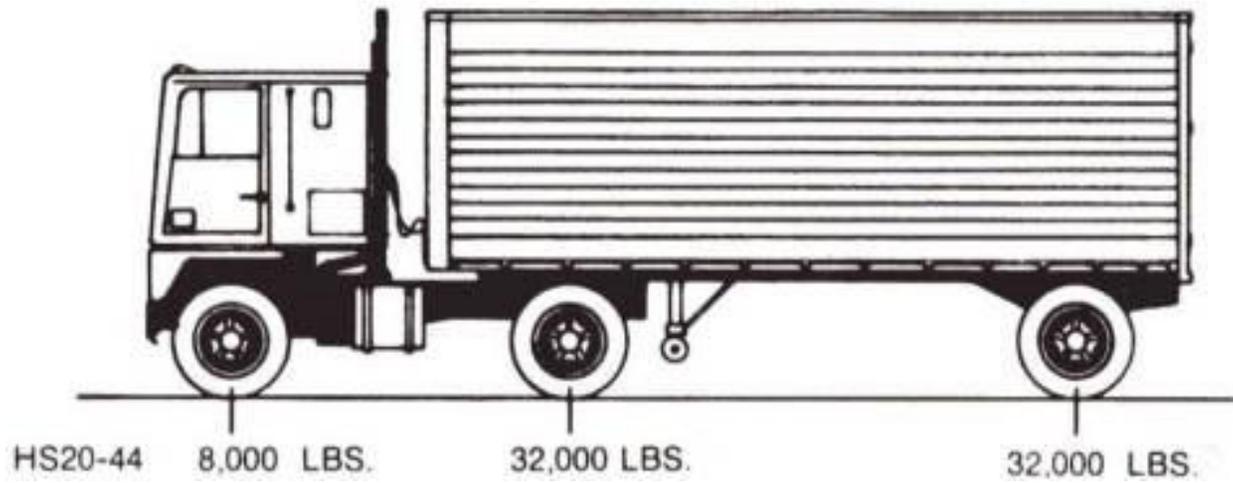
Figure 2: Standard Axle Loads for HS20-44 Truck
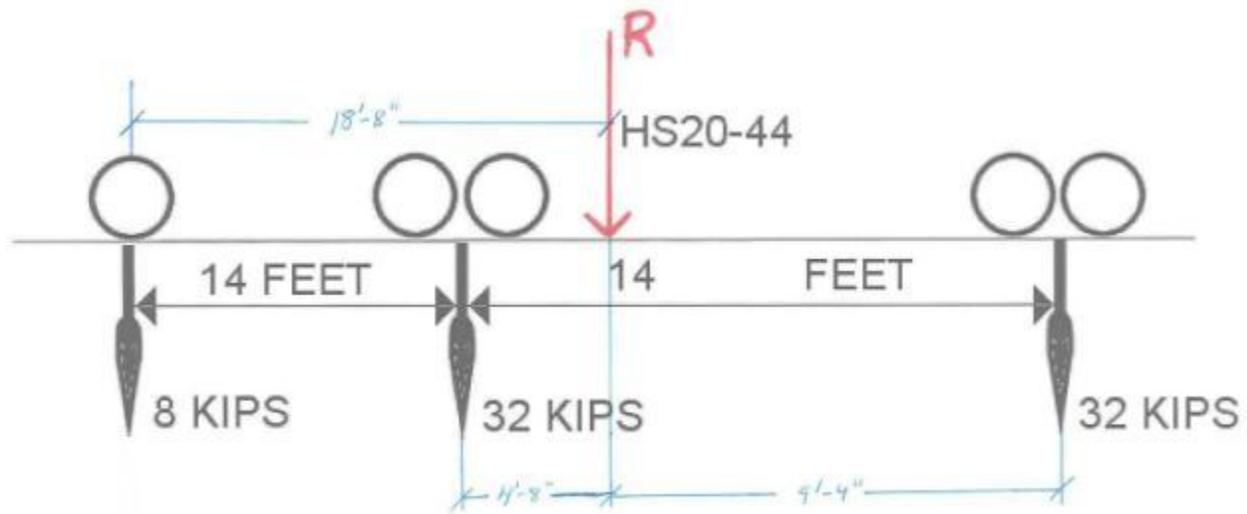
Figure 3: Load Resultant Location for Single HS20-44 Truck

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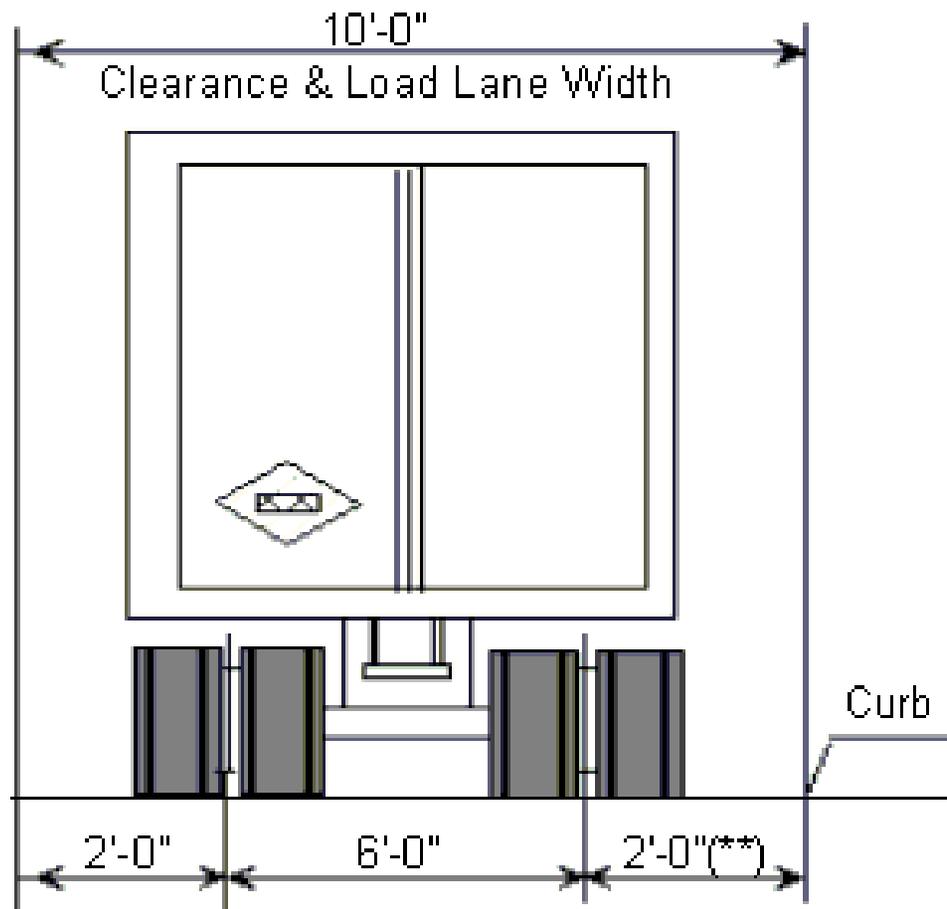
Figure 4: Standard Spacing Requirements for HS20-44 Truck

2.3 Rating Equation

A general rating equation is used for load rating via the Allowable Stress Method and the Load Factor Method. The general expression is used regardless of the method used for load rating. The general expression is as follows:

Equation 1: General Rating Factor Equation

_____

Table 1: Rating Factor Equation Coefficient Signification

Coefficient	Signification
RF	Rating Factor for live load carrying capacity
C	The capacity of the member
D	The dead load effect on the member
L	The live load effect on the member
I	The impact factor to be used with live load effect
A_1	Factor for dead loads (AS=1.0; LF=1.3)
A_2	Factor for live loads (AS=1.0; LF "IRL"=2.17; LF "ORL"=1.3)

The rating factor is the desired value for comparison with provided information. The capacity of the member, C, is dependent on section and material properties. The dead load effect should be correspondent with the existing conditions of the bridge members. The live load effect can be the result for any of the desired load effects, typically axial force, shear force, bending moment, or axial, shear, or bending stress. The impact factor is in accordance with AASHTO Specifications (1.3 for 005248 and 012296, 1.2553 for 005318).

Section 3 – Bridge Analysis

3.1 ALDOT Bridge 005248

3.1.1 Location of Bridge

Bridge 005248 is located in Horseshoe Bend National Historic Military Park near

Dadeville, AL. The bridge spans over the Tallapoosa River, connecting strips of State

Road 49. The bridge is two lanes wide with both steel and concrete girders. For analysis

purposes, the end span with reinforced concrete girders was modeled. The bridge was

constructed in 1955 according to the National Bridge Inventory Database (NBI).
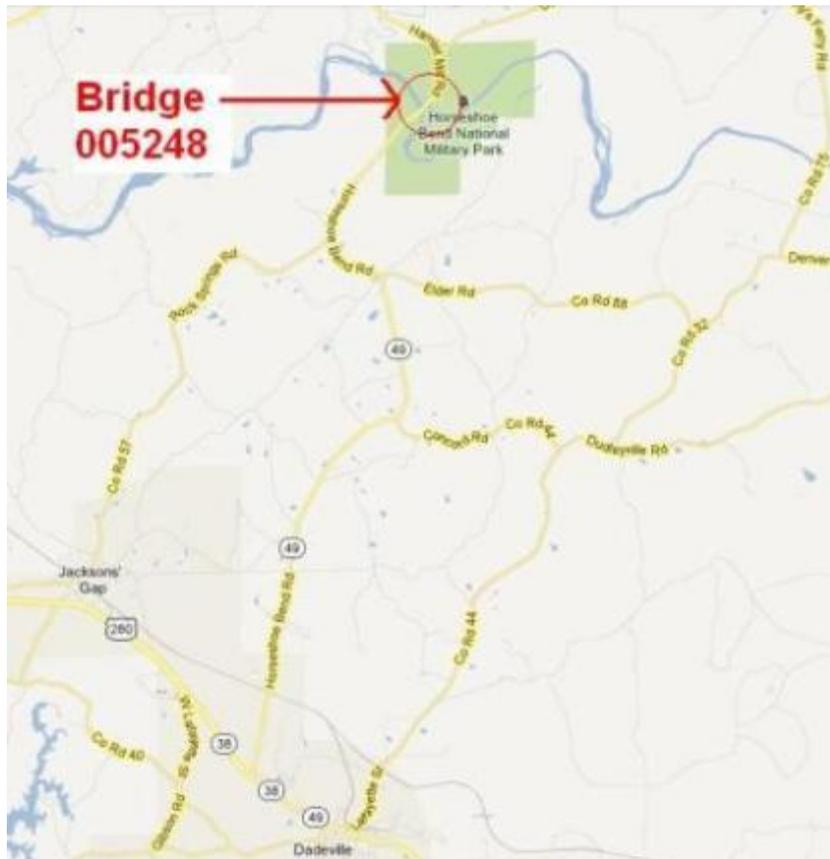
Figure 5: Location of ALDOT Bridge 005248

3.1.2 Bridge Information

Bridge Photos

Figure 6: Photo Along Span for Bridge 005248

Figure 7: Underside View of Bridge 005248

Figure 8: Elevation of 005248 from Original Drawings

Figure 9: Cross Section of 005248 from Original Drawings
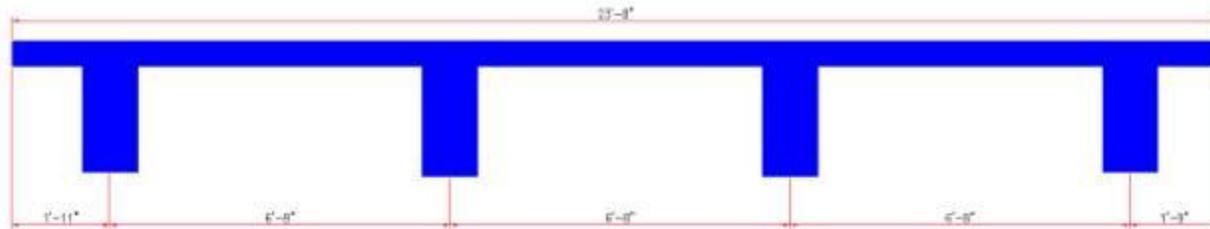
Figure 10: Cross Section of Bridge 005248 in AutoCAD
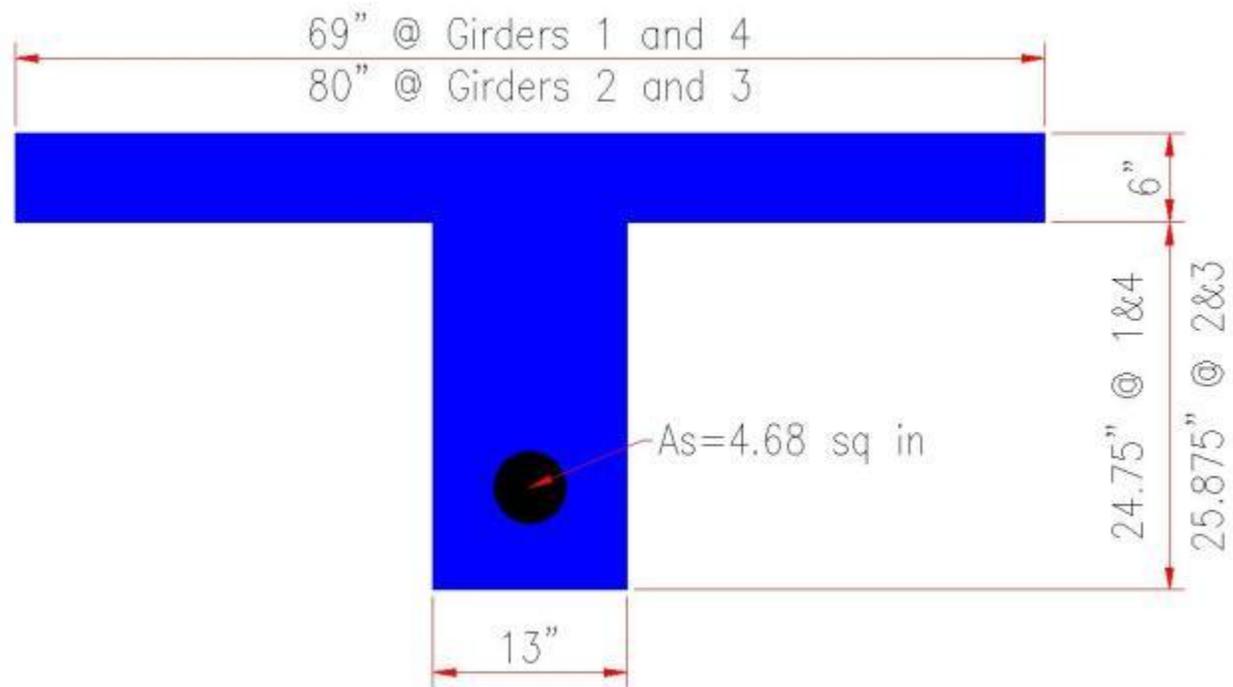
Figure 11: Test Span Girder Section for 005248 in AutoCAD

Sensor Placement

Sensor placement locations were used to determine at which point along the girder

moment information should be gathered to compare with experimental results. Moment

values at this exact location were converted to strain and compared with field values.
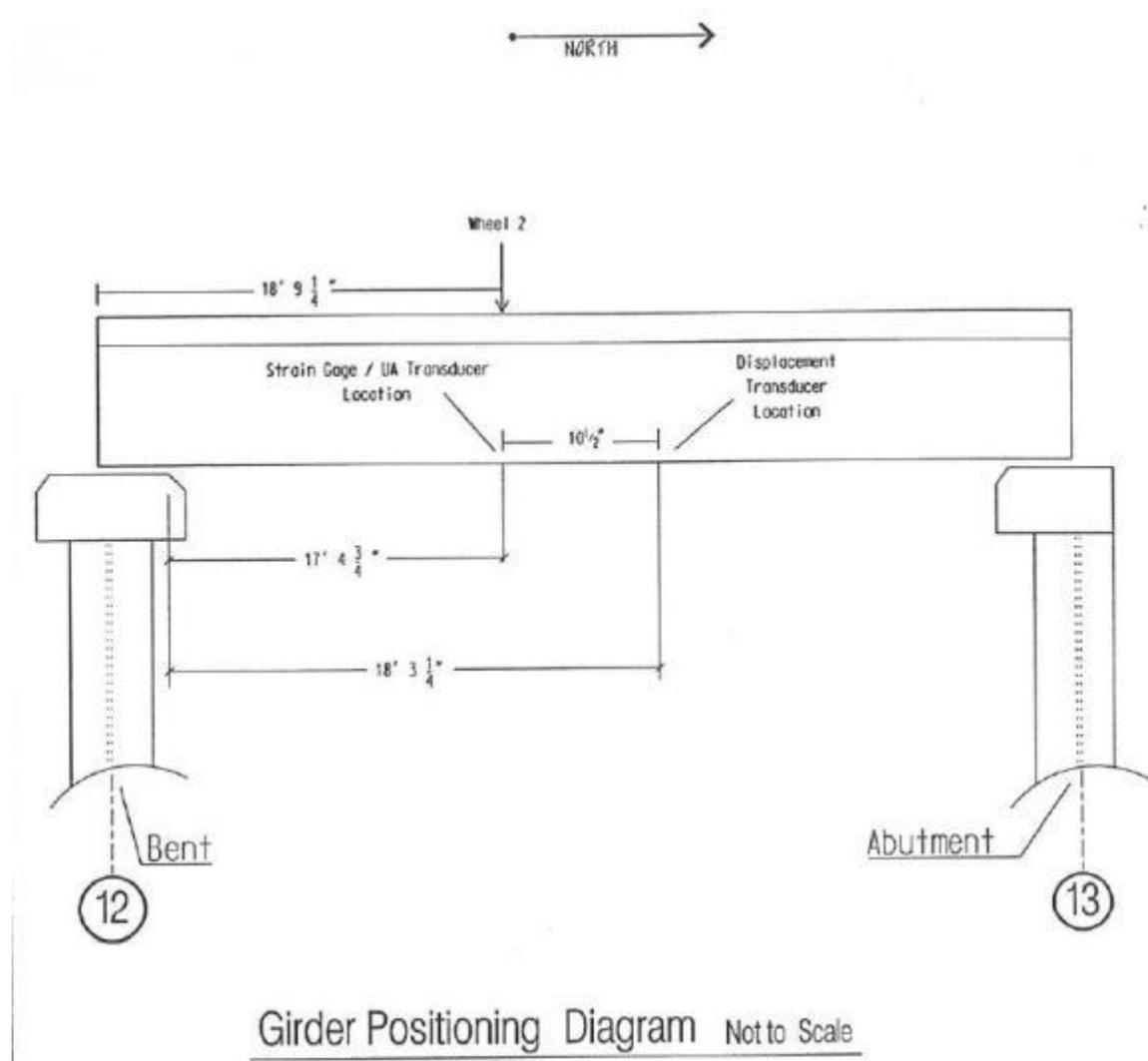
Figure 12: Sensor Location for 005248 Relative to Supports

Figure 13: Sensor Layout Plan View for 005248

3.1.3 Qualitative Assessment of Model

ALDOT had performed an analysis of Bridge 005248 in 2006 with Virtis and BRUFEM. In their analysis, two 3-axle trucks were used for loading on the bridge. The first two axles were spaced at 4'-9.5", and the spacing between the middle and rear axle was 18'-5.5". The axle loads in kips for the front, middle, and rear were 30.15, 32.075, and 22.875, respectively. These loads were used in SAP2000 for result comparison and qualitative assessment.

ALDOT performed five separate positioning cases in analysis. They can be found in the figure below. However, for modeling purposes, only sets 1, 3, and 5 were analyzed in SAP2000. Section properties for each girder and distances used in SAP2000 for loading values are tabulated below.

Table 2: Girder Section Properties for 005248

Girder	*c (in)*	I_x *(in^4)*	b_f(in)
1	20.68	63400	69.0
2	22.31	70443	80.0
3	22.31	70443	80.0
4	20.56	63400	69.0

The ALDOT calculation set includes a figure that portrays the location of the truck for each loading condition. A screenshot of these positions for each of the five sets has been included below. The distances of the point loads used in the SAP models were also tabulated for reference.
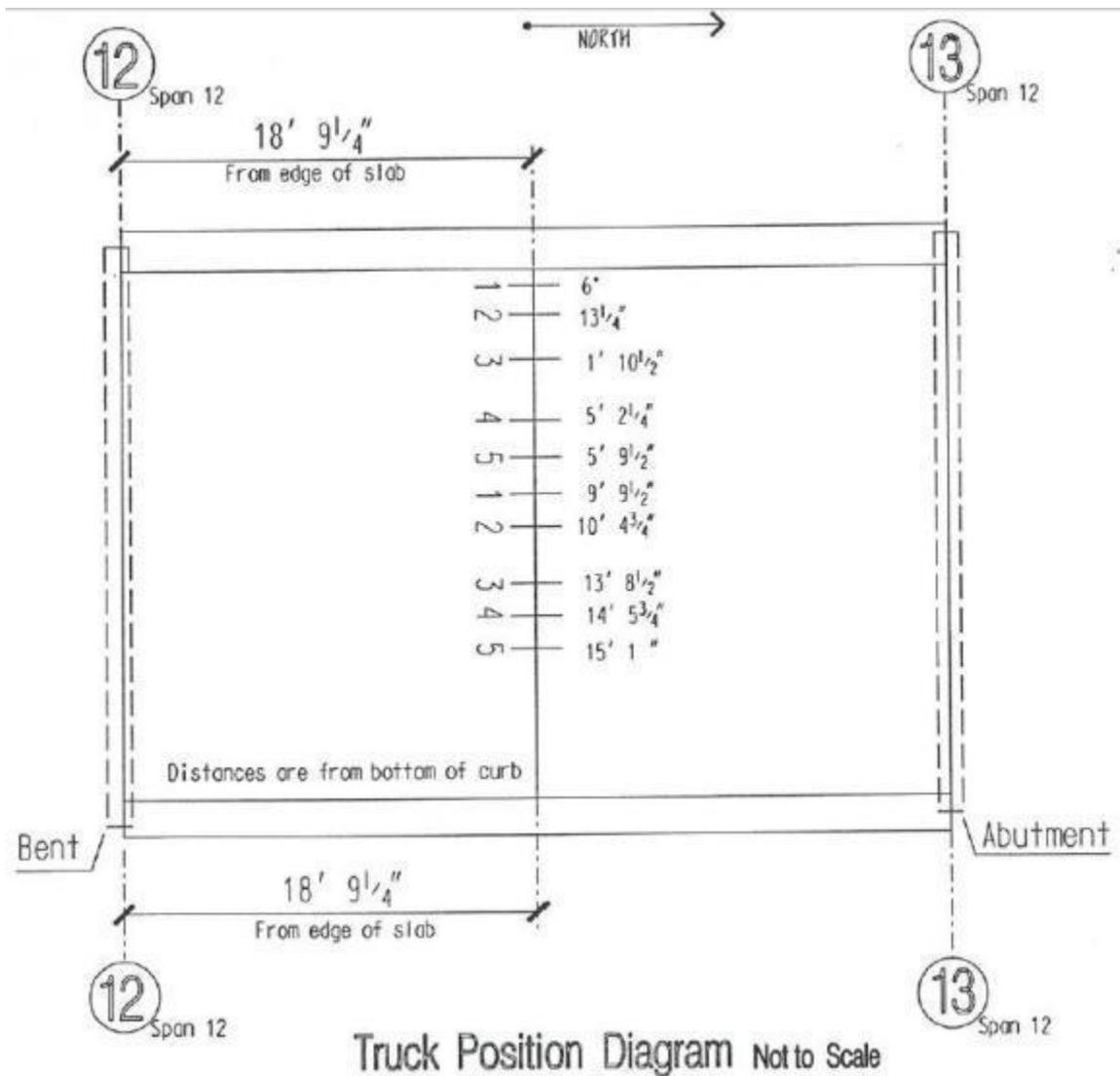
Figure 14: 005248 Truck Positioning Diagram for Analysis

Table 3: Loading Sets for 005248 Model in SAP2000

Set 1		Set 3		Set 5	
Truck 1	*Load Distance from Top of Model (in)*	Truck 1	*Load Distance from Top of Model (in)*	Truck 1	*Load Distance from Top of Model (in)*
Left Tire	23.75	Left Tire	40.25	Left Tire	87.25
Right Tire	98.75	Right Tire	115.25	Right Tire	162.25
Truck 2	*Load Distance from Top of Model (in)*	Truck 2	*Load Distance from Top of Model (in)*	Truck 2	*Load Distance from Top of Model (in)*
Left Tire	134.00	Left Tire	182.25	Left Tire	198.75
Right Tire	209.00	Right Tire	257.25	Right Tire	273.75

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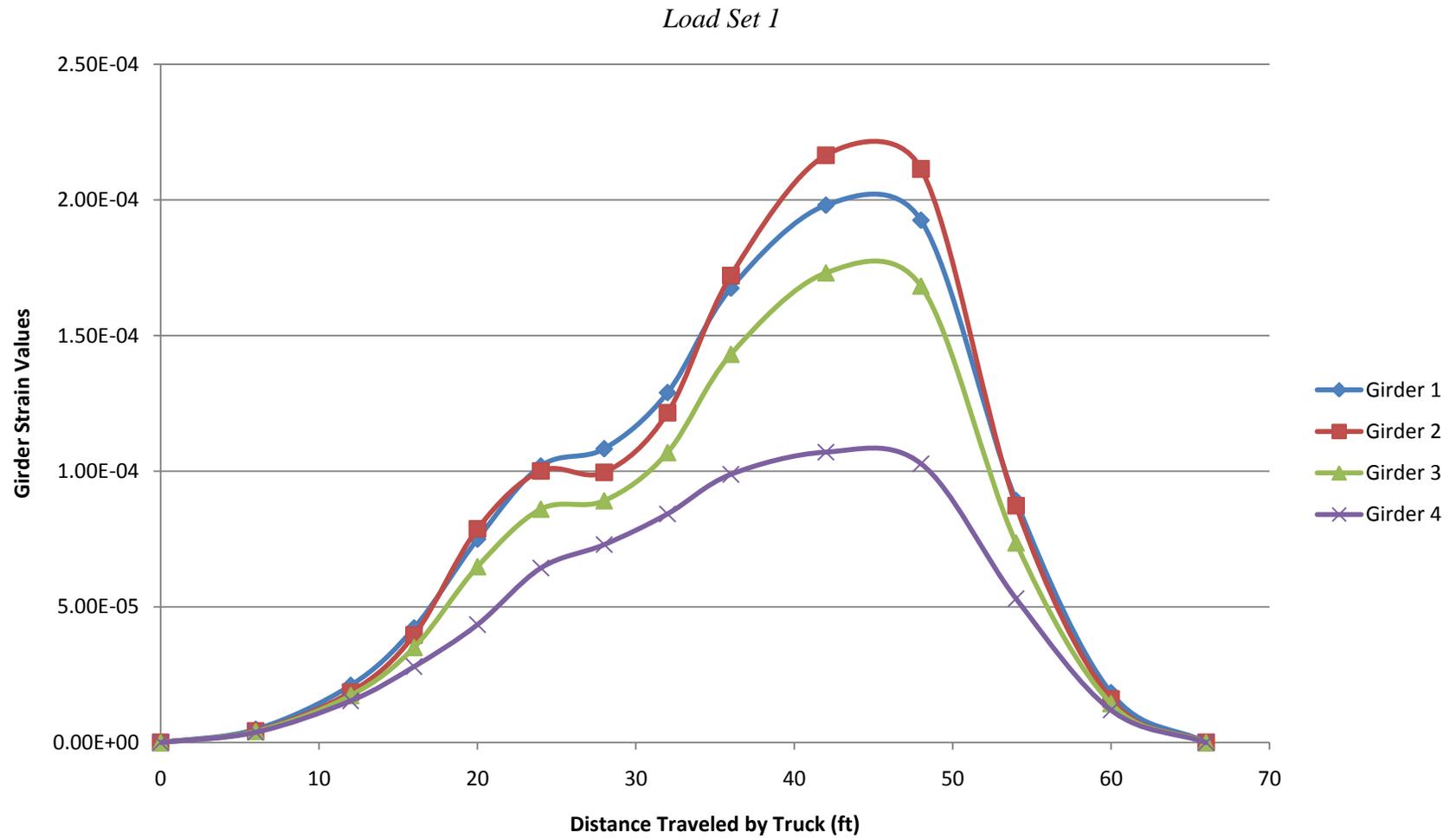
Figure 15: 005248 SAP Model Strains for Load Set 1
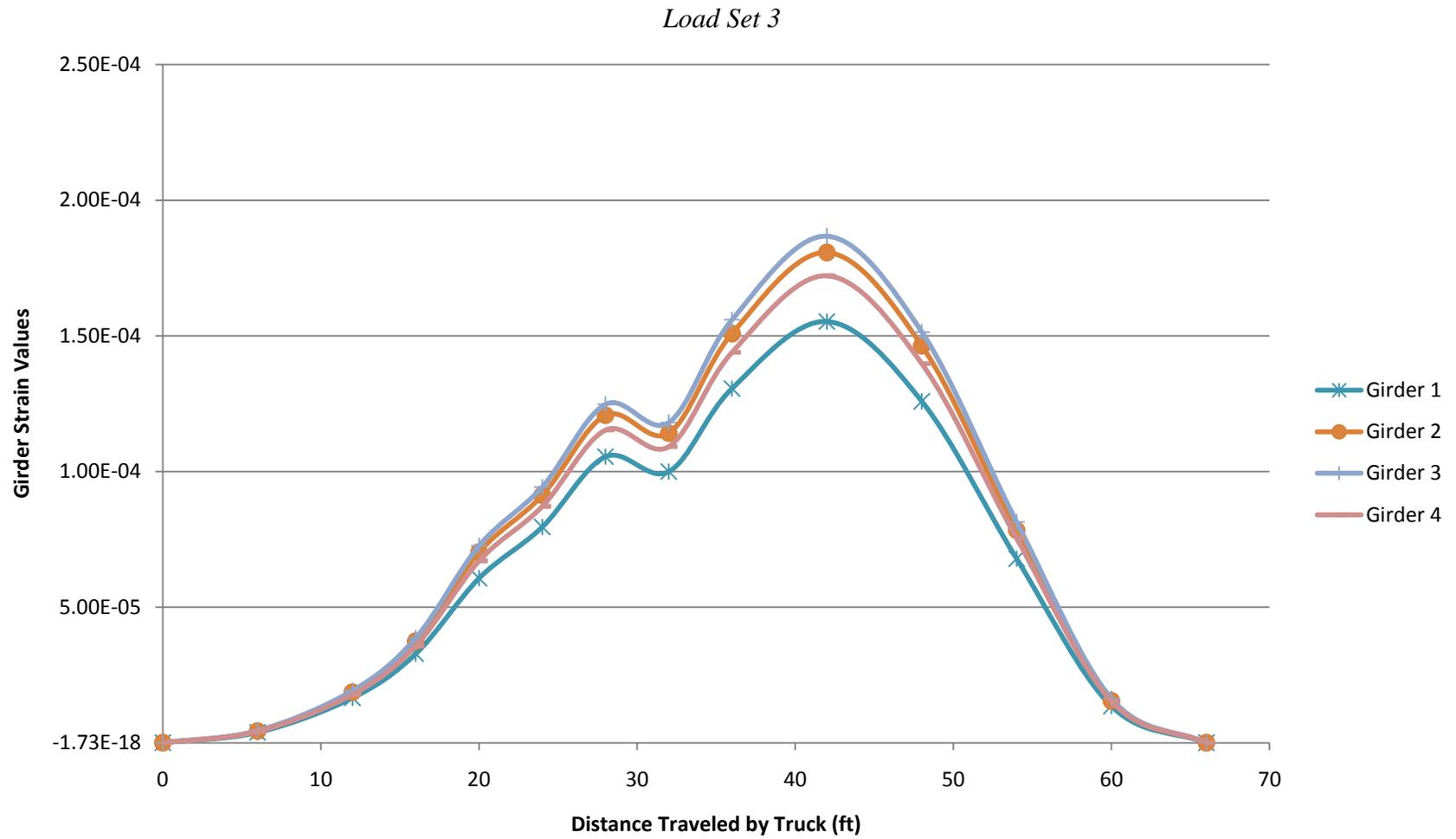
Figure 16: 005248 SAP Model Strains for Load Set 3
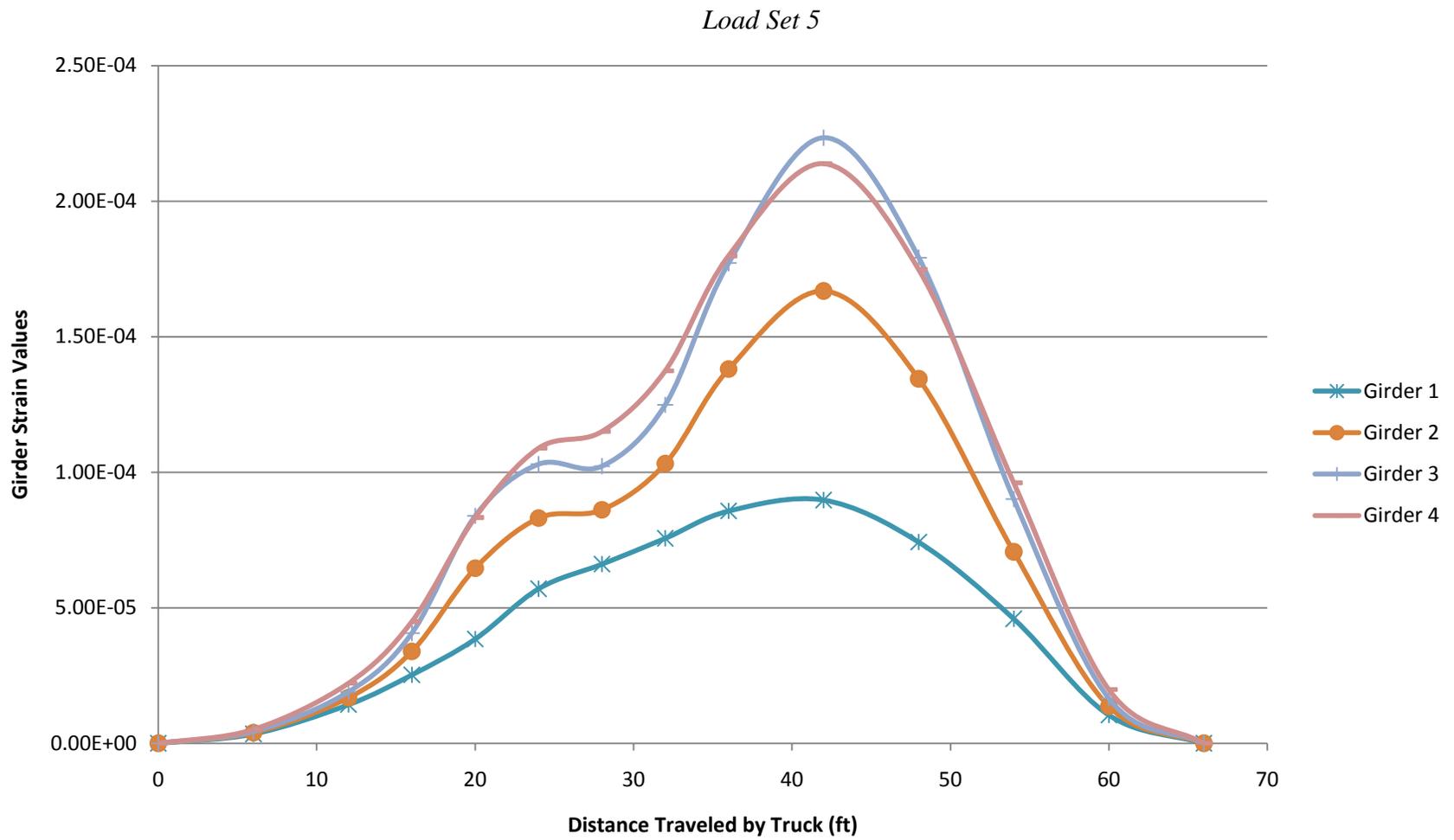
Figure 17: 005248 SAP Model Strains for Load Set 5

3.1.4 Modeling of Bridge in SAP2000

The bridge was modeled using SAP2000, developed by Computers and Structures, Inc. Dimensions and section properties for the bridge were obtained from the information given in construction documents and ALDOT analysis results, and the bridge was modeled as a true grid in SAP2000. Section properties were then defined for each frame modeled. All concrete was modeled with a compressive strength of 3000psi. Grade 40 reinforcing steel was defined as rebar material for the model. Screenshots of the model in SAP2000 are included below.
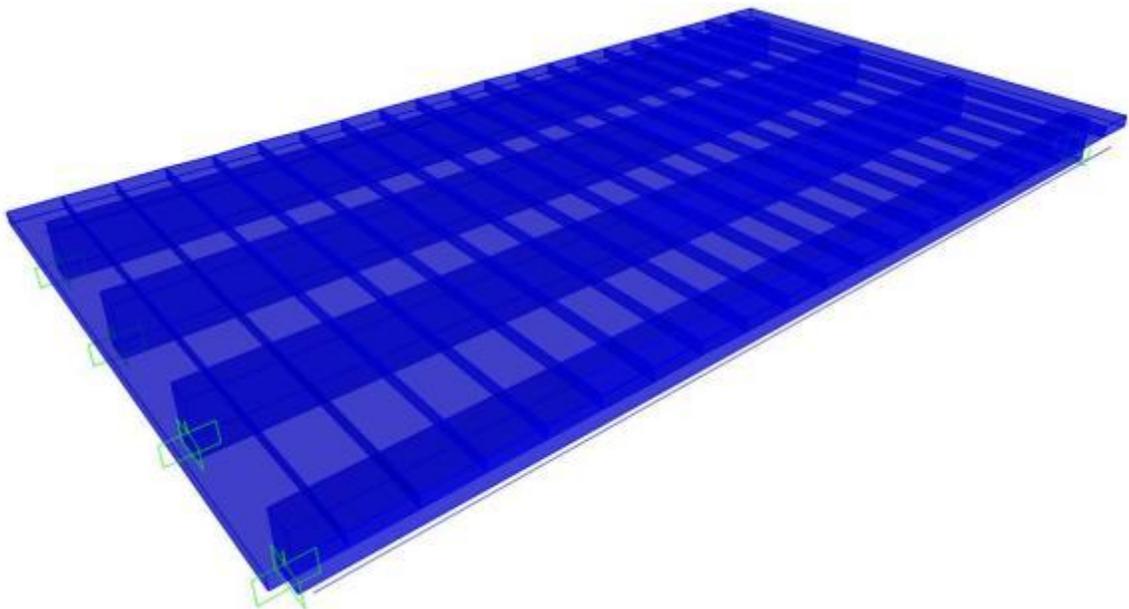
Figure 18: Bridge 005248 Model - Perspective Model

Figure 19: Bridge 005248 Model - 3D Side View
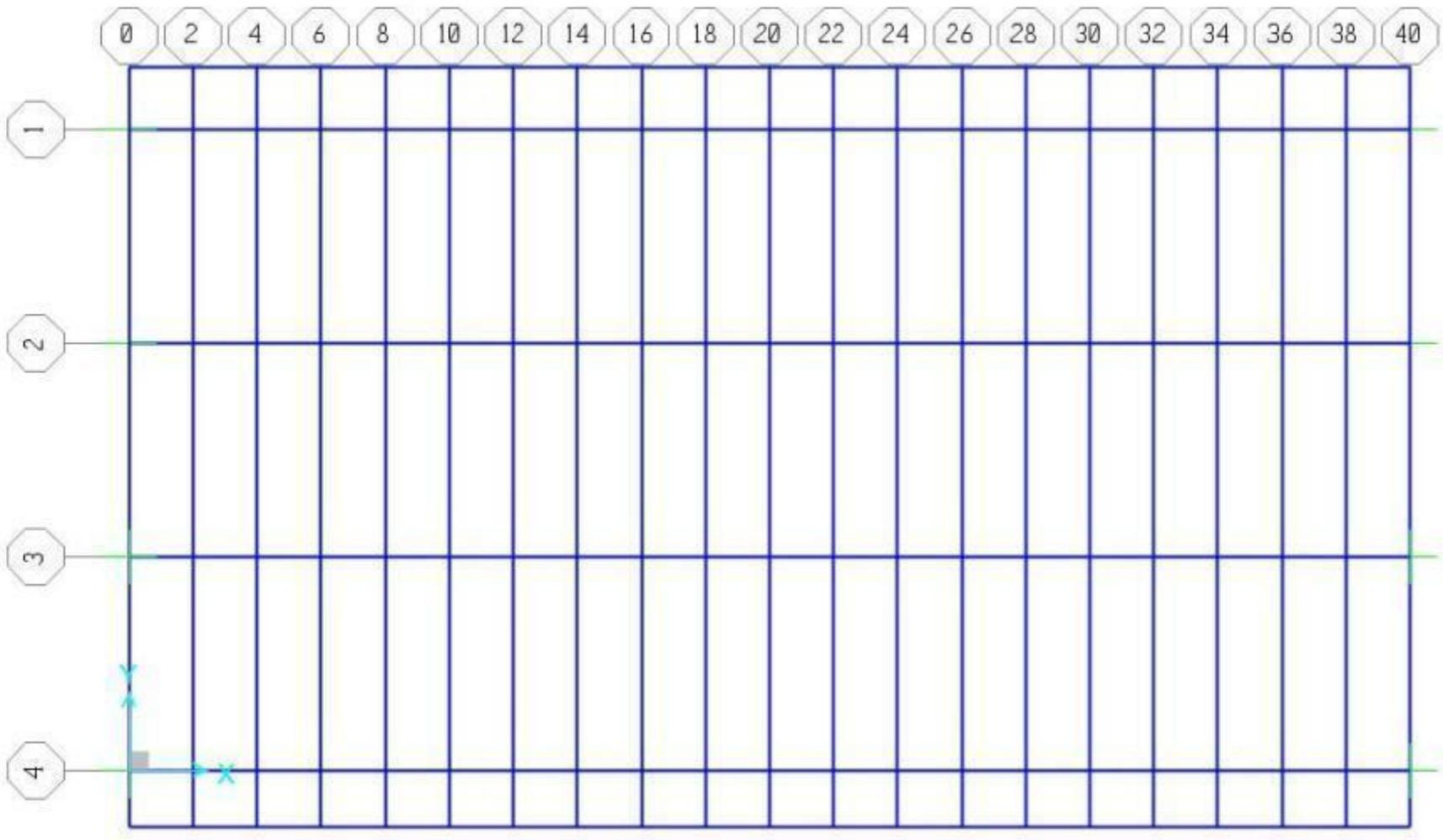
Figure 20: Bridge 005248 Model - Top 2D Frame View

3.1.5 Bridge Model Analysis

Loading Conditions

Fourteen test loading conditions were performed with truck increments from six to four feet. The truck loadings were modeled as traveling northbound. The resulting moments were used to develop strain values based on section properties. Wheel loads were modeled as concentrated loads relative to positions for sets 1, 3, and 5.

Results for Moments and Strains

For each set, moments were gathered from SAP2000 and converted to strain values comparable to experimental results. Moment values for all four girders were reported, and the results were compiled into tabular form. Moments at each girder are noted in Kip-in, and the strains are without unit.

Table 4: Moment and Strain Values for 005248 Load Set 1

	Moments via SAP (k-in)				Distance Traveled	Strains via SAP			
	Girder 1	Girder 2	Girder 3	Girder 4	*(ft)*	Girder 1	Girder 2	Girder 3	Girder 4
Cond. 1	0.0	0.0	0.0	0.0	66	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cond. 2	177.2	159.5	143.0	116.0	60	1.83E-05	1.60E-05	1.43E-05	1.19E-05
Cond. 3	862.6	869.2	733.2	515.8	54	8.92E-05	8.72E-05	7.36E-05	5.30E-05
Cond. 4	1861.9	2106.3	1676.2	999.8	48	1.92E-04	2.11E-04	1.68E-04	1.03E-04
Cond. 5	1915.6	2156.8	1724.5	1041.3	42	1.98E-04	2.16E-04	1.73E-04	1.07E-04
Cond. 6	1619.8	1714.4	1425.9	961.5	36	1.67E-04	1.72E-04	1.43E-04	9.88E-05
Cond. 7	1247.3	1210.5	1064.8	819.6	32	1.29E-04	1.21E-04	1.07E-04	8.42E-05
Cond. 8	1047.2	991.9	887.9	709.5	28	1.08E-04	9.95E-05	8.91E-05	7.29E-05
Cond. 9	985.5	997.3	857.1	625.6	24	1.02E-04	1.00E-04	8.60E-05	6.43E-05
Cond. 10	724.9	784.3	645.7	422.5	20	7.49E-05	7.87E-05	6.48E-05	4.34E-05
Cond. 11	408.2	394.2	349.0	272.0	16	4.22E-05	3.96E-05	3.50E-05	2.79E-05
Cond. 12	203.6	185.0	172.9	149.4	12	2.10E-05	1.86E-05	1.73E-05	1.54E-05
Cond. 13	46.8	42.0	40.6	36.7	6	4.84E-06	4.22E-06	4.07E-06	3.77E-06
Cond. 14	0.0	0.0	0.0	0.0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5: Moment and Strain Values for 005248 Load Set 3

	Moments via SAP (k-in)				Distance Traveled	Strains via SAP			
	Girder 1	Girder 2	Girder 3	Girder 4	(ft)	Girder 1	Girder 2	Girder 3	Girder 4
Cond. 1	0.0	0.0	0.0	0.0	66	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cond. 2	130.7	154.2	162.2	148.6	60	1.35E-05	1.55E-05	1.63E-05	1.53E-05
Cond. 3	656.5	780.1	810.9	733.3	54	6.79E-05	7.83E-05	8.14E-05	7.53E-05
Cond. 4	1217.5	1457.9	1508.7	1360.0	48	1.26E-04	1.46E-04	1.51E-04	1.40E-04
Cond. 5	1502.1	1800.5	1860.2	1675.3	42	1.55E-04	1.81E-04	1.87E-04	1.72E-04
Cond. 6	1263.4	1502.9	1553.6	1400.7	36	1.31E-04	1.51E-04	1.56E-04	1.44E-04
Cond. 7	966.9	1136.9	1175.9	1062.4	32	9.99E-05	1.14E-04	1.18E-04	1.09E-04
Cond. 8	1020.3	1202.8	1242.8	1121.7	28	1.05E-04	1.21E-04	1.25E-04	1.15E-04
Cond. 9	769.4	908.7	939.3	848.0	24	7.95E-05	9.12E-05	9.43E-05	8.71E-05
Cond. 10	586.6	699.7	723.5	652.5	20	6.06E-05	7.02E-05	7.26E-05	6.70E-05
Cond. 11	317.7	372.9	385.2	347.7	16	3.28E-05	3.74E-05	3.87E-05	3.57E-05
Cond. 12	160.3	185.9	191.6	173.2	12	1.66E-05	1.87E-05	1.92E-05	1.78E-05
Cond. 13	37.0	43.1	44.9	41.1	6	3.83E-06	4.32E-06	4.51E-06	4.22E-06
Cond. 14	0.0	0.0	0.0	0.0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 6: Moment and Strain Values for 005248 Load Set 5

	Moments via SAP (k-in)				Distance Traveled	Strains via SAP			
	Girder 1	Girder 2	Girder 3	Girder 4	(ft)	Girder 1	Girder 2	Girder 3	Girder 4
Cond. 1	0.0	0.0	0.0	0.0	66	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cond. 2	101.0	136.3	165.6	192.9	60	1.04E-05	1.37E-05	1.66E-05	1.98E-05
Cond. 3	444.5	703.9	897.5	935.0	54	4.59E-05	7.06E-05	9.01E-05	9.61E-05
Cond. 4	718.1	1339.9	1785.4	1700.7	48	7.42E-05	1.34E-04	1.79E-04	1.75E-04
Cond. 5	868.3	1662.9	2225.8	2081.1	42	8.97E-05	1.67E-04	2.23E-04	2.14E-04
Cond. 6	829.3	1375.6	1765.2	1750.5	36	8.57E-05	1.38E-04	1.77E-04	1.80E-04
Cond. 7	731.7	1028.6	1244.3	1337.5	32	7.56E-05	1.03E-04	1.25E-04	1.37E-04
Cond. 8	639.5	858.6	1018.7	1119.7	28	6.61E-05	8.62E-05	1.02E-04	1.15E-04
Cond. 9	551.7	828.1	1026.0	1059.6	24	5.70E-05	8.31E-05	1.03E-04	1.09E-04
Cond. 10	372.2	643.5	835.8	810.9	20	3.85E-05	6.46E-05	8.39E-05	8.33E-05
Cond. 11	244.3	337.6	404.8	436.7	16	2.53E-05	3.39E-05	4.06E-05	4.49E-05
Cond. 12	138.0	168.0	189.3	215.7	12	1.43E-05	1.69E-05	1.90E-05	2.22E-05
Cond. 13	33.5	39.3	43.3	50.1	6	3.46E-06	3.94E-06	4.35E-06	5.14E-06
Cond. 14	0.0	0.0	0.0	0.0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00

3.1.6 Verification with Experimental Data

The strains gathered from SAP2000 were compared with experimental values provided. The strains were graphed accordingly versus the distance that the truck had traveled along the bridge.

It is important to note that with the strain data provided, an accurate Strain vs. Distance graph cannot be created. Strain data was given in units of time, and without knowing if the truck crossed the bridge at a constant speed or stopped momentarily, this time cannot accurately be converted to distance.

For graphing purposes, a constant speed across the bridge for the truck was assumed. A factor was used to convert the time data into distance. The experimental data peaks at a certain time and levels off for a few moments. It is safe to assume that the truck paused in the center of the bridge for accurate static strain data recording.

The dashed lines for the SAP strains versus the distance of the loading points along the bridge simulate a truck crossing the bridge without pause. Therefore, there is no flattening of the graph at the peak strain value obtained. Since the peak strain value experienced by the truck is the most critical for calibration, the graphs generated are sufficient for accurate calibration.

Adjusting boundary conditions is one of the easiest methods of modifying the SAP model. In the field, true pin-roller conditions may not apply. With Bridge 005248, a fixed-roller condition provided the most accurate results. The model was modified until deemed acceptable, and the results were graphed as shown below.
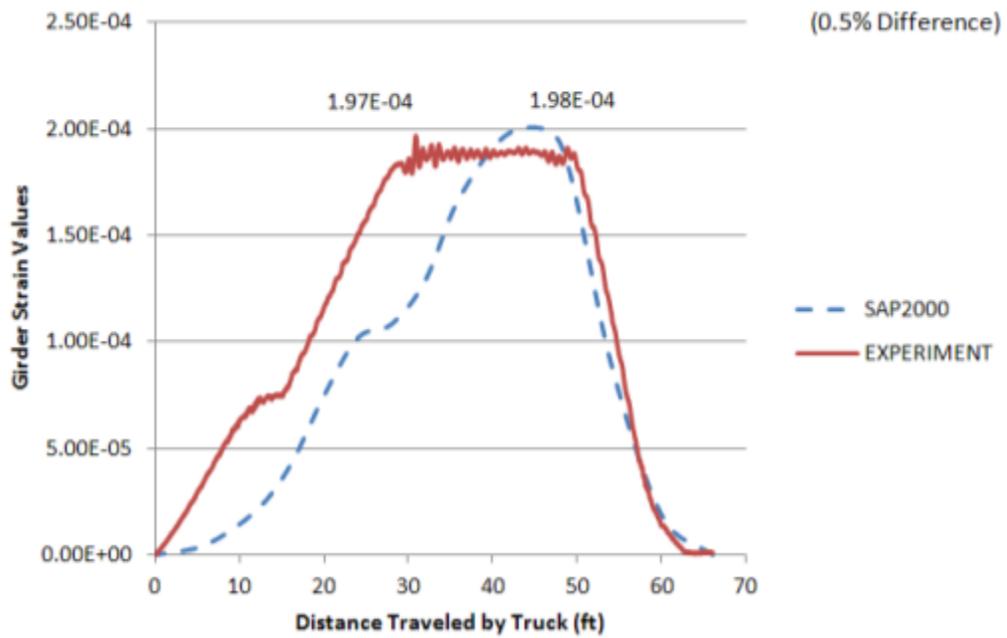
Figure 21: Strain Comparison – Set 1, Girder 1
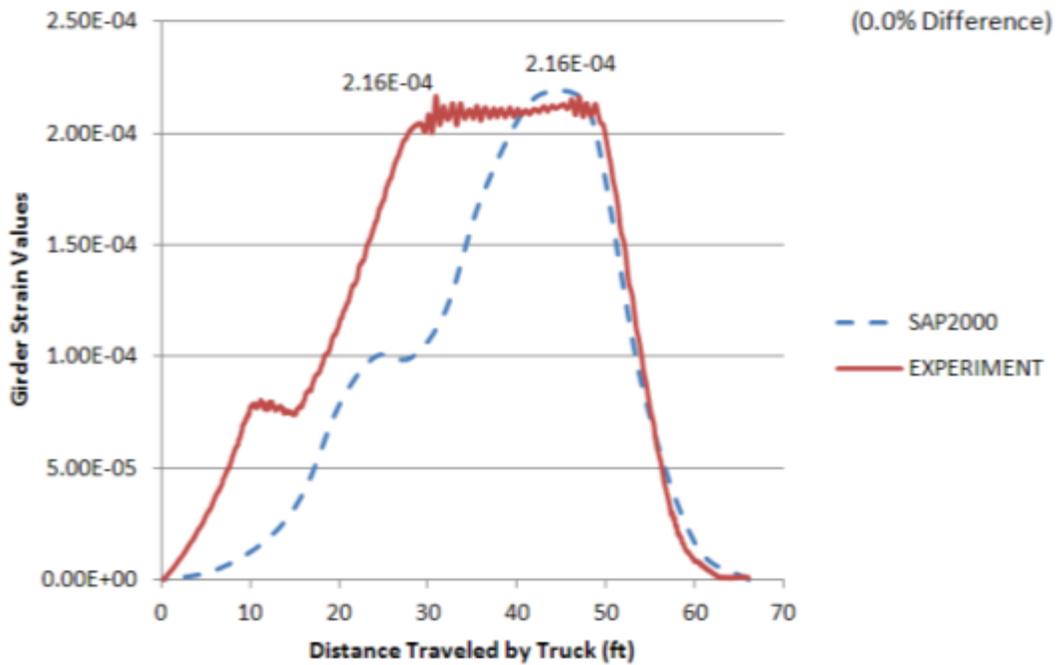
Figure 22: Strain Comparison – Set 1, Girder 2

(2.9% Difference)
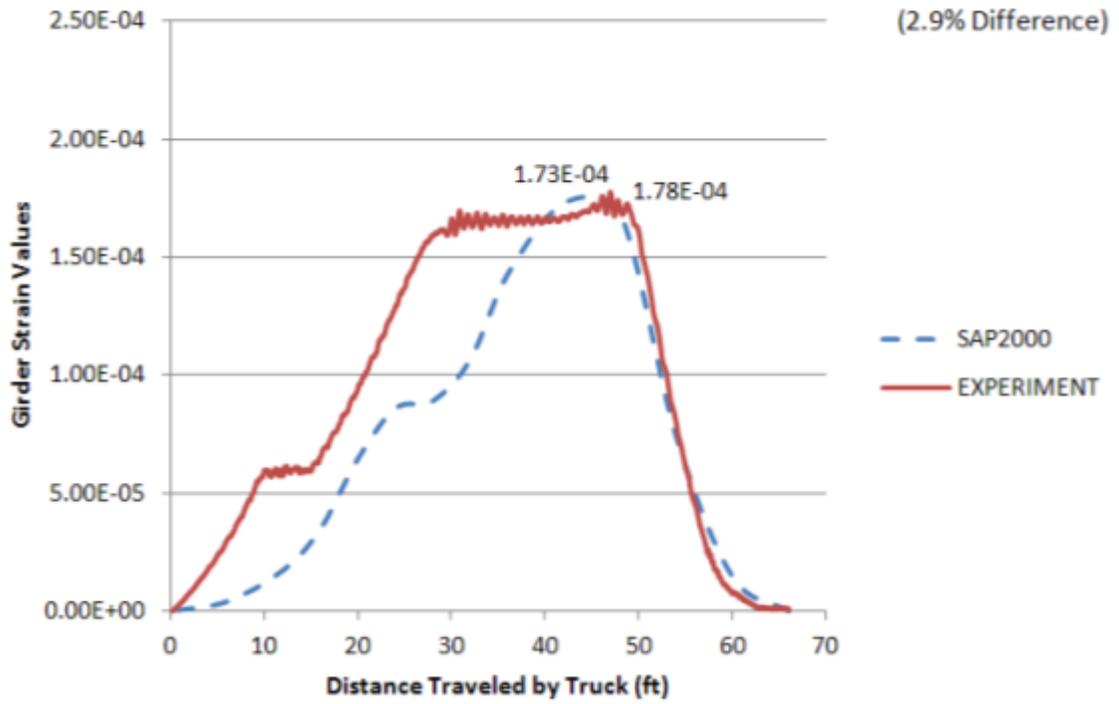
Figure 23: Strain Comparison – Set 1, Girder 3

(22.5% Difference)
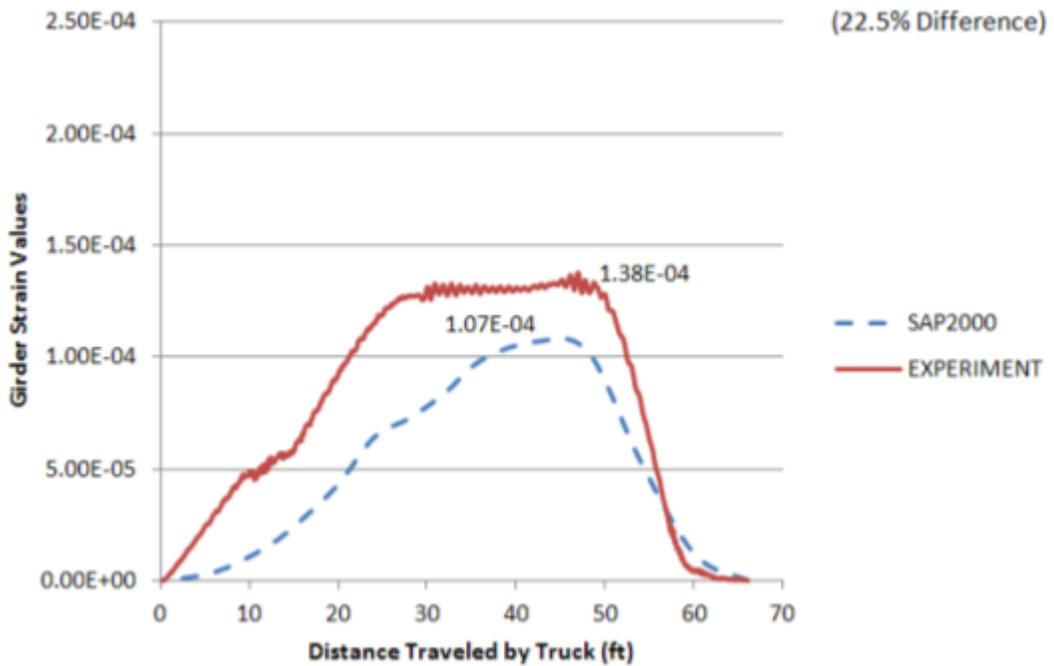
Figure 24: Strain Comparison – Set 1, Girder 4

(1.9% Difference)
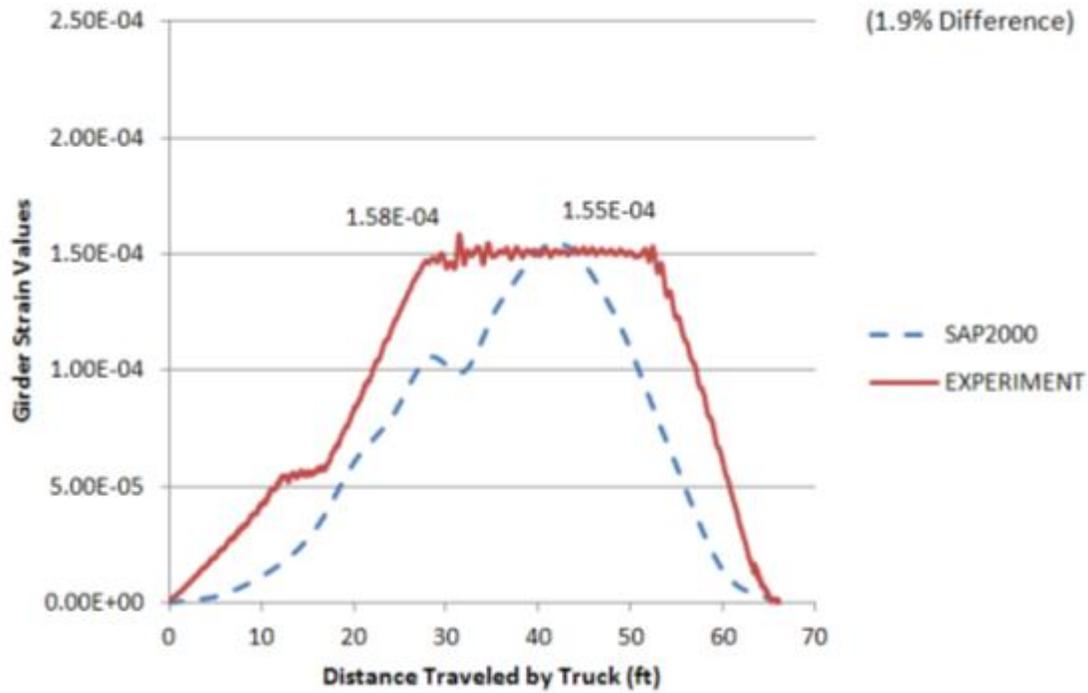
Figure 25: Strain Comparison – Set 3, Girder 1

(4.7% Difference)
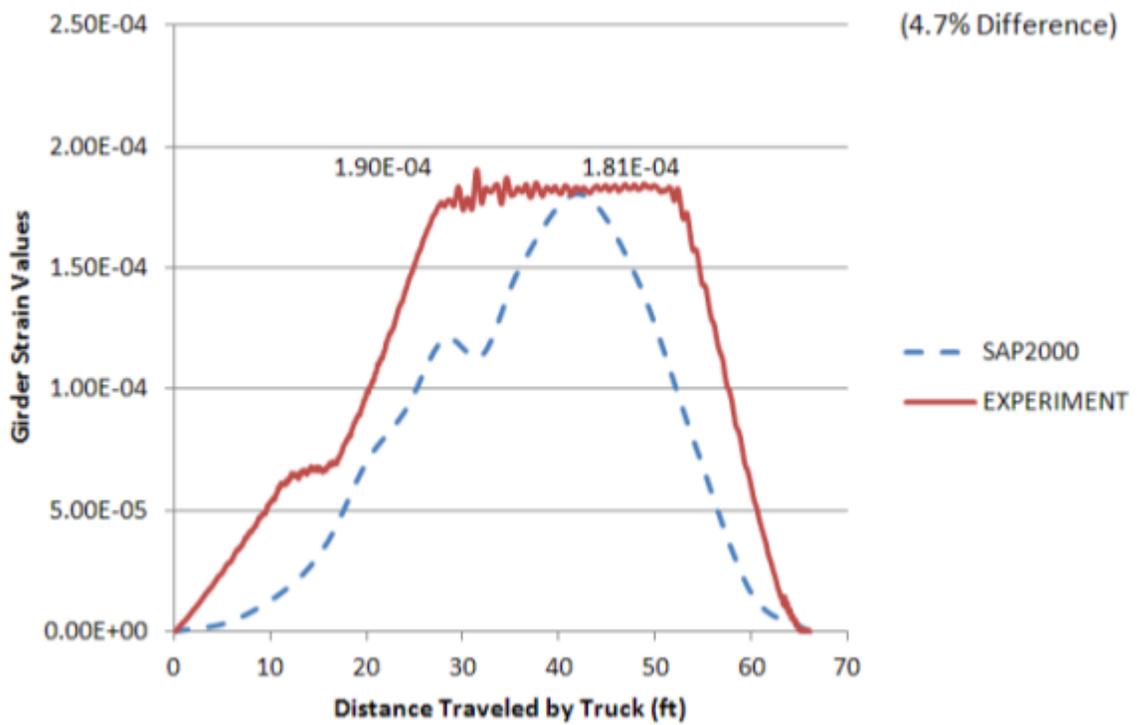
Figure 26: Strain Comparison – Set 3, Girder 2
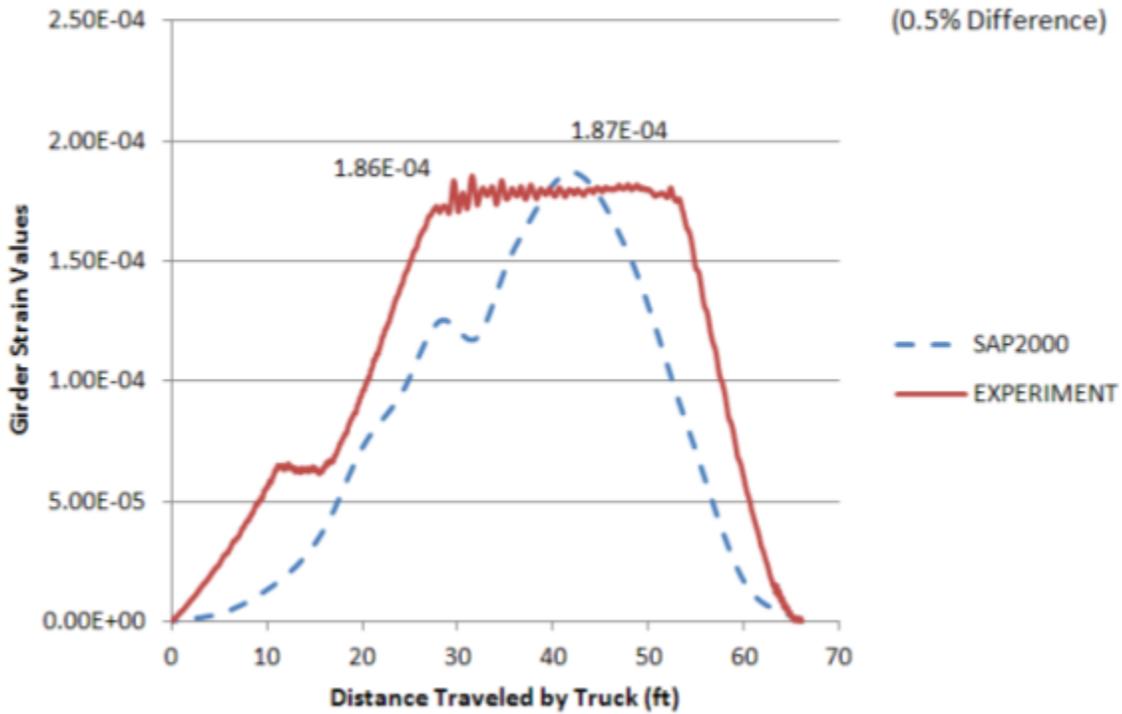
Figure 27: Strain Comparison – Set 3, Girder 3
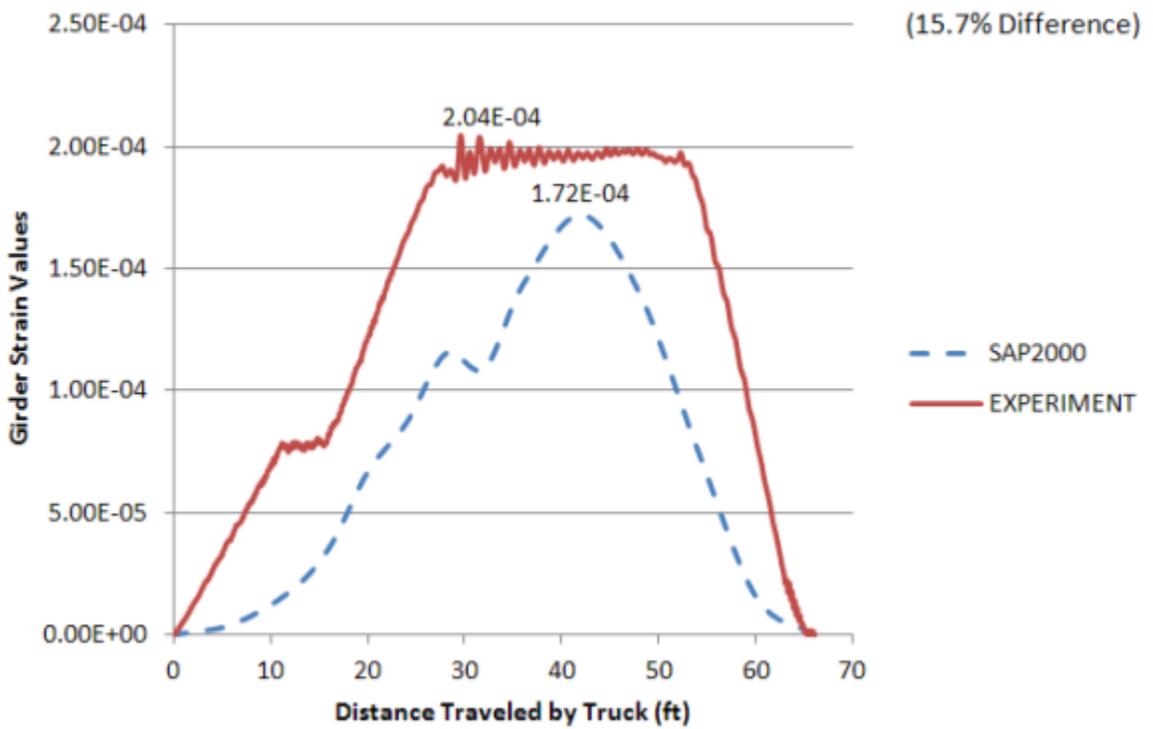
Figure 28: Strain Comparison – Set 3, Girder 4
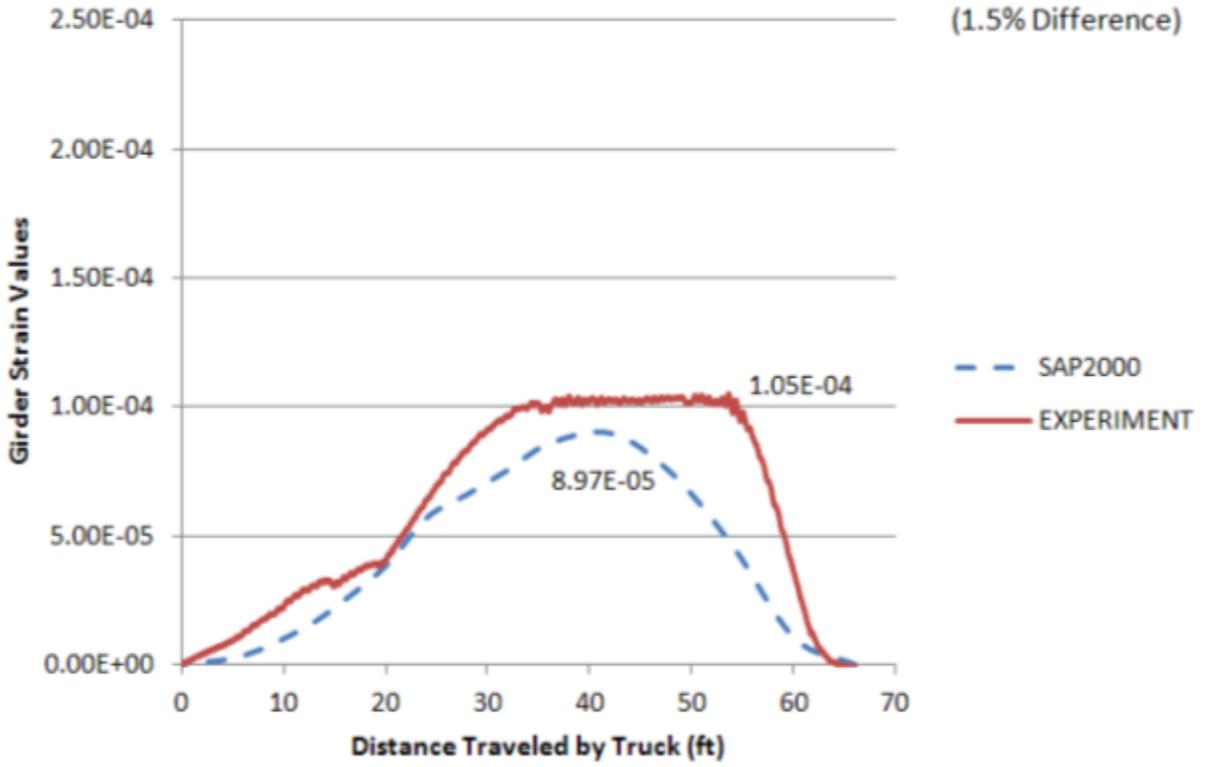
Figure 29: Strain Comparison – Set 5, Girder 1
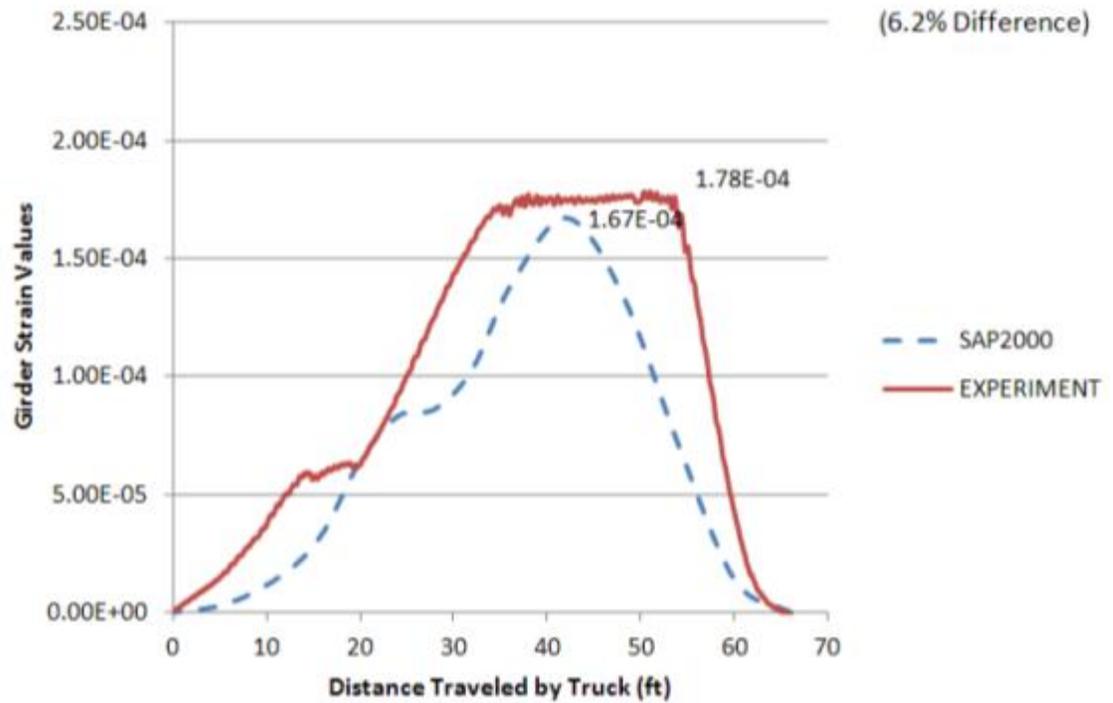
Figure 30: Strain Comparison – Set 5, Girder 2
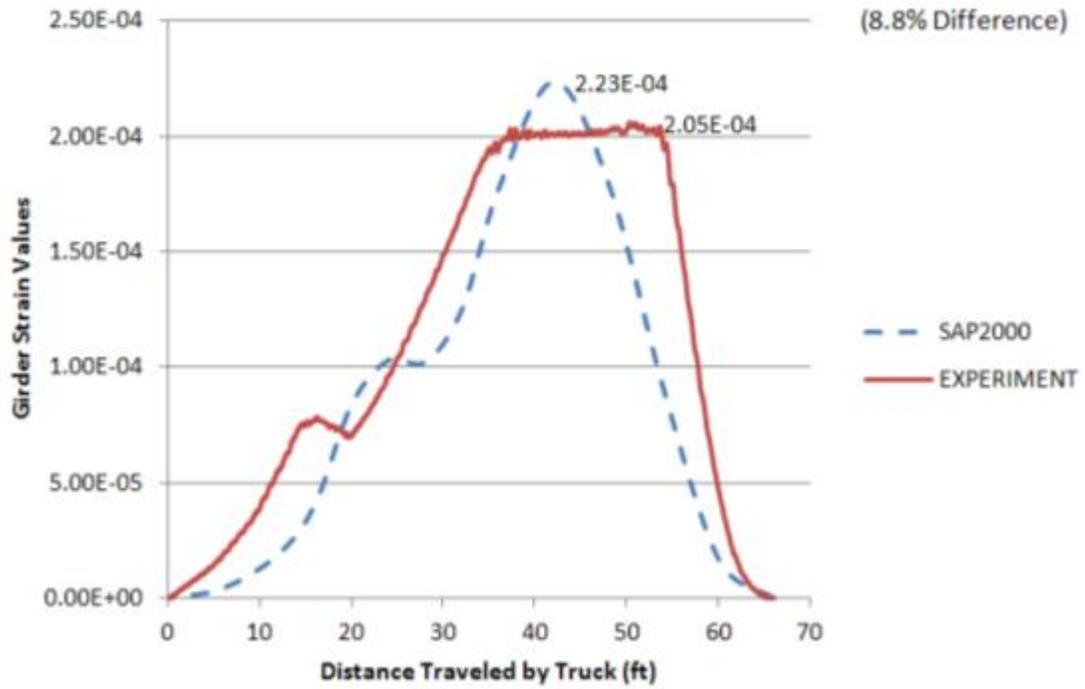
Figure 31: Strain Comparison – Set 5, Girder 3
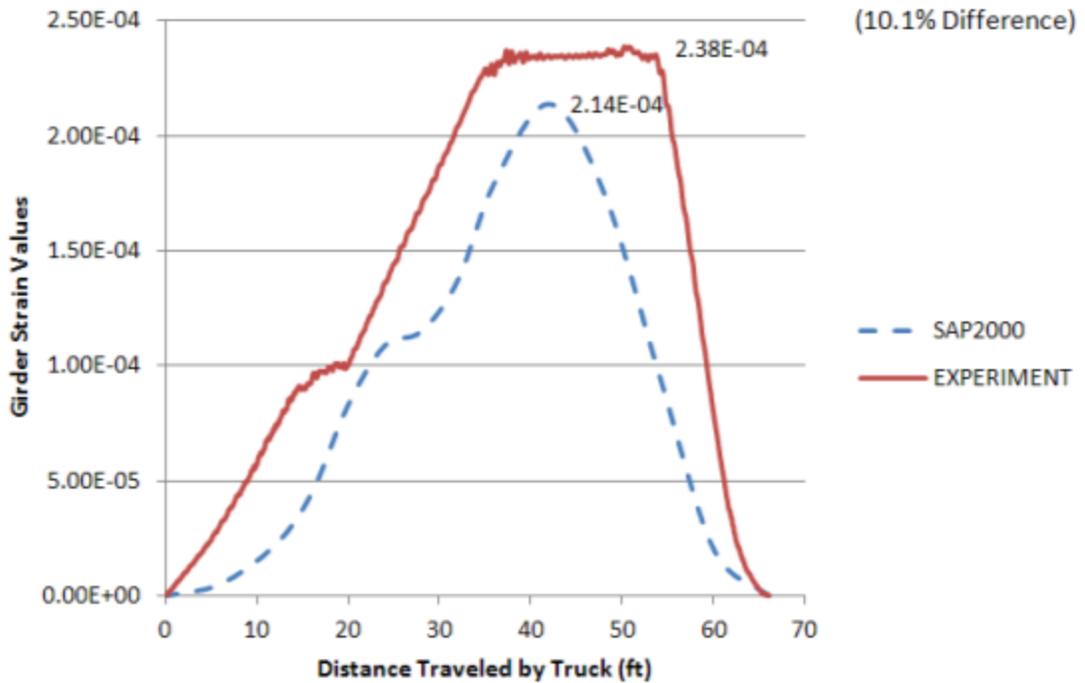
Figure 32: Strain Comparison – Set 5, Girder 4

3.1.7 Load Rating for Bridge 005248

Both the Allowable Stress Method and Load Factor Method were performed in

determining the Load Rating Factors for ALDOT Bridge 005248. The first step in

determining the load-rating factor for the traditionally reinforced concrete girder bridge

was to calculate the section properties for the girders. The table below summarizes the

section properties for each girder.

Table 7: Girder Section Properties for Bridge 005248

	Girder 1	**Girder 2**	**Girder 3**	**Girder 4**
I_g (in^4)	63400	70443	70443	63400
I_{cr} (in^4)	40901	47079	47079	40617
b (in)	63.00	80.00	80.00	61.00
b_w (in)	13.00	13.00	13.00	13.00
h_f (in)	6.00	6.00	6.00	6.00
A_s (in^2)	9.36	9.36	9.36	9.36
A_v (in^2)	0.39	0.39	0.39	0.39
d (in)	26.00	27.13	27.13	26.00
c for I_{cr} (in)	7.17	6.64	6.64	7.27
f'c (psi)	3000	3000	3000	3000
n	10.00	10.00	10.00	10.00

The girder section properties were used to determine the live and dead load stress effects

on the members for use in the general rating equation as discussed in section 2.3. The

bridge was loaded using standard HS20-44 trucks in a manner to retrieve the maximum

moment and shear that each member would experience when loaded. The resultant of two

HS20-44 trucks was assumed in the center of the bridge, and axle loads in the form of

point-loads were added accordingly.

The maximum moment and shear values due to the live load only were recorded. Then all live loads were deleted to determine the dead load effect on the structure. The resulting values for each girder are included in the following table.

Table 8: SAP2000 Max Moment and Shear for Bridge 005248

	G1	G2	G3	G4
M_{Lmax} (k-in)	2459	2555	2555	2459
M_{Dmax} (k-in)	1828	2088	2081	1806
V_{Lmax} (k)	24.4	25.9	25.9	24.4
V_{Dmax} (k)	18.7	21.3	21.3	18.7

The live and dead load stress effects can be calculated from the values obtained in SAP. The stress effect values will remain constant for the Allowable Stress and Load Factor Methods.

Table 9: Bridge 005248 SAP Stress Effects for Moment Rating

	G1	G2	G3	G4
$L_{concrete}$ (psi)	431.14	360.19	360.19	440.08
$D_{concrete}$ (psi)	320.39	294.36	293.44	323.09
L_{steel} (psi)	11322.01	11760.48	11760.48	11322.01
D_{steel} (psi)	8413.72	8586.13	8559.21	8326.99

Table 10: Bridge 005248 SAP Stress Effects for Shear Rating

	G1	G2	G3	G4
L (psi)	72.64	73.95	73.95	72.56
D (psi)	55.62	61.00	61.00	55.56

The first rating method performed for Bridge 005248 was the Allowable Stress Method. The Operating and Inventory factors were calculated for the moment experienced by the concrete and the steel, along with the shear in the bridge girders. The nominal capacity,

C, for a reinforced concrete girder bridge in regards to shear and moment rating is dictated by the code. AASHTO allows for the operating nominal capacity of the concrete to be 1900psi, with an inventory capacity of 1200psi. The code also dictates that the nominal capacity for the reinforcing steel (unknown, constructed after 1954) to be 28000psi at the operating level and 20000psi at the inventory level. These values were used in the general rating equation along with other coefficients discussed in section 2.3 to determine the moment rating factors for the bridge.

Table 11: ASR Moment Rating Factors for 005248

	G1	G2	G3	G4
RF_{conc} (Op)	2.82	3.43	3.43	2.76
RF_{conc} (Inv)	1.57	1.93	1.94	1.53
RF_{steel} (Op)	1.33	1.27	1.27	1.34
RF_{steel} (Inv)	0.79	0.75	0.75	0.79

The allowable shear stress was calculated based on the section properties. AASHTO provides an equation to calculate the nominal shear capacity to be used in the general rating equation. The shear capacity was calculated per the equation provided below, and the shear rating factors for Operating and Inventory levels were determined utilizing the general rating equation. These results were tabulated and are provided.

Equation 2: Shear Capacity of Reinforced Concrete Girder

___

Table 12: ASR Shear Rating Factors for 005248

	G1	G2	G3	G4
RF (Op)	2.03	1.99	1.99	2.03
RF (Inv)	2.29	3.05	3.05	2.29

All of the calculated rating factors were compared to determine the minimum factor. The Allowable Stress Method minimum rating factors for Bridge 005248 were 1.27 and 0.75 for Operating and Inventory levels, respectively.

The second rating method performed for Bridge 005248 was the Load Factor Method. Similarly, the Operating and Inventory factors were calculated for this method. Contrary to dictated allowable stresses for ASR, LFR uses the actual calculated capacities using equations in the AASHTO Specifications as nominal capacities. The moment and shear capacity equations used are as follows:

Equation 3: Moment Capacity for Reinforced Concrete Girders

$$-$$

Equation 4: Shear Capacity for Reinforced Concrete Girders

Equation 5: Shear Strength of Concrete for Reinforced Concrete Girders

$$-$$

Equation 6: Shear Strength of Steel for Reinforced Concrete Girders

$$-$$

The calculated values for   and   were used as nominal capacities in the general rating equation along with the coefficients for LFR as noted in section 2.3 above. The Load Factor Method minimum rating factors for Bridge 005248 were 1.40 and 0.84 for

Operating and Inventory levels, respectively. The following tables summarize the rating

factors calculated for each entity.

Table 13: LFR Moment Rating Factors for 005248

	G1	G2	G3	G4
RF_{conc} (Op)	1.44	1.40	1.40	1.45
RF_{conc} (Inv)	0.86	0.84	0.84	0.87
RF_{steel} (Op)	1.52	1.45	1.45	1.52
RF_{steel} (Inv)	0.91	0.87	0.87	0.91

Table 14: LFR Shear Rating Factors for 005248

	G1	G2	G3	G4
RF (Op)	1.58	1.41	1.41	1.58
RF (Inv)	0.95	0.84	0.84	0.95

The structure rating results provided by ALDOT noted that Load Factor methodology

was used in determining the controlling rating factor for the bridge. ALDOT determined

that the Operating and Inventory Ratings for Bridge 005248 were 1.30 and 0.76,

respectively. These load factors were multiplied by the weight of an HS20-44 truck (36

tons) for an allowable weight posting. Only the factors calculated for LFR using values

via the SAP model are to be compared to ALDOT"s results. The following table

summarizes the comparison of ALDOT and SAP model load rating results.

	ALDOT LR Factor	SAP LR Factor	ALDOT Rating	SAP Rating	Difference
Operating Level	1.30	1.40	46.8 Tons	50.4 Tons	7.69%
Inventory Level	0.76	0.84	27.4 Tons	30.2 Tons	10.53%

The SAP model values resulted in higher ratings than ALDOT. The SAP model is

producing results based on more accurate bridge behavior; hence, the original rating is

considered conservative. The rating is reduced using values obtained in the bridge model.

3.2 ALDOT Bridge 005318

3.2.1 Location of Bridge

Bridge 005318 is located in near the Shelby and Chilton County line. The bridge spans

over Waxahatchee Creek near the intersection of the Coosa river, connecting strips of

State Road 145. Bridge 005318 is a two lane bridge with five sections. The end span with

composite steel girders was analyzed in SAP2000. However, for rating purposes, only the

steel section properties were used as in the ALDOT analysis. The bridge was designed in

July of 1955 according to the National Bridge Inventory Database.
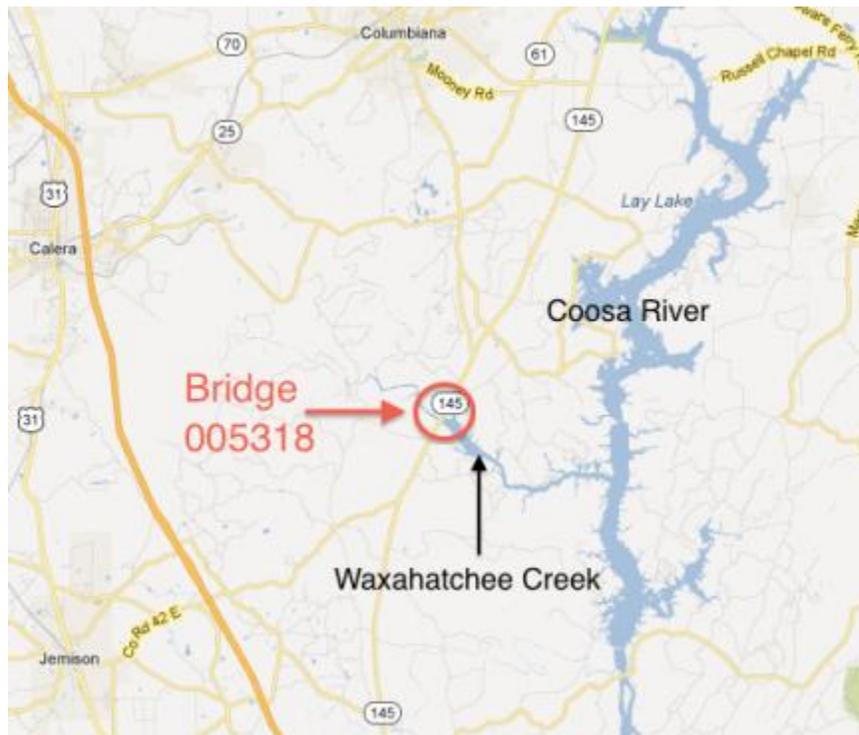
Figure 33: Location of ALDOT Bridge 005318

3.2.2 Bridge Information

Bridge Photos

Figure 34: Photo Along Span for Bridge 005318

Figure 35: Satellite Plan View of Bridge 005318

38
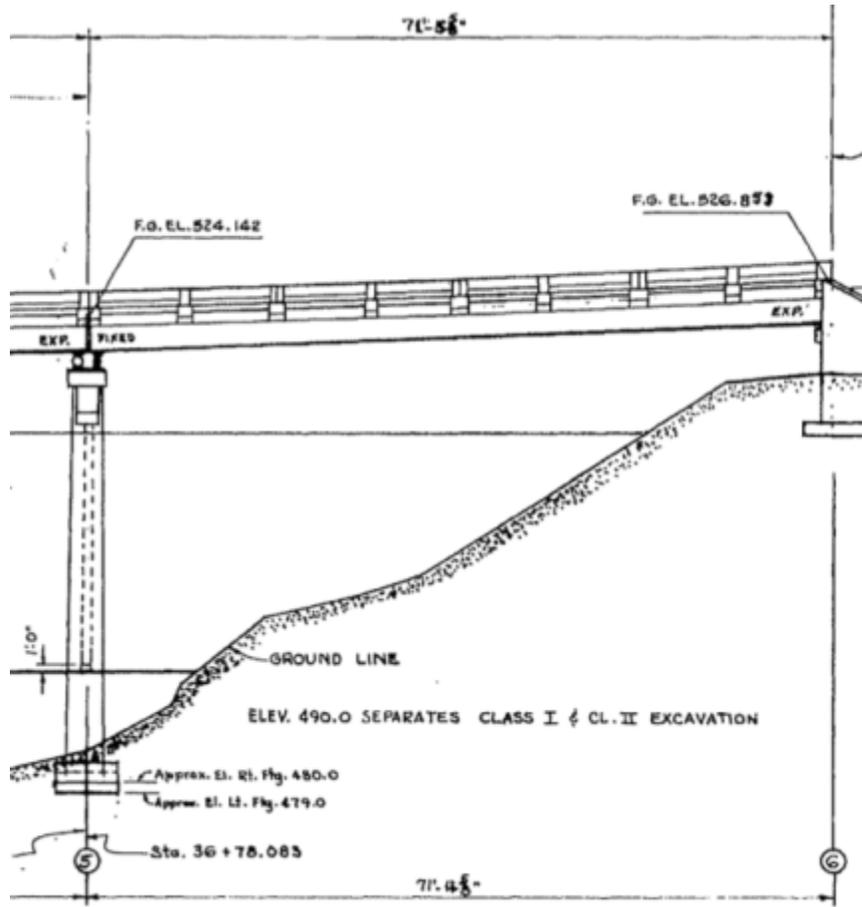
Figure 36: Elevation of 005318 from Original Drawings
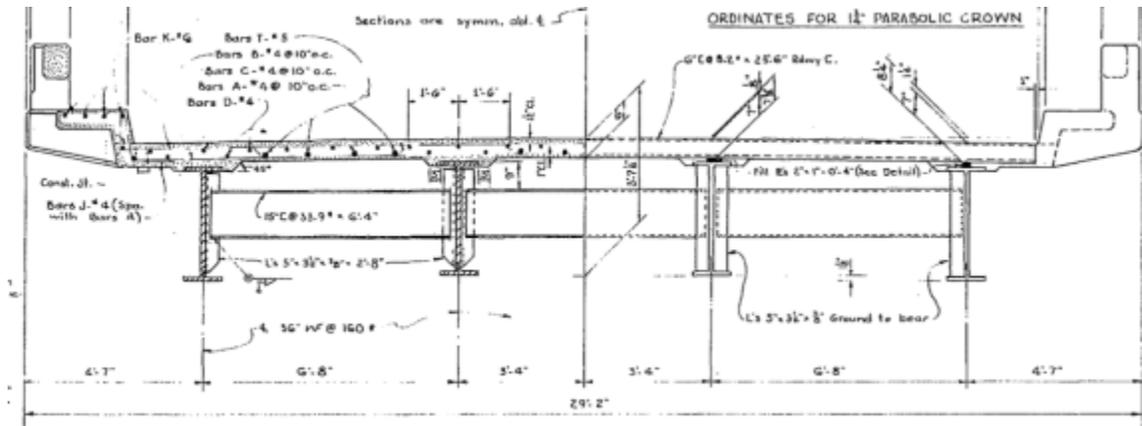
Figure 37: Cross Section of 005318 from Original Drawings
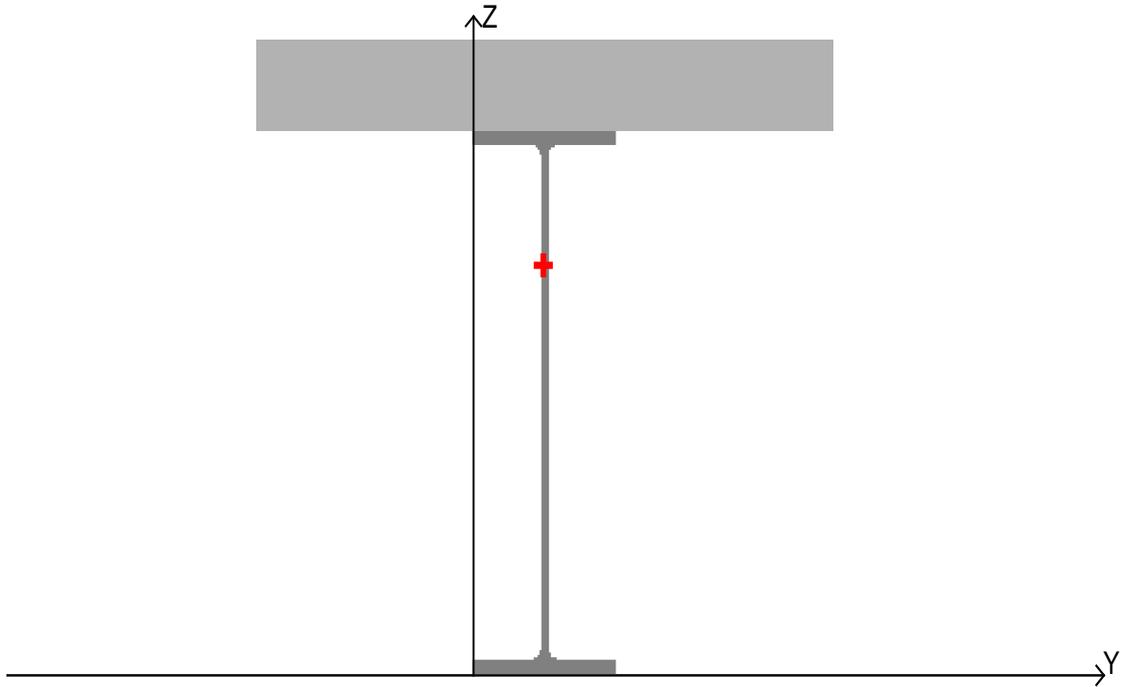
Figure 38: Test Span Girder Section for 005318 in StaadPRO

Sensor Placement

The test span girder section above was created using the Section Wizard using a similar

structural analysis program called StaadPRO. The Section Wizard is useful in quickly

obtaining section properties when multiple materials and shapes are combined. Moments

experienced by each girder were gathered at the location of the sensor as defined by the

experimental results from ALDOT. A figure providing the location of the sensor in

distance relation to the supports is included below. The following figures were copied

from the structure rating results to portray the sensor location and truck positioning for

each load set.

NORTH

Wheel 2

34' 3 ¾"

Weldable Strain Gage
Location

32' 11 ¾"

Bent

Bent

2

3
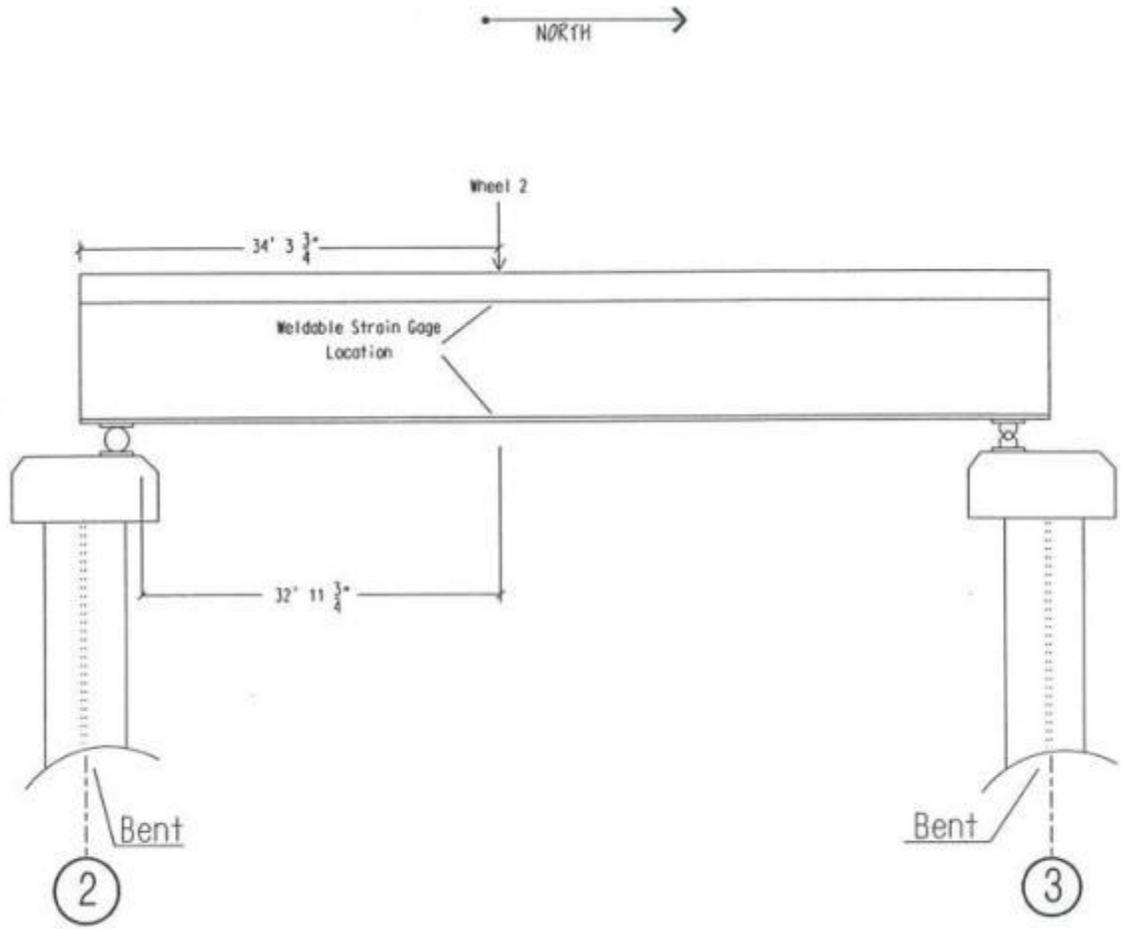
Girder Positioning Diagram Not to Scale

Figure 39: Sensor Location for 005318 Relative to Supports

Figure 40: Sensor Layout Plan View for 005318

3.2.3 Qualitative Assessment of Model

Bridge 005318 was loaded and analyzed in February, 2008 by ALDOT with Virtis and

BRUFEM. Two 3-axle trucks were used in five different positions for the initial analysis

of Bridge 005318. Similar to the analysis for 005248, the first two axles were spaced at

4'-9.5", and the spacing between the middle and rear axle was 18'-5.5". The total loads

for the front, middle, and rear axles were 30.15 kips, 32.075 kips, and 22.875 kips,

respectively. Axle loads were distributed into two point loads to represent each wheel for

SAP2000.

There were five loading positions performed by ALDOT. However, only sets 1, 3, and 5

were modeled in SAP for calibration verification. The table below indicates section

properties that were used to convert moment values to strain, and the figure below taken

from the initial ALDOT experiment shows the location of each truck in the respective

loading set. For simplification, each composite steel girder was assumed to have the

same effective width of concrete contributing to the strength of the section.

Table 15: Girder Section Properties for 005318

Girder	c (in)	I_x (in^4)	b_f(in)
1	26.99	18723	48.0
2	26.99	18723	48.0
3	26.99	18723	48.0
4	26.99	18723	48.0

The truck-positioning diagram below was copied from the ALDOT results to portray the

location of the truck in relation to the bridge curb. These values were used to generate a

tabulate the location of the truck point loads in SAP from the top of the model.
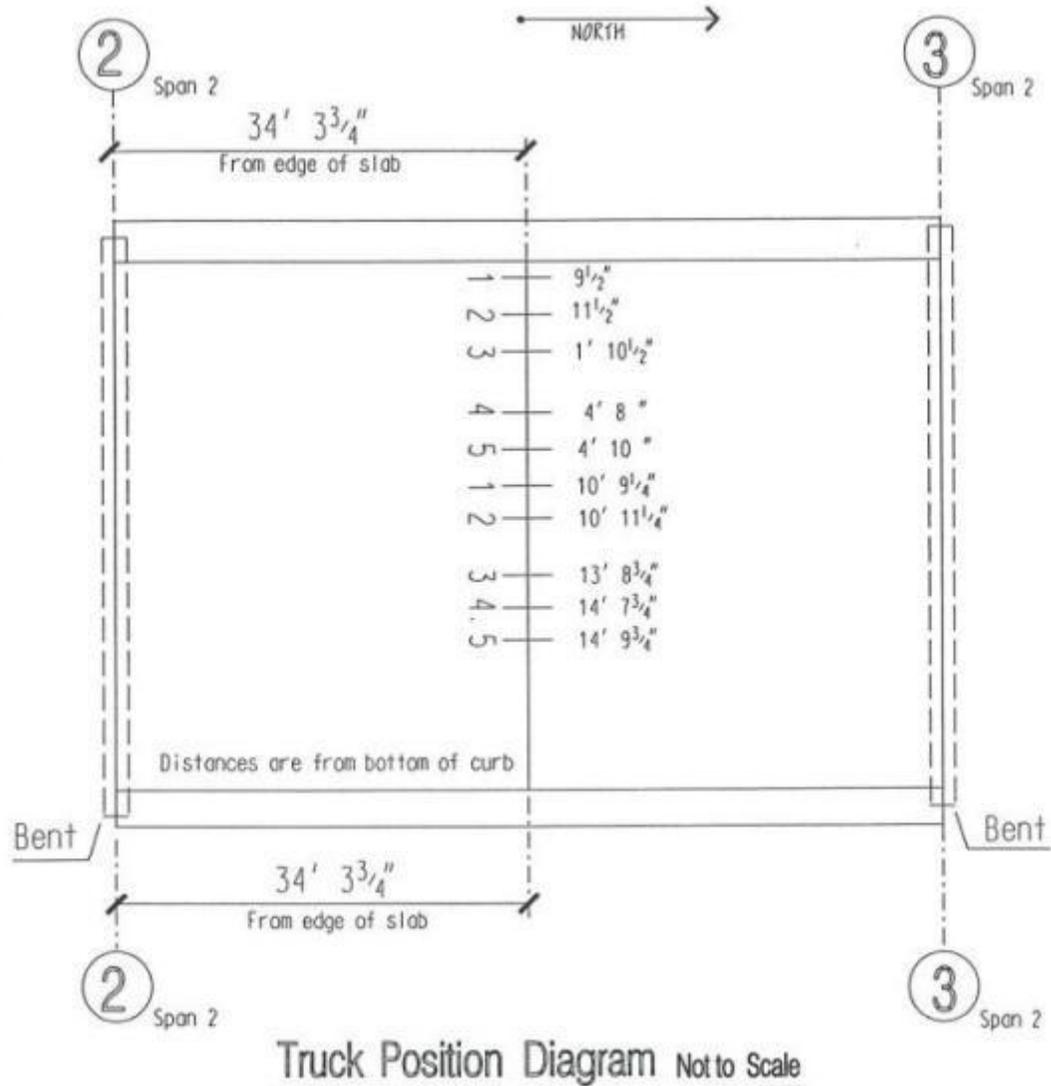
Figure 41: 005318 Truck Positioning Diagram for Analysis

Table 16: Loading Sets for 005318 Model in SAP2000

Set 1		Set 3		Set 5	
Truck 1	*Load Distance from Top of Model (in)*	Truck 1	*Load Distance from Top of Model (in)*	Truck 1	*Load Distance from Top of Model (in)*
Left Tire	20.56	Left Tire	33.56	Left Tire	69.06
Right Tire	95.56	Right Tire	108.56	Right Tire	144.06
Truck 2	*Load Distance from Top of Model (in)*	Truck 2	*Load Distance from Top of Model (in)*	Truck 2	*Load Distance from Top of Model (in)*
Left Tire	140.31	Left Tire	175.81	Left Tire	188.81
Right Tire	215.31	Right Tire	250.81	Right Tire	263.81
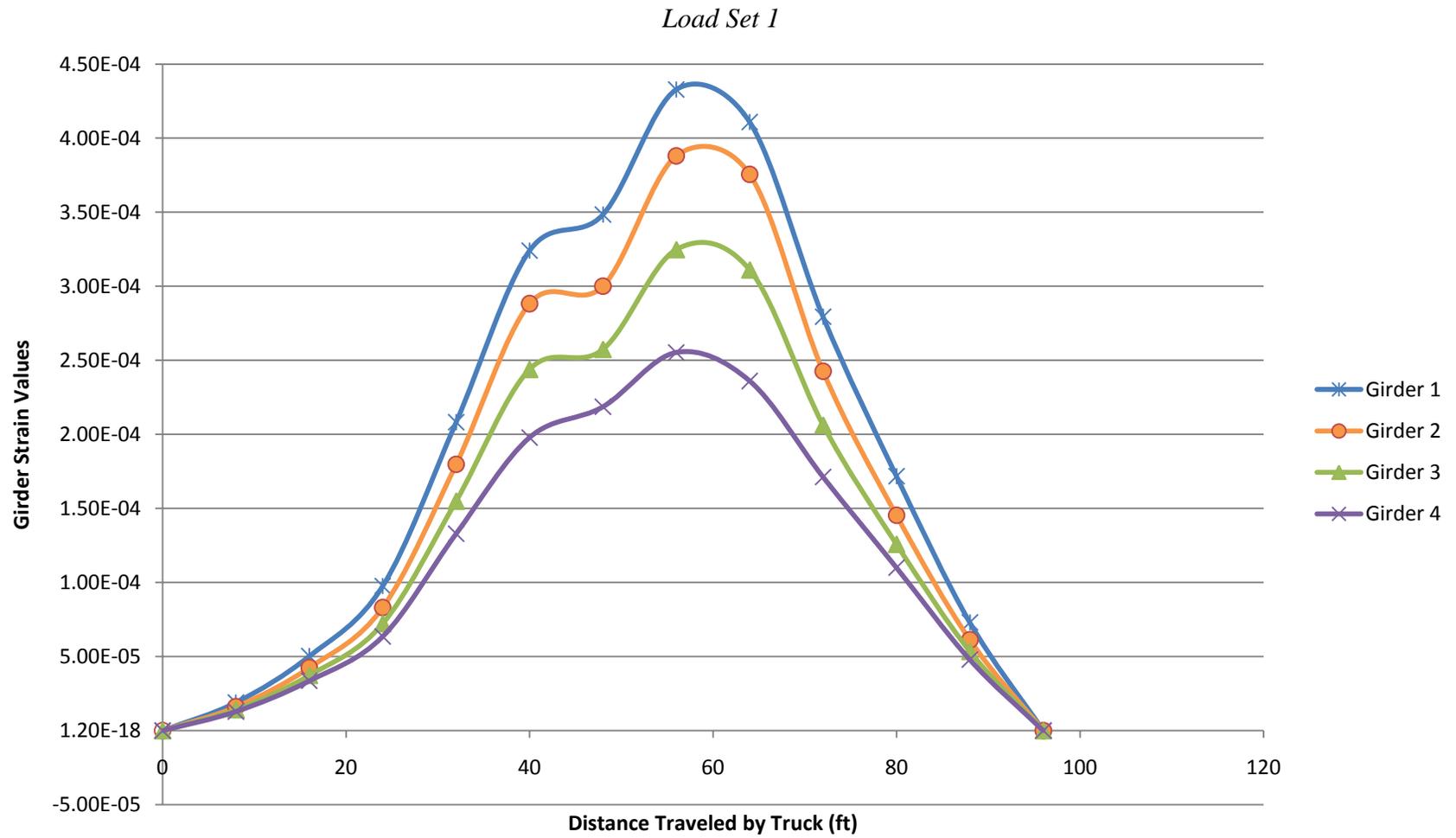
Figure 42: 005318 SAP Model Strains for Load Set 1
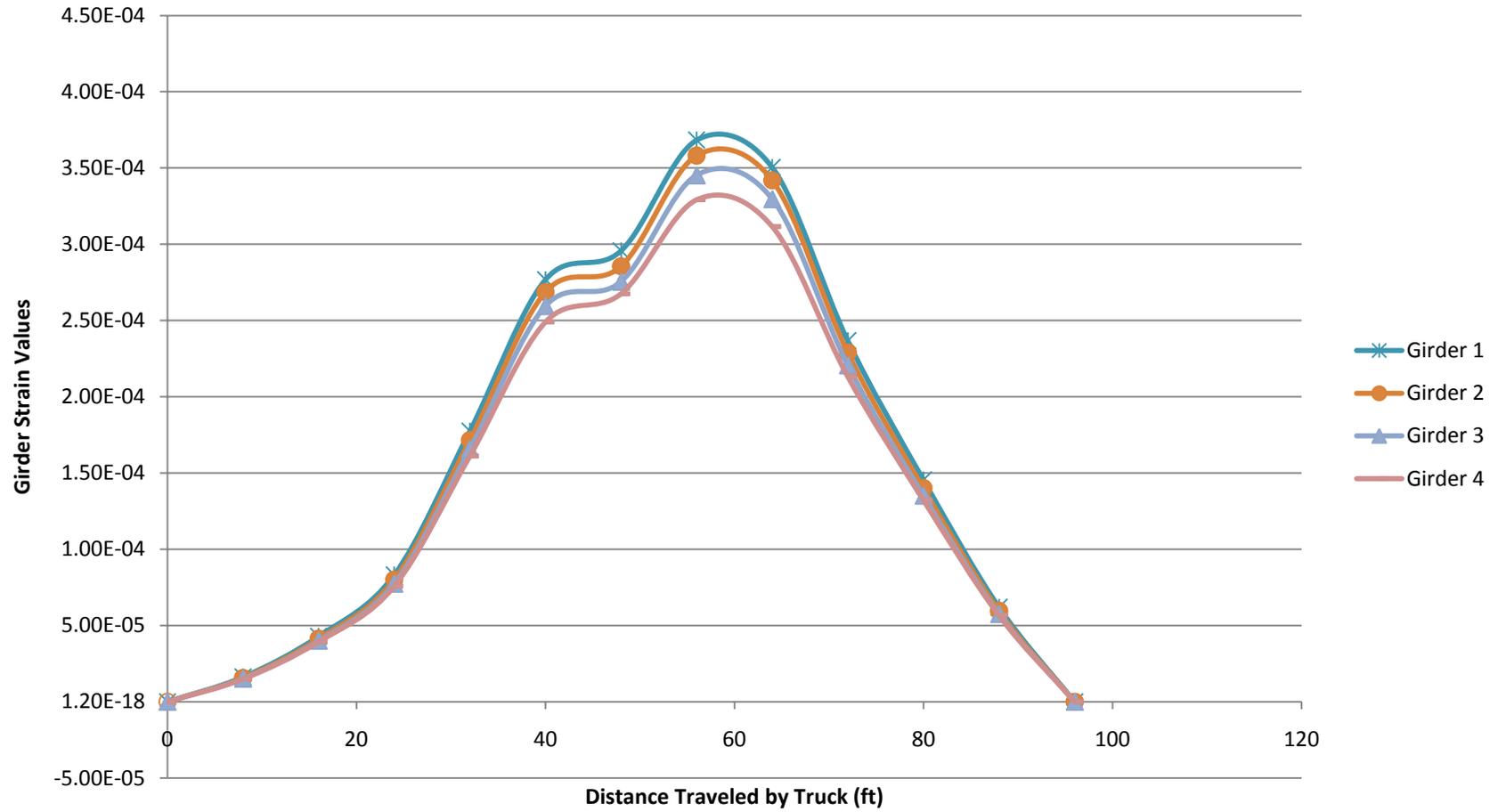
Figure 43: 005318 SAP Model Strains for Load Set 3
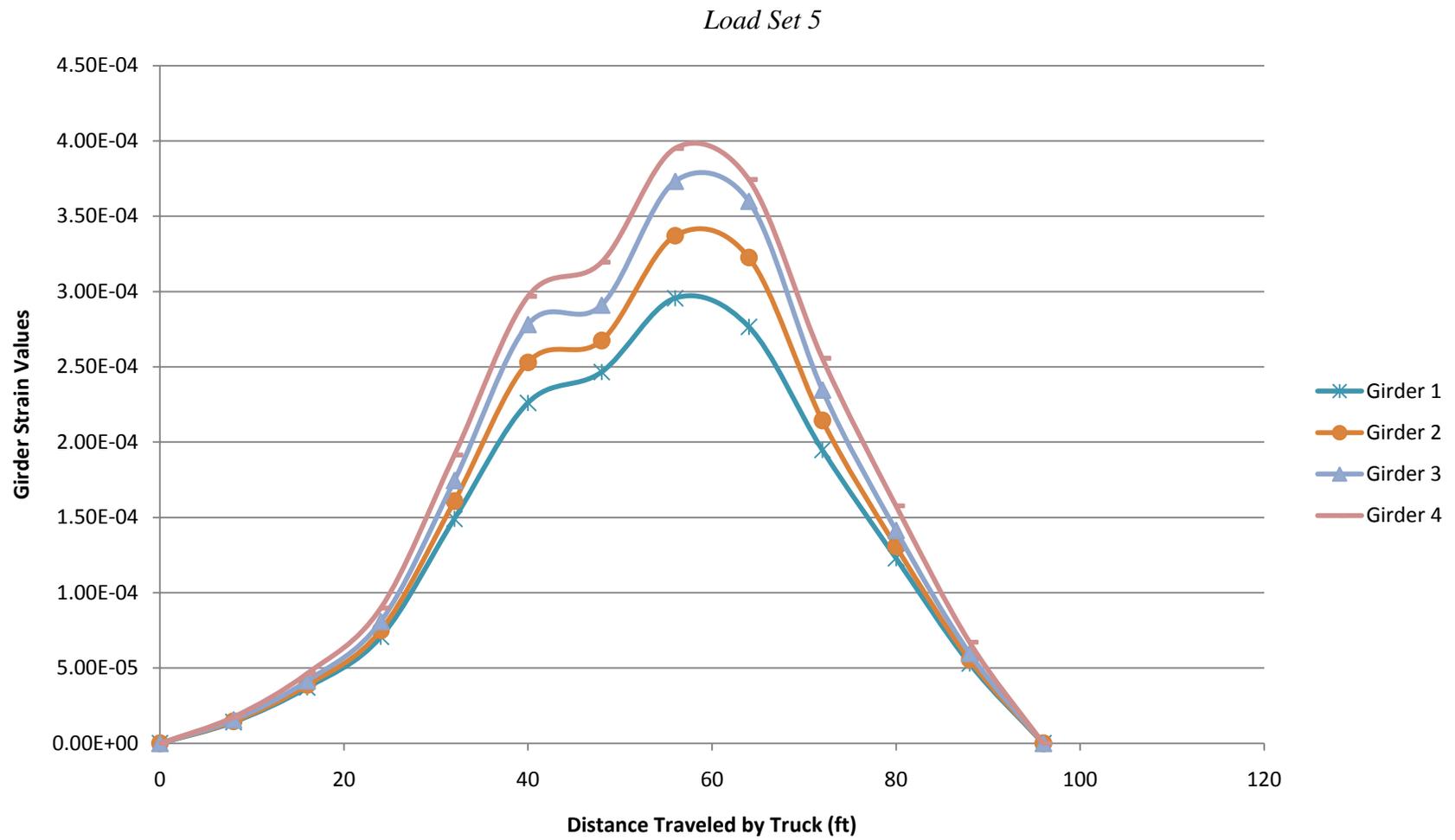
Figure 44: 005318 SAP Model Strains for Load Set 5

3.2.4 Modeling of Bridge in SAP2000

After all critical and girder spacing dimensions were determined from the experimental

portfolio provided by ALDOT, Bridge 005318 was then modeled in SAP2000. A true

grid condition was used to begin laying out the bridge in the grid system developed. The

steel girders were modeled as W36X160 with a six-inch concrete slab above. The

concrete was modeled with strength of 3000psi. Screenshots of the model for

visualization purposes have been included below.
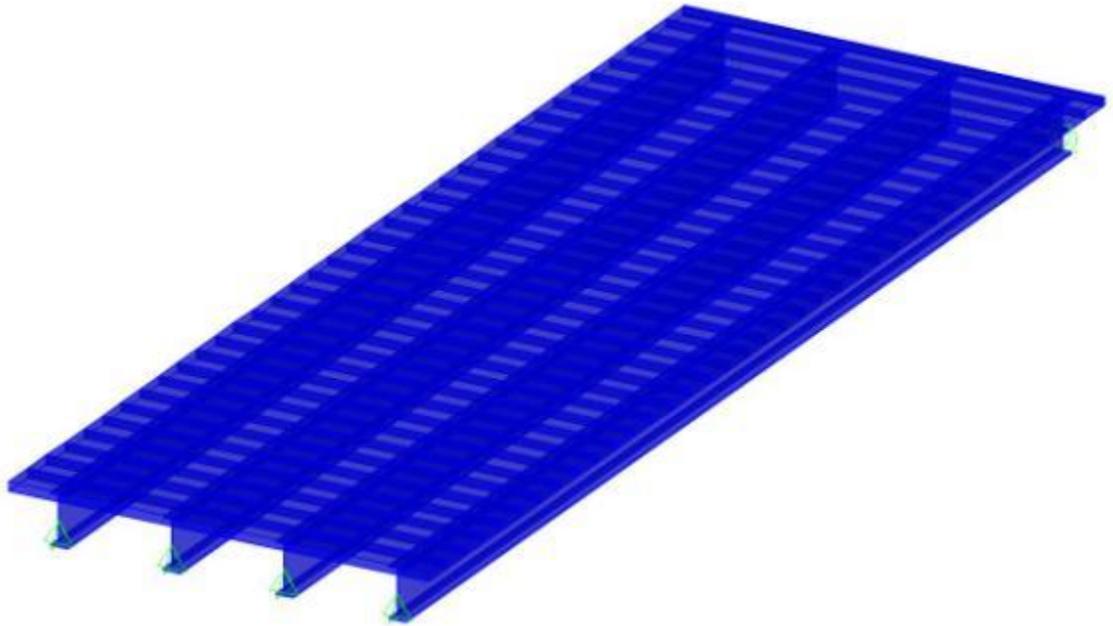
Figure 45: Bridge 005318 Model - Perspective Model
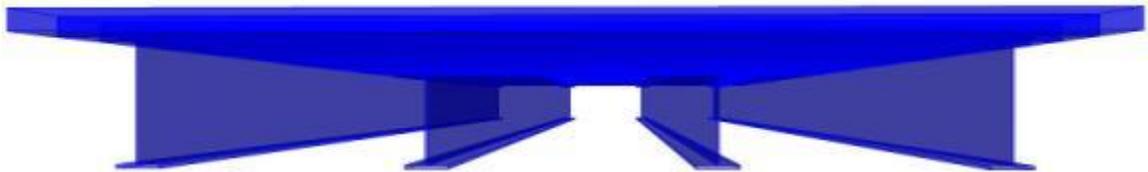
Figure 46: Bridge 005318 Model - 3D Side View
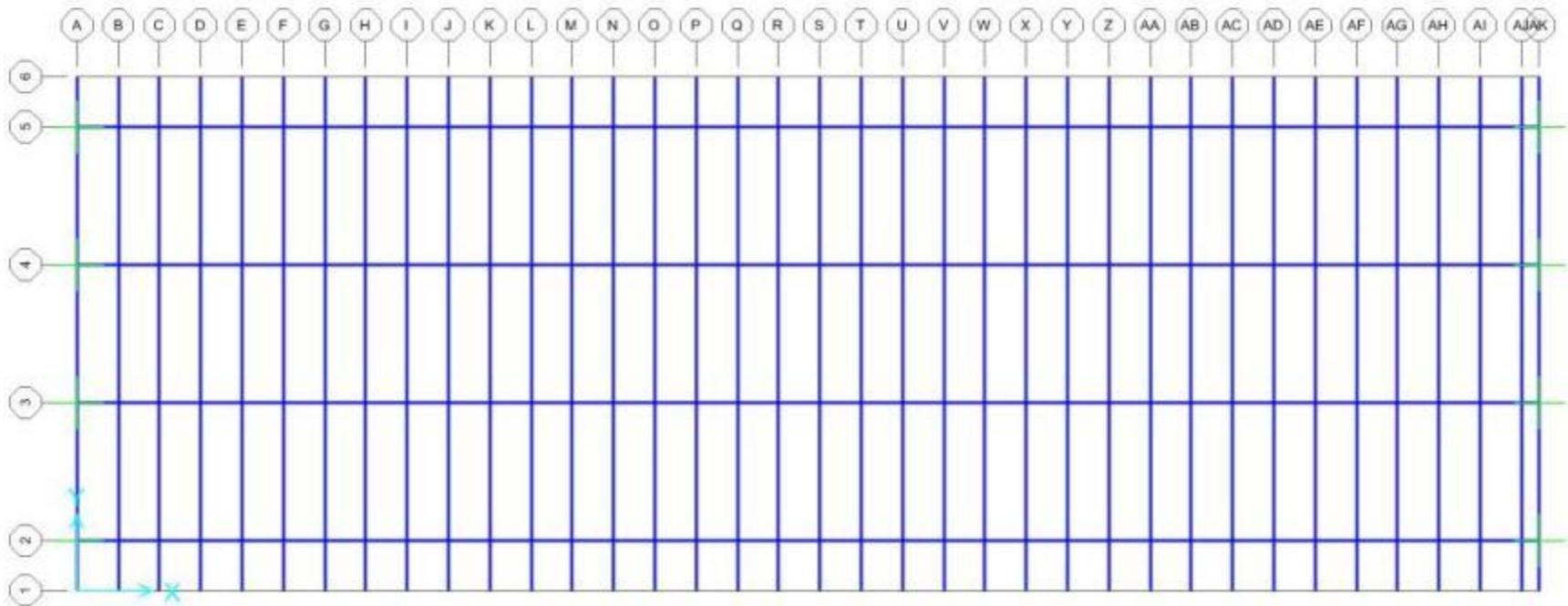
Figure 47: Bridge 005318 Model - Top 2D Frame View

3.2.5 Bridge Model Analysis

Loading Conditions

Moments were gathered in SAP2000 for thirteen separate loading conditions along the bridge. The trucks were modeled as point loads in eight feet increments along the transverse frames lines of the slab. It is imperative that the slab frames modeled are meshed with the steel girders to effectively generate load distribution. This also allows for composite action to occur.

Results for Moments and Strains

Bridge 005318 is also a four-girder bridge. For each truck loading position along the bridge, moment values were obtained at the location of the strain sensor. All four girders were considered for recording moment values for conversion to strain. The moment values were noted in Kip-in units, and the strains calculated have no unit.

Table 17: Moment and Strain Values for 005318 Load Set 1

	Moments via SAP (k-in)				Distance Traveled	Strains via SAP			
	Girder 1	Girder 2	Girder 3	Girder 4	*(ft)*		Girder 1	Girder 2	Girder 3	Girder 4
Cond. 1	0.0	0.0	0.0	0.0	96	Cond. 1	0.00E+00	0.00E+00	0.00E+00
Cond. 2	1467.9	1231.9	1075.8	963.5	88	Cond. 2	7.30E-05	6.12E-05	5.35E-05
Cond. 3	3455.3	2924.8	2530.8	2212.5	80	Cond. 3	1.72E-04	1.45E-04	1.26E-04
Cond. 4	5620.8	4880.6	4150.0	3443.5	72	Cond. 4	2.79E-04	2.43E-04	2.06E-04
Cond. 5	8265.4	7555.9	6257.3	4747.7	64	Cond. 5	4.11E-04	3.76E-04	3.11E-04
Cond. 6	8708.0	7806.6	6533.1	5135.5	56	Cond. 6	4.33E-04	3.88E-04	3.25E-04
Cond. 7	7009.0	6036.3	5178.1	4397.1	48	Cond. 7	3.48E-04	3.00E-04	2.57E-04
Cond. 8	6518.0	5798.6	4906.4	3979.9	40	Cond. 8	3.24E-04	2.88E-04	2.44E-04
Cond. 9	4188.7	3615.6	3117.2	2673.7	32	Cond. 9	2.08E-04	1.80E-04	1.55E-04
Cond. 10	1963.2	1671.6	1453.6	1278.2	24	Cond. 10	9.76E-05	8.31E-05	7.23E-05
Cond. 11	1010.4	854.7	750.4	675.6	16	Cond. 11	5.02E-05	4.25E-05	3.73E-05
Cond. 12	380.7	322.0	284.3	259.1	8	Cond. 12	1.89E-05	1.60E-05	1.41E-05
Cond. 13	0.0	0.0	0.0	0.0	0	Cond. 13	0.00E+00	0.00E+00	0.00E+00

Table 18: Moment and Strain Values for 005318 Load Set 3

	Moments via SAP (k-in)				Distance Traveled	Strains via SAP			
	Girder 1	Girder 2	Girder 3	Girder 4	(ft)	Girder 1	Girder 2	Girder 3	Girder 4
Cond. 1	0.0	0.0	0.0	0.0	96	Cond. 1	0.00E+00	0.00E+00	0.00E+00
Cond. 2	1246.4	1197.5	1157.2	1137.8	88	Cond. 2	6.20E-05	5.95E-05	5.75E-05
Cond. 3	2927.7	2817.4	2719.0	2659.4	80	Cond. 3	1.46E-04	1.40E-04	1.35E-04
Cond. 4	4763.0	4604.9	4438.5	4288.4	72	Cond. 4	2.37E-04	2.29E-04	2.21E-04
Cond. 5	7049.7	6877.3	6631.3	6267.9	64	Cond. 5	3.50E-04	3.42E-04	3.30E-04
Cond. 6	7410.4	7204.8	6946.0	6621.9	56	Cond. 6	3.68E-04	3.58E-04	3.45E-04
Cond. 7	5950.3	5744.8	5542.6	5382.8	48	Cond. 7	2.96E-04	2.86E-04	2.76E-04
Cond. 8	5567.9	5405.2	5220.9	5008.8	40	Cond. 8	2.77E-04	2.69E-04	2.60E-04
Cond. 9	3571.4	3449.2	3332.9	3241.7	32	Cond. 9	1.78E-04	1.71E-04	1.66E-04
Cond. 10	1672.7	1611.6	1557.8	1524.5	24	Cond. 10	8.31E-05	8.01E-05	7.74E-05
Cond. 11	863.7	831.2	804.7	791.5	16	Cond. 11	4.29E-05	4.13E-05	4.00E-05
Cond. 12	326.7	314.3	304.7	300.4	8	Cond. 12	1.62E-05	1.56E-05	1.51E-05
Cond. 13	0.0	0.0	0.0	0.0	0	Cond. 13	0.00E+00	0.00E+00	0.00E+00

Table 19: Moment and Strain Values for 005318 Load Set 5

	Moments via SAP (k-in)				Distance Traveled	Strains via SAP			
	Girder 1	Girder 2	Girder 3	Girder 4	(ft)	Girder 1	Girder 2	Girder 3	Girder 4
Cond. 1	0.0	0.0	0.0	0.0	96	Cond. 1	0.00E+00	0.00E+00	0.00E+00
Cond. 2	1067.2	1118.1	1202.2	1351.5	88	Cond. 2	5.30E-05	5.56E-05	5.98E-05
Cond. 3	2473.1	2631.6	2845.7	3173.1	80	Cond. 3	1.23E-04	1.31E-04	1.41E-04
Cond. 4	3918.4	4313.8	4720.2	5142.3	72	Cond. 4	1.95E-04	2.14E-04	2.35E-04
Cond. 5	5563.1	6489.9	7241.6	7531.6	64	Cond. 5	2.77E-04	3.23E-04	3.60E-04
Cond. 6	5945.9	6781.1	7507.9	7948.2	56	Cond. 6	2.96E-04	3.37E-04	3.73E-04
Cond. 7	4958.6	5380.2	5853.8	6427.9	48	Cond. 7	2.46E-04	2.67E-04	2.91E-04
Cond. 8	4547.9	5088.2	5595.6	5971.1	40	Cond. 8	2.26E-04	2.53E-04	2.78E-04
Cond. 9	2998.6	3235.2	3510.9	3850.5	32	Cond. 9	1.49E-04	1.61E-04	1.75E-04
Cond. 10	1421.9	1509.1	1627.9	1807.6	24	Cond. 10	7.07E-05	7.50E-05	8.09E-05
Cond. 11	744.6	778.5	834.9	933.2	16	Cond. 11	3.70E-05	3.87E-05	4.15E-05
Cond. 12	284.0	294.7	315.0	352.5	8	Cond. 12	1.41E-05	1.46E-05	1.57E-05
Cond. 13	0.0	0.0	0.0	0.0	0	Cond. 13	0.00E+00	0.00E+00	0.00E+00

3.2.6 Verification with Experimental Data

Only the section properties for the steel W-section were used when load rating the steel girder bridge. However, the bridge girder acts in accidental composite action when loaded. Accidental composite action occurs when the strength of the bond between the concrete slab and the beam or the cohesion is larger than the shear force experienced along the connecting plane. This simply means that the concrete slab will aid the steel girder in adding stiffness to the bridge.

Shear studs were not located in the bridge construction documents provided. Shear studs are welded to the top flange of steel beams and the concrete slab is poured along the bridge span. These studs are casted into the concrete slab and provide stiffness and capacity to the steel girder, acting now as a true composite section.

In reality, some composite action will occur when a concrete deck is cast on steel girders. This phenomenon is called accidental composite action as mentioned above. Therefore, when modeled in SAP, composite action can be considered in calibration techniques.

Using the composite section properties was the most efficient way to calibrate the model for actual bridge behavior. The composite girder section properties determined above were used for conversion to strain. Similar to Bridge 005248, only the peak strain values can be used to verify proper calibration. This is due to unknown loading truck behavior in experimental data; hence, accurate conversion of time to distance is impossible. The model was tweaked until the peak strains for SAP and Experimental graphs below matched.
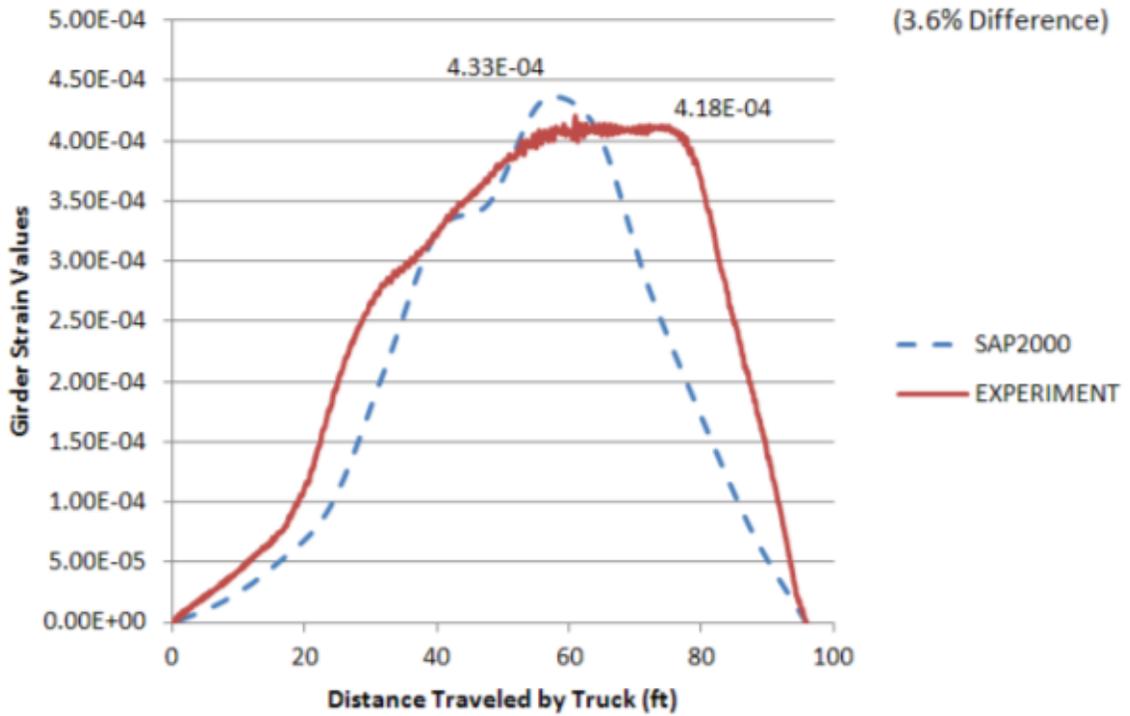
Figure 48: Strain Comparison – Set 1, Girder 1
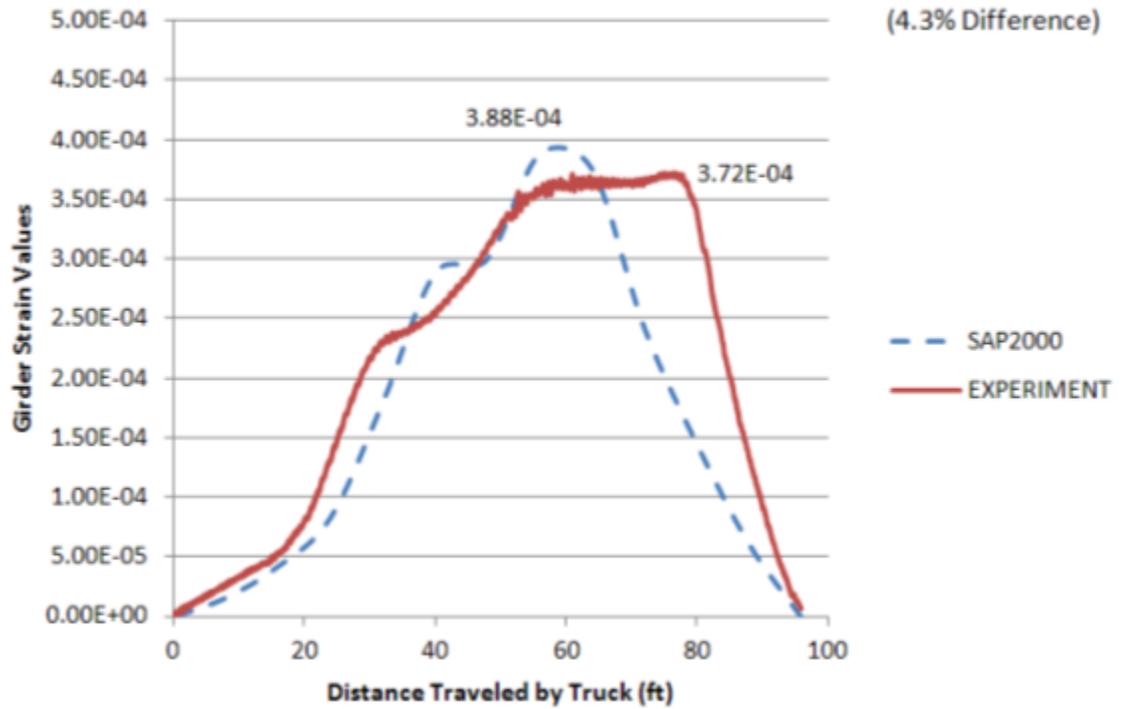
Figure 49: Strain Comparison – Set 1, Girder 2
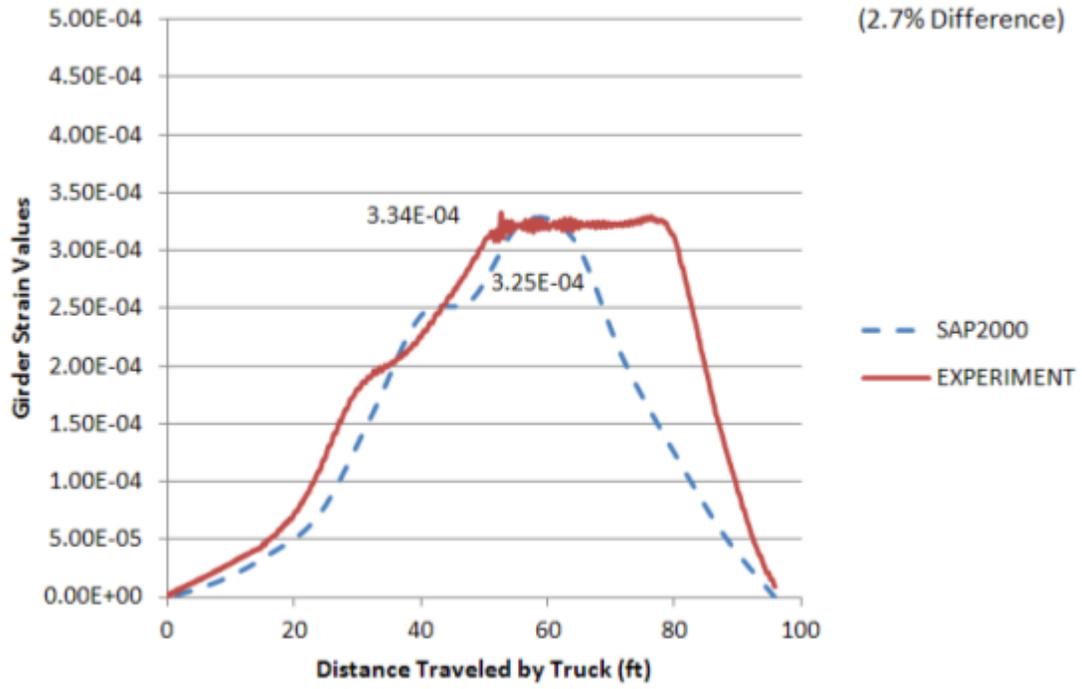
Figure 50 Strain Comparison – Set 1, Girder 3
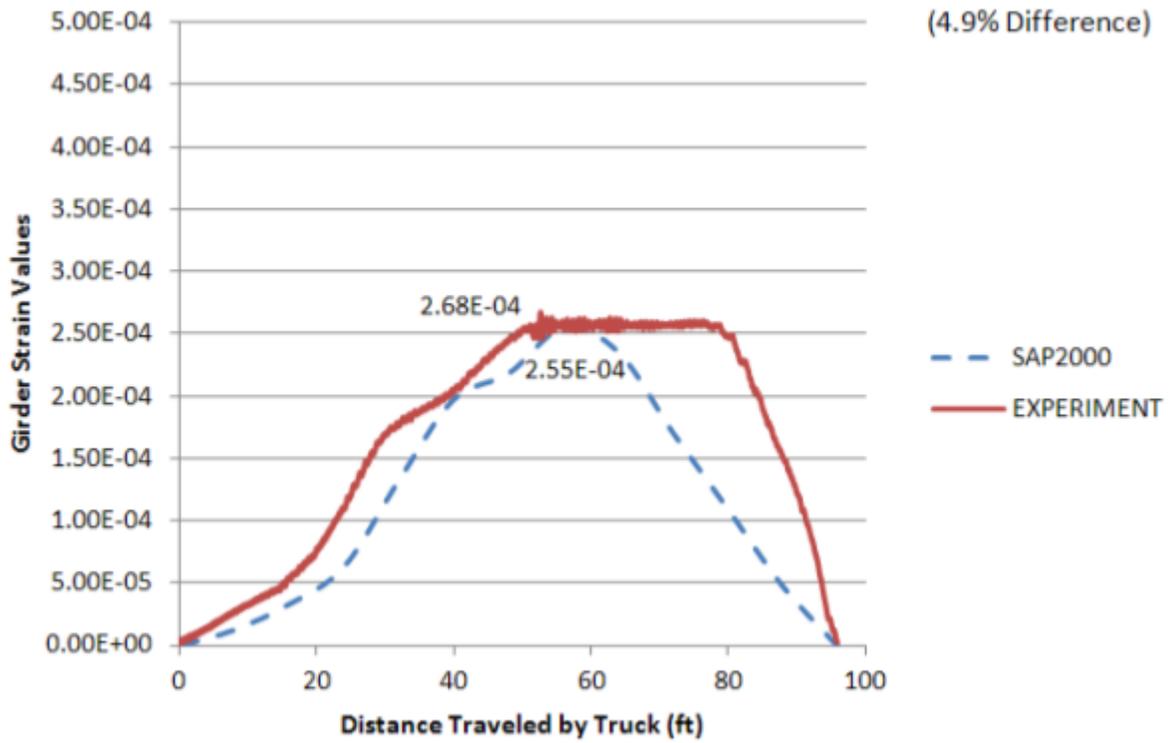
Figure 51: Strain Comparison – Set 1, Girder 4

(8.2% Difference)
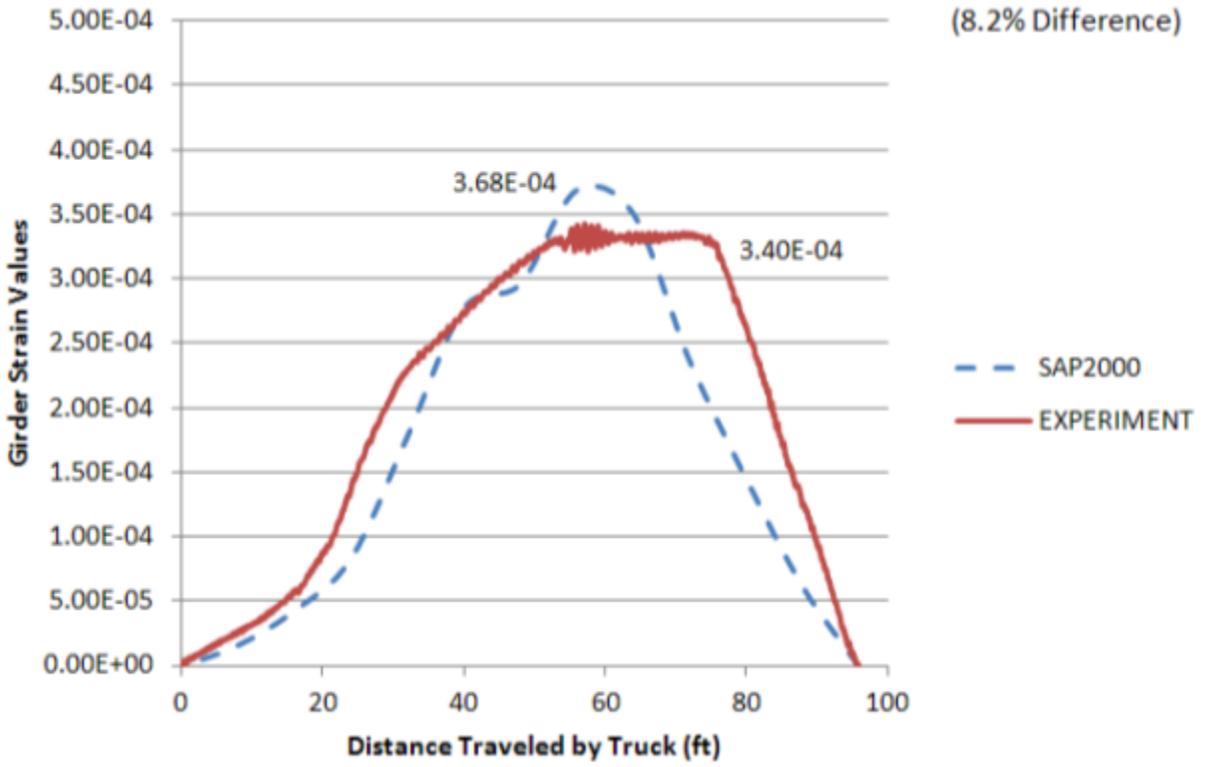
Figure 52: Strain Comparison – Set 3, Girder 1

(10.5% Difference)
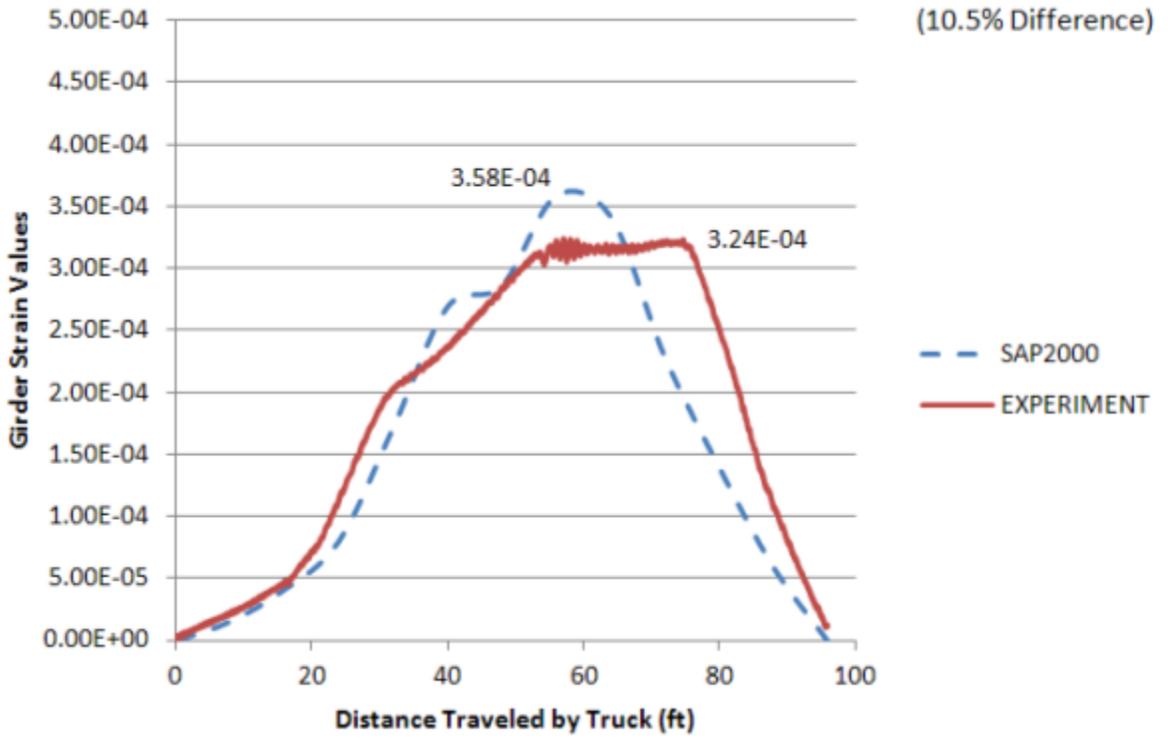
Figure 53: Strain Comparison – Set 3, Girder 2
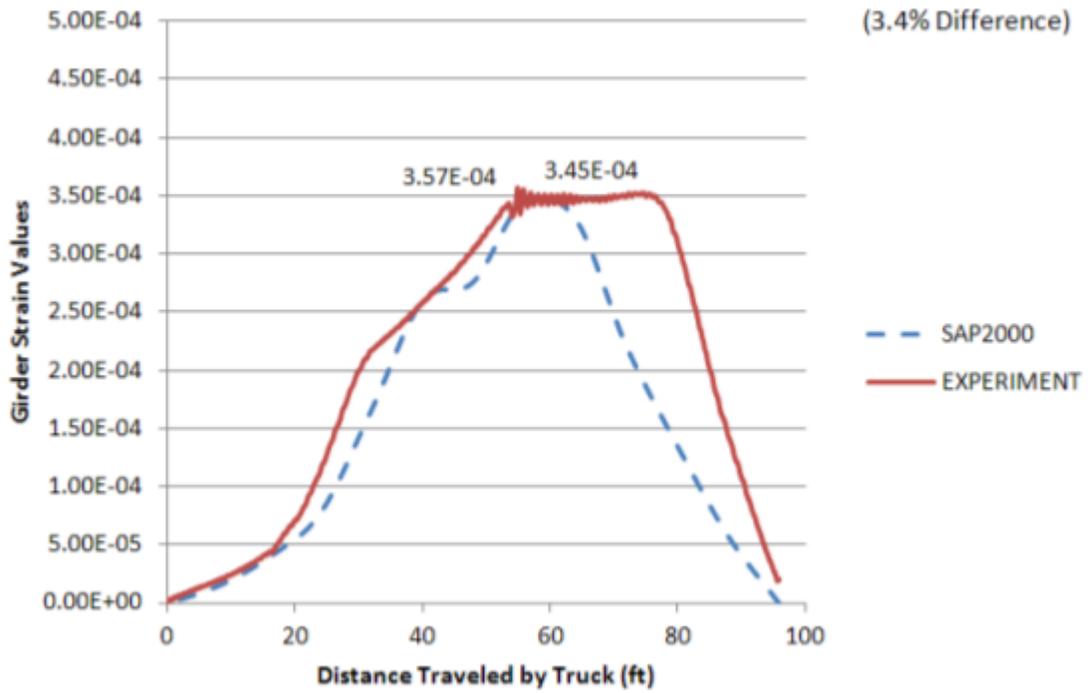
Figure 54: Strain Comparison – Set 3, Girder 3
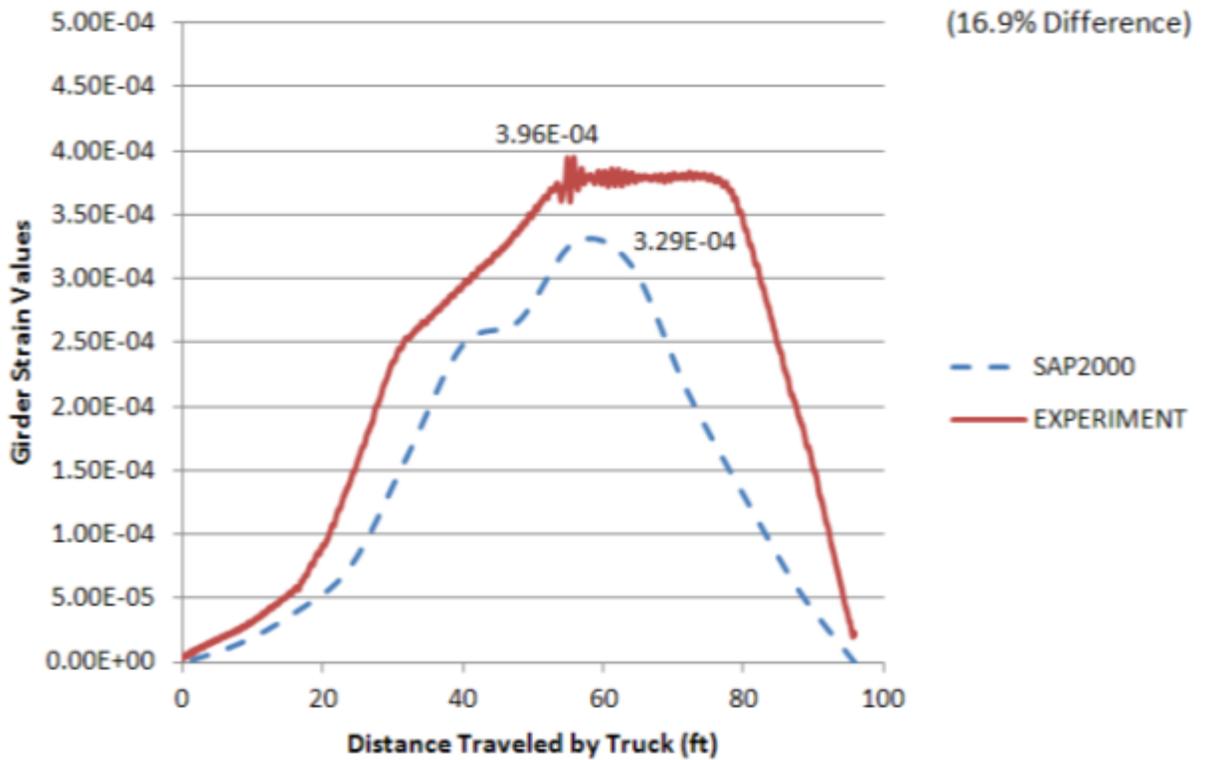
Figure 55: Strain Comparison – Set 3, Girder 4
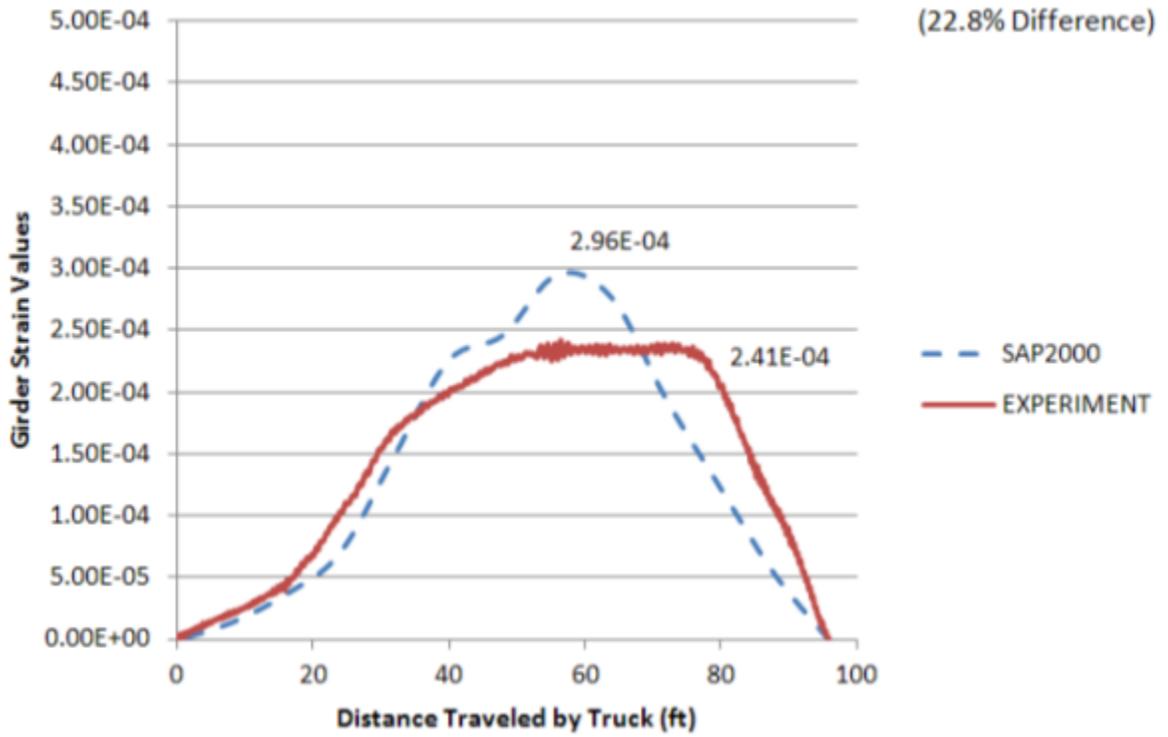
Figure 56: Strain Comparison – Set 5, Girder 1
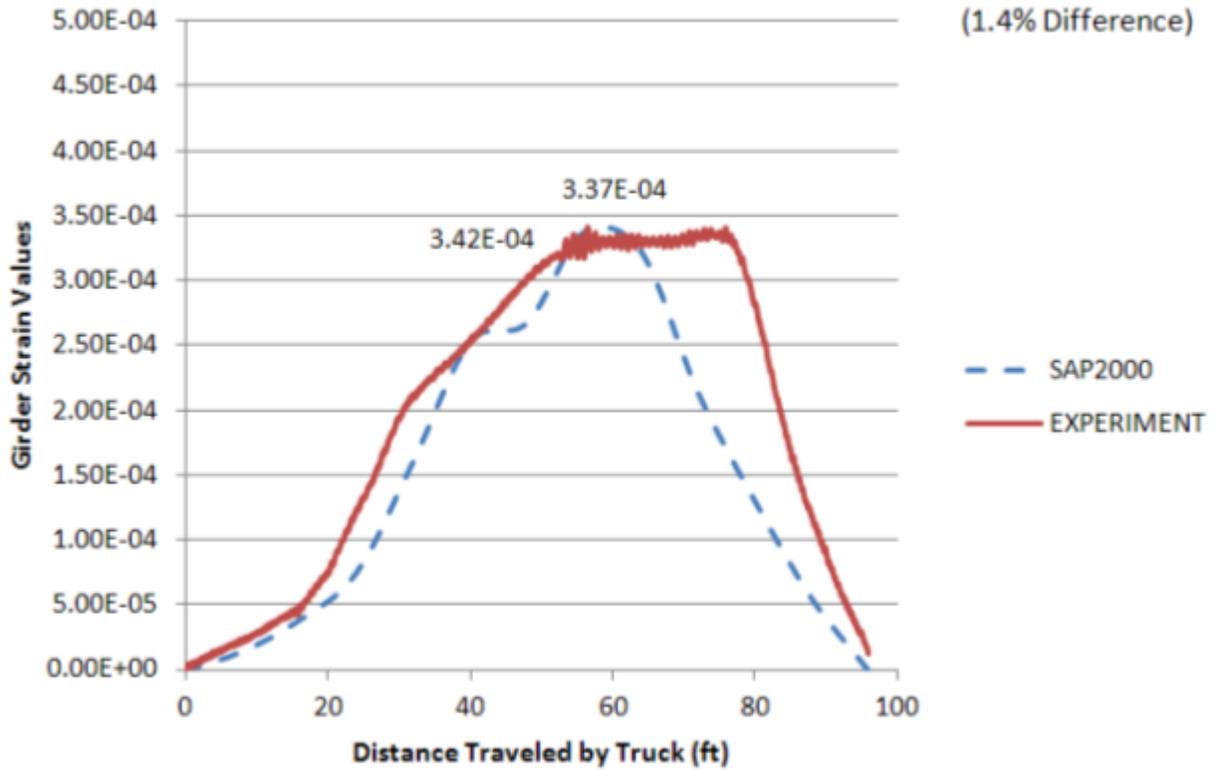
Figure 57: Strain Comparison – Set 5, Girder 2
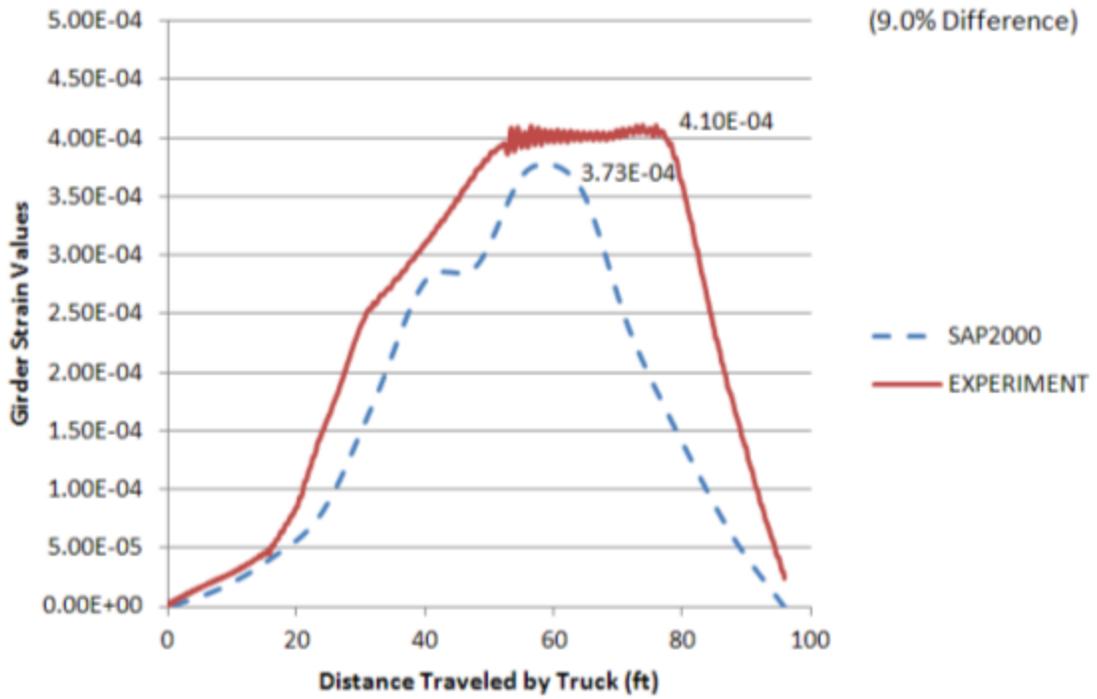
Figure 58: Strain Comparison – Set 5, Girder 3
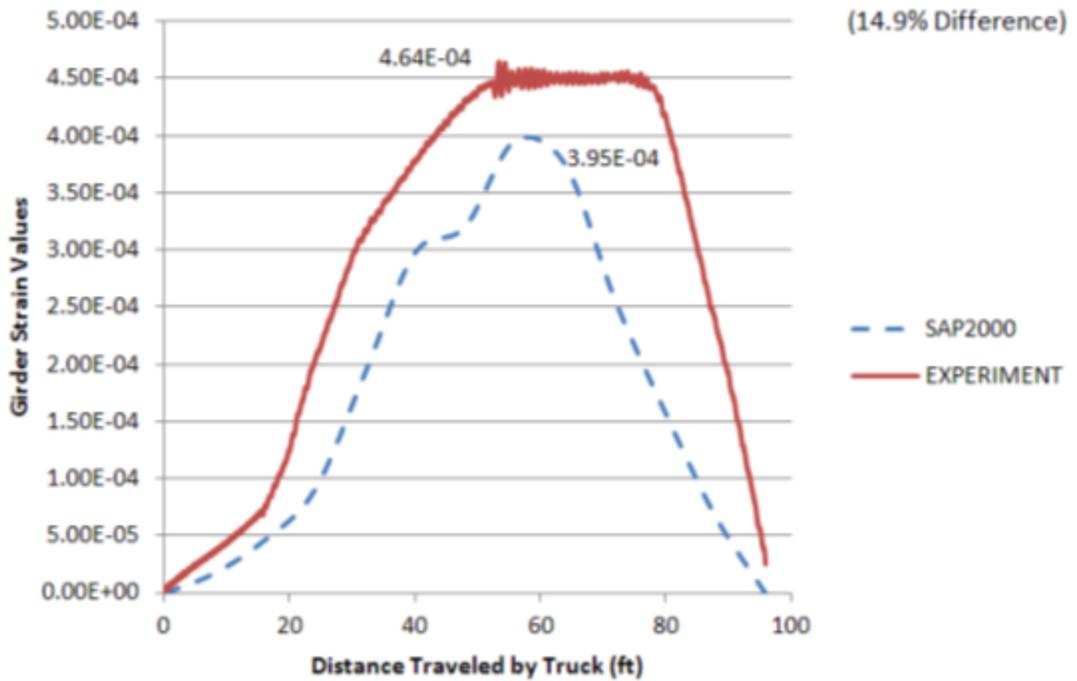
Figure 59: Strain Comparison – Set 5, Girder 4

3.2.7 Load Rating for Bridge 005318

Load rating using the Allowable Stress Method and the Load Factor Method were considered in rating Bridge 005318. The American Institute of Steel Construction (AISC) provides section properties for rolled steel members in the AISC Manual. Although the bridge was model to imitate composite action, load rating must use section properties for the rolled W36x160 only. The table below summarizes the necessary properties gathered from the AISC Construction Manual.

Table 20: Girder Section Properties for Bridge 005318

	Girder 1	Girder 2	Girder 3	Girder 4
I_g (in^4)	9760	9760	9760	9760
A_s (in^2)	47.00	47.00	47.00	47.00
A_v (in^2)	23.40	23.40	23.40	23.40
Z_x (in^3)	624	624	624	624
S_x (in^3)	541	541	541	541
F_y (ksi)	33	33	33	33
Impact, I	1.26	1.26	1.26	1.26

The area of steel contributing to the shear capacity of the girder, A_v, was calculated by multiplying the thickness of the web by the girder height. The steel yield strength, F_y, and the Impact factor were both taken directly from the analysis by ALDOT. Using the properties above, the live and dead load stresses that the girder experienced can be calculated. These stresses can be used in the same general load rating equation as above. Placing the resultant of two standard HS20-44 trucks in the center of the bridge produced the maximum moment and shear experienced by the bridge.

Only the truck live load was considered when gathering the maximum moment and strain values from SAP. This was necessary to calculate the stress effect of the live load only.

All truck point loads were deleted from the model and the maximum moment and shear due to the weight of the bridge was recorded. All of the maximum values are included in the table below.

Table 21: SAP2000 Max Moment and Shear for Bridge 005318

	G1	G2	G3	G4
M_{Lmax} (k-in)	8676	7800	7800	8676
M_{Dmax} (k-in)	5892	5892	5892	5892
V_{Lmax} (k)	47.1	43.1	43.1	47.1
V_{Dmax} (k)	27.4	27.4	27.4	27.4

The values above were used to calculate the live and dead stress effects on the structure. In this case, the moment values were divided by the section modulus of the W36x160. The live load stress effect includes the impact factor, but the dead load stress has no impact to be accounted for.

Table 22: Bridge 005318 SAP Stress Effects for Moment Rating

	G1	G2	G3	G4
L_{steel} (psi)	11322.01	11760.48	11760.48	11322.01
D_{steel} (psi)	8413.72	8586.13	8559.21	8326.99

Table 23: Bridge 005318 SAP Stress Effects for Shear Rating

	G1	G2	G3	G4
L (psi)	2530	2310	2310	2530
D (psi)	1170	1170	1170	1170

The Allowable Stress Method was considered first when rating the bridge using the values obtained above. Both the Operating and Inventory level factors were calculated. As for the moment nominal capacity for a steel girder, AASHTO allows for $0.75*F_y$ at

the Operating Level and $0.55*F_y$ at the Inventory Level. This nominal capacity is to

utilized in the general rating equation for load rating of the structure..

Table 24: ASR Moment Rating Factors for 005318

	G1	G2	G3	G4
RF_{steel} (Op)	0.69	0.77	0.77	0.69
RF_{steel} (Inv)	0.36	0.36	0.36	0.36

For the Allowable Stress Method, AASHTO also provides nominal stress values to be

used in the general equation. The allowable shear stress at the Operating Level is to be

13,500psi, and the allowable stress at the Inventory Level is 11,000psi. These given

values were placed in the general rating equation and the following factors were

calculated.

Table 25: ASR Shear Rating Factors for 005318

	G1	G2	G3	G4
RF (Op)	4.88	5.33	5.33	4.88
RF (Inv)	3.89	4.25	4.25	3.89

The minimum rating factor for the Operating and Inventory Levels governs the rating of

the bridge. The Allowable Stress Method minimum rating factors for Bridge 005318

were 0.69 and 0.36 for Operating and Inventory levels, respectively.

Next, the Operating and Inventory Level ratings for the Load Factor Method were

calculated. The nominal capacity coefficients for use in the LFR equations are based on

the code dictated capacities of the section. If certain parameters for the section are met

and the section is compact, AASHTO allows for one to use the plastic limit state as the

section modulus for the steel girder. In the case for Bridge 005318, these parameters were

met and the plastic limit state Z_x was used in calculating the section moment capacity. The moment and shear capacity equations used are as follows:

Equation 7: Moment Capacity for Rolled Steel Girders

Equation 8: Shear Capacity for Rolled Steel Girders

The calculated values for   and   were used as nominal capacities in the general rating equation along with the coefficients for LFR as noted in section 2.3 above. The Load Factor Method minimum rating factors for Bridge 005318 were 0.91 and 0.55 for Operating and Inventory levels, respectively. The following tables summarize the rating factors calculated for each entity.

Table 26: LFR Moment Rating Factors for 005248

	G1	G2	G3	G4
RF_{steel} (Op)	0.91	1.02	1.02	0.91
RF_{steel} (Inv)	0.55	0.61	0.61	0.55

Table 27: LFR Shear Rating Factors for 005248

	G1	G2	G3	G4
RF (Op)	9.58	10.47	10.47	9.58
RF (Inv)	5.74	6.27	6.27	5.74

With large steel bridge girders, moment will most likely control the rating factor for the bridge. This is due to the fact that large W-sections have thick webs that provide adequate shear resistance. ALDOT used the load test rating when determining the rating factor for the bridge. Results versus the SAP model will vary slightly, as only ASR and LFR were used. ALDOT determined that the Operating and Inventory Ratings for Bridge 005318

were 1.19 and 0.59, respectively. These load factors were multiplied by the weight of an

HS20-44 truck (36 tons) for an allowable weight posting. Only the factors calculated for

LFR using values via the SAP model are to be compared to ALDOT"s results. The

following table summarizes the comparison of ALDOT and SAP model load rating

results.

	ALDOT LR Factor	SAP LR Factor	ALDOT Rating	SAP Rating	Difference
Operating Level	1.19	0.91	42.9 Tons	32.7 Tons	23.5%
Inventory Level	0.59	0.55	21.5 Tons	19.8 Tons	6.8%

For the steel girder bridge, the ratings were lower than the ALDOT calculated ratings

using the Load Test Method. One reason for the lower postings is that the maximum

moment in a girder was achieved at the end girders. When comparing the SAP strain

values to the experimental strain values, one will notice that the SAP values represent a

less stiff bridge. For a more accurate load rating, the factored difference can be taken

account in the load rating factor.

Another place for error lies in the difference in calculations for the load rating factor. In

ALDOT's initial assessment, a 2D line with wheel loads was used to calculate live load

moment for the girder. However, SAP realizes and includes the load distribution to

nearby girders for a more accurate analysis of the structure. Note that the rating factor for

Bridge 005318 at the Operating Level is below 1.0, so bridge posting is necessary.

3.3 ALDOT BRIDGE 012296

3.3.1 Location of Bridge

Bridge 012296 serves as a connector for I-459 over Sulphur Springs Road. The bridge is near the I-459 and SR-150 Interchange, which is noted as Exit 10. The bridge drawings are dated for the fiscal year of 1978, and the bridge was constructed in 1980. A map is included below to display the location of the bridge in relation to Exit 10.

Figure 60: Location of ALDOT Bridge 012296

The bridge has ten girders spaced at 7'-1" over a 46'-4" span. The girders are AASHTO Type II for the end spans, including the one load rated via SAP2000. However, the middle span utilizes AASHTO Type III girders.

The Type II girders are three feet in depth, and these specifically have a total of twelve pre-stressing strands with a yield stress of 270,000 psi. Elevations and cross-sections of the bridge girders are included as figures below.

3.3.2 Bridge Information

Bridge Photos

Figure 61: Elevation Photo of Bridge 012296
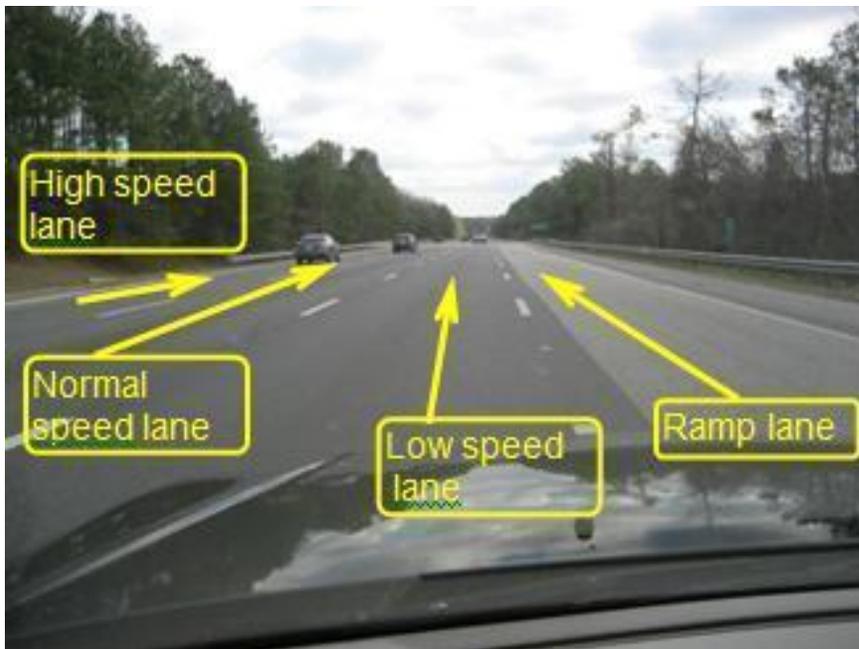
Figure 62: Lane Details Bridge 012296
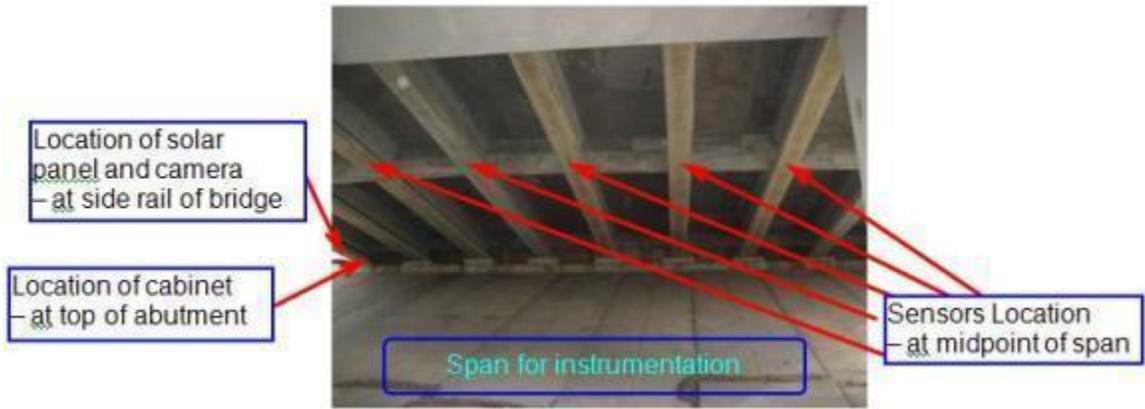
Figure 63: Underside Span Photo for Bridge 012296

Elevations and Cross Sections
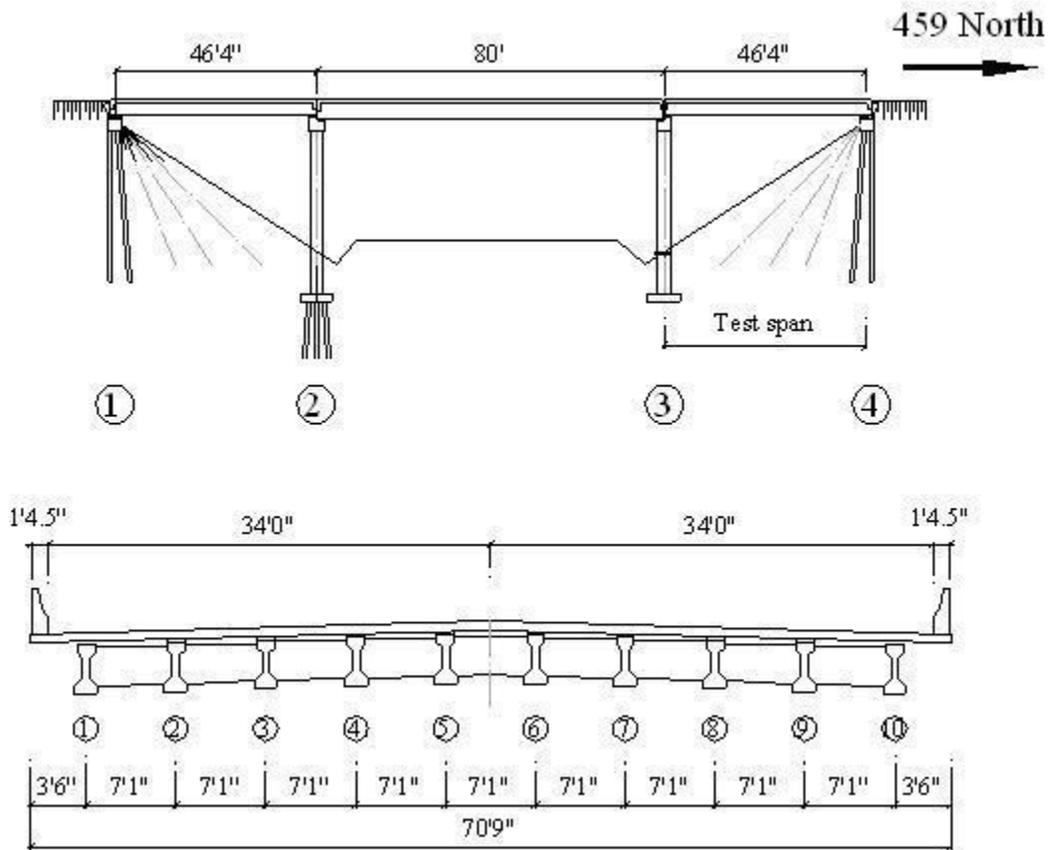
Figure 64: Elevation and Cross-section of Bridge 012296
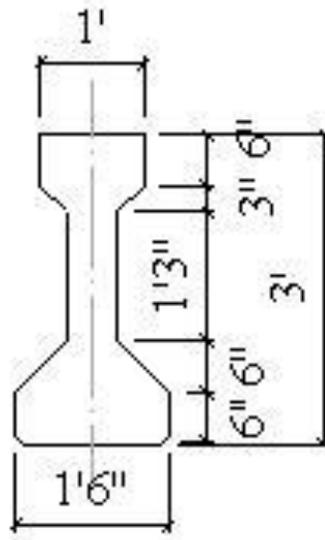
Figure 65: Test Span Girder Section for Bridge 012296
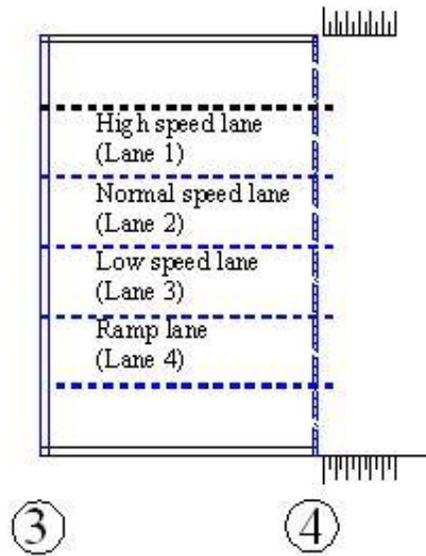
Figure 66: Test Span Lane Details for Bridge 012296

For the pre-stressed girder bridge, Bridge 012296, there was no set of ALDOT load factor calculations provided. However, strain data gathered from loading the bridge with three separate trucks was given for bridge calibration purposes. Sensor data for each of the three trucks was recorded.

Similar to the other bridges modeled in SAP, determining the correct location of the sensor in relation to the span supports was crucial in calibrating the model. The sensors were placed near mid-span, as this location is expected to experience the maximum moment.

The sensors were placed 22'-0" from the North end support of the bridge. SAP can generate a moment and shear along any frame line at a certain distance from the support. This location was used for calibration of the bridge.
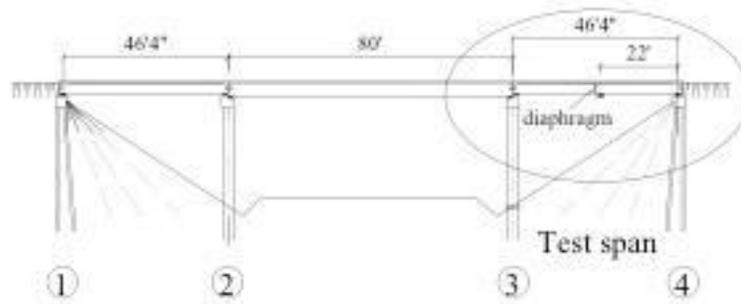
Figure 67: Bridge 012296 Test Span Elevation
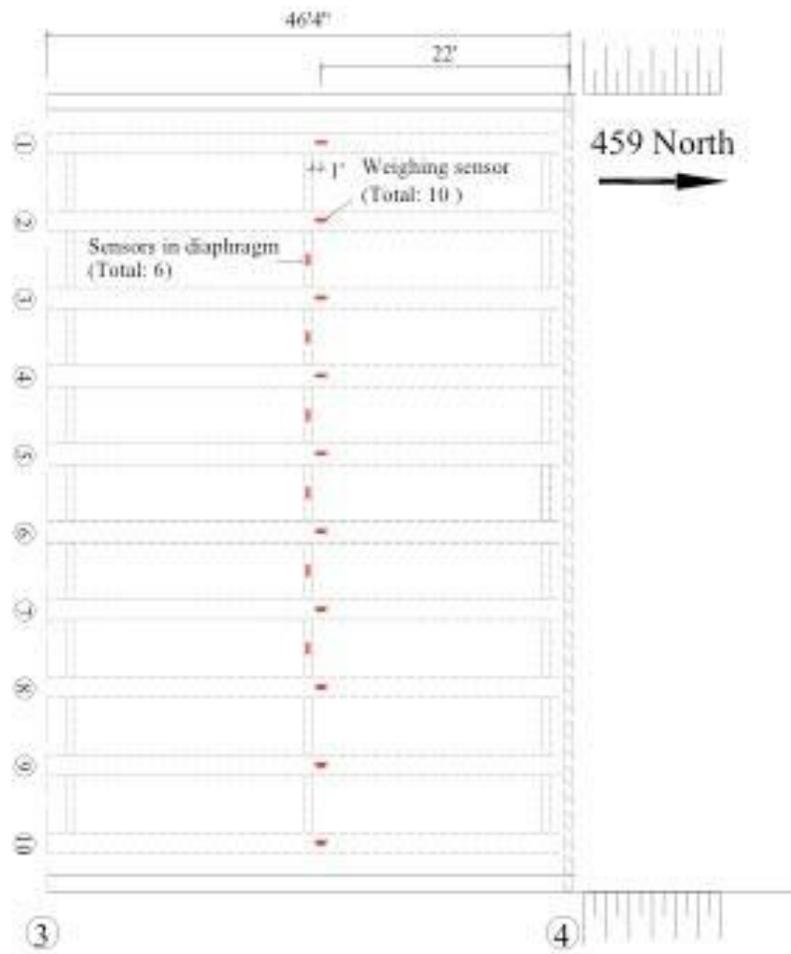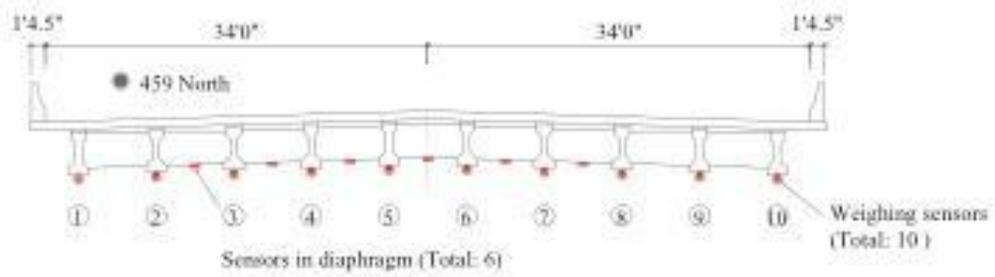
Figure 68: Weighing Sensor Locations for Bridge 012296
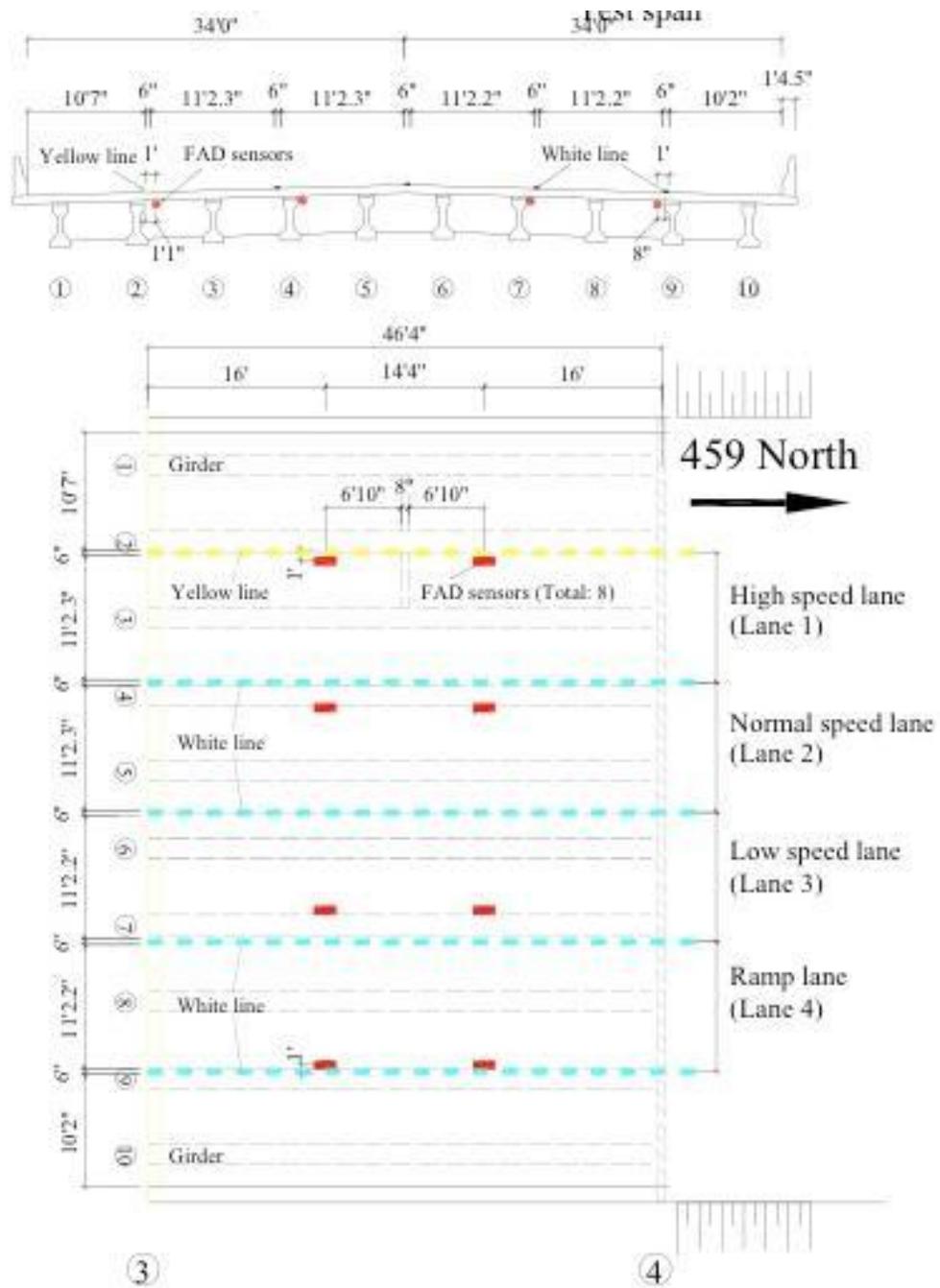
Figure 69: AMDP Sensor Locations and Lane Dimensions for Bridge 012296

3.3.3 Qualitative Assessment of Model

Bridge 012296 measurements were recorded during the week of March 17, 2008. The test was completed in a five day period from March 18-22. The SiWIM Bridge weigh-in-motion system was calibrated and used for obtaining experimental data. ALDOT trucks were used for experimentation and data collection in the first two days. Gross weights and axel loads of vehicles pulled from traffic were used in the remaining three days of experimentation. These loads were statically weighed by ALDOT, and compared to the values obtained by the SiWIM.
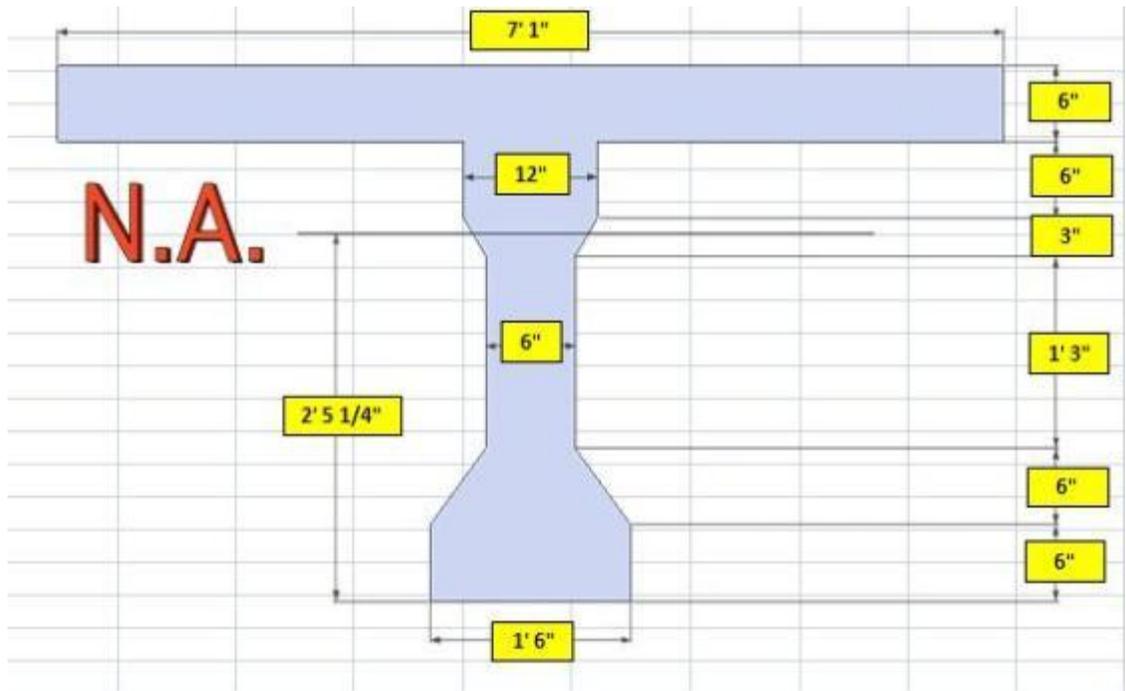
Figure 70: Girder and Slab Section Dimensions for Bridge 012296

Table 28: Composite Girder Section Properties for 012296

I (in^4)	$f'c$	E (psi)	c (in)
167453	5000	4030508	29.27

Table 29: AASHTO Type II Beam Section Properties for 012296

I (in^4)	$f'c$	E (psi)	c (in)
50980	5000	4030508	15.83

Table 30: Loading Information for Test Trucks 1, 3, and 4

Number				1						
Tag No				IC 35 J0						
Axle Number	US unit					SI unit				
	Wheel Weight		Axle or Group Weight	Axle Spacing	Legal	Wheel Weight		Axle or Group Weight	Axle Spacing	Legal
	Left	Right	Total							
1	5600	5450								
2	7300	8000		24'5"						
3	7350	7900		4'3"						
4	8800	8550		34'6"						
5	7950	8350		10'3"						
			75250							

Weighing time: 03-20-08 10:30AM

Number				3						
Tag No				1003803						
Axle Number	US unit					SI unit				
	Wheel Weight		Axle or Group Weight	Axle Spacing	Legal	Wheel Weight		Axle or Group Weight	Axle Spacing	Legal
	Left	Right	Total							
1	5550	5750								
2	8850	8550		18'8"						
3	8450	8450		4'4"						
4	9400	9650		33'2"						
5	8150	8000		4'1"						
			80750							

Weighing time: 03-20-08 11:25AM

Number				4						
Tag No				1013995						
Axle Number	US unit					SI unit				
	Wheel Weight		Axle or Group Weight	Axle Spacing	Legal	Wheel Weight		Axle or Group Weight	Axle Spacing	Legal
	Left	Right	Total							
1	5250	5450								
2	7850	8950		19'3"						
3	7750	8550		4'4"						
4	8550	9200		28'6"						
5	8600	8750		4'4"						
			78900							

Weighing time: 03-20-08 12:08PM

Test Truck 1
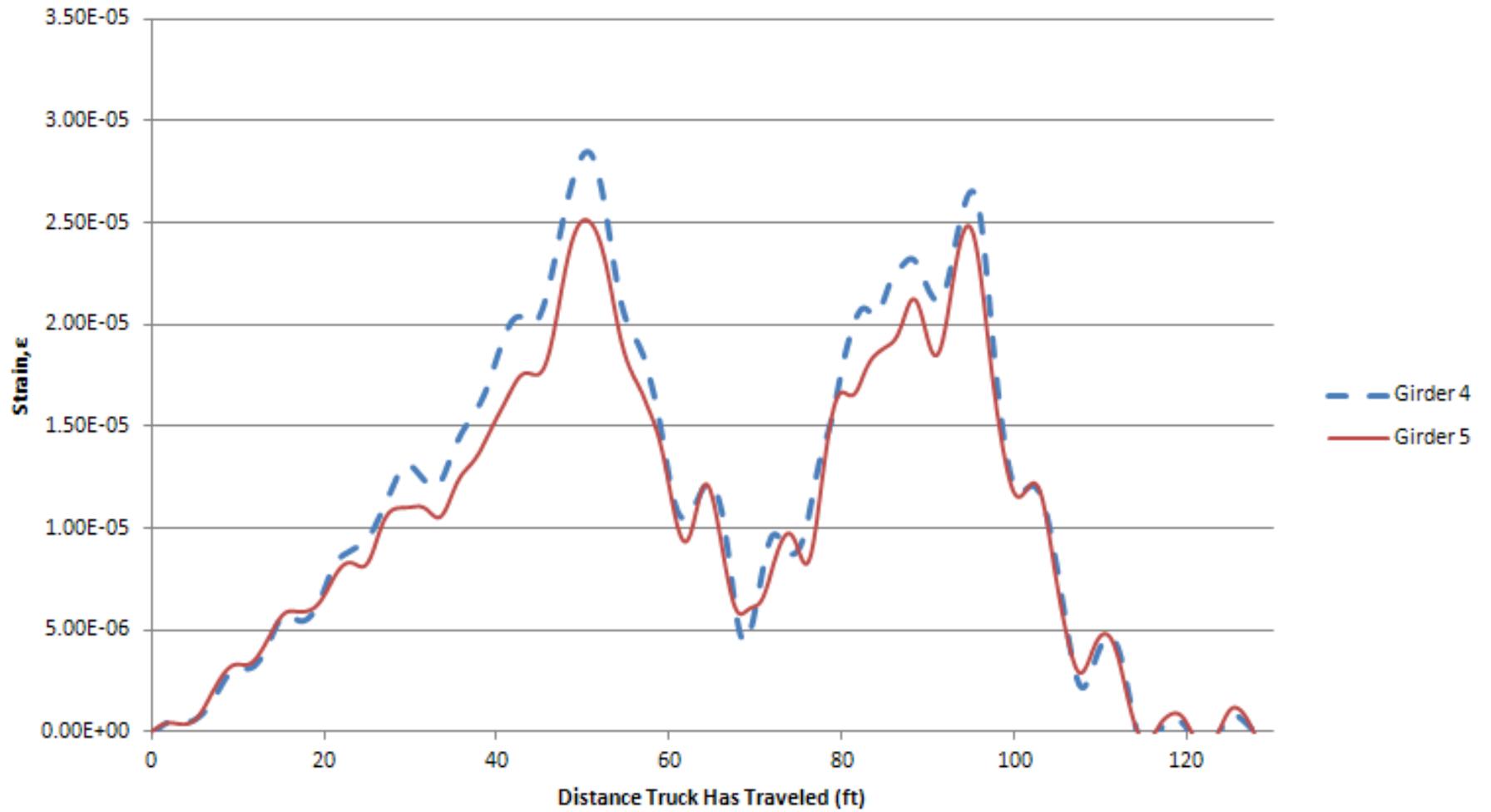
Figure 71: Experimental Strains for Test Truck 1

73
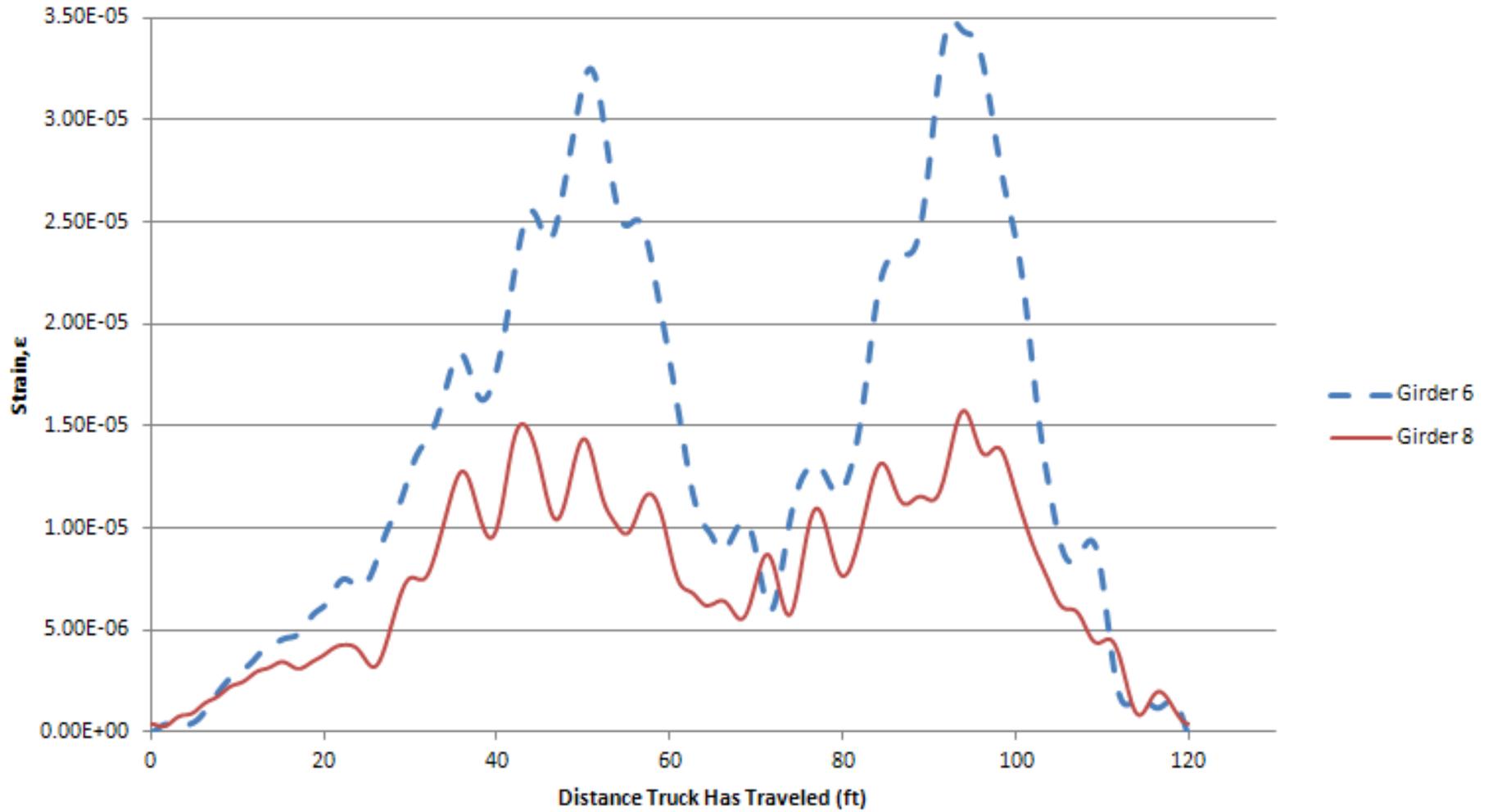
Figure 72: Experimental Strains for Test Truck 3

Test Truck 4
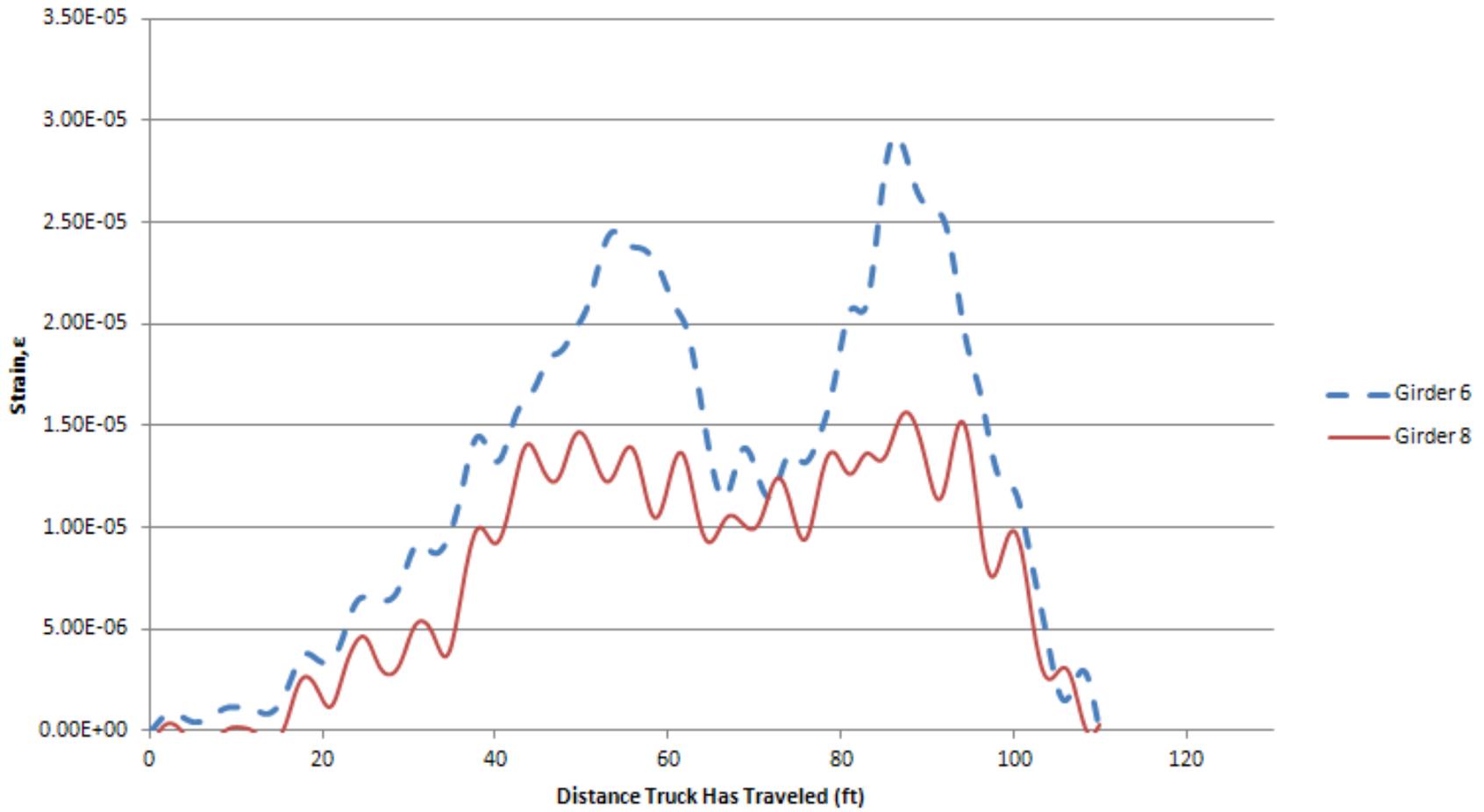
Figure 73: Experimental Strains for Test Truck 4

3.3.4 Modeling of Bridge in SAP2000

Dimensions and section properties for the ALDOT Bridge 012296 were obtained from the information given above, and the bridge was modeled as a true grid in SAP2000. Section properties were then defined for each frame modeled. The concrete girders were modeled at a concrete strength of 5000psi, and slab sections were modeled as 3000psi. Screenshots of the model in SAP2000 are included below.
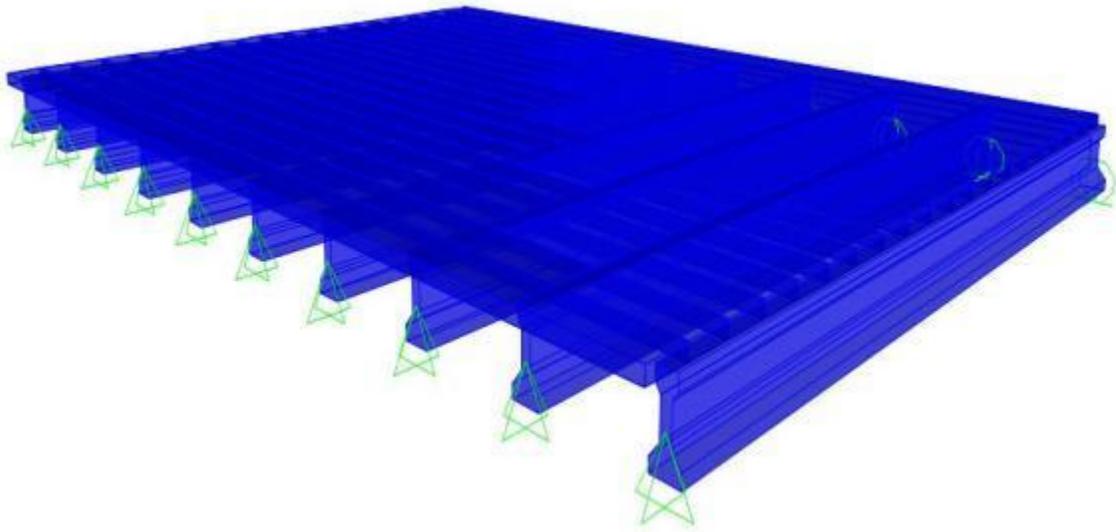
Figure 74: Bridge 012296 Model - Perspective Model

Figure 75: Bridge 012296 Model - 3D Side View
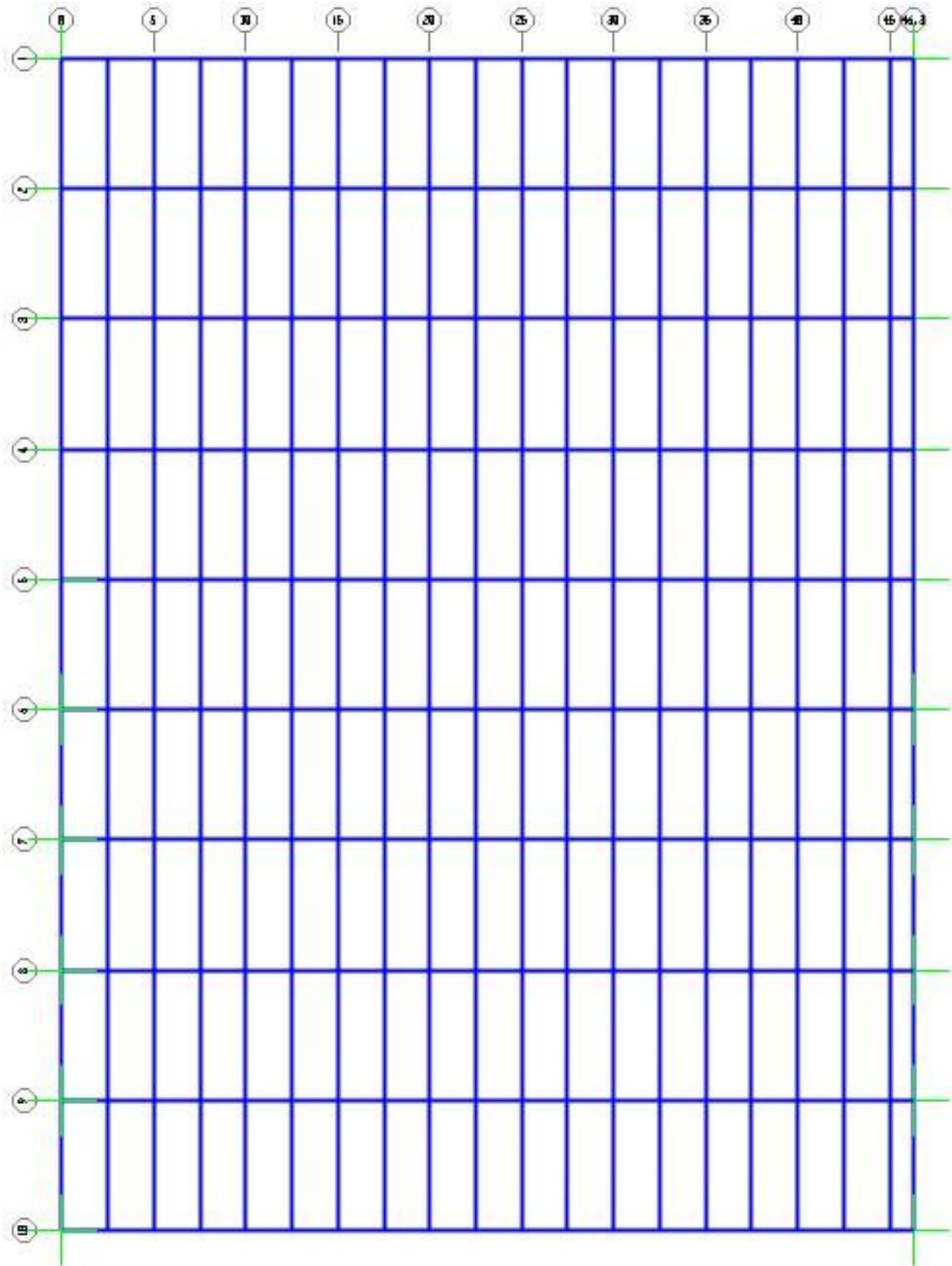
Figure 76: Bridge 012296 Model - Top 2D Frame View

3.3.5 Bridge Model Analysis

Loading Conditions

For Test Trucks 1, 3, and 4, static loading conditions were determined with the truck

moving ten feet headed north each condition. These conditions were modeled and

analyzed in SAP2000 to generate a strain curve reflecting the experimental curves. The

frames in SAP2000 were loaded using point loads in the respective lanes noted in the

experimental results.

Results for Moments and Strains

For each test truck, moments were gathered from SAP2000 and converted to

strain to compare to experimental results. There were two girders chosen for comparison,

and the results were compiled into tabular form. Moments at each Girder are noted in

Kip-in, and the strains are without unit.

Table 31: Moment and Strain Values for 012296 Test Truck 1

Moments via SAP (k-in)		Strains via SAP		*Distance Traveled*
	Girder 4	Girder 5	Girder 4	Girder 5	*(ft)*
Cond. 1	0.0	0.0	0.0	0.0	0
Cond. 2	76.3	69.5	3.3E-06	3.0E-06	10
Cond. 3	211.6	221.0	9.2E-06	9.6E-06	20
Cond. 4	229.7	227.8	1.0E-06	9.9E-06	30
Cond. 5	343.0	320.3	1.5E-05	1.4E-05	40
Cond. 6	678.1	755.4	2.9E-05	3.3E-05	50
Cond. 7	397.7	400.4	1.7E-05	1.7E-05	60
Cond. 8	145.8	131.3	6.3E-06	5.7E-06	70
Cond. 9	258.7	244.2	1.1E-05	1.1E-05	80
Cond. 10	643.2	687.9	2.8E-05	3.0E-05	90
Cond. 11	585.8	638.9	2.5E-05	2.8E-05	100
Cond. 12	176.4	168.6	7.6E-06	7.3E-06	110
Cond. 13	16.1	14.6	7.0E-07	6.3E-07	120

Table 32: Moment and Strain Values for 012296 Test Truck 3

Moments via SAP (k-in)		Strains via SAP		Distance Traveled
	Girder 4	Girder 5	Girder 4	Girder 5	(ft)
Cond. 1	0.0	0.0	0.0	0.0	0
Cond. 2	73.1	90.4	3.2E-06	3.9E-06	10
Cond. 3	221.9	169.6	9.6E-06	7.4E-06	20
Cond. 4	299.2	292.2	1.3E-05	1.3E-05	30
Cond. 5	591.7	522.7	2.6E-05	2.3E-05	40
Cond. 6	761.2	502.6	3.3E-05	2.2E-05	50
Cond. 7	241.1	261.1	1.0E-05	1.1E-05	60
Cond. 8	185.5	236.0	8.0E-06	1.0E-05	70
Cond. 9	561.1	477.3	2.4E-05	2.1E-05	80
Cond. 10	768.2	513.9	3.3E-05	2.2E-05	90
Cond. 11	242.0	263.1	1.0E-05	1.1E-05	100
Cond. 12	15.0	18.7	6.5E-07	8.1E-07	110
Cond. 13	0.0	0.0	0.0	0.0	120

Table 33: Moment and Strain Values for 012296 Test Truck 4

Moments via SAP (k-in)		Strains via SAP		Distance Traveled
	Girder 4	Girder 5	Girder 4	Girder 5	(ft)
Cond. 1	0.0	0.0	0.0	0.0	0
Cond. 2	75.6	93.3	3.3E-06	4.0E-06	10
Cond. 3	250.1	205.9	1.1E-05	8.9E-06	20
Cond. 4	397.5	403.7	1.7E-05	1.8E-05	30
Cond. 5	684.5	515.8	3.0E-05	2.2E-05	40
Cond. 6	521.5	411.0	2.3E-05	1.8E-05	50
Cond. 7	225.6	271.4	9.8E-06	1.2E-05	60
Cond. 8	332.9	333.6	1.4E-05	1.4E-05	70
Cond. 9	616.1	484.3	2.7E-05	2.1E-05	80
Cond. 10	481.0	380.6	2.1E-05	1.7E-05	90
Cond. 11	114.3	127.8	5.0E-06	5.5E-06	100
Cond. 12	0.0	0.0	0.0	0.0	110
Cond. 13	0.0	0.0	0.0	0.0	120

3.3.6 Verification with Experimental Data

The strains calculated using the moments gathered from SAP were compared with experimental values provided. The graphs for Bridge 012296 differ from the previously analyzed bridges. Since this bridge is located on an Interstate, it can be safely assumed that the truck crosses the bridge at a constant speed.

Although strain values are taken at extremely small time increments, distance traveled across the bridge can be shown assuming a constant speed. The strain data was analyzed to find at what point the truck first approaches the bridge. The point at which the strain values begin to rise in the positive direction can be assumed to be the first sign of the truck on the bridge.

A factor was determined using the number of data points remaining and knowing the total span length of the bridge. This factor was multiplied by the time data to convert into distance. Peak strain values remain the crucial part of calibration, however.

In the graphs below, one will see that there is no plateau for strain values gathered from experimental data. The absence of the strain plateau as seen in the previous bridge examples, further proves that the truck crossed the bridge at a constant speed. Strain values gathered from SAP were graphed versus the distance traveled along the bridge, and these graphs were joined for comparison. Peak strain values are the only values of interest. One will notice that the farther away the girder is from the load concentration, the less accurate the strain values are representative of bridge behavior. Since load rating involves gathering maximum values a certain girder experiences, there will be a high load concentration at that girder. Therefore girder moments used for load ratings are precise.
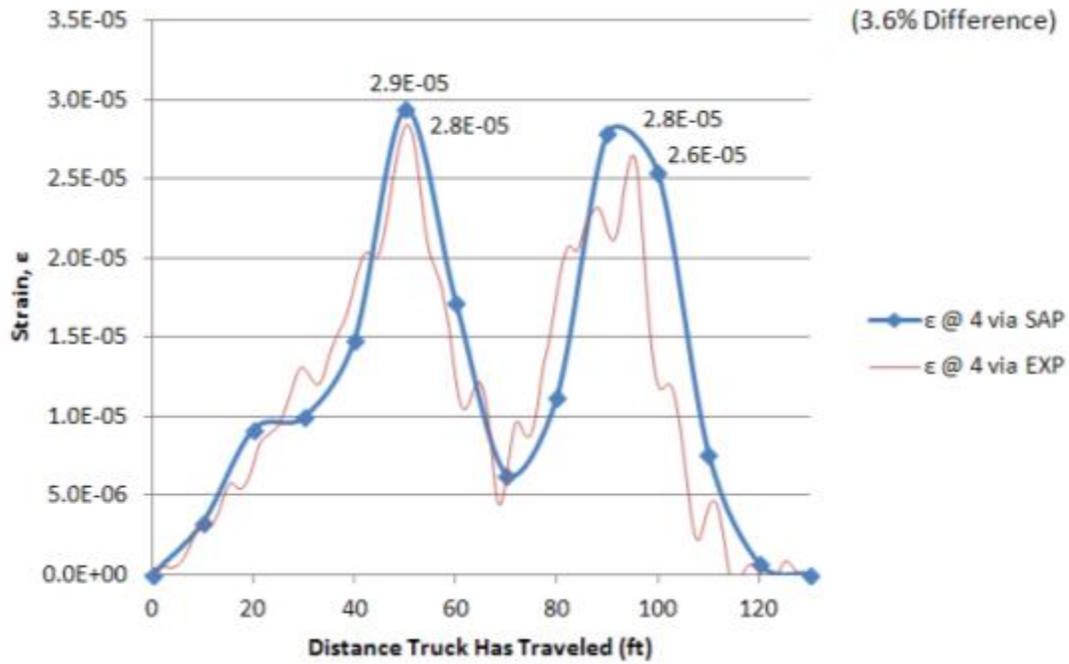
Figure 77: Strain Comparison – Truck 1, Girder 5
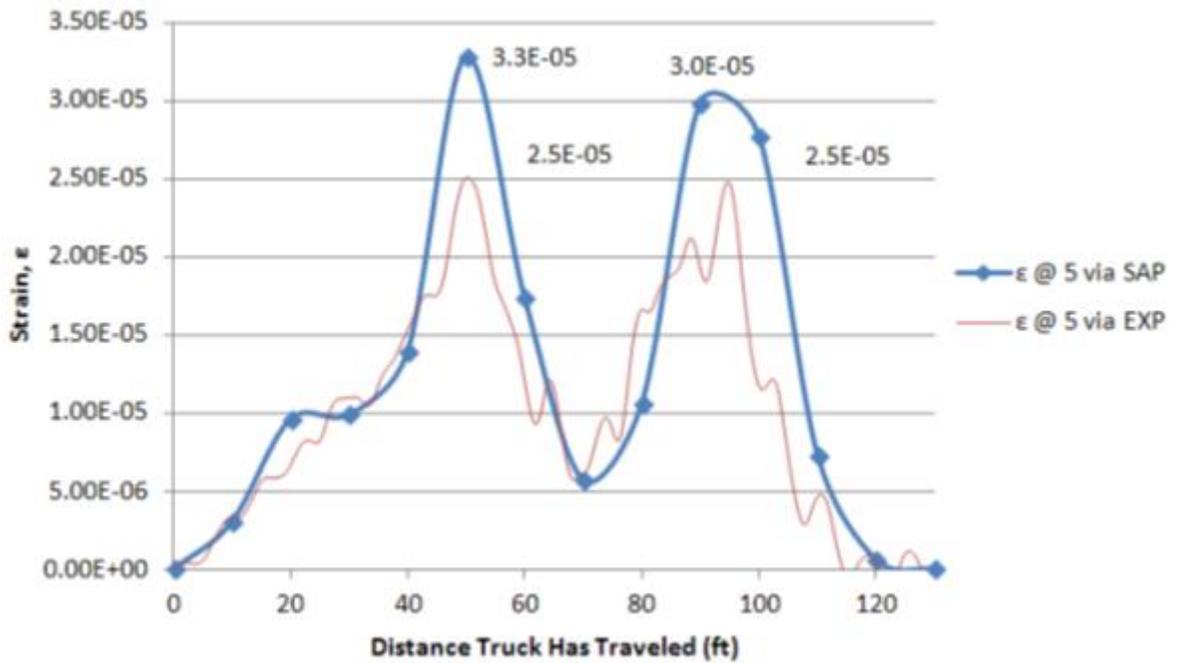
Figure 78: Strain Comparison – Truck 1, Girder 4
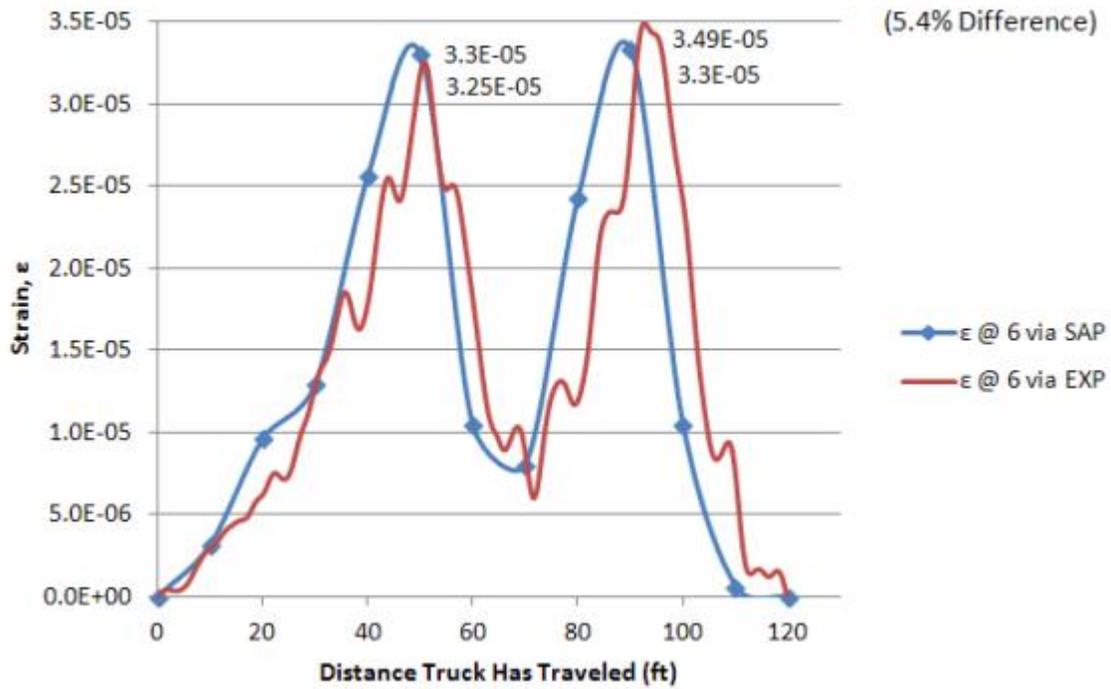
Figure 79 Strain Comparison – Truck 3, Girder 6
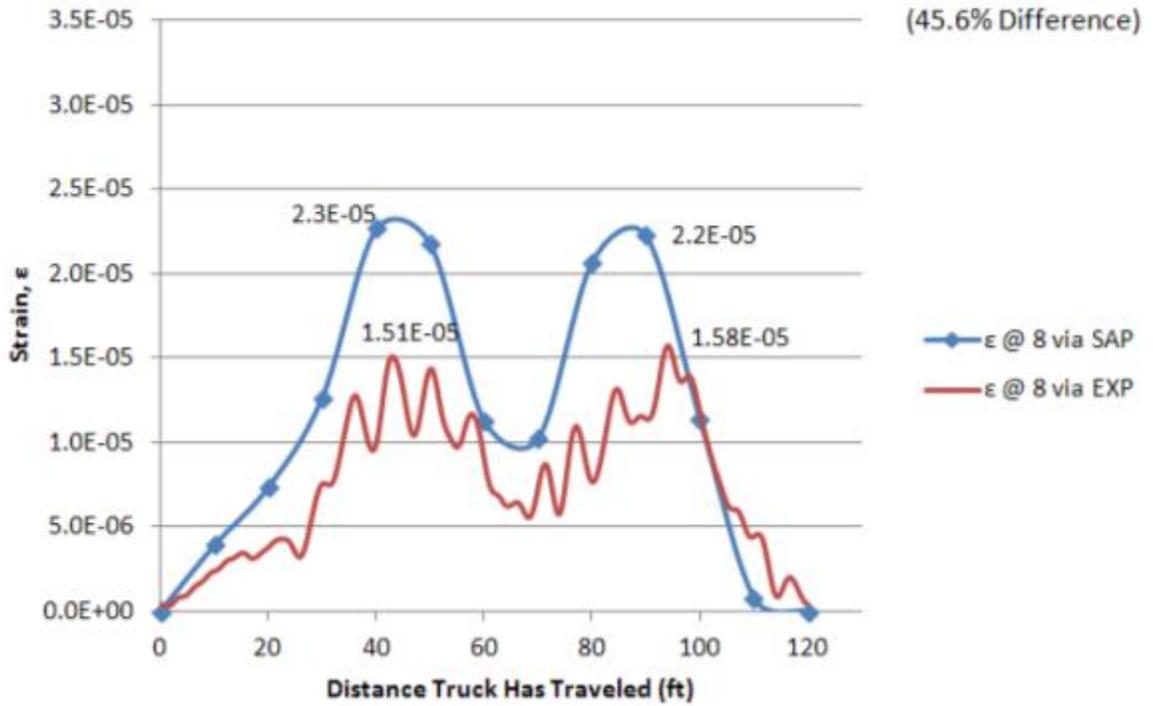
Figure 80: Strain Comparison – Truck 3, Girder 8
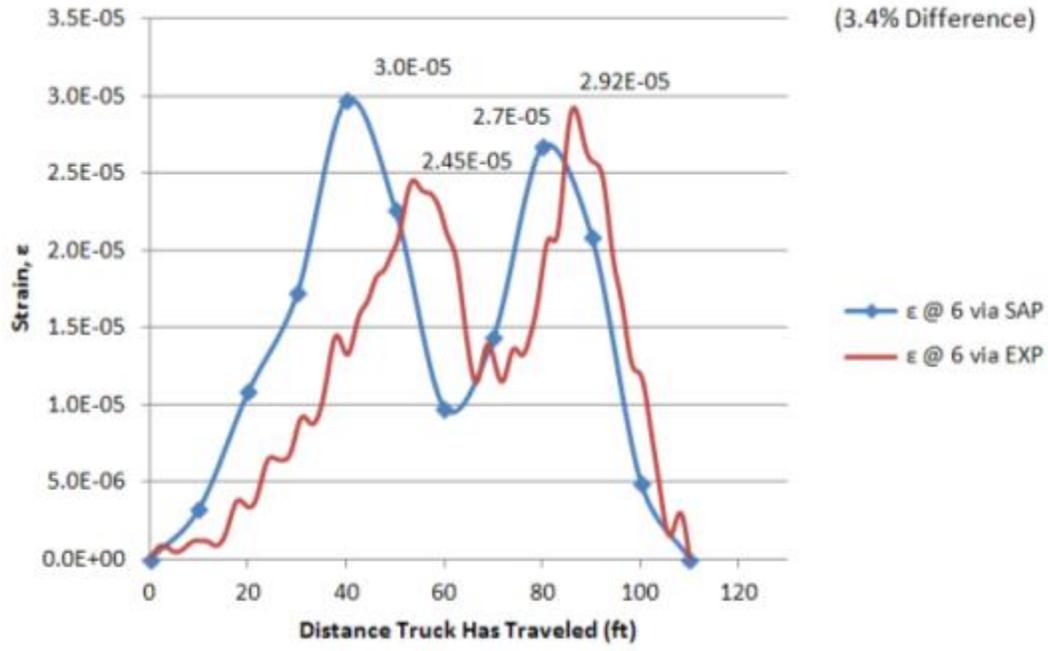
Figure 81: Strain Comparison – Truck 4, Girder 6
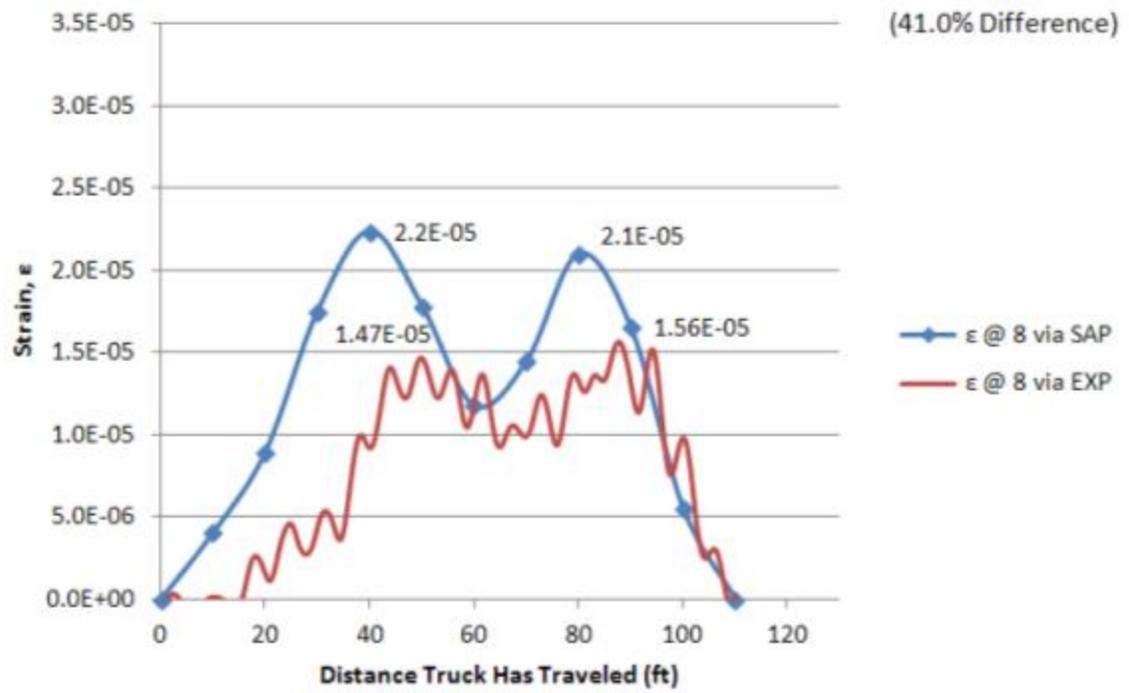
Figure 82: Strain Comparison – Truck 4, Girder 8

3.3.7 Load Rating for Bridge 012296

Prestressed girder bridges are to be rated in accordance with the AASHTO Standard

Specification at both the Operating and Inventory Levels. However, the Inventory Level

must also consider the allowable stresses of the girder entities. Typically, the minimum

reinforcement requirements will be met in a prestressed girder bridge. Unlike standard

reinforced concrete, there is no strength reduction factor for moment capacity, and the

reduction factor for shear is 0.90.

There were six rating equations used in calculating the ratings at Inventory Level. Four of

these equations are service limit rating equations using the Allowable Stress Method,

while the other two are the LF rating factors for moment and shear. Concrete

Compression is to be rated using separate equations. The first concrete compression

rating utilizes the section properties for the full composite member, while the second one

only considers the Type II Beam properties. All stresses calculated shall use merely the

Type II Beam section properties. The following equations were considered:

Equation 9: ASR Concrete Tension Inventory Rating

Equation 10: ASR Concrete Compression Inventory Rating

Equation 11: ASR Concrete Compression Inventory Rating

Equation 12: ASR Prestressing Steel Tension Inventory Rating

Equation 13: LFR Flexural Strength Inventory Rating

Equation 14: LFR Shear Strength Inventory Rating

At the Operating Rating Level for prestressed concrete members, there are only three equations that must be considered. The girder was rated for moment and shear capacity, and the prestressing steel tension rating was also calculated. The following equations were used with the section properties to determine these ratings:

Equation 15: LFR Flexural Strength Operating Rating

Equation 16: LFR Shear Strength Operating Rating

Equation 17: LFR Prestressing Steel Tension Operating Rating

The service load stresses were first calculated to ensure that the rating factors for concrete tension, concrete compression, and prestressing steel tension were acceptable. Concrete tension was rated using the stresses at the bottom of the beam, and compression was rated using the stresses at the top of the beam. The prestressing steel service rating factor was calculated using parameters at the bottom of the beam, after converting stresses from concrete at the center of gravity of the prestressing strands. The results for the Allowable Stress Inventory Ratings were as follows:

Table 34: Allowable Stress Inventory Ratings for Bridge 012296

Allowable Stress Inventory Ratings	
Entity	Rating Factor
Concrete Tension (Bottom)	1.71
Concrete Compression (Top)	13.97
Concrete Compression (Top)	9.96
Prestressing Steel Tension (Bottom)	8.56

Inventory Ratings must also be calculated using strength parameters. The flexural and shear rating for the prestressing girders were considered using the calculated capacities for each. The table below summarizes the ratings for flexure and shear.

Table 35: Strength Inventory Ratings for Bridge 012296

Strength Inventory Ratings	
Entity	Rating Factor
Flexural Rating for Section	1.54
Shear Rating for Section	1.86

Operating Ratings for the prestressed girder bridge were also calculated per the Manual

for Bridge Evaluation. These ratings also use the calculated capacities for moment and

shear, as shown in the rating equations included above for prestressed girders. Ratings

were calculated for flexural, shear, and prestressing steel tension and are included in

tabular form below.

Table 36: Strength Inventory Ratings for Bridge 012296

Strength Operating Ratings	
Entity	*Rating Factor*
Flexural Rating for Section	2.58
Shear Rating for Section	3.11
Prestressing Steel Tension	13.93

The controlling ratings for the section are the minimum Inventory and Operating ratings.

Bridge 012296 was rated at 1.54 and 2.58 for Inventory and Operating Levels,

respectively. The Flexural Rating for each level was determined to be the controlling

rating. There were no ALDOT ratings provided for comparison, but NBI notes the bridge

to "[meet] currently acceptable standards". The calculated ratings do not require bridge

posting, so they are considered to be accurate. Parameters used in the calculation of all

ratings are included in Appendix B.

Section 4 - Conclusion

Two ALDOT bridges were used to prove that accurate load rating for bridges can be prepared using Finite Element Modeling software. SAP2000, developed by Computers and Structures, Inc. was used to model both bridges. Bridge 005248, a traditionally reinforced concrete girder bridge, and Bridge 005318, a steel girder bridge, were provided for comparison. The bridges were modeled and calibrated to equal experimental strain data provided by ALDOT. After calibration, loads for HS20-44 trucks were applied to the models for load rating values to be compared to ALDOT's calculations.

At locations of directly affected bridge girders, SAP2000 strain values for Bridge 005248 ranged an average of 3.0% from provided experimental values. As for Bridge 005318, there was a difference of 8.8% between the strain values. It was determined that strain accuracy decreases as girder distance from the concentrated loading increases. However, maximum moment is induced in a girder at concentrated loading, and the bridges were deemed to accurately portray actual bridge behavior with percentage differences below 10%. The controlling ratings calculated for Bridge 005248 at the Inventory and Operating Levels were 30.2 tons and 50.7 tons, respectively. The Inventory Rating for 005318 was 19.8 tons, and the Operating Rating was 32.7 tons.

With two bridges of different girder materials calibrated and proven accurate, a third bridge was modeled and calibrated. Experimental strain data was supplied for Bridge 012296 for calibration purposes. The model for the prestressed girder bridge was

also developed in SAP2000. The strain data was compared to the strains obtained from SAP and the model was considered to imitate actual bridge behavior when loaded, with an average range at directly affected girders of 4.1% from experimental values. Rating calculations were performed to obtain Inventory and Operating Level ratings for the bridge. The HS20-44 ratings at Inventory and Operating Levels were calculated to be 55.4 tons and 92.9 tons, respectively. Therefore, the bridge meets currently acceptable standards, as also noted by the NBI database.

Finite Element Modeling was proven to be an accurate method for bridge load rating. FEM has the distinct ability to distribute loads with precision. Using finite element software can be an economical alternative to load rate bridges accurately, and it also allows for simplicity in revising loads for different rating vehicles. However, limitations to economical benefits include the software training required and the behavior research of other rating trucks. As determined by bridge behavior research for Bridges 005248, 005318, and 012296, Finite Element Modeling can provide a more accurate means for load rating, and bridge postings can be reduced or even removed with such analysis.

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Appendices

A: LOADING CONDITIONS FOR SAP MODELS

Bridge 005248 Loading Conditions								
Condition 1			Condition 2			Condition 3		
Truck 1			**Truck 1**			**Truck 1**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	0	15.075	15.075	6	15.075	15.075	12
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	---	16.0375	16.0375	2	16.0375	16.0375	8
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	---	11.4375	11.4375	---	11.4375	11.4375	---
Truck 2			**Truck 2**			**Truck 2**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	0	15.075	15.075	6	15.075	15.075	12
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	---	16.0375	16.0375	2	16.0375	16.0375	8
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	---	11.4375	11.4375	---	11.4375	11.4375	---

Bridge 005248 Loading Conditions								
Condition 4			Condition 5			Condition 6		
Truck 1			**Truck 1**			**Truck 1**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	16	15.075	15.075	20	15.075	15.075	24
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	12	16.0375	16.0375	16	16.0375	16.0375	20
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	---	11.4375	11.4375	---	11.4375	11.4375	2
Truck 2			**Truck 2**			**Truck 2**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	16	15.075	15.075	20	15.075	15.075	24
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	12	16.0375	16.0375	16	16.0375	16.0375	20
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	---	11.4375	11.4375	---	11.4375	11.4375	2

Bridge 005248 Loading Conditions								
Condition 7			Condition 8			Condition 9		
Truck 1			**Truck 1**			**Truck 1**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	28	15.075	15.075	32	15.075	15.075	36
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	24	16.0375	16.0375	28	16.0375	16.0375	32
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	6	11.4375	11.4375	10	11.4375	11.4375	14
Truck 2			**Truck 2**			**Truck 2**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	28	15.075	15.075	32	15.075	15.075	36
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	24	16.0375	16.0375	28	16.0375	16.0375	32
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	6	11.4375	11.4375	10	11.4375	11.4375	14

Bridge 005248 Loading Conditions								
Condition 10			Condition 11			Condition 12		
Truck 1			**Truck 1**			**Truck 1**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	---	15.075	15.075	---	15.075	15.075	---
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	38	16.0375	16.0375	---	16.0375	16.0375	---
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	20	11.4375	11.4375	26	11.4375	11.4375	32
Truck 2			**Truck 2**			**Truck 2**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	---	15.075	15.075	---	15.075	15.075	---
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	38	16.0375	16.0375	---	16.0375	16.0375	---
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	20	11.4375	11.4375	26	11.4375	11.4375	32

Bridge 005248 Loading Conditions						
Condition 13				Condition 14		
Truck 1				**Truck 1**		
Axel 1				*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)		Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	---		15.075	15.075	---
Axel 2						
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)		Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	---		16.0375	16.0375	---
Axel 3						
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)		Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	38		11.4375	11.4375	---
Truck 2						
Axel 1						
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)		Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	---		15.075	15.075	--
Axel 2						
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)		Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	---		16.0375	16.0375	---
Axel 3						
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)		Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	38		11.4375	11.4375	---

Bridge 005318 Loading Conditions								
Condition 1			Condition 2			Condition 3		
Truck 1			**Truck 1**			**Truck 1**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	0	15.075	15.075	8	15.075	15.075	16
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	---	16.0375	16.0375	4	16.0375	16.0375	12
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	---	11.4375	11.4375	---	11.4375	11.4375	---
Truck 2			**Truck 2**			**Truck 2**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	0	15.075	15.075	8	15.075	15.075	16
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	---	16.0375	16.0375	4	16.0375	16.0375	12
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	---	11.4375	11.4375	---	11.4375	11.4375	---

Bridge 005318 Loading Conditions								
Condition 4			Condition 5			Condition 6		
Truck 1			**Truck 1**			**Truck 1**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	24	15.075	15.075	32	15.075	15.075	40
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	20	16.0375	16.0375	28	16.0375	16.0375	36
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	2	11.4375	11.4375	10	11.4375	11.4375	18
Truck 2			**Truck 2**			**Truck 2**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	24	15.075	15.075	32	15.075	15.075	40
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	20	16.0375	16.0375	28	16.0375	16.0375	36
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	2	11.4375	11.4375	10	11.4375	11.4375	18

Bridge 005318 Loading Conditions								
Condition 7			Condition 8			Condition 9		
Truck 1			**Truck 1**			**Truck 1**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	48	15.075	15.075	56	15.075	15.075	64
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	44	16.0375	16.0375	52	16.0375	16.0375	60
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	26	11.4375	11.4375	34	11.4375	11.4375	42
Truck 2			**Truck 2**			**Truck 2**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	48	15.075	15.075	56	15.075	15.075	64
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	44	16.0375	16.0375	52	16.0375	16.0375	60
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	26	11.4375	11.4375	34	11.4375	11.4375	42

Bridge 005318 Loading Conditions								
Condition 10			Condition 11			Condition 12		
Truck 1			**Truck 1**			**Truck 1**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	---	15.075	15.075	---	15.075	15.075	---
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	68	16.0375	16.0375	---	16.0375	16.0375	---
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	50	11.4375	11.4375	58	11.4375	11.4375	66
Truck 2			**Truck 2**			**Truck 2**		
Axel 1			*Axel 1*			*Axel 1*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	---	15.075	15.075	---	15.075	15.075	---
Axel 2			*Axel 2*			*Axel 2*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	68	16.0375	16.0375	---	16.0375	16.0375	---
Axel 3			*Axel 3*			*Axel 3*		
Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)	Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	50	11.4375	11.4375	58	11.4375	11.4375	66

Bridge 005318 Loading Conditions

Condition 13

Truck 1

Axel 1

Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	---

Axel 2

Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	---

Axel 3

Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	---

Truck 2

Axel 1

Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
15.075	15.075	---

Axel 2

Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
16.0375	16.0375	---

Axel 3

Left Tire Load (k)	Right Tire Load (k)	Distance From Line "0" (ft)
11.4375	11.4375	---

Bridge 012296 Test Truck 1 Loading Conditions					
	AXEL LOCATIONS AND LOADS				
CONDITION	**AXEL 1** **Left Tire** **Right Tire**	**AXEL 2** **Left Tire** **Right Tire**	**AXEL 3** **Left Tire** **Right Tire**	**AXEL 4** **Left Tire** **Right Tire**	**AXEL 5** **Left Tire** **Right Tire**
Condition 1	0 ft	---	---	---	---
	5550 lbs	---	---	---	---
	5750 lbs	---	---	---	---
Condition 2	10 ft	---	---	---	---
	5550 lbs	---	---	---	---
	5750 lbs	---	---	---	---
Condition 3	20 ft	0 ft	---	---	---
	5550 lbs	8850 lbs	---	---	---
	5750 lbs	8550 lbs	---	---	---
Condition 4	30 ft	10 ft	5 ft	---	---
	5550 lbs	8850 lbs	8450 lbs	---	---
	5750 lbs	8550 lbs	8450 lbs	---	---
Condition 5	40 ft	20 ft	15 ft	---	---
	5550 lbs	8850 lbs	8450 lbs	---	---
	5750 lbs	8550 lbs	8450 lbs	---	---
Condition 6	---	30 ft	25 ft	---	---
	---	8850 lbs	8450 lbs	---	---
	---	8550 lbs	8450 lbs	---	---
Condition 7	---	40 ft	35 ft	0 ft	---
	---	8850 lbs	8450 lbs	9400 lbs	---
	---	8550 lbs	8450 lbs	9650 lbs	---
Condition 8	---	---	45 ft	10 ft	5 ft
	---	---	8450 lbs	9400 lbs	8150 lbs
	---	---	8450 lbs	9650 lbs	8000 lbs
Condition 9	---	---	---	20 ft	15 ft
	---	---	---	9400 lbs	8150 lbs
	---	---	---	9650 lbs	8000 lbs
Condition 10	---	---	---	30 ft	25 ft
	---	---	---	9400 lbs	8150 lbs
	---	---	---	9650 lbs	8000 lbs
Condition 11	---	---	---	40 ft	35 ft
	---	---	---	9400 lbs	8150 lbs
	---	---	---	9650 lbs	8000 lbs
Condition 12	---	---	---	---	45 ft
	---	---	---	---	8150 lbs
	---	---	---	---	8000 lbs
Condition 13	---	---	---	---	---
	---	---	---	---	---
	---	---	---	---	---

CONDITION	AXEL 1 Left Tire Right Tire	AXEL 2 Left Tire Right Tire	AXEL 3 Left Tire Right Tire	AXEL 4 Left Tire Right Tire	AXEL 5 Left Tire Right Tire
	Bridge 012296 Test Truck 3 Loading Conditions				
	AXEL LOCATIONS AND LOADS				
	AXEL 1	**AXEL 2**	**AXEL 3**	**AXEL 4**	**AXEL 5**
	Left Tire	**Left Tire**	**Left Tire**	**Left Tire**	**Left Tire**
	Right Tire	**Right Tire**	**Right Tire**	**Right Tire**	**Right Tire**
Condition 1	0 ft	---	---	---	---
	5650 lbs	---	---	---	---
	6000 lbs	---	---	---	---
Condition 2	10 ft	---	---	---	---
	5650 lbs	---	---	---	---
	6000 lbs	---	---	---	---
Condition 3	20 ft	2.5 ft	---	---	---
	5650 lbs	8050 lbs	---	---	---
	6000 lbs	7450 lbs	---	---	---
Condition 4	30 ft	12.5 ft	7.5 ft	---	---
	5650 lbs	8050 lbs	7250 lbs	---	---
	6000 lbs	7450 lbs	7950 lbs	---	---
Condition 5	40 ft	22.5 ft	17.5 ft	---	---
	5650 lbs	8050 lbs	7250 lbs	---	---
	6000 lbs	7450 lbs	7950 lbs	---	---
Condition 6	---	32.5 ft	27.5 ft	---	---
	---	8050 lbs	7250 lbs	---	---
	---	7450 lbs	7950 lbs	---	---
Condition 7	---	42.5 ft	37.5 ft	7.5 ft	---
	---	8050 lbs	7250 lbs	7950 lbs	---
	---	7450 lbs	7950 lbs	9100 lbs	---
Condition 8	---	---	---	17.5 ft	7.5 ft
	---	---	---	7950 lbs	8600 lbs
	---	---	---	9100 lbs	8100 lbs
Condition 9	---	---	---	27.5 ft	17.5 ft
	---	---	---	7950 lbs	8600 lbs
	---	---	---	9100 lbs	8100 lbs
Condition 10	---	---	---	37.5 ft	27.5 ft
	---	---	---	7950 lbs	8600 lbs
	---	---	---	9100 lbs	8100 lbs
Condition 11	---	---	---	---	37.5 ft
	---	---	---	---	8600 lbs
	---	---	---	---	8100 lbs
Condition 12	---	---	---	---	---
	---	---	---	---	---
	---	---	---	---	---

CONDITION	AXEL 1 Left Tire / Right Tire	AXEL 2 Left Tire / Right Tire	AXEL 3 Left Tire / Right Tire	AXEL 4 Left Tire / Right Tire	AXEL 5 Left Tire / Right Tire

Bridge 012296 Test Truck 4 Loading Conditions

AXEL LOCATIONS AND LOADS

CONDITION	AXEL 1	AXEL 2	AXEL 3	AXEL 4	AXEL 5
	Left Tire	Left Tire	Left Tire	Left Tire	Left Tire
	Right Tire	Right Tire	Right Tire	Right Tire	Right Tire
Condition 1	0 ft	---	---	---	---
	5600 lbs	---	---	---	---
	5450 lbs	---	---	---	---
Condition 2	10 ft	---	---	---	---
	5600 lbs	---	---	---	---
	5450 lbs	---	---	---	---
Condition 3	20 ft	---	---	---	---
	5600 lbs	---	---	---	---
	5450 lbs	---	---	---	---
Condition 4	30 ft	5 ft	---	---	---
	5600 lbs	7300 lbs	---	---	---
	5450 lbs	8000 lbs	---	---	---
Condition 5	40 ft	15 ft	10 ft	---	---
	5600 lbs	7300 lbs	7350 lbs	---	---
	5450 lbs	8000 lbs	7900 lbs	---	---
Condition 6	---	25 ft	20 ft	---	---
	---	7300 lbs	7350 lbs	---	---
	---	8000 lbs	7900 lbs	---	---
Condition 7	---	35 ft	30 ft	---	---
	---	7300 lbs	7350 lbs	---	---
	---	8000 lbs	7900 lbs	---	---
Condition 8	---	45 ft	40 ft	5 ft	---
	---	7300 lbs	7350 lbs	8800 lbs	---
	---	8000 lbs	7900 lbs	8550 lbs	---
Condition 9	---	---	---	15 ft	5 ft
	---	---	---	8800 lbs	7950 lbs
	---	---	---	8550 lbs	8350 lbs
Condition 10	---	---	---	25 ft	15 ft
	---	---	---	8800 lbs	7950 lbs
	---	---	---	8550 lbs	8350 lbs
Condition 11	---	---	---	35 ft	25 ft
	---	---	---	8800 lbs	7950 lbs
	---	---	---	8550 lbs	8350 lbs

B: CALCULATION PARAMETERS FOR LOAD RATING BRIDGE 012296

Input Parameters		
Coeff.	*Value*	*Signification*
$f'_{c\,(Girder)}$	5000 psi	Concrete Compressive Strength of Girders
$f'_{c\,(Deck)}$	3000 psi	Concrete Compressive Strength of Deck
$6\sqrt{f'_c}$	-424 psi	Allowable Concrete Tensile Strength
$F_{d\,(Bottom)}$	-989 psi	Unfactored Dead Load Stress at Bottom
$F_{d\,(Top)}$	1237 psi	Unfactored Dead Load Stress at Top
$F_{p\,(Bottom)}$	1814 psi	Unfactored Stress due to Prestress Force After Loss at Bot
$F_{p\,(Top)}$	-588 psi	Unfactored Stress due to Prestress Force After Loss at Top
$F_{s\,(T\&B)}$	0 psi	Unfactored Stress due to Secondary Prestress Forces T&B
$F_{L\,(Top)}$	168 psi	Unfactored Live Load Stress for Comp.Section Inc. Impact
$F_{L\,(Bottom)}$	-732 psi	Unfactored Live Load Stress Including Impact
φM_n	18248 kip-in	Nominal Flexural Strength of Composite Section
φV_n	148.5 kips	Nominal Shear Strength of Composite Section
GUTS	270000 psi	Guaranteed Ultimate Tensile Strength
f^*_y	243000 psi	Prestressing Ultimate Stress
I	1.3	Impact Factor

Bridge Parameters	
Coeff.	*Value*
Total Span	46.33 ft
Beam Wt	384 plf
Eff. Deck	553 plf
Beam Area	369 in^2
Barrier Wt	40 plf
Slab Height	6.25 in
Beam Depth	36 in
E_s/E_c	7.07

Rating Moment and Shear Values via SAP2000		
Coeff.	*Value*	*Signification*
D	3242 kip-in	Unfactored Dead Load Moment
S	0 kip-in	Unfactored Prestress Secondary Moment
L	3220 kip-in	Unfactored Live Load Moment
D	23.7 kips	Unfactored Dead Load Shear
S	0.0 kips	Unfactored Prestress Secondary Shear
L	22.4 kips	Unfactored Live Load Shear

Elastic Shortening Parameters		
Coeff.	*Value*	*Signification*
E_s	28500 ksi	Modulus of Elasticity for Pretensioning Reinforcement
E_{ci}	3491 ksi	Modulus of Elasticity of the Beam Concrete at Transfer
E_c	4031 ksi	Modulus of Elasticity of the Concrete
f_{cir}	1.52 ksi	Average Concrete Stress at Prestress C.O.G. at Transfer
P	346.9 kips	Initial Force Due to Pretension
P_{si}	324.2 kips	Pretension Force After Initial Losses
M_g	1237 kip-in	Moment Due to Beam Self Weight
M_D	0 kip-in	Moment Due to Diaphragm Weight
e_c	12.16 in	Eccentricity of the Span at Midspan

Concrete Creep Parameters		
Coeff.	*Value*	*Signification*
f_{cds}	0.467 ksi	Concrete Stress at C.O.G. of Prestressing Steel Due to DL
M_s	1876 kip-in	Slab and Haunch Moment
M_{SDL}	129 kip-in	Super Imposed DL Moment
y_{bs}	3.67 in	Distance From C.O.G. of Strand to Bottom of Beam

Prestress Losses		
Coeff.	**Value**	**Signification**
SH	6.50 ksi	Shrinkage; Assuming Relative Humidity = 70%
ES	12.44 ksi	Elastic Shortening
Cr_c	15.02 ksi	Creep of Concrete
Cr_s	2.68 ksi	Relaxation of Pretensioning Steel
P_{si}	324.2 kips	Effective Pretension Force After Initial Losses
P_{se}	279.7 kips	Effective Pretension Force After Losses at Service Loads

SAP Moment and Shear Results for 1-Truck Resultant		
Girder	**Moment (kip-in)**	**Shear (kips)**
1	1969	7.4
2	2273	12.9
3	2829	20.2
4	3115	22.2
5	3212	22.3
6	3220	22.4
7	3124	22.1
8	2865	20.4
9	2326	13.6
10	2033	7.8

SAP Moment and Shear Results for Dead Load Only		
Girder	**Moment (kip-in)**	**Shear (kips)**
1	2922	18.9
2	2992	22.0
3	3052	22.5
4	3093	22.7
5	3113	22.8
6	3113	22.8
7	3093	22.7
8	3052	22.5
9	2992	22.0
10	2922	18.9

C: NATIONAL BRIDGE INVENTORY (NBI) DATABASE INFORMATION

State:	AL
NBI Structure Number:	005248
Route Sign Prefix:	State Highway
Route Number:	49
Facility Carried:	SR 49
Feature Intersected:	TALLAPOOSA RIVER
Location:	HORSESHOE BEND
Year Built:	1955
RecordType:	Roadway is carried ON the structure
Level of Service:	Mainline roadway
Owner:	State Highway Agency
Highway Agency District:	04
Maintenance Responsibility:	State Highway Agency
Functional Class:	Minor Arterial, Rural
Service On Bridge:	Highway
Service Under Bridge:	Waterway
Latitude:	32 58 33.02 N
Longitude:	85 44 27.98 W
Material Design:	Steel continuous
Design Construction:	Stringer/Multi-beam or Girder
Approach Material Design:	Concrete
Approach Design Construction:	Tee Beam
Structure Length (m):	263.7
Approach Roadway Width (m):	7.3
Lanes on Structure:	2
Average Daily Traffic:	1020
Year of Average Daily Traffic:	2009
Design Load:	MS 13.5
Scour:	Bridge foundations determined to be stable for the assessed or calculated scour condition.
Bridge Railings:	Do not meet currently acceptable standards.
Historical Significance:	Bridge is not eligible for the National Register of Historic Places.
# of Spans in Main Structure:	8

# of Spans in Approach Structures:	4
Bridge Median:	No Median
StructureFlared:	No flare
Transitions:	Does not meet currently acceptable standards.
Approach Guardrail:	Does not meet currently acceptable standards.
Approach Guardrail Ends:	Does not meet currently acceptable standards.
Navigation Control:	No Navigation Control on waterway (bridge permit not required).
Structure Open?:	Open, no restrictions
Deck:	Satisfactory Condition
Superstructure:	Satisfactory Condition
Substructure:	Satisfactory Condition
Structural Evaluation:	Equal to present minimum criteria
Sufficiency Rating (%):	68.4

State:	AL
NBI Structure Number:	005318
Route Sign Prefix:	State Highway
Route Number:	145
Facility Carried:	SR 145
Feature Intersected:	WAXAHATCHEE CREEK
Location:	CHILTON & SHELBY CO LINE
Year Built:	1955
Status:	Functionally Obsolete
RecordType:	Roadway is carried ON the structure
Level of Service:	Mainline roadway
Owner:	State Highway Agency
Highway Agency District:	05
Maintenance Responsibility:	State Highway Agency
Functional Class:	Minor Arterial, Rural
Service On Bridge:	Highway
Service Under Bridge:	Waterway
Latitude:	33 02 31.69 N
Longitude:	86 35 32.49 W
Material Design:	Steel
Design Construction:	Stringer/Multi-beam or Girder
Approach Material Design:	Concrete
Approach Design Construction:	Tee Beam
Structure Length (m):	86.6
Approach Roadway Width (m):	13.4
Lanes on Structure:	2
Average Daily Traffic:	2460
Year of Average Daily Traffic:	2009
Design Load:	M 13.5
Scour:	Bridge foundations determined to be stable for the assessed or calculated scour condition.
Bridge Railings:	Do not meet currently acceptable standards.
Historical Significance:	Bridge is not eligible for the National Register of Historic Places.
# of Spans in Main	3

Structure:	
# of Spans in Approach Structures:	2
Bridge Median:	No Median
StructureFlared:	No flare
Transitions:	Meets currently acceptable standards.
Approach Guardrail:	Does not meet currently acceptable standards.
Approach Guardrail Ends:	Does not meet currently acceptable standards.
Navigation Control:	No Navigation Control on waterway (bridge permit not required).
Structure Open?:	Open, no restrictions
Deck:	Satisfactory Condition
Superstructure:	Satisfactory Condition
Substructure:	Satisfactory Condition
Structural Evaluation:	Somewhat better than minimum adequacy to tolerate being left in place as is
Sufficiency Rating (%):	50.4

State:	AL
NBI Structure Number:	012296
Route Sign Prefix:	Interstate
Route Number:	459
Facility Carried:	I 459
Feature Intersected:	SULPHUR SPRINGS RD
Location:	I459 & SULPHUR SPRINGS RD
Year Built:	1980
RecordType:	Roadway is carried ON the structure
Level of Service:	Mainline roadway
Owner:	State Highway Agency
Highway Agency District:	03
Maintenance Responsibility:	State Highway Agency
Functional Class:	Principal Arterial - Interstate, Urban
Service On Bridge:	Highway
Service Under Bridge:	Highway, with or without pedestrian
Latitude:	33 21 34.69 N
Longitude:	86 50 49.41 W
Material Design:	Prestressed concrete continuous *
Design Construction:	Stringer/Multi-beam or Girder
Approach Material Design:	Prestressed concrete continuous *
Approach Design Construction:	Stringer/Multi-beam or Girder
Structure Length (m):	52.6
Approach Roadway Width (m):	18.9
Lanes on Structure:	4
Lanes under Structure:	2
Average Daily Traffic:	32705
Year of Average Daily Traffic:	2009
Design Load:	MS 18
Bridge Railings:	Meet currently acceptable standards.
Historical Significance:	Bridge is not eligible for the National Register of Historic Places.
# of Spans in Main Structure:	1
# of Spans in Approach Structures:	2
Bridge Median:	No Median
StructureFlared:	No flare

Transitions:	Meets currently acceptable standards.
Approach Guardrail:	Meets currently acceptable standards.
Approach Guardrail Ends:	Does not meet currently acceptable standards.
Navigation Control:	Not Applicable
Structure Open?:	Open, no restrictions
Deck:	Good Condition
Superstructure:	Good Condition
Substructure:	Good Condition
Structural Evaluation:	Equal to present minimum criteria
Sufficiency Rating (%):	90.9

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