MONITORING LIVE LOAD FORCES ON 150 FOOT PRE-STRESSED BULB-T GIRDERS DURING TRANSIT AND INSTALLATION

SUBMITTED TO:

Louisiana Department of Transportation and Development
1201 Capital Access Road
PO Box 94245
Baton Rouge LA 70804

SUBMITTED BY:

BRIDGE DIAGNOSTICS, INC.
1965 57th Court North Suite 120
Boulder, CO 80302
303.494.3230
www.bridgetest.com

January 2007

Table of Contents

List of Figures

List of Tables

EXECUTIVE SUMMARY

In October, 2006, Bridge Diagnostics, Inc. (BDI) performed structural monitoring on two approximately 150-foot long bulb-tee bridge girders as they were loaded onto trucks, transported to the site, and erected on State Highway 165 near Columbia, LA. The goal of this project was to quantify the actual forces that these types of structural elements undergo during normal construction and transportation procedures.

Both of the over year old pre-stressed concrete girders were instrumented at critical locations with strain sensors while they were still at the casting yard. The following day, both girders were loaded on specialized hauling vehicles and simultaneously transported to the construction site located approximately 110 miles from the casting yard. The hauling route included Interstate 20, where speeds exceeded 60 miles per hour and secondary highways where several sharp curves had to be negotiated at crawl speed. By the time the girders arrived on site and were installed on the substructure, they had seen quite wide spectrum of live loads.

Part of the testing process included tracking the transport vehicle's positions along the hauling route by utilizing Global Positioning System (GPS) technology. This was critical for matching the response data collected on the girders with the type of load they were undergoing at the time. During this time approximately 40 data files were produced for each girder.

Upon review of the strain data, it was noted that most of the responses from both girders undergoing the same loads were similar with only moderate differences in magnitudes. However, two of the instrumented cross-sections on Girders A had significantly higher responses, and was explained by a large crack observed in these locations. The other girder did not have this same crack and therefore, its responses were probably more typical of that associated with most girder moving operations.

In addition, the sharp turns produced the largest responses in both girders, with the worst case being the final U-turn into the construction site. It was apparent that these large weak-axis bending forces were primarily due to the asyncronization of steering between the front and rear trailers. The strain envelope for each girder can be seen in Table 1.

The results from these tests can be compared to the stress envelopes that were expected during the girder design process. To aid in this effort, all of the digitized field data along with an outline of its format is provided with this report for possible future in-depth reviews. Also, due to the higher-than-expected responses and the cracked condition of Girder A, it is recommended that once the bridge is completed, this span of the structure be load tested and rated to ensure that the integrity of the structure was not compromised.

The main body of this report contains information relating to the field test procedures, data collection, and collected data. Relevant information regarding the organization of data files and the data acquisition system used is provided in the report appendices.

Table 1 Strain envelopes for U-turn near construction site.

	File Name:	Beam A *COLUMBIA*		Beam B *Columbia*		
Cross-Section	Gage Number	Positive	Negative	Gage Number	Positive	Negative
A	B1061	82	-43	B1128	93	-12
	B1045	26	-27	B1127	41	-23
	B1132	19	-100	5833	23	-93
	B1190	12	-39	8688	24	-51
B	B1119	776	-156	B1126	673	-68
	B1097	280	-74	B1129	287	-49
	B1130	97	-529	5690	97	-501
	B1140	71	-322	6327	72	-307
C	B1122	1990	-1893	B1087	717	-45
	B1046	390	-122	B1125	398	-71
	B1131	59	-604	4792	202	-660
	B1118	101	-409	B1124	77	-414
D	B1120	839	-239	B1095	1236	-146
	B1014	564	-187	B1133	497	-120
	B1100	1172	-790	8865	113	-713
	B1088	156	-564	5567	136	-565
E	B1062	121	-70	B1116	132	-56
	B1032	100	-34	B1123	106	-19
	B1094	47	-138	8860	57	-131
	B1039	27	-112	9065	21	-113

INTRODUCTION AND GENERAL OVERVIEW

Bridge Diagnostics, Inc. (BDI) was contracted by the Louisiana Department of Transportation and Development (LaDoTD) to perform data collection on two bulb-T bridge girders as they were transported from the casting yard near Shreveport to the jobsite near Columbia, a distance of approximately 110 miles. The goal of the testing was to collect data during different stages of transportation from the time they were loaded onto the transportation vehicle until they were installed onto their substructure supports. The testing was performed during the week of October 23, 2006 and took two days to complete.

This report contains an overview of the installation and testing procedures along with a review of the recorded data. General observations are noted in the *Test Results* section of the report. Note that this report contains results from two separate beams that were tested simultaneously.

INSTRUMENTATION AND GIRDER MONITORING PROCEDURES

PRE-MONITORING DATA COLLECTION:

Prior to installation of the monitoring instrumentation, the haul route was driven to find the areas of interest such as sharp turns, rough areas in the road, and typical stretches of highway to be representative of many haul routes. In order to ensure data was collected at these selected areas, a GPS map was produced with "pushpins" at the starting location of each area of interest. An example portion of this GPS map can be seen in Figure 1 and the map in its entirety can be seen below in the *Girder Monitoring Data Collection Information* section in Figure 7 thru Figure 13. For back-up purposes, the odometer of the vehicle was set to zero at the casting yard and the mileage was noted at each test location. During this same time, notes and a picture were taken for each area of interest. At each pushpin there is a feature name and in most cases, a three digit number below the name (e.g. 365) that correlates to the first three numbers of the picture files supplied on the CD with this report. Note that every feature does not have a picture file related to it due some of the files being added "on the fly" during the actual girder monitoring. BDI would like to thank the DOTD personnel who helped in the process!

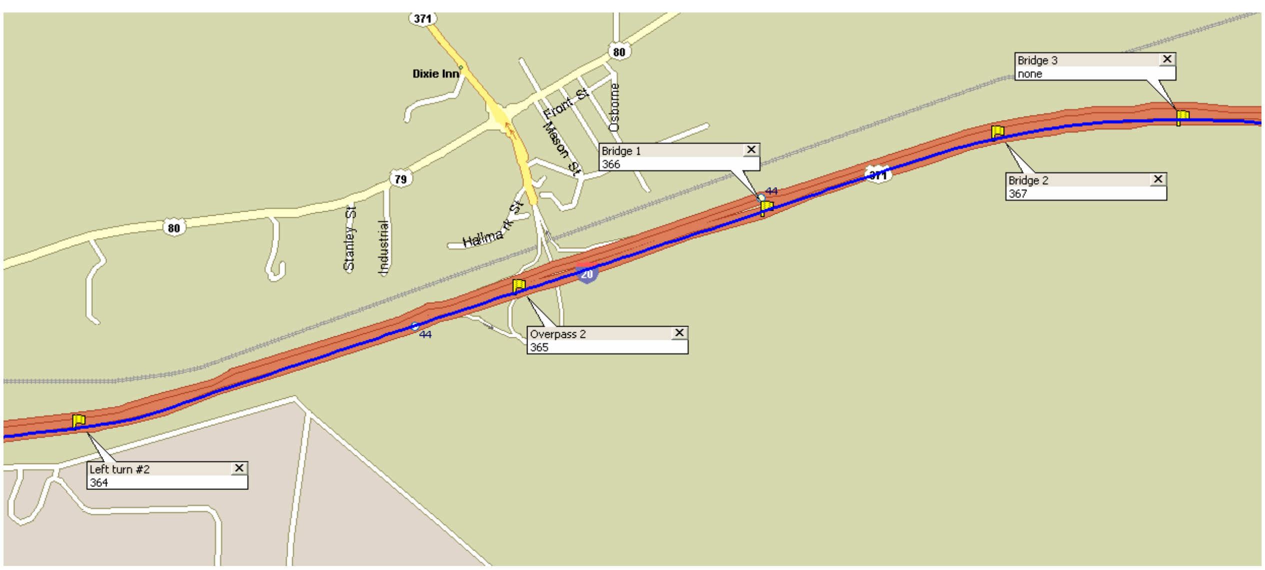

Figure 1 Portion of GPS map of the girder transportation route.

After the route was driven, the notes, picture files and all other information gathered during the drive was compiled into a spreadsheet that was used during the girder monitoring. This spreadsheet also contains the file names for each area of interest and marker information (clicks) for each test file. Note that the girder monitor information spreadsheet can be found in the *Girder Monitoring Data Collection Information* section after the route maps, in Table 3 and Table 4 for Beam A and B, respectively.

STRAIN TRANSDUCER INSTALLATION:

In order to calculate stresses in both strong and weak axis bending, a strain transducer was placed at each corner of each cross-section as seen in Figure 2. Each girder was gaged at five cross sections, including near each bearing location, near the second set of chains on the rear trailer, one at the girder's midspan, and one at the midspan between the front bearing location and the second set of chains on the rear trailer. A summary of gaged cross-sections along with gage ID information is shown below in Figure 3 and Figure 4. These locations were chosen to reflect the portion of the beams where the highest stresses were anticipated.

Due to the uncertainty of the anticipated stress levels in the beams, mechanical concrete anchors were used to secure the strain transducers to the concrete girders rather than using the standard adhesive technique. In order to install the anchors, two ¼ inch holes were drill at the proper locations and a cam style anchor was inserted with a hammer. A strain transducer was then slid over the two anchors and ¼-20 nuts were used to secure the transducer to the girder face. A complete strain transducer assembly can be seen in Figure 5. A 4-Channel BDI STSII data acquisition box (STSII-box) was located at each gaged cross-section and a single communication cable was then run between the boxes.

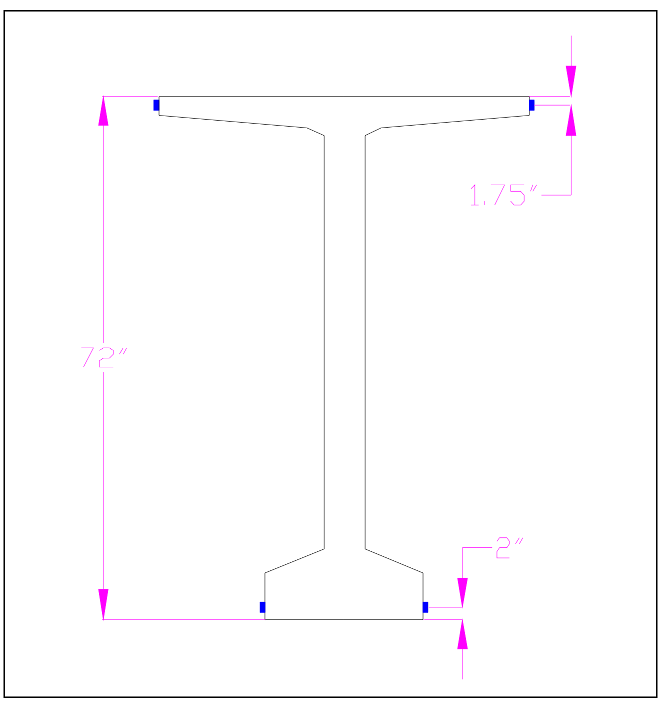

Figure 2 Typical location of strain transducers.

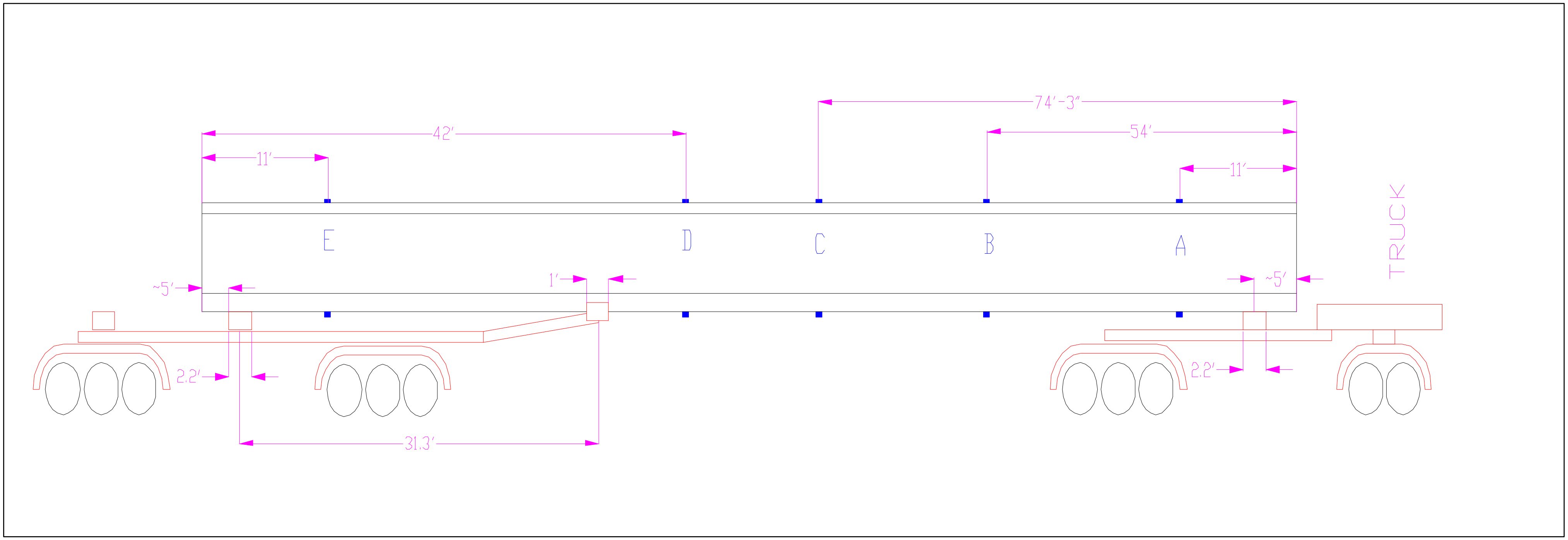

Figure 3 Gaged cross-section locations and dimensions.

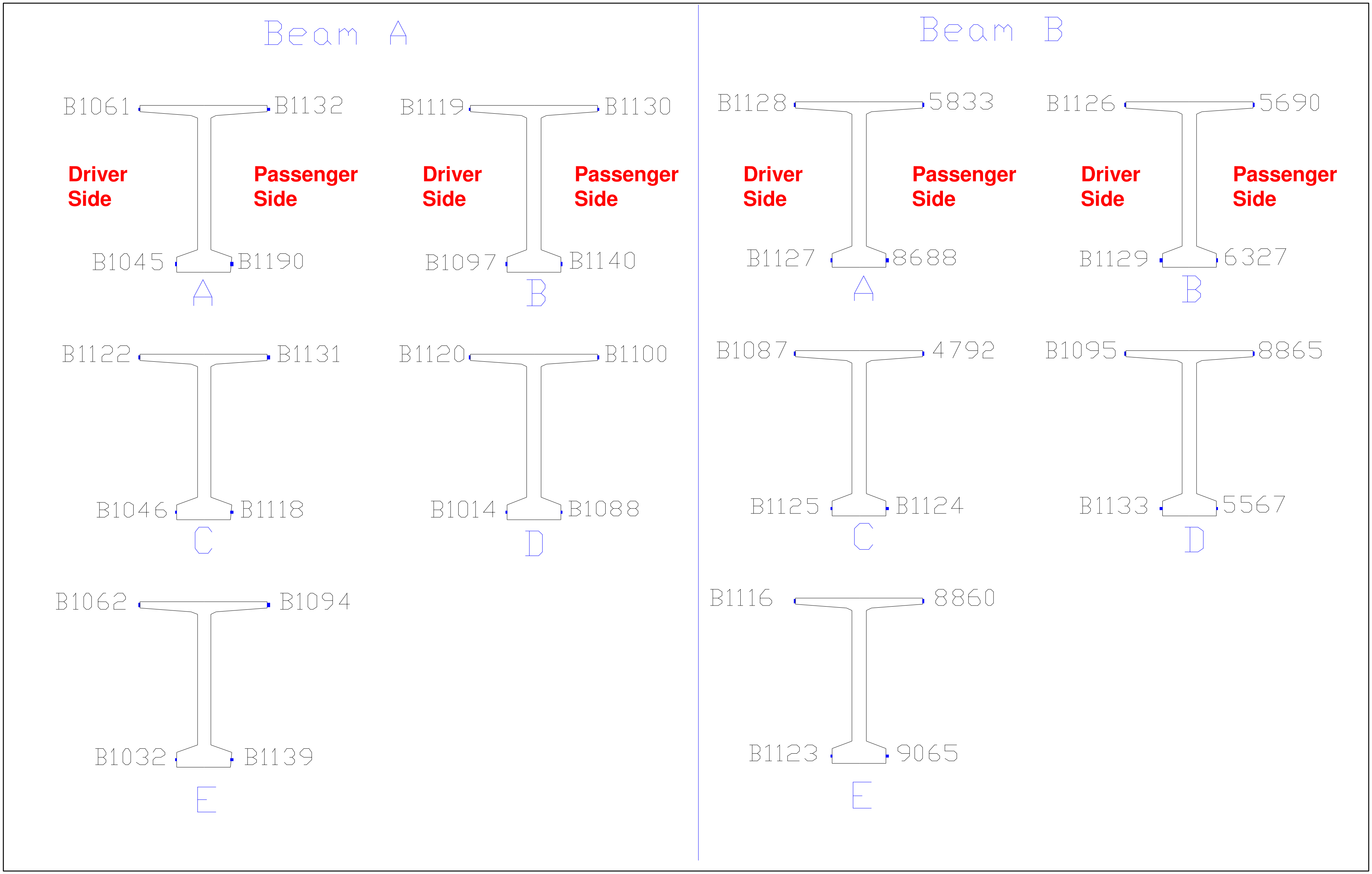

Figure 4 Gage IDs for each gaged cross-section.

Figure 5 Installed strain transducer B1088.

Due to the varying environmental conditions, such as wind due to the speed of the truck, location of the sun, etc. each strain transducer was covered with a 3/8" thick foam gage cover. These covers were secured in place with double-sided sticky tape and then sealed with aluminum tape to make the gaged area virtually air tight. This was done to reduce the thermal drift induced by the different environmental conditions. A covered gage area can be seen in Figure 6.

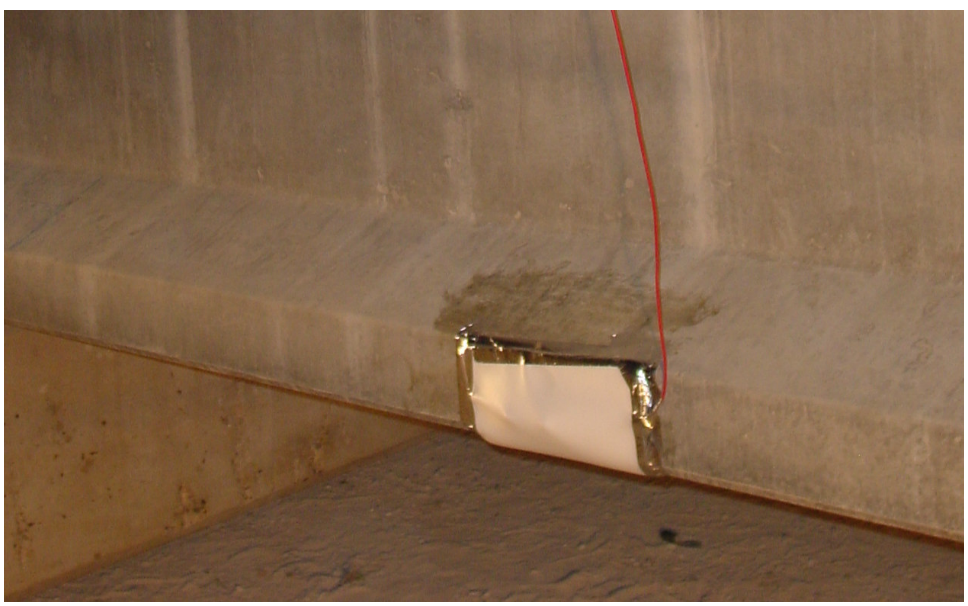

Figure 6 Completed gage cover over gaged area.

Once the gaging was complete, a single 200-foot communication cable was connected to the string of STS II boxes and connected to a laptop computer. At this point the girders were ready to be loaded onto the transport vehicles.

GIRDER MONITORING DATA COLLECTION PROCEDURES AND INFORMATION:

Two cranes were used to load each girder on the transporters, one at each end. Once the beams were hooked to the cranes, a test was started and a signal was given to proceed with the loading of the girders. Event markers were added to the data to note significant points during the loading process, and tests were run successively until each beam was secured to the trailers. At this point, the vehicles moved slowly to the front of the casting yard. During this time, a sharp left turn was made and data was collected on the beams during this turning operation. Testing information can be found after the route maps in Table 2.

When the crews were ready to leave, the 200’ communication cables were removed and replaced with cable that had already been strung from the cabs of the semi tractors to the respective first STS II box. Both systems were tested to ensure all of the data acquisition equipment was in working order. Once the convoy began to move, the BDI personnel in the front transport (Girder A) was in charge of calling out when it was time to start to collect data for the areas of interest. This was done by tracking the convoy on the GPS and as the test area approached, the front vehicle crew relayed to the trailing vehicle crew when to start each test via handheld radio. Once the test was completed, the file number and click information was noted on the girder monitor information spreadsheet. This process was repeated for each area of interest along the entire route. The complete girder monitor information spreadsheet for both Girders A and B can be seen in Table 3 and Table 4, respectively. Once the trucks approached the entrance of the city of Columbia, they were flagged over to a staging area north of the newly constructed bridge. The girders were then taken one at a time through the city and parked at the pick point for the cranes. Note that all test information for the transportation of the girders through Columbia can be found in Table 2. Once the girders were attached to the cranes, tests were run successively until the girder was set in place and attached to the bents. Again, test information for this portion of testing can be found in Table 2. At this point, the data collection was complete and all of the instrumentation was removed from the girders by BDI personnel.

ROUTE MAPS:

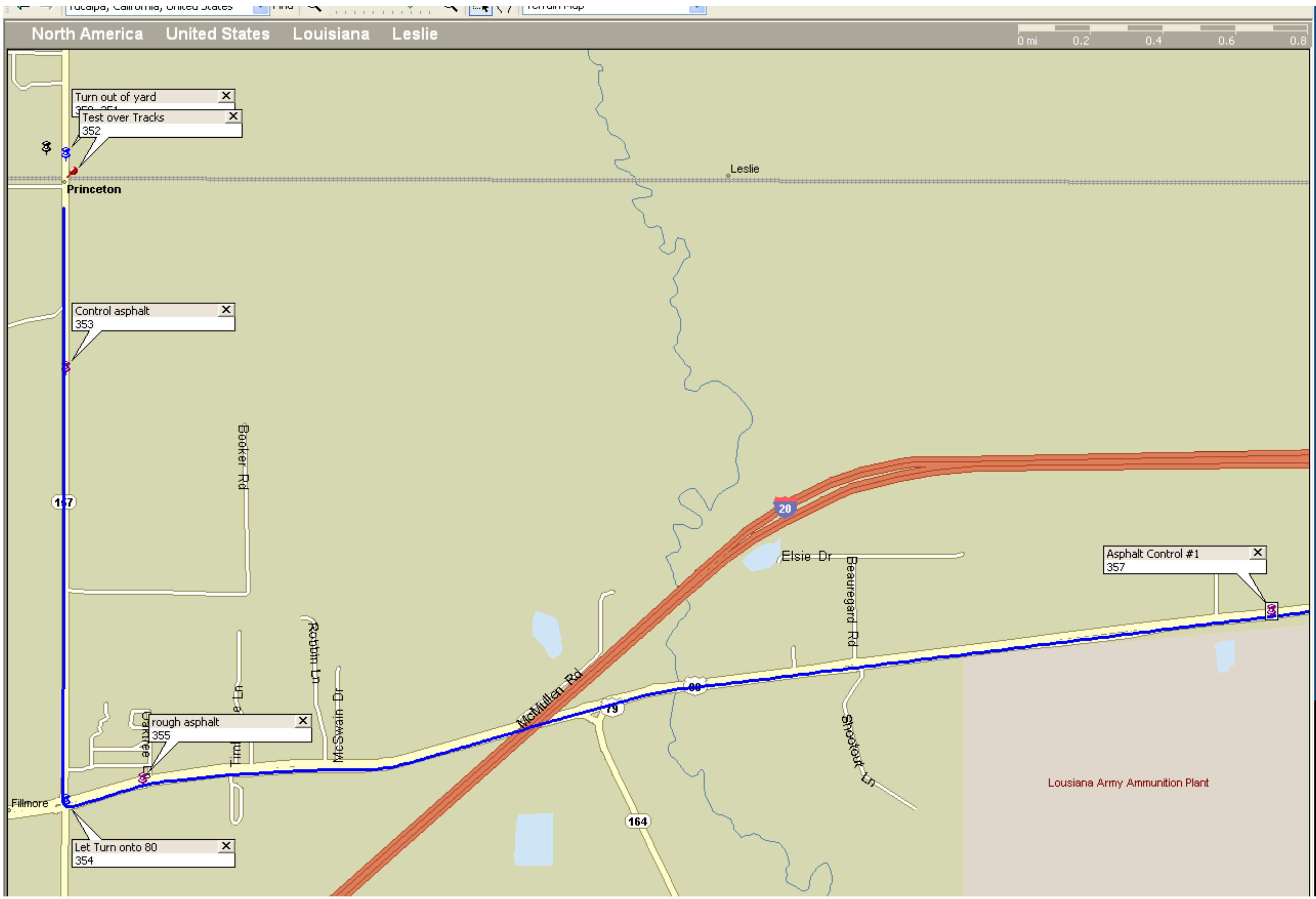

Figure 7 Route map.

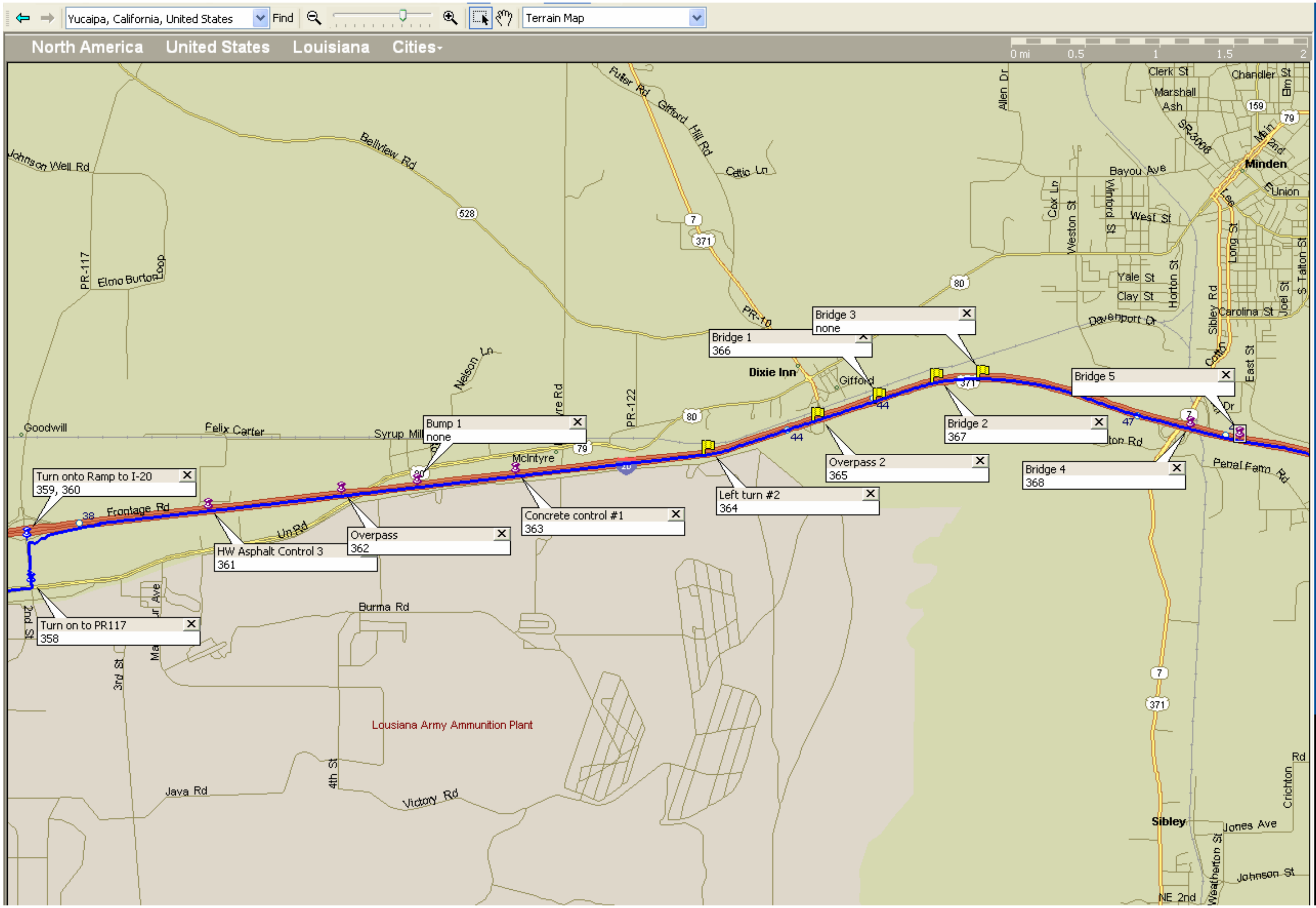

Figure 8 Route map (con't).

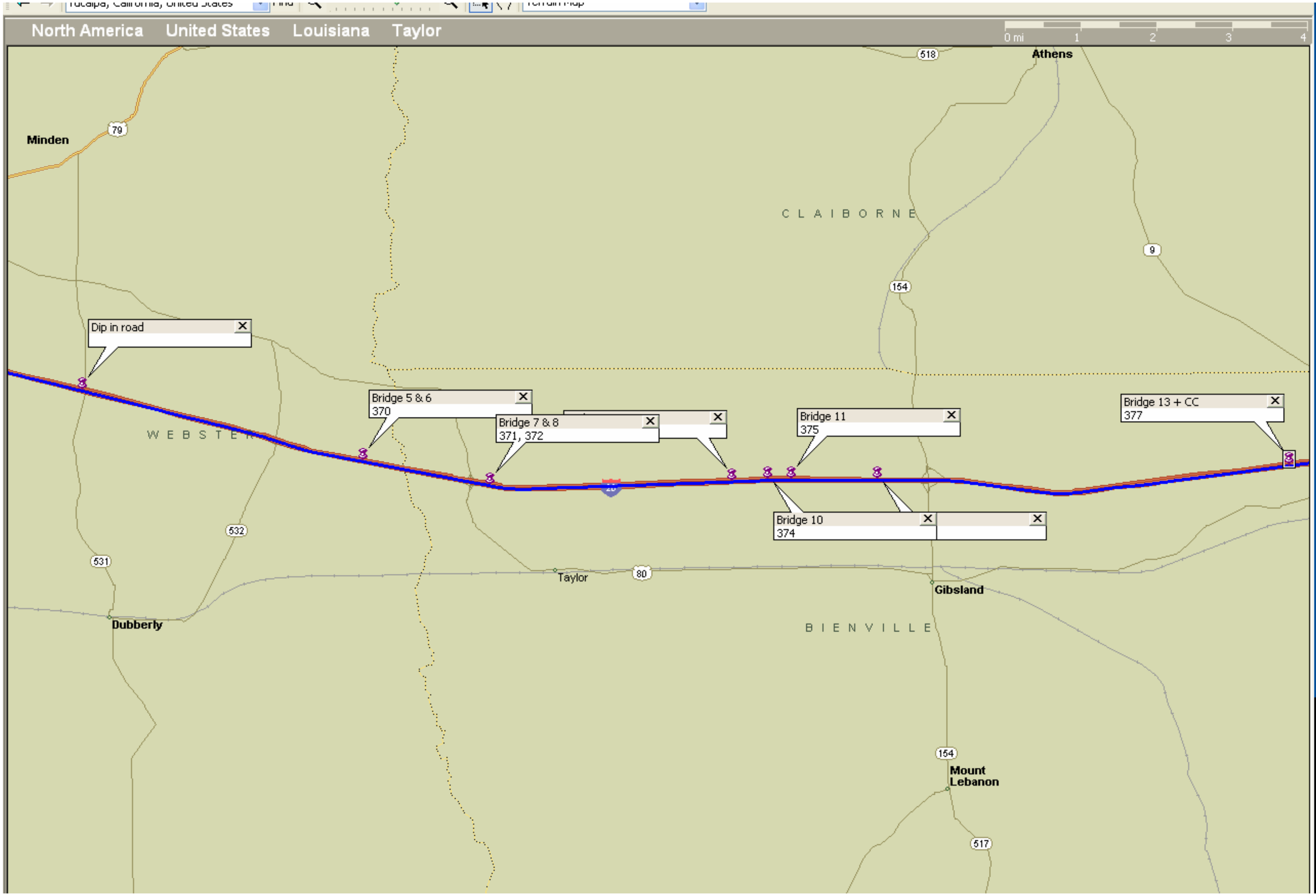

Figure 9 Route map (con't).

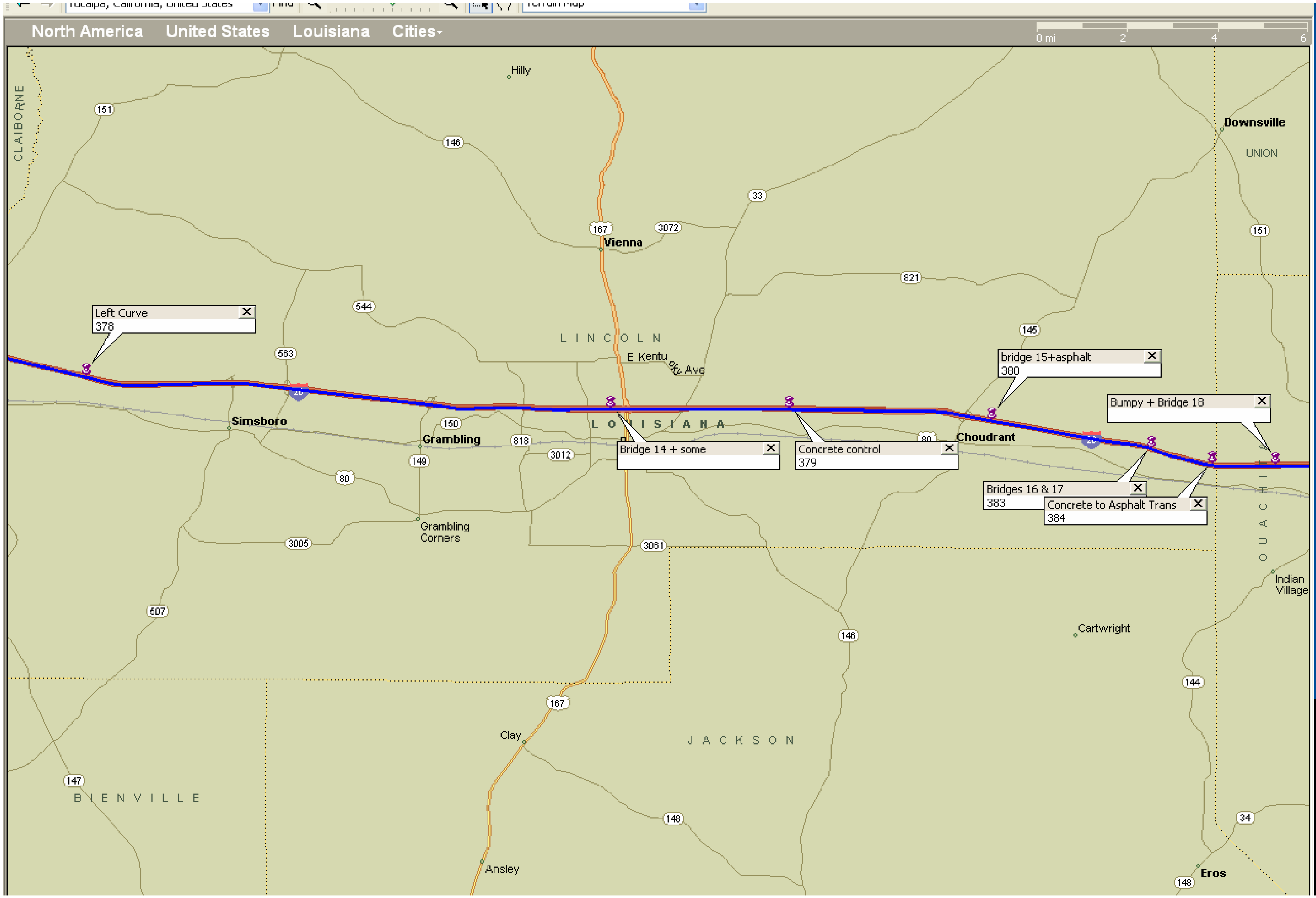

Figure 10 Route map (con't).

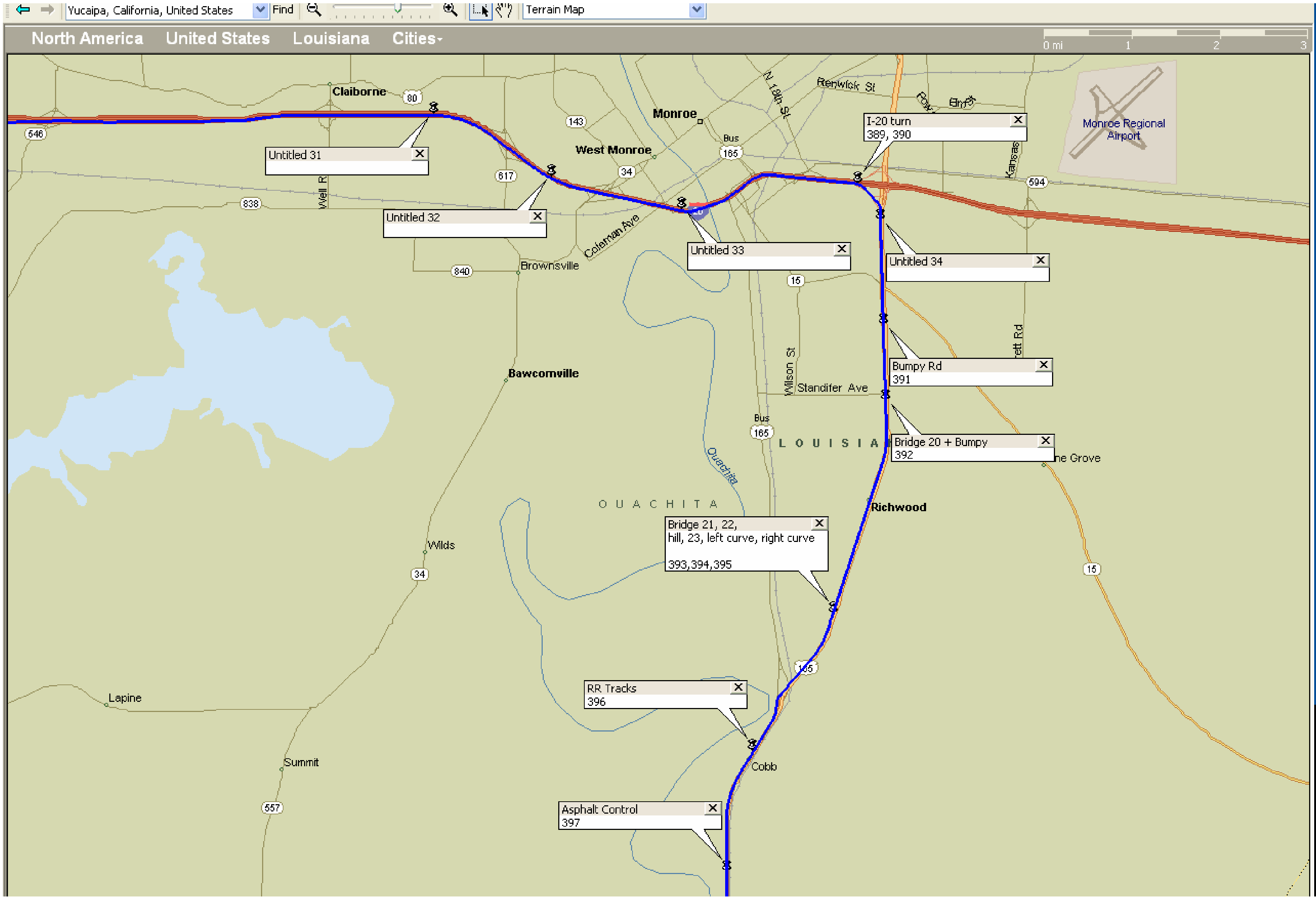

Figure 11 Route map (con't).

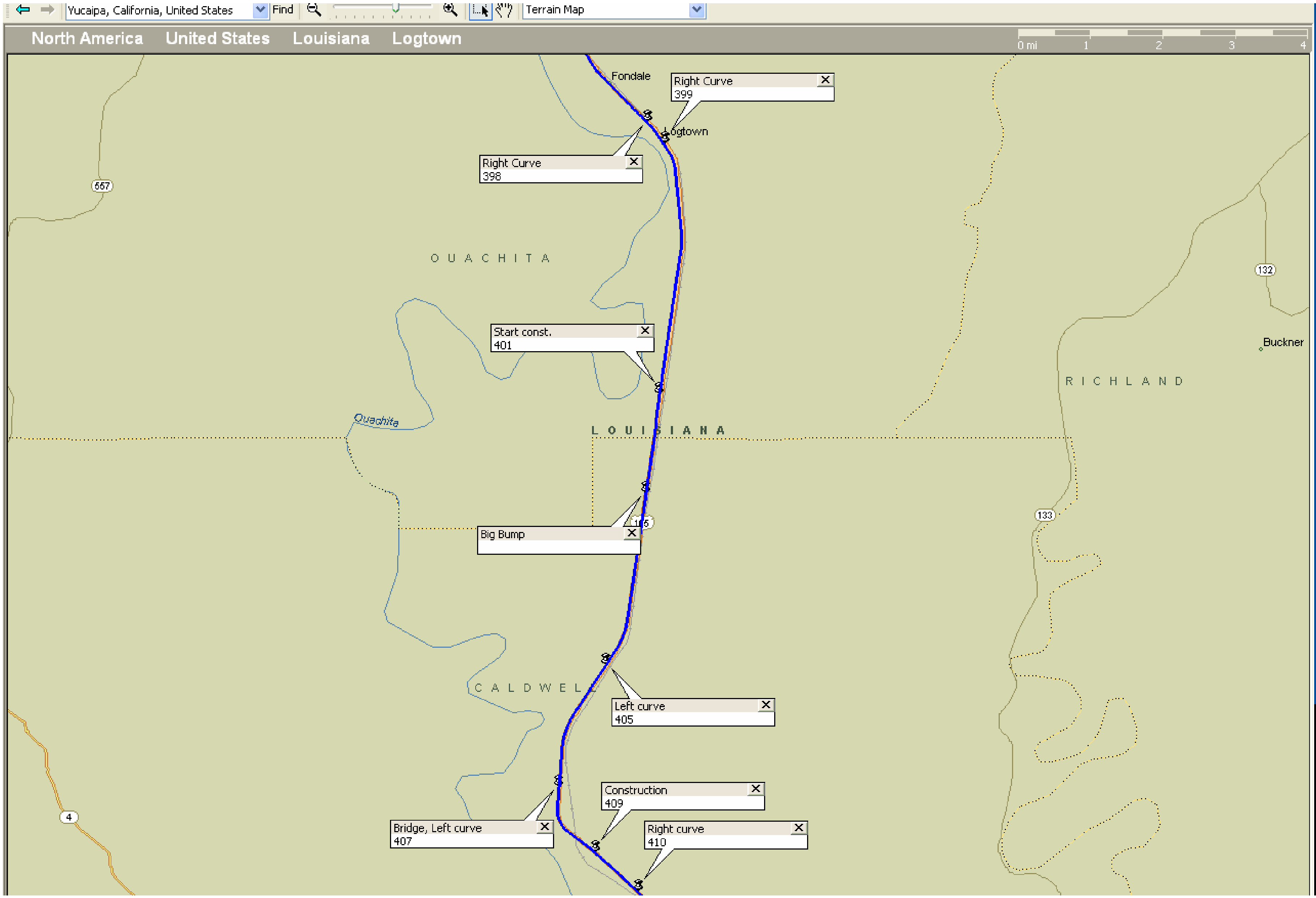

Figure 12 Route map (con't).

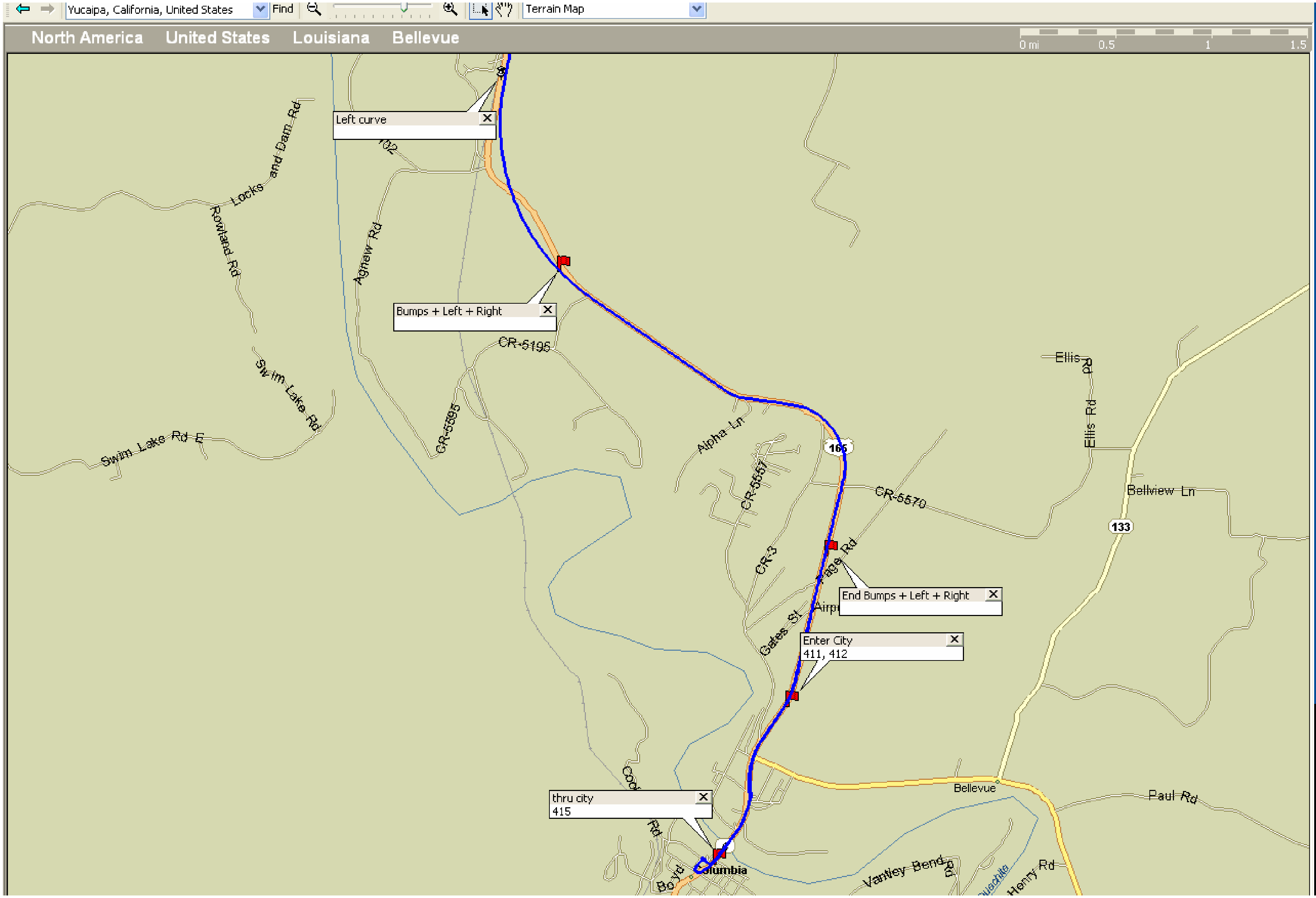

Figure 13 Route map (con't).

MONITORING INFORMATION SPREADSHEETS.

Table 2 Casting yard and erection data collection information.

Girder	File Description	File Name	Clicks
A	Loading girder onto trailer in casting yard.	GirderA_(lift_Truck)_1.dat	1- Start test 2- Lift from storage location in yard 3- Cranes begin moving 4- girder set onto trailer 5- Crane cables loosened and removed from girders
A	Left turn inside yard	GirderA_(Yard_Turn1)_1.dat	1- Start test 2- Truck begins moving
A	Remove beam from trailer and place onto bents at the construction site.	Beam A (Erect-Full).dat	1- Start test ~930sec crane cables tightened ~1200sec crane cables slacked ~1240sec girder picked from trailer ~3400sec girder placed on bearing locations ~3800sec cranes cables detached from beams.
B	Loading girder onto trailer in casting yard.	GirderB_(Lift_Truck)_1.dat	1- Start test ~40sec girder picked and cranes begin to move ~270sec girder set onto trailer ~660sec front trailer adjusted ~970-1100sec crane cables loosed
B	Left turn inside yard	GirderB_(Yard_Turn1)_1.dat	1- start test ~85sec Truck begins moving
B	Remove beam from trailer and place onto bents at the construction site.	Girder_B_(Erect-Full)_2.dat	1- start test ~50sec girder picked from trailer ~1000sec girder set onto bearing ~1075sec cables loosened slightly ~1200sec cables loosened slightly ~1400sec cables slacked and removed from girder

Table 3 Beam A girder monitor information spreadsheet.

Feature	Est. Sample Rate	Mi #	Picture #	File Name	Speed	Clicks / Notes
Turn out of yard	40	0	350, 351	1		
RR Tracks	50	0.2	352	1		#2 truck hits tracks
Asphalt Control	50	0.8	353	2	19	Hilly
Left onto 80	50	1.8	354	3		#1 start test, #2 start turn, #3 truck straight, #4 load straight
Rough Asphalt	~~100~~ 50	2.1	355	4	8	
Asphalt Control	100	5.4	357	5	38	
Left turn to get to I-20 (PR-117)	50	6.8	358	6		Balanced 500 gain, truck went on curb # 2 start turn Clicks are wheels hitting curb
right onto I-20 (include on-ramp)	50	7.1	359, 360	8		Click @ start Diff in load due to road elevation
Asphalt Control	100	8.5	361	=======	======	**SKIPPED ===================**
Overpass	50	9.4	362	**9** |	42	#2 tired hit bridge
Bump 1	100	9.8		| |		#3
Concrete control 1	100	10.6	363	**9**		#4
Left turn 1	50	12.1	364	10		
Overpass 2	50	12.9	365	11	55	
Bridge 1	50	13.2	366	**12** |		

Bridge 2	50	13.6	367	| |		
Bridge 3	50	14		| |		
Bridge 4	50	15.6	368	**12**		
Bridge 5	50	15.8		**=======**	**=======**	**MISSED ==================**
Dip in road	~~100~~ 50	18.2				
Bumps + Bridge 5 & 6	50	22		13		Balance Clicks @ bridges
Bridge 7 & 8	50	23.7	371, 372	14	60	Clicks @ bridges
Bridge 9, 10, 11	50	27	373, 374, 375	15	60	#2 rough !
Bridge 12	50	29	376	16		Missed ½
Bridge 13 + Concrete control	50	34.6	377	17	45-55	#2 bridge, #3 CC
Left curve	50	41.8	378	18	Balance	
Bridge 14 + some	50	54		19	60	
Concrete control 4	50	58	379	20	65	32 secs slowing down
Bridge 15 + Asphalt	50	62.3	380	21, 22	55	File 21: bridge, File 22: asphalt File 23: leaving rest area
Bridge 16, 17	50	66	383	24 |	58	NOTE – actually 3 bridges here
Asphalt/ concrete control	100	67	384	24	58	85 secs as moving through cones
Bump + Bridge #19	75	68.7- 73.7		25	60	#2 bridge, #3 bridge very bumpy, #4 new aasphalt
Right curve	50	81.8		26		

Transition + concrete+ overpass (include exit to 165)	75	83.4	389	27	55	280 second slow down; #2 change; #3 bridge; #4 rough bridge; #5 stop 6 start turn to I65; #7 bridge; #8 2^{nd} turn
Bumpy	50	89	391	**28** |	30-45	Balance
Bumpy + Bridge 20	50	89.7	392	**28**		#2 @ bridge
Bridge 21, 22 + hill, br 23, left and right curve	100	91.8	394 thru 395	29		#2 start uphill bridge Round corner left ; round corner right
RR Tracks	100	94	396	=====	=====	**MISSED ==================**
Asphalt Control	50	95.5	397	=====	=====	**SKIPPED ====================**
Right curve to dbl lanes	50	99	398	30	40	
Right curve	50	99.5	399	30	50	2^{nd} click
left thru const. + 1min (3.8 miles total)	100	103		31		#2 superelevation; #3 bumps; #4 bumps
left turn + bridge 25 + bumps	100	109	405	32		150 sec curve; hill; bridge
Const.	100	109.8		**33** |		#2 superelevation change
Right curve	50	110.7		**33**		
Left curve + big bump @ 112.5	50	111.9		**34** |		Balance; #2 start corner;
Bumps + left + right	50	113.2		**34**		#3 big bump; #4 grade change #5 hard right; #6 superelevation change
enter city	50	116.4	411, 412	35, 36, 37 **combined to "beam A_COLUMBIA" ***		

Table 4 Beam B girder monitor information spreadsheet.

Feature	Est. Sample Rate	Mi #	Picture #	File Name	Speed	Clicks
Turn out of yard	40	0	350, 351	**1** |		#2 hit street
RR Tracks	50	0.2	352	**1**		#2 RR tracks
Asphalt Control	50	0.8	353	2	27-30	
Left onto 80	50	1.8	354	3	<5	
Rough Asphalt	~~100~~ 50	2.1	355	4	20	
Asphalt Control	100	5.4	357	5	40	
Left turn to get to I-20 (PR-117)	50	6.8	358	6 & 7	--	#2 front tire; #3 rear tires
right onto I-20 (include on-ramp)	50	7.1	359, 360	8	--	#2 tires onto median; #3 rear on median #4 straight line travel
Asphalt Control	100	8.5	361	=====	=====	Balance on I-20 30mph
Overpass	50	9.4	362	9		#2 on bridge
Bump 1	100	9.8		10	50	+ bridge
Concrete control 1	100	10.6	363	======	======	**SKIPPED** ==============
Left turn 1	50	12.1	364	11	55	
Overpass 2	50	12.9	365	**12** |	57	#2 click
Bridge 1	50	13.2	366	|		#3 click

				|		
Bridge 2	50	13.6	367	| |		#4 click
Bridge 3	50	14		**12**		#5 click
Bridge 4	50	15.6	368	13	55	#2 click
Bridge 5	50	15.8		|		#3 click (B)
Dip in road	100	18.2		14		Click at start
Bumps + Bridge 5 & 6	50	22		15	57	
Bridge 7 & 8	50	23.7	371, 372	16	50	#2 bridge 7; #3 bridge 8
Bridge 9, 10, 11	50	27	373, 374, 375	17		#2 bridge 9; #3 bridge 10; #4 bridge 11
Bridge 12	50	29	376	18		
Bridge 13 + Concrete control	50	34.6	377	19	48	#2 bridge 13 + #3 CCC
Left curve	50	41.8	378	20		[Check mark]
Bridge 14 + some	50	54		21		Rough road
Concrete control 4	50	58	379	22		
Bridge 15 + Asphalt	50	62.3	380	23		**Test #24 – rolling out of rest area**
Bridge 16, 17 &18	50	66	383	**25** |		#2; #3 bridge 17; #4 bridge 18
Asphalt/ concrete control	100	67	384	**25**		#5 joint
Bump + Bridge #19 5mile test	75	68.7-73.7		26	60	#2 @ 63 mph; #3 bridge 19; curve right @ 190 seconds #4 twist in road

Right curve	50	81.8		27		
Transition + concrete+ overpass (include exit to 165)	75	83.4	389	28		(Missed transition); #2 overpass; #3 left turn; #4 left turn; #5 right turn; #6 right turn (165) #7 straightening
Bumpy	50	89	391		=======	**MISSED ============**
Bumpy + Bridge 20	50	89.7	392	29		#1 bridge 20
Bridge 21, 22 + hill, br 23, left and right curve	100	91.8	394 thru 395	30		#2 bridge 21; #3 bridge 22; #4 hill; #5 bridge 23 (hill); #6 left turn; #7 right turn
RR Tracks	100	94	396	31		Click @ tracks
Asphalt Control	50	95.5	397		======	**SKIPPED ==============**
Right curve to dbl lanes	50	99	398	**32** |		#2 right turn onto double lanes; #3 right turn (curve)
Right curve	50	99.5	399	**32**		
left thru const. + 1min (3.8 miles total)	100	103		33 **34**		**Bridge # 24**
left turn + bridge 25 + bumps	100	109	405	**35** |		#2 left turn; #3 right turn; #4 bridge 25
Const.	100	109.8		**35**		#5 right turn after construction
Right curve	50	110.7		**======**	======	**SKIPPED ==============**
Left curve + big bump @ 112.5	50	111.9		37		#2 big bump; #3 super elevation change; #4 left turn; #5 super elevation change, right
Bumps + left + right	50	113.2		37		
enter city	50	116.4	411, 412	(Columbia)		

TEST RESULTS

All measurements were recorded as a function of time; however, during the monitoring, event markers ("clicks") were added to the data and notes were taken to track specific occurrences. In the above spreadsheet, there is a column called "Clicks" and in this column there are numbers with descriptions (e.g. #2 start turn). For example, file number three for Girder A (Beam_A_3.dat) contains the data was taken during the left turn onto HW-80 and had four clicks (see Table 3). The first click started the test, the second click was when the truck initiated the turn, the third was the truck straightening out on HW-80 and the fourth was when the entire load was straight and continuing its drive down the highway. These clicks displayed on one of *Beam_A_3.dat's* response histories can be seen below in Figure 14 with the clicks referenced. Note that most of the clicks occur in data files that have more than one feature in attempt to have a reference to what induced the load on the girders, but in some cases, the files that only contain a single feature have a click when the truck makes contact with the feature. The depth of information kept for each feature was based primarily on the amount of time between the features and the amount of time it took to record the information.

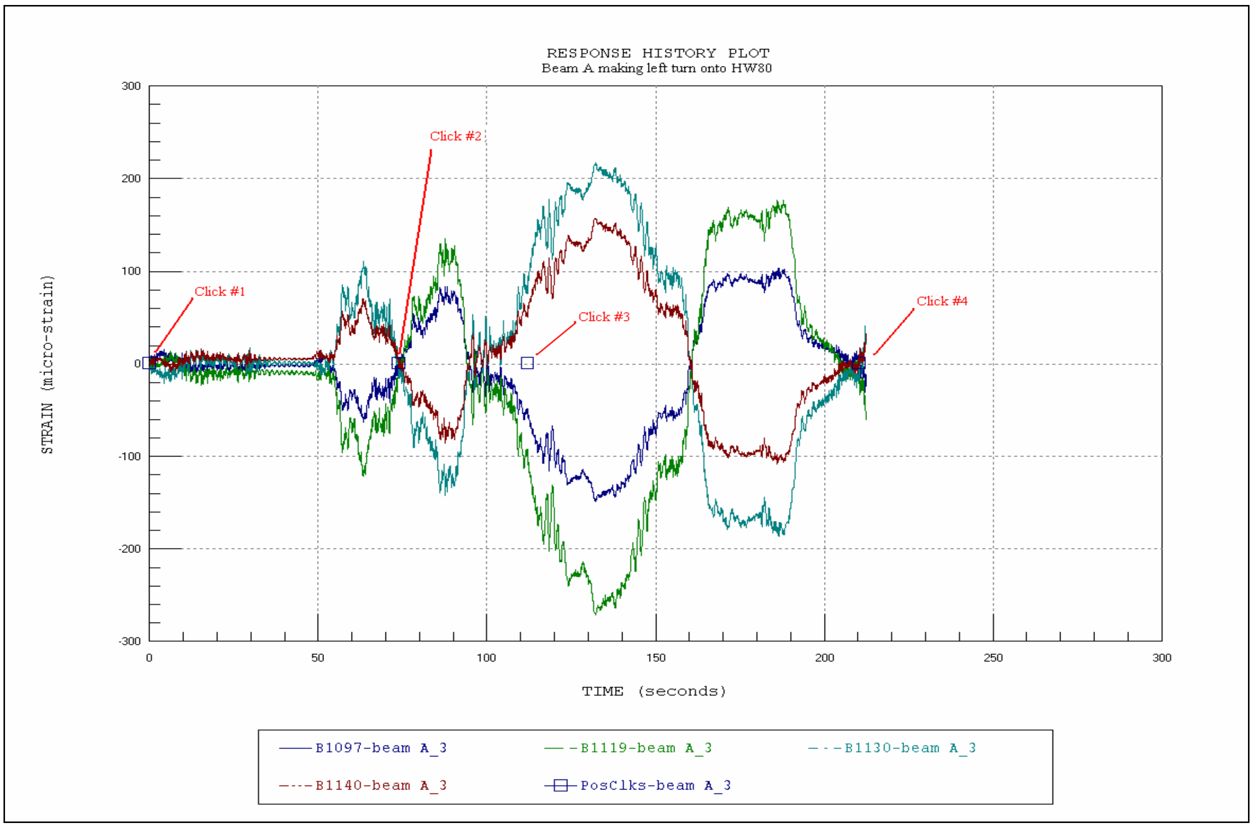

Figure 14 Beam_A_3.dat click information example.

General Observations:

Below are observations made by BDI during the gage installation, girder monitoring, and data processing.

- During the gage installation procedures, it was noticed that the top flange of Girder A was severely cracked on the driver's side of the beam (see Figure 15). This crack was approximately 35 feet in length and spanned gage cross-sections C and D. As seen in the monitoring results, the strains were considerably higher in the cracked cross-sections on Girder A than in the same cross-sections on the uncracked Girder B. It is expected that this was the result of these cracked cross-sections being significantly more flexible.

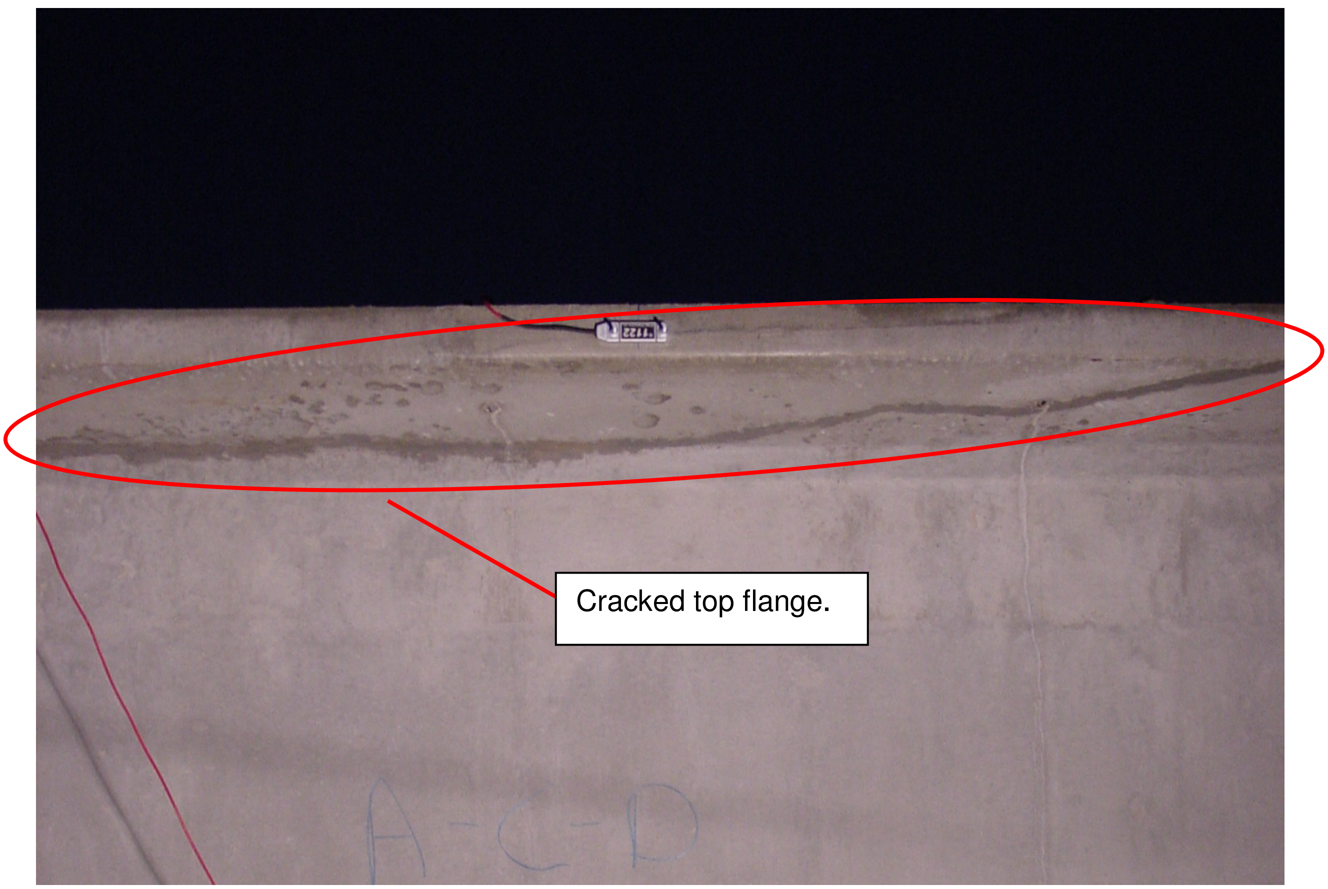

Figure 15 Cracked top flange of Girder A.

- During the loading process of Girder B, the pin that attaches the front portion of the trailer to the semi tractor became unlatched and the beam dropped about one foot. When this occurred, the front end of the beam was crushed but during a quick visual inspection the rest of the beam appeared to be undamaged. This inspection was performed simply to locate any visible cracking, but no non-destructive testing was performed to locate microscopic cracks, if any occurred. Figure 16 shows the damaged end of the girder immediately after it was reloaded unto the trailer. Note that the damaged end was patched during the night before the beams were transported to the job site in Columbia.

Figure 16 Beam B damage.

MONITORING RESULTS

During the monitoring procedures, over 40 data files were collected for each girder. Due to this large amount of data, not every response history could be graphed for this report. Response histories for each gaged cross-section are displayed below for major events such as loading the beams onto the semi trailers, sharp turns, and erecting the beams. Each of these response histories has a title consisting of a beam number (Girder A or B), a cross-section label (A thru E), and a test file name (_1 thru _37). For example, for test file 1 at Cross-Section A on Girder A the title reads Beam A-A-1. Note that the test file can be correlated with the roadway feature using Table 2, Table 3, and Table 4 for Girder loading and unloading.

Casting yard operations:

While the girders were in the casting yard, monitoring was performed during two phases. First, two gantry cranes, one at each end of the beam, were used to haul each beam from their storage site in the casting yard to the semi trailers. The second phase was performed while the semi moved the beams from the loading area to the staging area at the front of the casting yard. Field notes for this portion of the monitoring can be found above in Table 2. A strain envelope and response histories for each cross-section can be found below for the loading of the girders onto the semi trailers. For the left turn in the casting yard, a strain envelope of each cross-section has been included and only a response history for Cross-Section C. Additional response histories for this monitoring operation can be found on the included CD in the *Additional Graphs* folder under *Left turn in casting yard.*

FEATURE: LOADING GIRDERS ONTO SEMI TRAILERS

File Names: GirderA_(lift_Truck)_1.dat

GirderB_(lift_Truck)_1.dat

Details: This portions of monitoring occurred when the girders were taken from their storage location on the yard and loaded onto the trailers.

Figure 17 Girder A being loaded onto semi trailer.

GIRDER A RESPONSES:

CLICKS:
1- Start test
2- Lift from storage location in yard
3- Cranes begin moving
4- Girder set onto trailer
5- Crane cables loosened and removed from girders

Table 5 Girder A loading onto trailer strain envelopes.

Beam A *File Name:* *GriderA_(lift_truck)_1*			
Cross-Section	Gage Number	Positive	Negative
A	B1061	5	-30
	B1045	11	-19
	B1132	6	-21
	B1190	19	-2
B	B1119	15	-128
	B1097	10	-76
	B1130	104	-29
	B1140	73	-15
C	B1122	27	-180
	B1046	10	-123
	B1131	110	-28
	B1118	94	-21
D	B1120	22	-224
	B1014	7	-222
	B1100	478	-22
	B1088	184	-19
E	B1062	7	-68
	B1032	5	-38
	B1094	57	-6
	B1039	11	-21

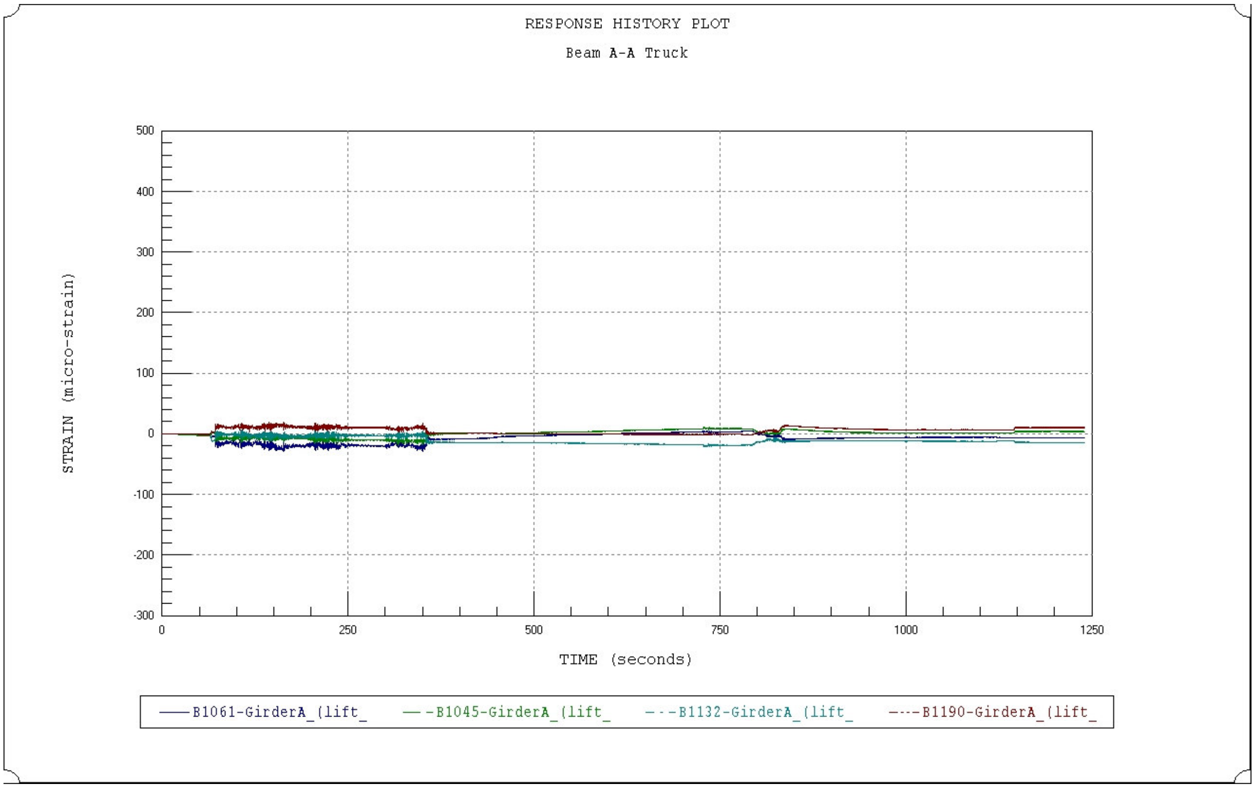

Figure 18 Girder A, Cross-Section A, File Lift Truck.

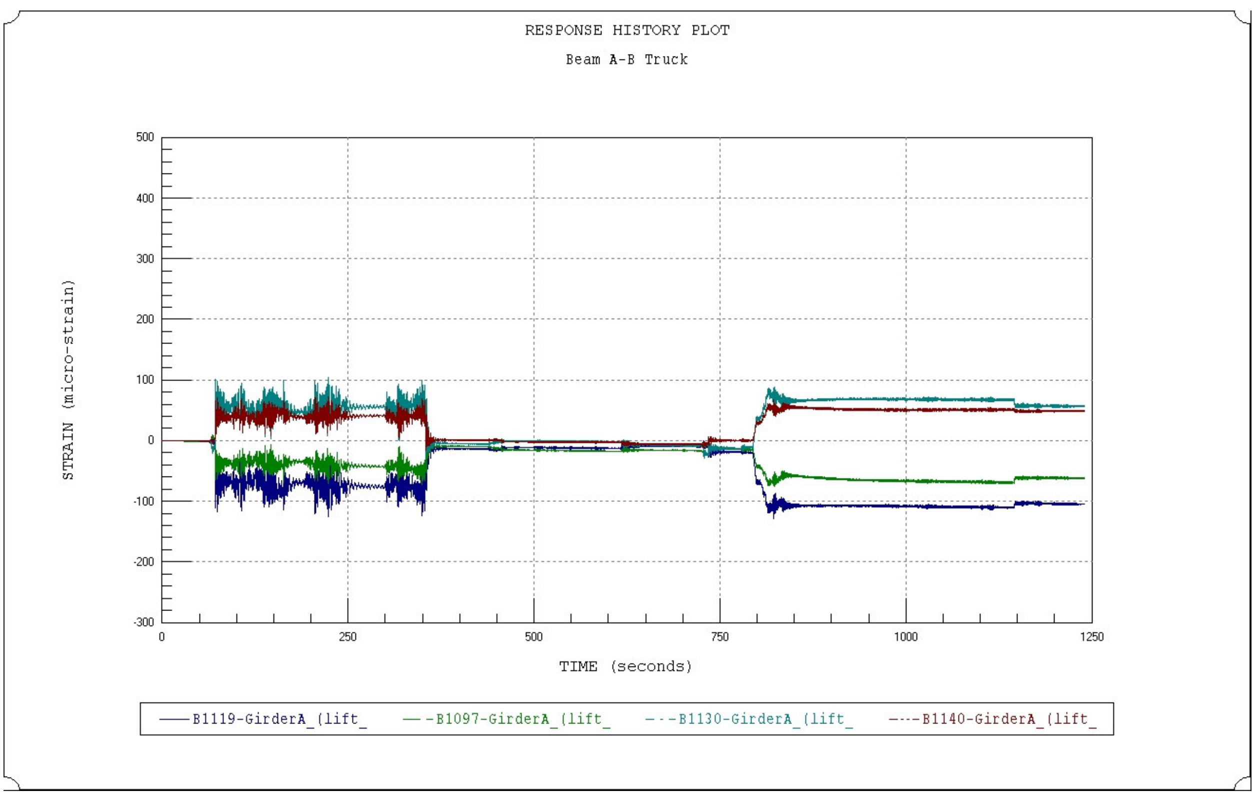

Figure 19 Girder A, Cross-Section B, File Lift Truck.

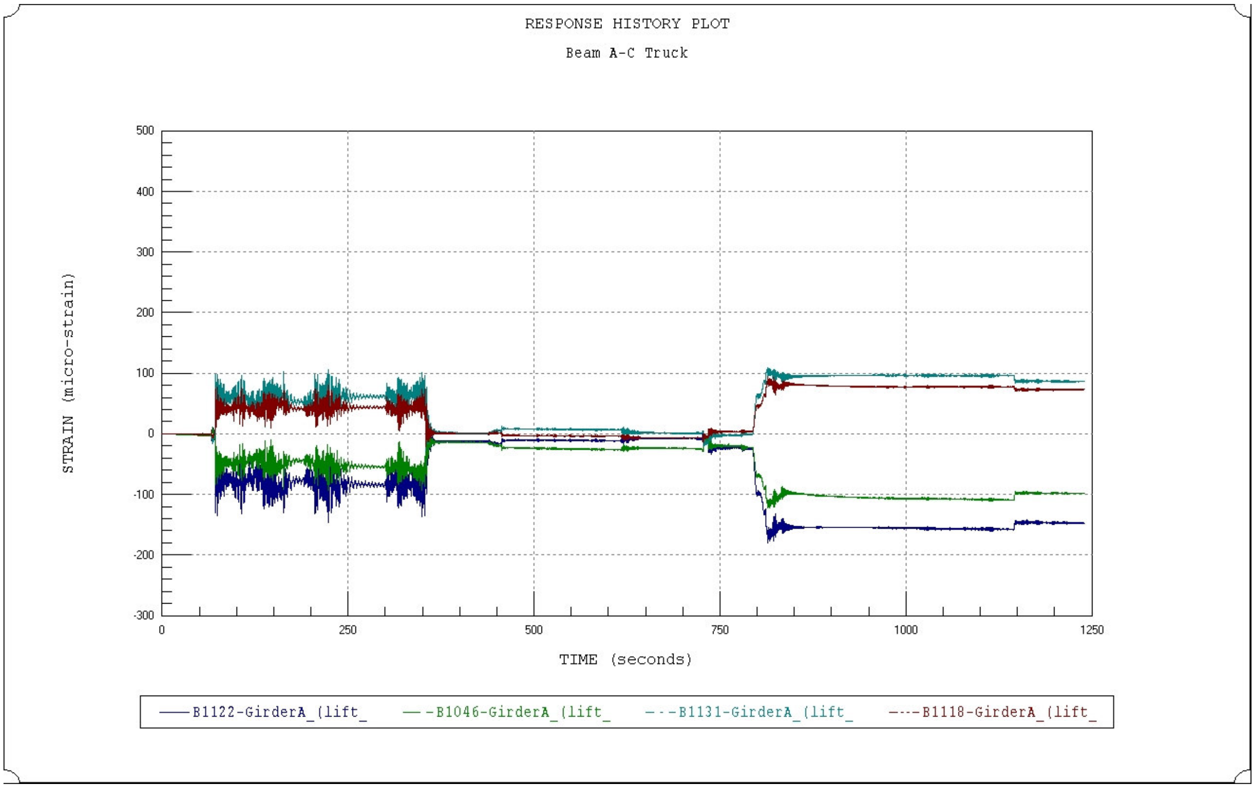

Figure 20 Girder A, Cross-Section C, File Lift Truck.

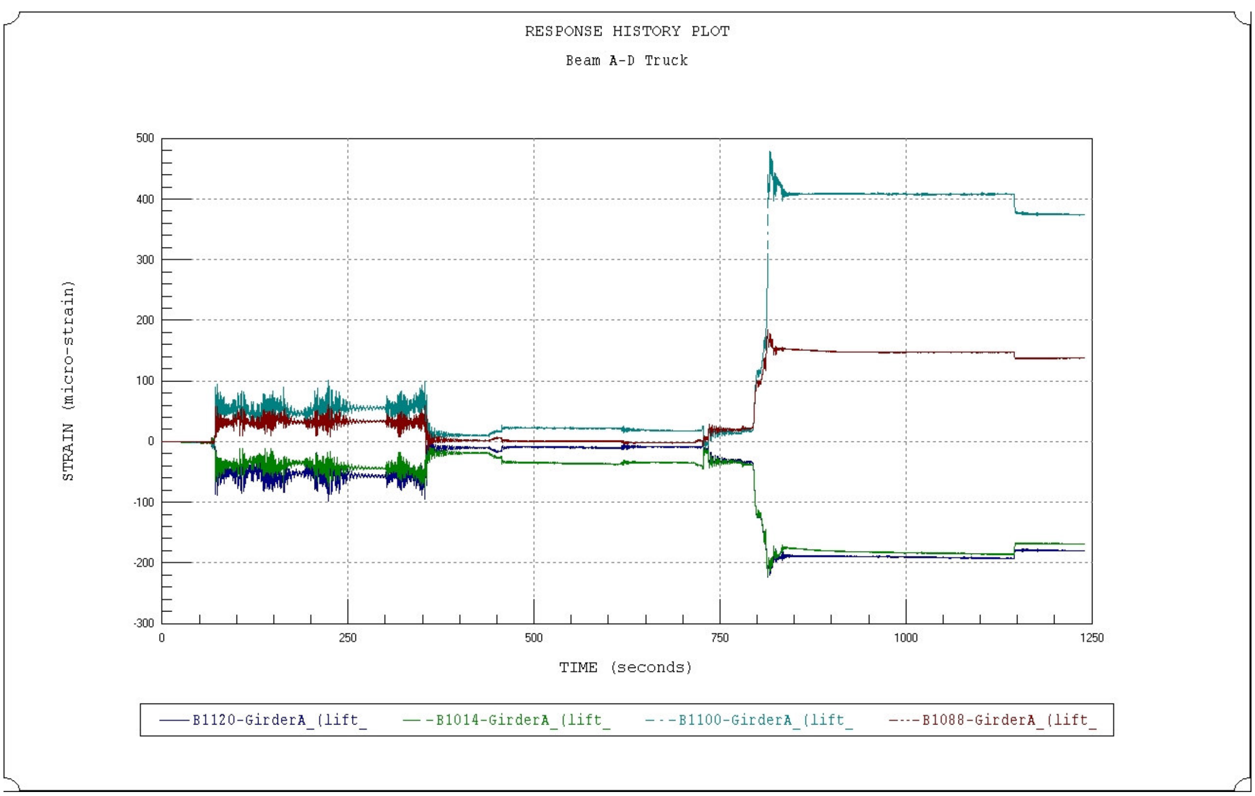

Figure 21 Girder A, Cross-Section D, File Lift Truck.

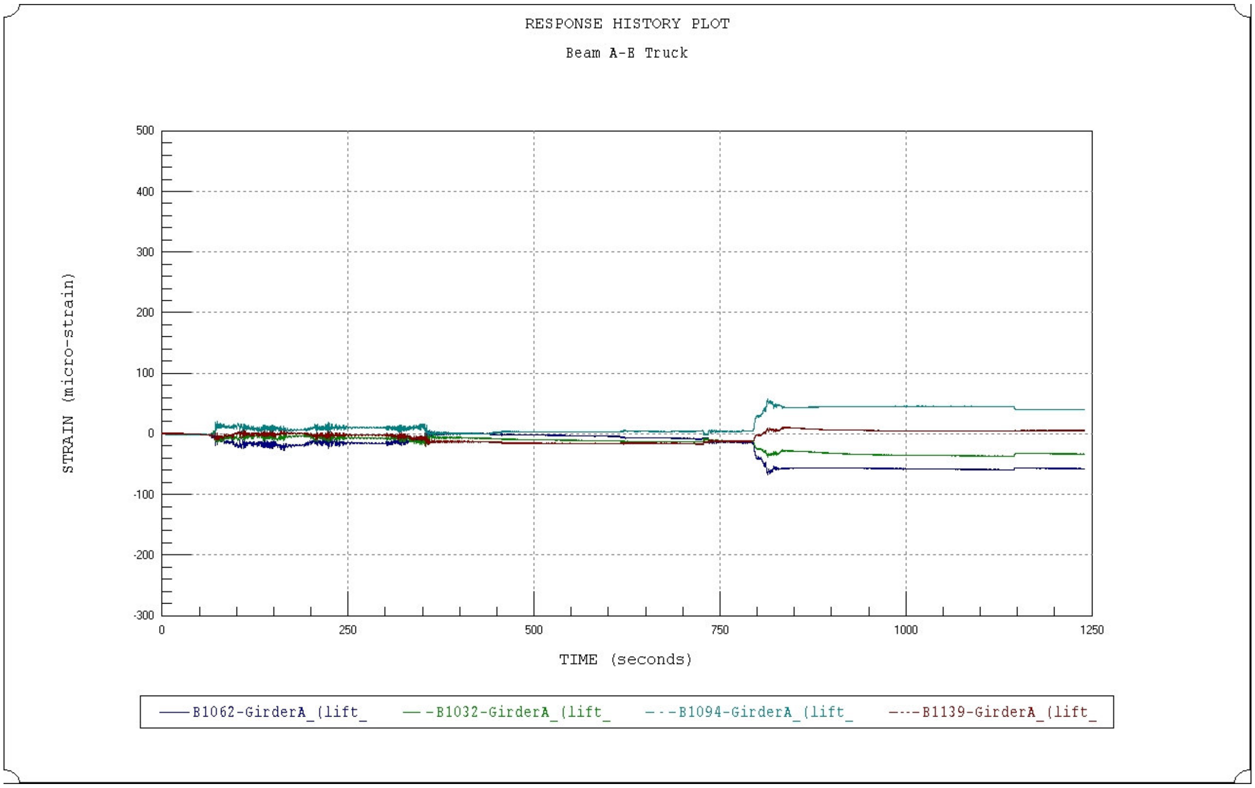

Figure 22 Girder A, Cross-Section E, File Lift Truck.

GIRDER B RESPONSES:

CLICKS: 1- Start test
~930sec crane cables tightened
~1200sec crane cables slacked
~1240sec girder picked from trailer
~3400sec girder placed on bearing locations
~3800sec cranes cables detached from beams.

Table 6 Girder B loading onto trailer strain envelopes.

Beam B *File Name:* *GriderB_(lift_truck)_1*			
Cross-Section	Gage Number	Positive	Negative
A	B1128	14	-13
	B1127	14	-10
	5833	0	-48
	8688	6	-22
B	B1126	68	-66
	B1129	38	-42
	5690	79	-91
	6327	52	-58
C	B1087	81	-84
	B1125	39	-50
	4792	95	-95
	B1124	46	-55
D	B1095	49	-82
	B1133	31	-43
	8865	74	-63
	5567	52	-54
E	B1116	23	-11
	B1123	32	0
	8860	3	-36
	9065	0	-42

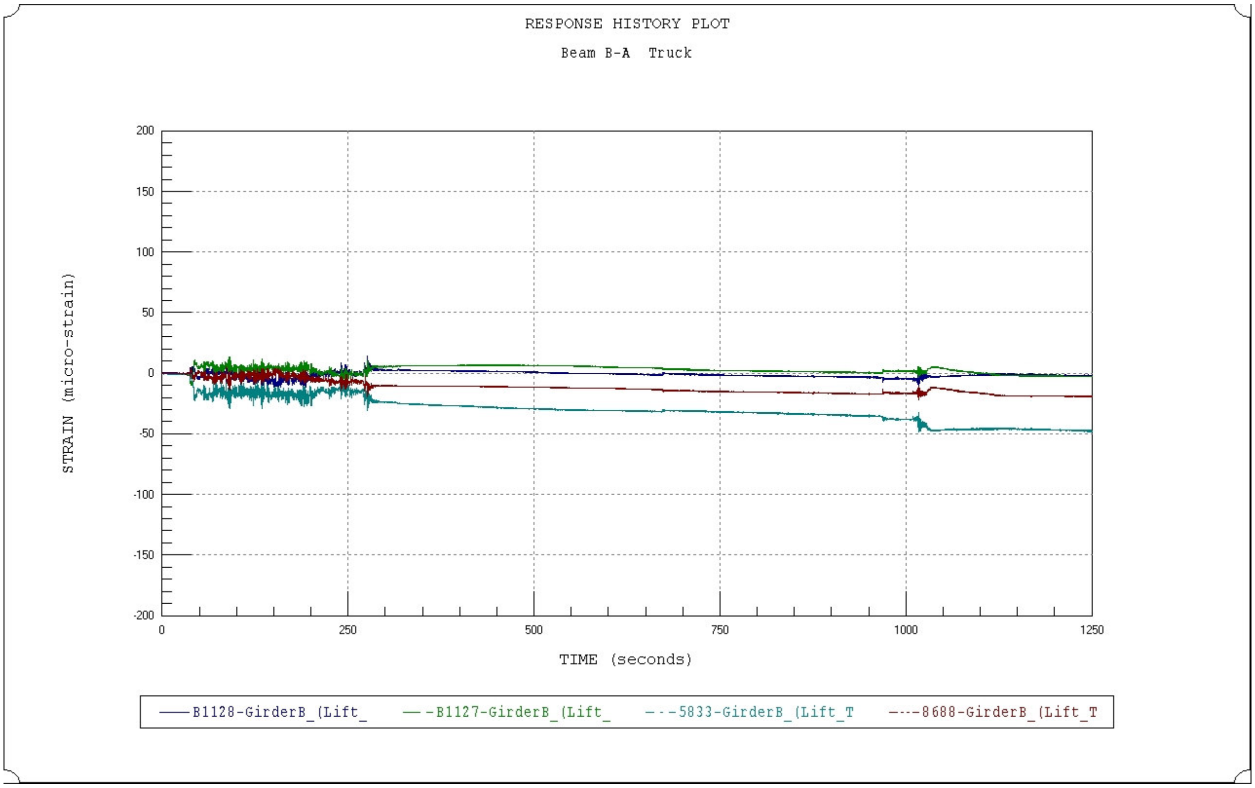

Figure 23 Girder B, Cross-Section A, File Lift Truck.

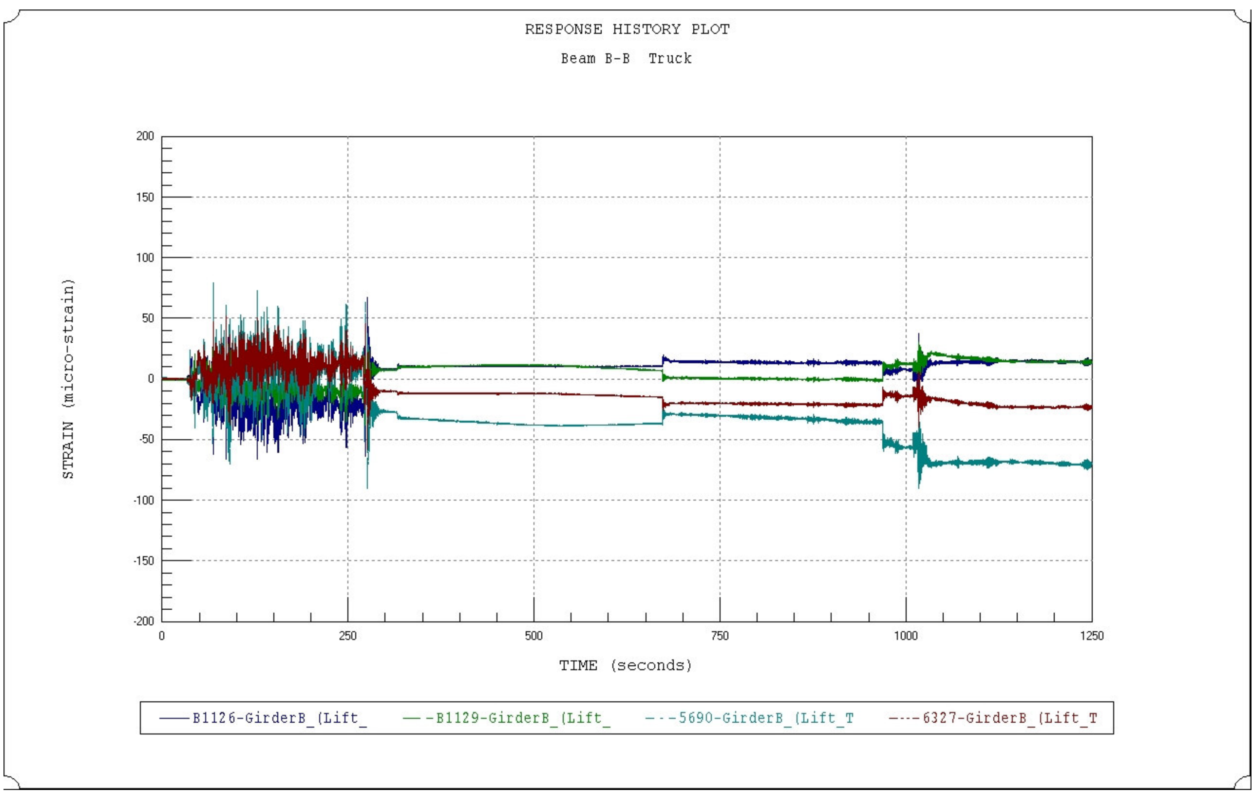

Figure 24 Girder B, Cross-Section B, File Lift Truck.

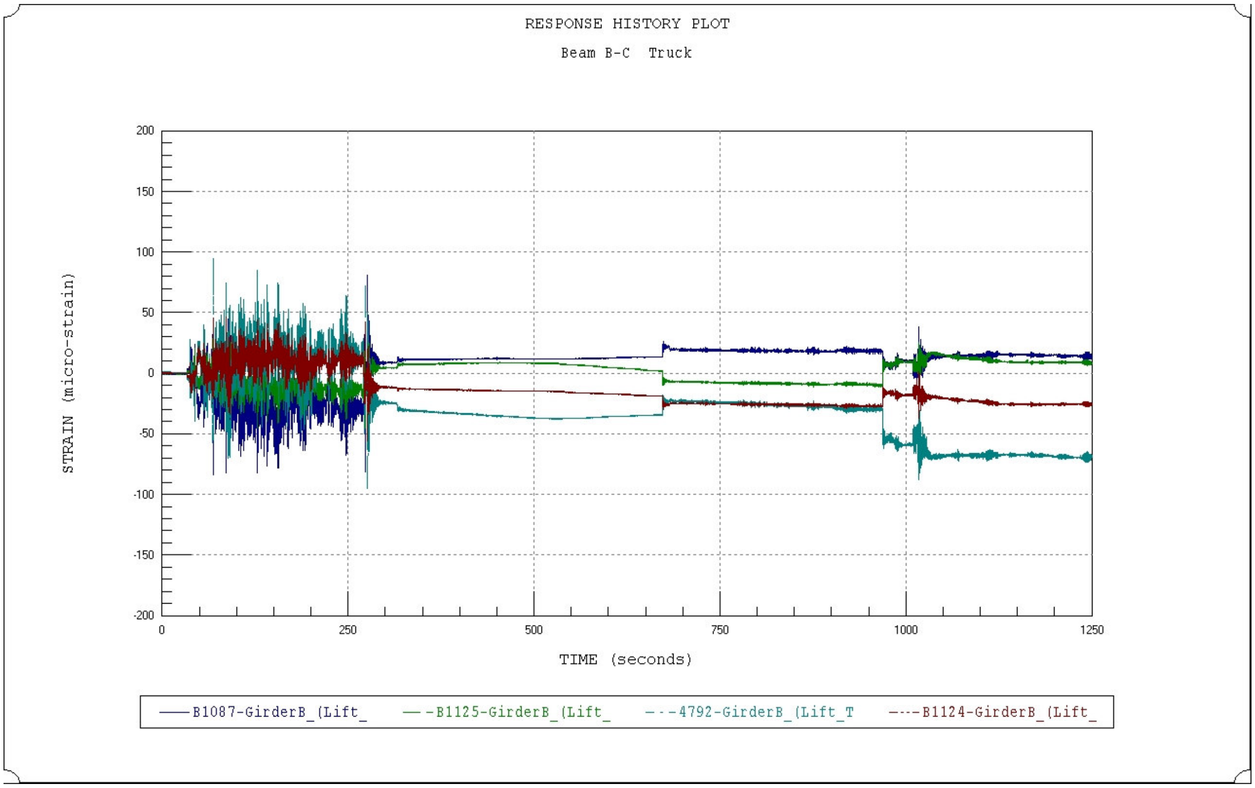

Figure 25 Girder B, Cross-Section C, File Lift Truck.

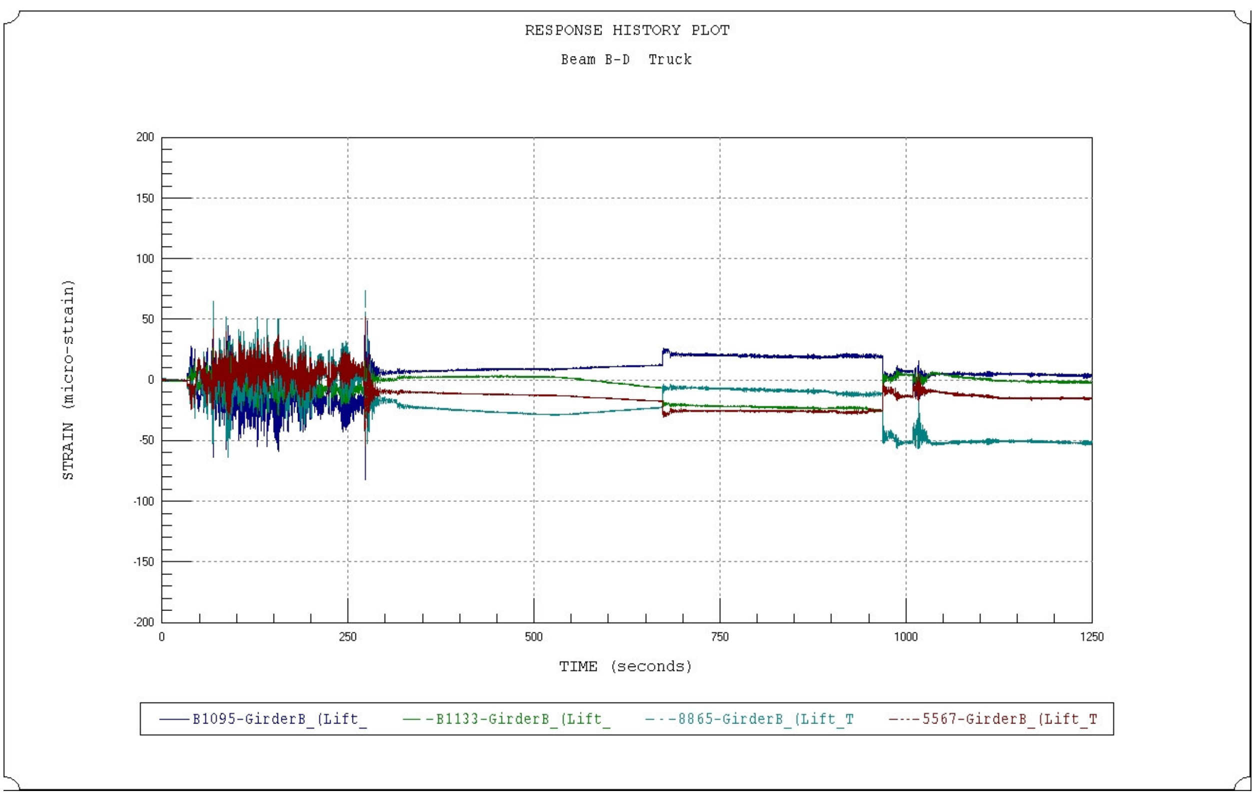

Figure 26 Girder B, Cross-Section D, File Lift Truck.

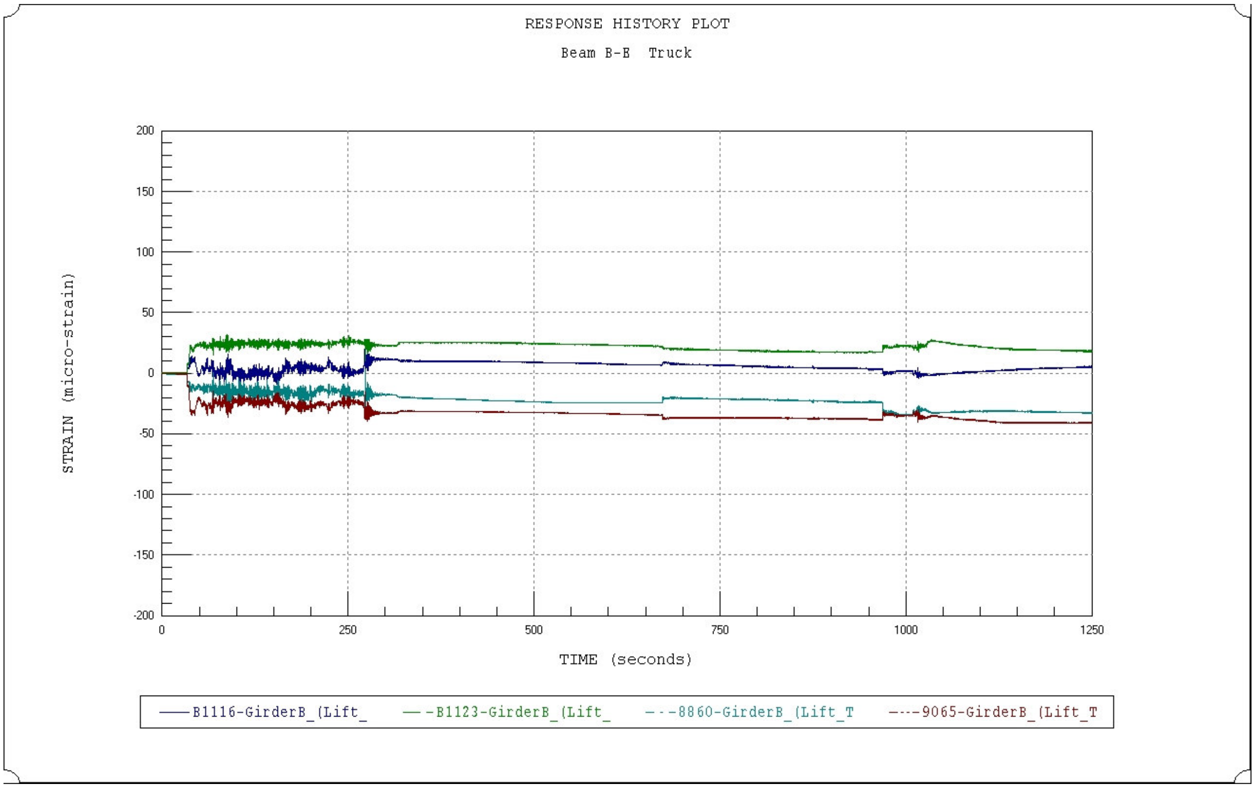

Figure 27 Girder B, Cross-Section A, File Lift Truck.

Feature: Hard left turn in casting yard

File Names: GirderA_(Yard_Turn1)_1.dat

GirderB_(Yard_Turn1)_1.dat

Details: After the girders were loaded onto the trailers, the trucks had to make a sharp left turn into the staging area at the front of the casting yard. To make this turn the trailer steering was used.

Figure 28 Girder A making left turn to staging area.

GIRDER A RESPONSES:

CLICKS: 1- Start test

2- Truck begins moving

Table 7 Girder A left turn in casting yard strain envelopes.

Beam A *File Name:* *GriderA_(yard_turn1)_1*			
Cross-Section	Gage Number	Positive	Negative
A	B1061	21	-19
	B1045	21	-15
	B1132	13	-27
	B1190	5	-20
B	B1119	190	-74
	B1097	110	-42
	B1130	65	-188
	B1140	44	-113
C	B1122	259	-109
	B1046	169	-71
	B1131	49	-228
	B1118	64	-146
D	B1120	311	-120
	B1014	271	-116
	B1100	822	-422
	B1088	100	-249
E	B1062	79	-29
	B1032	44	-21
	B1094	26	-80
	B1039	19	-40

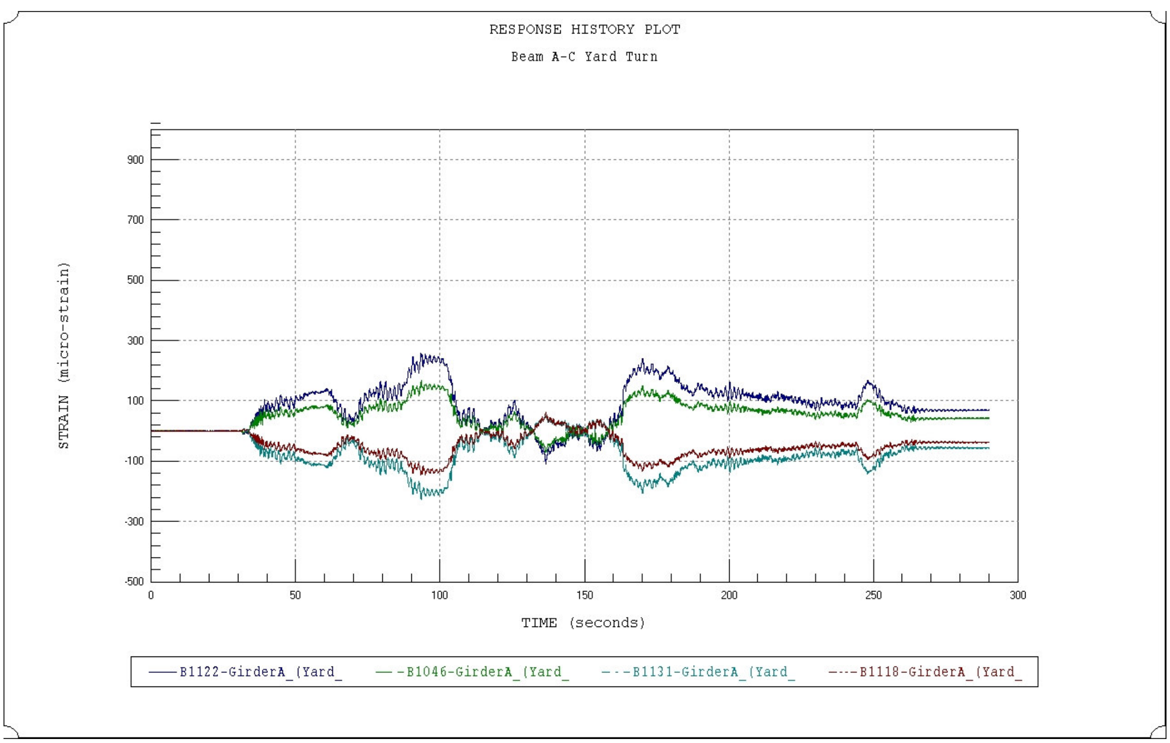

Figure 29 Girder A, Cross-Section C, File Yard Turn.

GIRDER B RESPONSES:

CLICKS: 1- Start test
2- Truck begins moving

Table 8 Girder B left turn in casting yard strain envelopes.

Beam B *File Name:* *GriderB_(yard_turn1)_1*			
Cross-Section	Gage Number	Positive	Negative
A	B1128	18	-38
	B1127	18	-20
	5833	35	-24
	8688	21	-23
B	B1126	119	-203
	B1129	69	-129
	5690	241	-146
	6327	146	-91
C	B1087	183	-277
	B1125	96	-163
	4792	306	-192
	B1124	159	-103
D	B1095	247	-311
	B1133	140	-209
	8865	306	-282
	5567	240	-164
E	B1116	48	-83
	B1123	25	-46
	8860	81	-64
	9065	49	-29

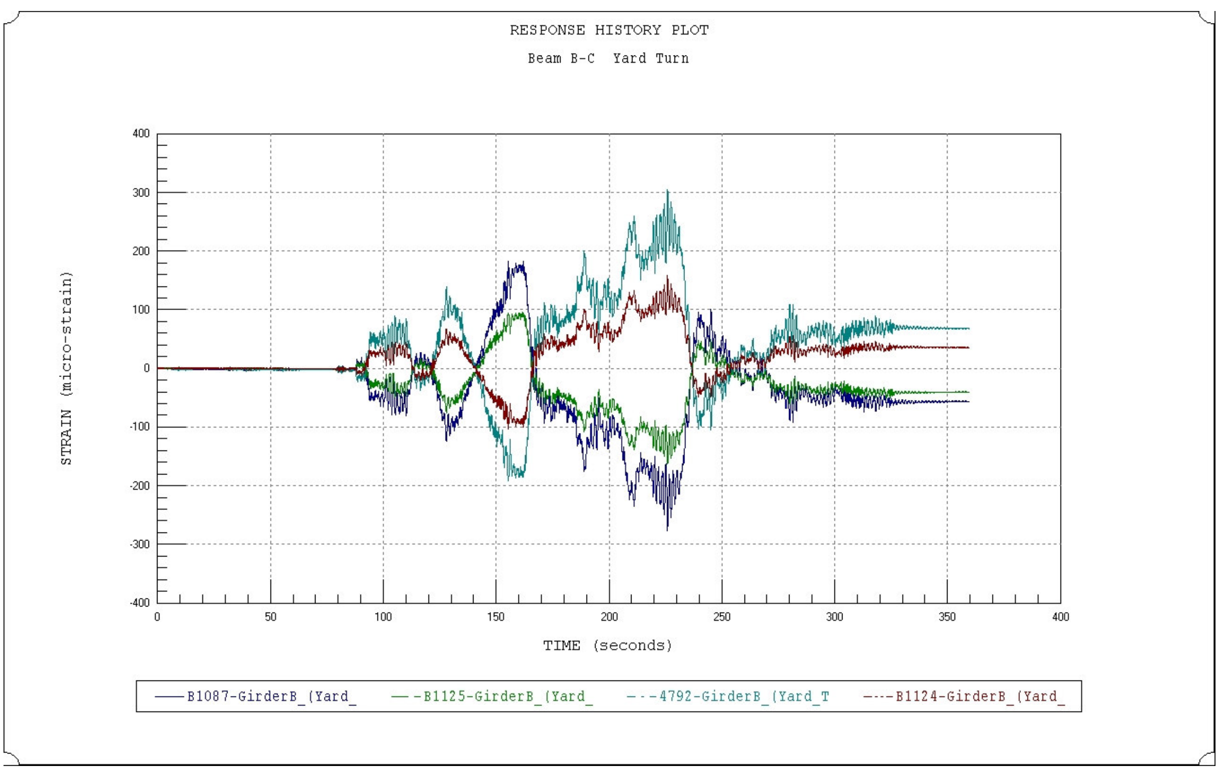

Figure 30 Girder B, Cross-Section C, File Yard Turn.

Sharp Turns:

There were five sharp turns where the rear trailer wheels were manually operated in order to allow the girders to make the sharp turn. This operation caused the highest strains during the entire monitoring operation. For this section, each turn is titled with the feature name from Table 3 and Table 4 followed by the file names, any important details noted during the monitoring, a picture of the turn, and a response history for each cross-section on both girders.

FEATURE: TURN OUT OF YARD

File Names: Beam_A_1.dat

Girder_B_1.dat

Details: This turn was a sharp right turn going from gravel to an asphalt roadway.

Figure 31 Right turn out of casting yard.

GIRDER A RESPONSES:

CLICKS: 1- Truck hits street (Asphalt)
2- Truck hits railroad tracks.

Table 9 Girder A turn out of yard strain envelopes.

Beam A *File Name:* *Beam_A_1.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1061	17	-26
	B1045	20	-29
	B1132	21	-20
	B1190	15	-19
B	B1119	80	-84
	B1097	44	-49
	B1130	78	-87
	B1140	51	-51
C	B1122	109	-110
	B1046	73	-69
	B1131	85	-101
	B1118	58	-65
D	B1120	146	-116
	B1014	128	-97
	B1100	358	-191
	B1088	87	-122
E	B1062	47	-40
	B1032	24	-16
	B1094	33	-51
	B1039	19	-25

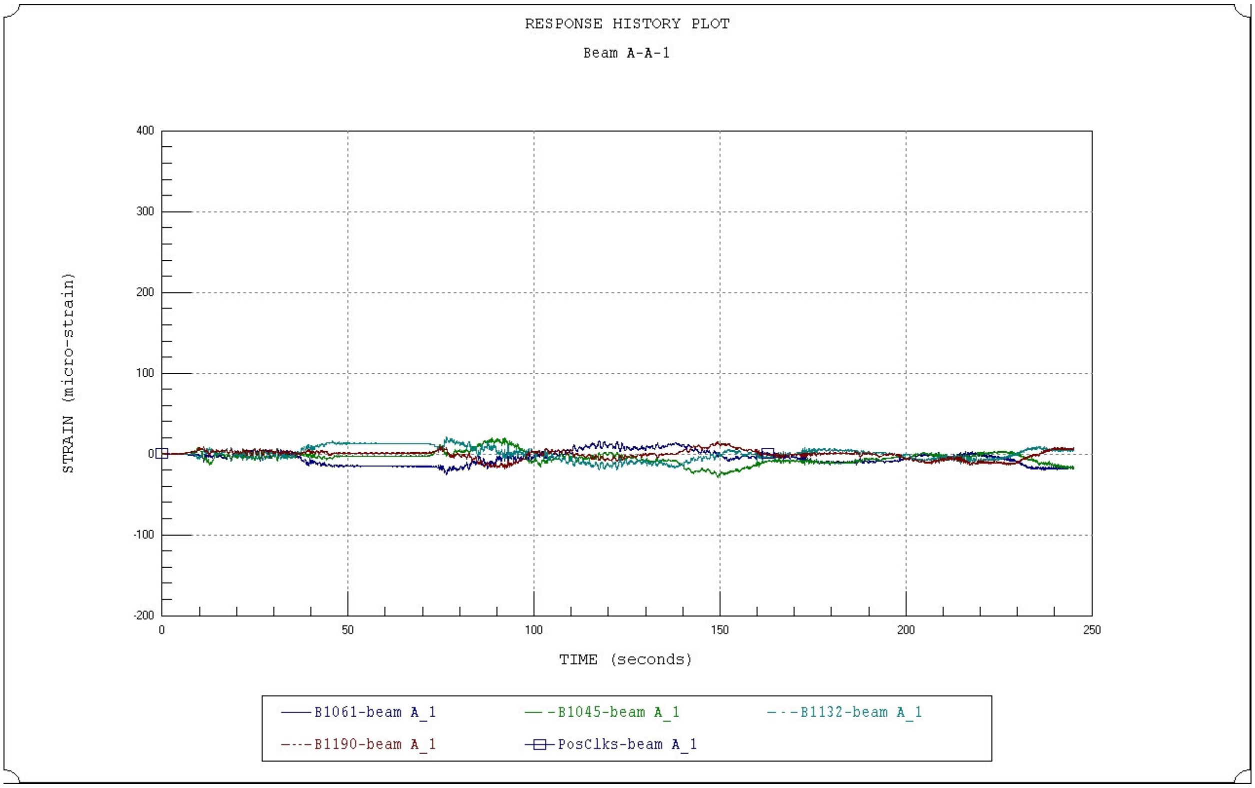

Figure 32 Girder A, Cross-Section A, File 1.

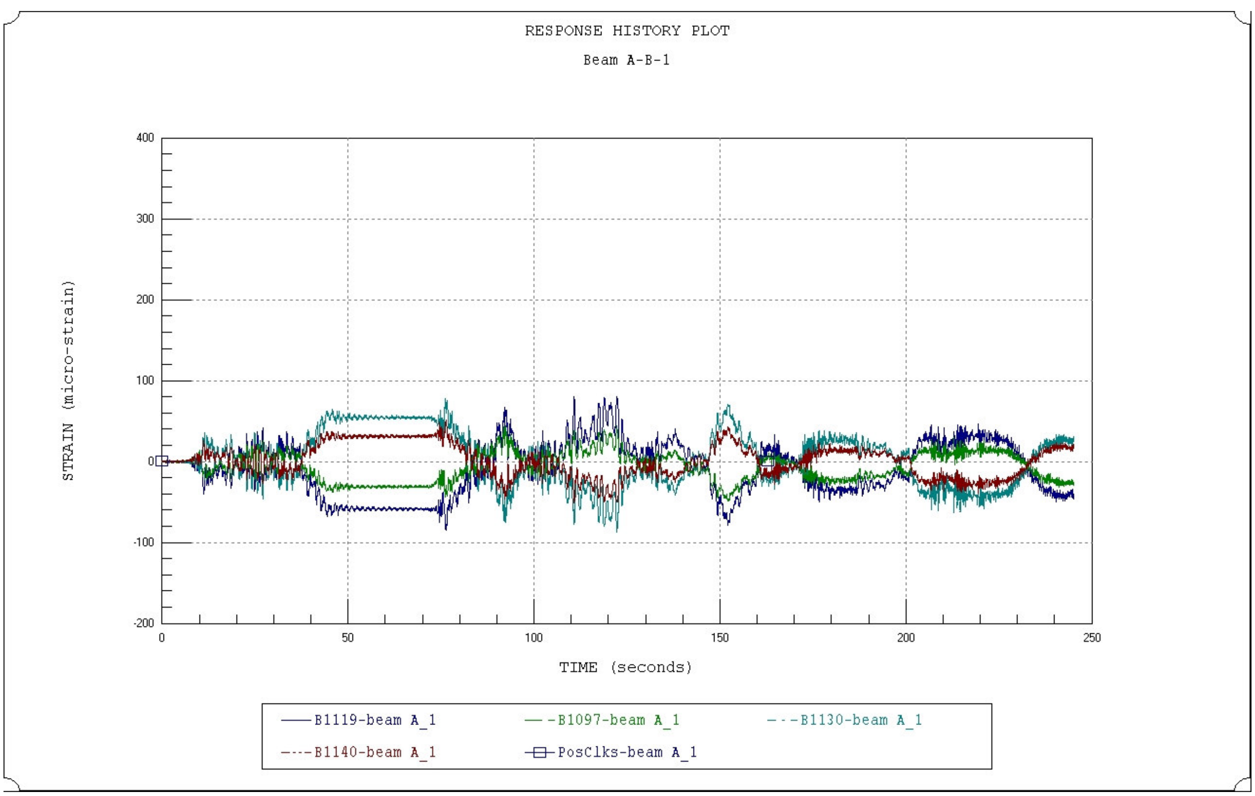

Figure 33 Girder A, Cross-Section B, File 1.

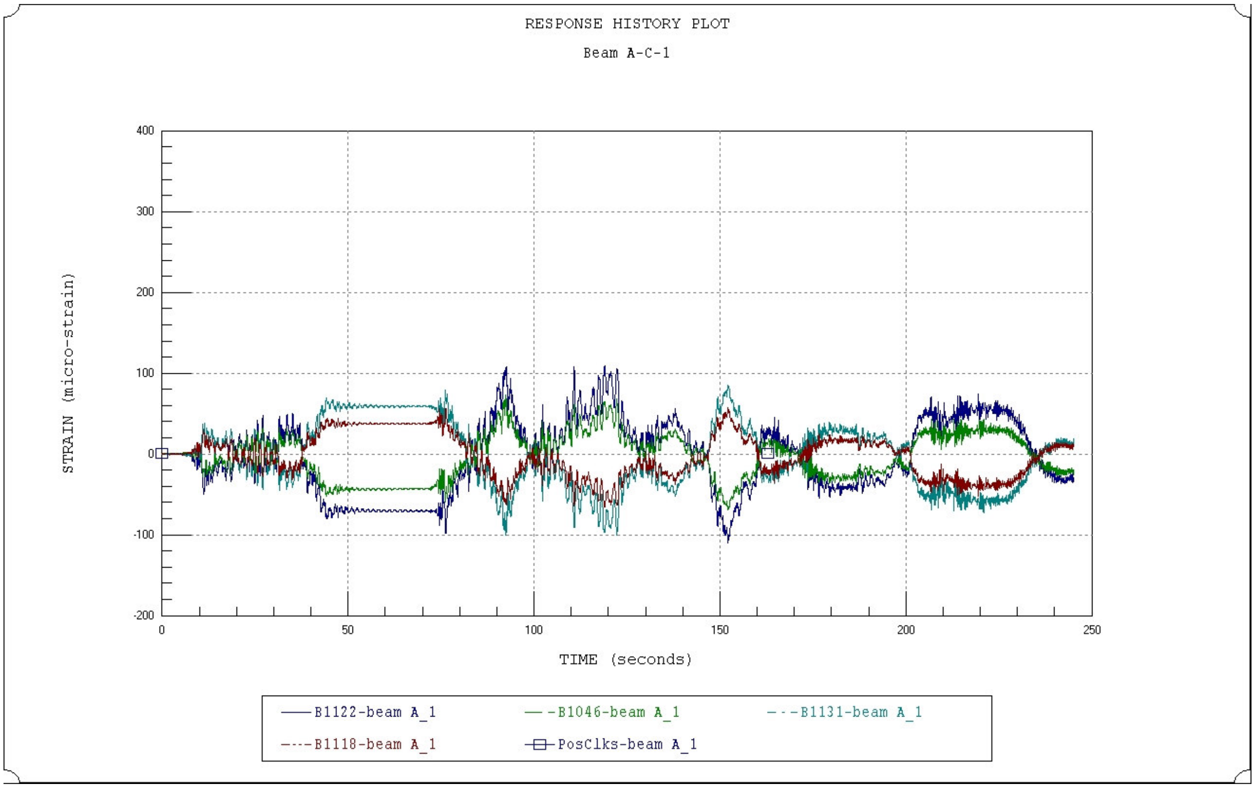

Figure 34 Girder A, Cross-Section C, File 1.

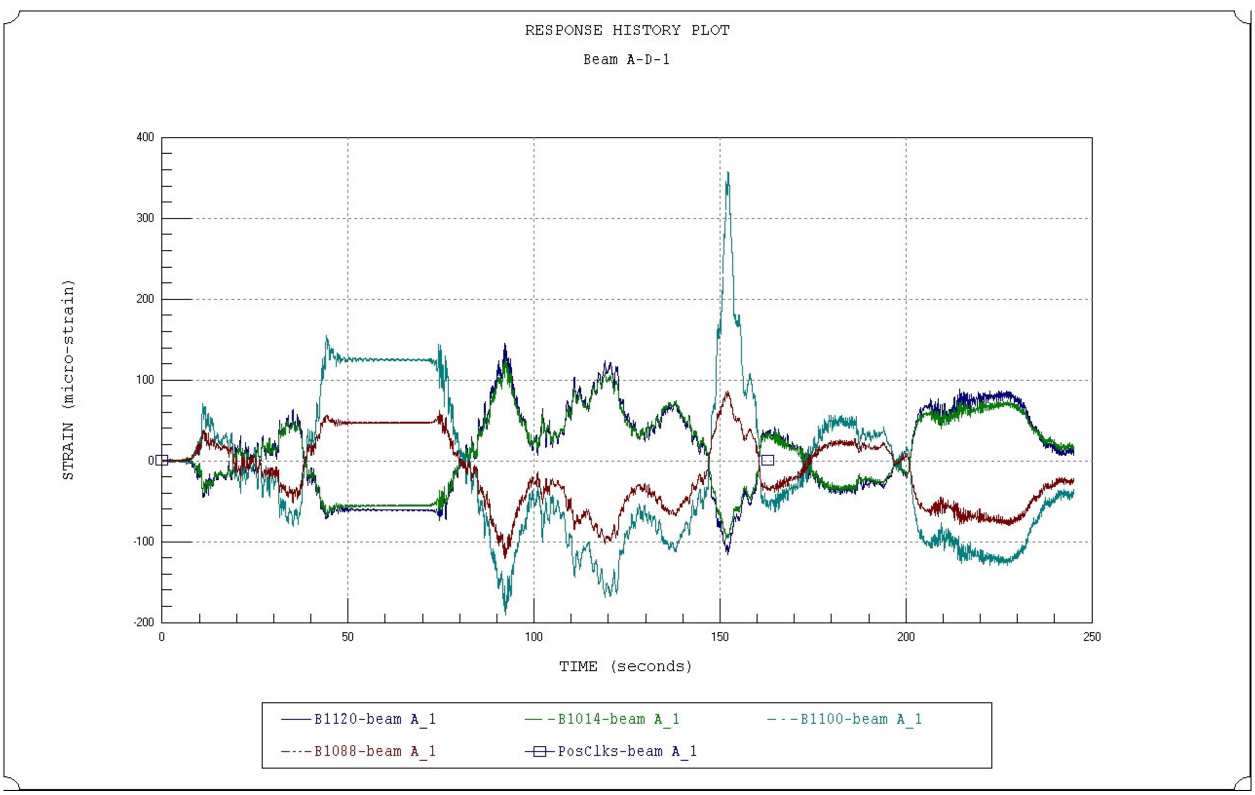

Figure 35 Girder A, Cross-Section D, File 1.

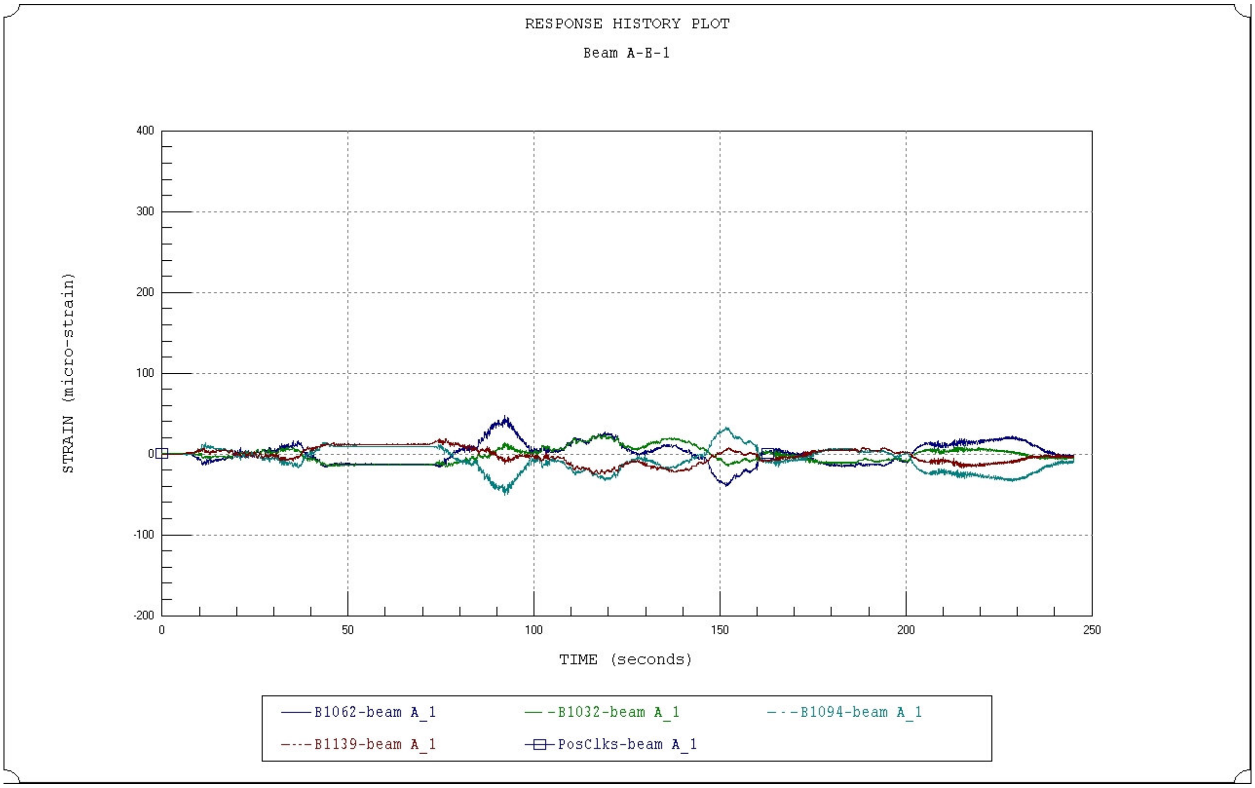

Figure 36 Girder A, Cross-Section E, File 1.

GIRDER B RESPONSES:

CLICKS: 1- Truck hits street (Asphalt)
2- Truck hits railroad tracks.

Table 10 Girder B turn out of yard strain envelopes.

Beam B *File Name:* *Girder_B_1.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1128	2	-43
	B1127	12	-35
	5833	46	-5
	8688	24	-7
B	B1126	7	-155
	B1129	6	-99
	5690	189	-12
	6327	110	-8
C	B1087	6	-222
	B1125	7	-122
	4792	235	-10
	B1124	118	-5
D	B1095	5	-288
	B1133	6	-179
	8865	296	-10
	5567	208	-5
E	B1116	1	-78
	B1123	2	-40
	8860	83	-3
	9065	45	-1

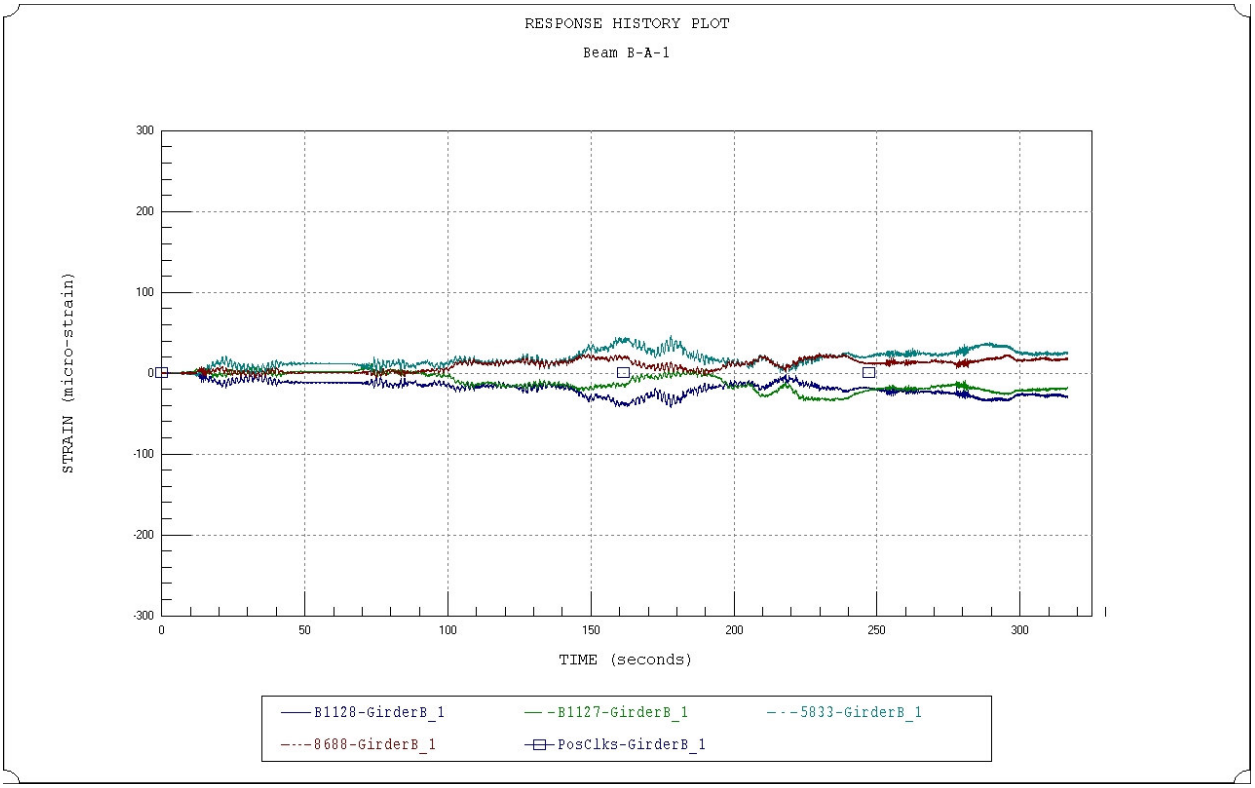

Figure 37 Girder B, Cross-Section A, File 1.

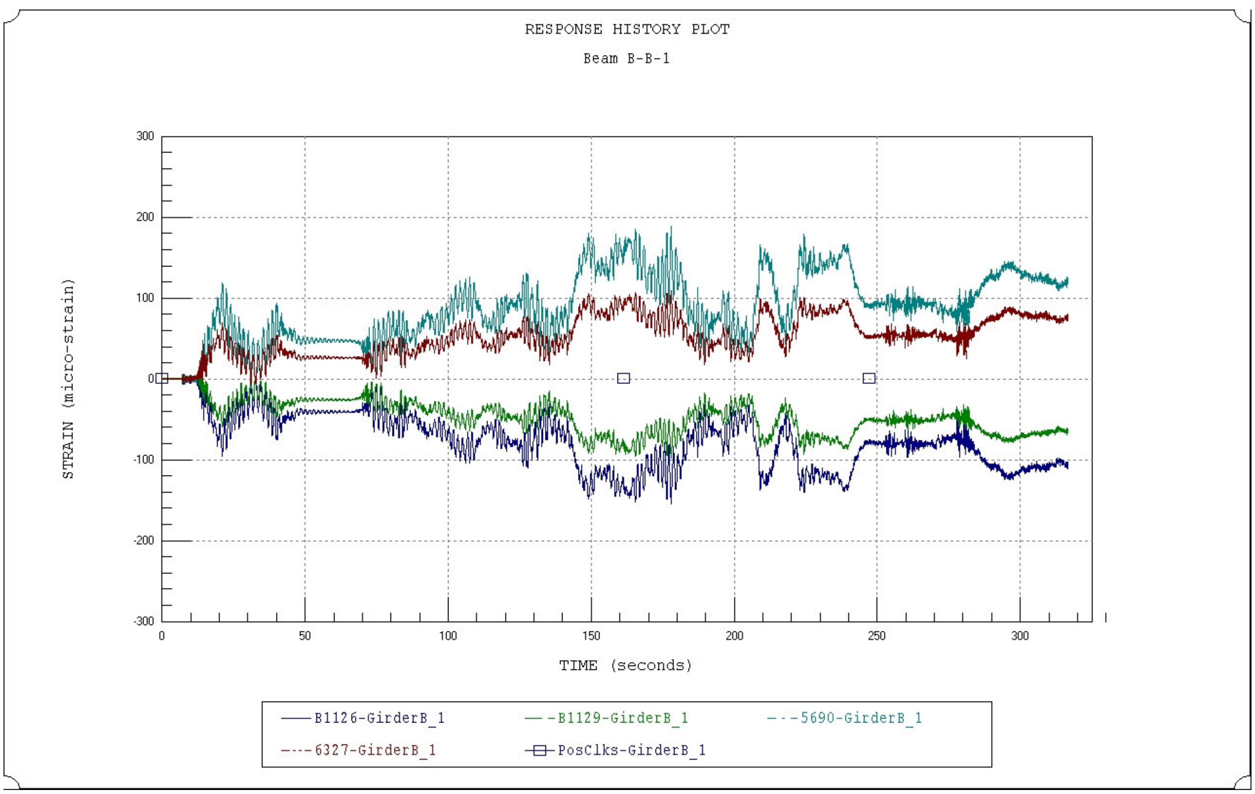

Figure 38 Girder B, Cross-Section B, File 1.

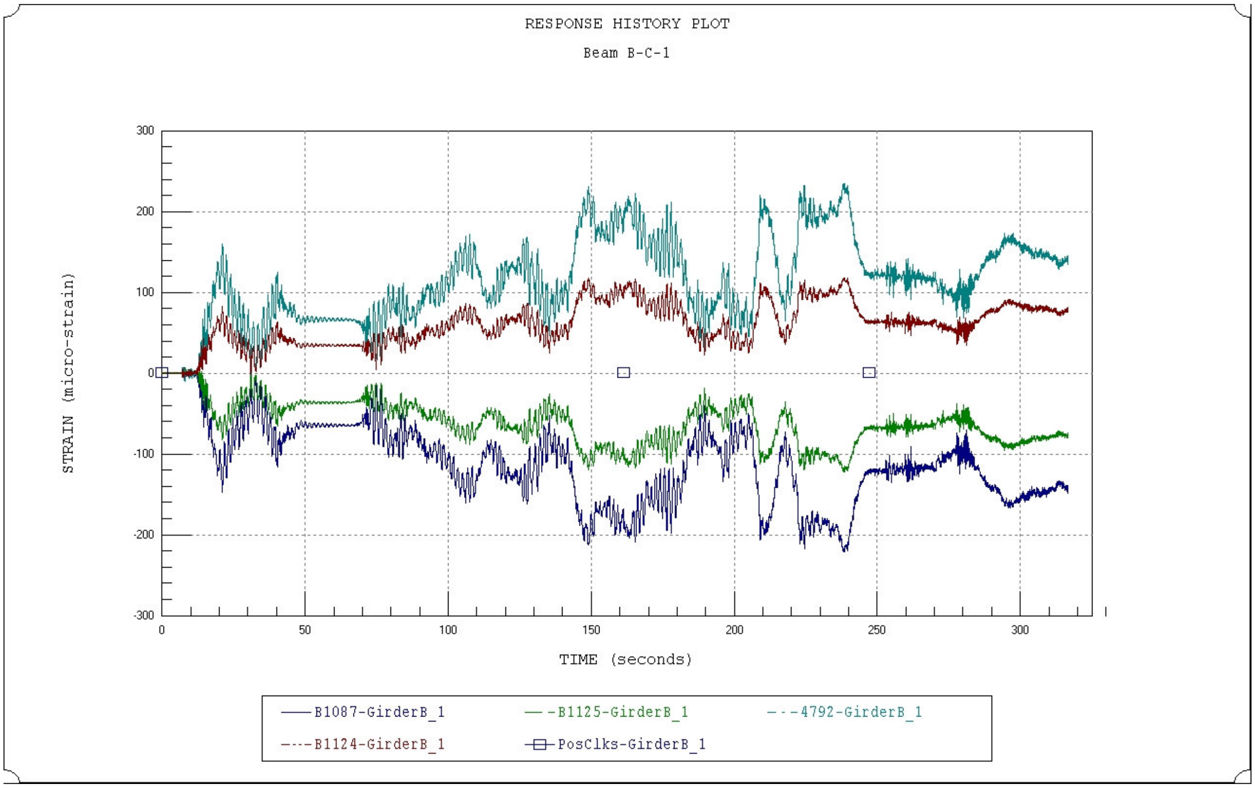

Figure 39 Girder B, Cross-Section C, File 1.

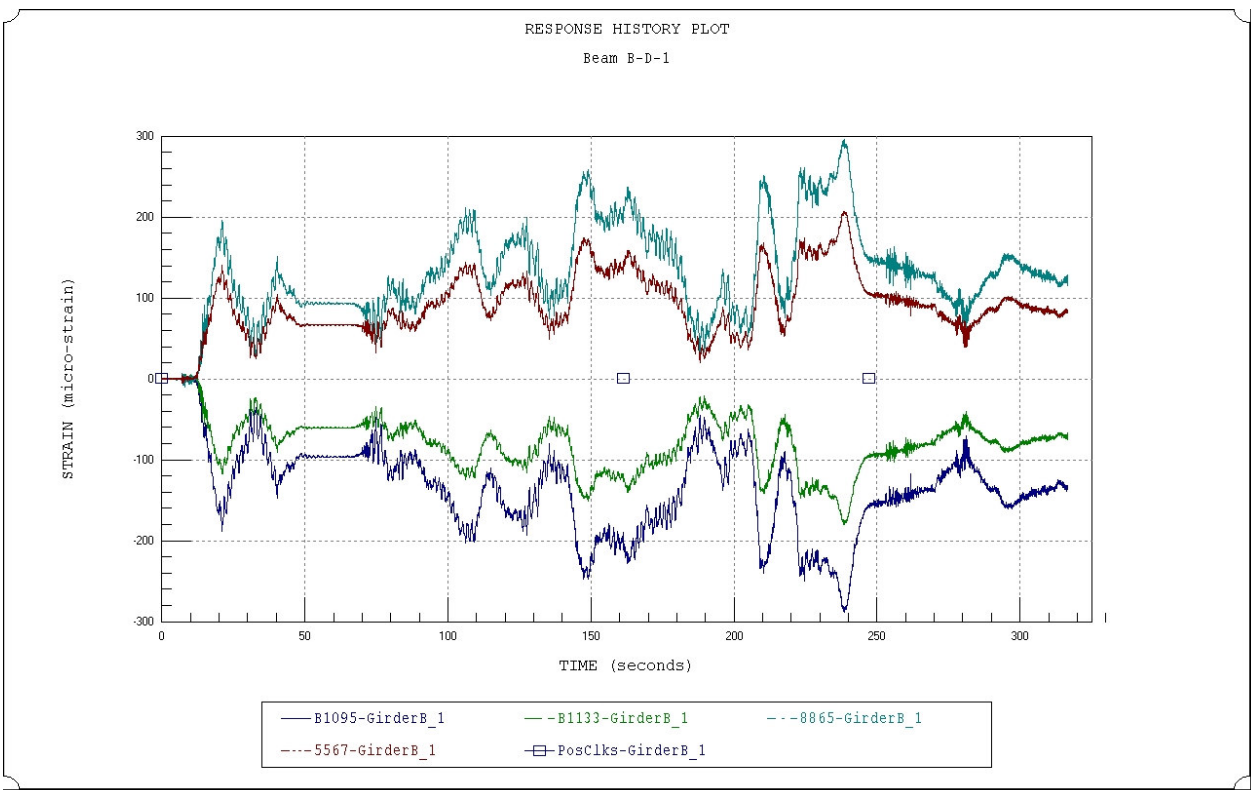

Figure 40 Girder B, Cross-Section D, File 1.

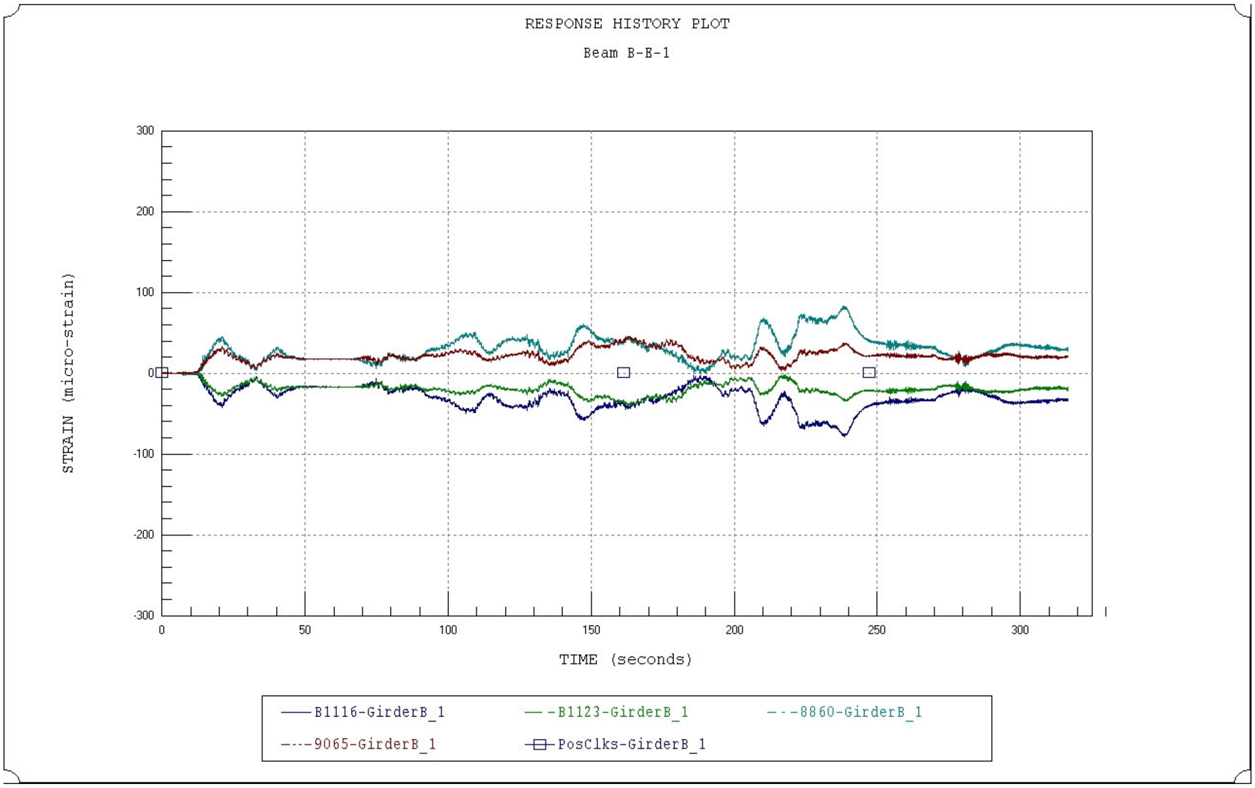

Figure 41 Girder B, Cross-Section E, File 1.

FEATURE: LEFT ONTO 80

File Names: Beam_A_3.dat

Girder_B_3.dat

Details: Hard left turn onto HW-80. Both the tractor and the trailer had to use the dirt medians in order to make the turn. Due to the very high strains, Girder A has a data clip during this turn. As a result, the peak strain was not read. Data acquisition equipment was modified to allow for the reading of higher strain before Girder B initiated this turn. Pictures of the girders making this turn can be seen on the attached CD under "DOTD Picts", files 464 thru 468.

Figure 42 Left turn onto HW-80.

GIRDER A RESPONSES:

CLICKS: 1- start test
2- truck initiates left turn
3- truck straight on HW-80
4- Trailer straight on HW-80

Table 11 Girder A turn onto HW-80 strain envelopes.

Beam A *File Name:* *Beam_A_3.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1061	22	-46
	B1045	29	-18
	B1132	32	-35
	B1190	20	-24
B	B1119	177	-271
	B1097	103	-148
	B1130	217	-186
	B1140	157	-108
C	B1122	251	-392
	B1046	150	-250
	B1131	158	-221
	B1118	228	-136
D	B1120	316	-406
	B1014	196	-336
	B1100	1097	-459
	B1088	427	-187
E	B1062	54	-99
	B1032	35	-67
	B1094	91	-64
	B1039	55	-35

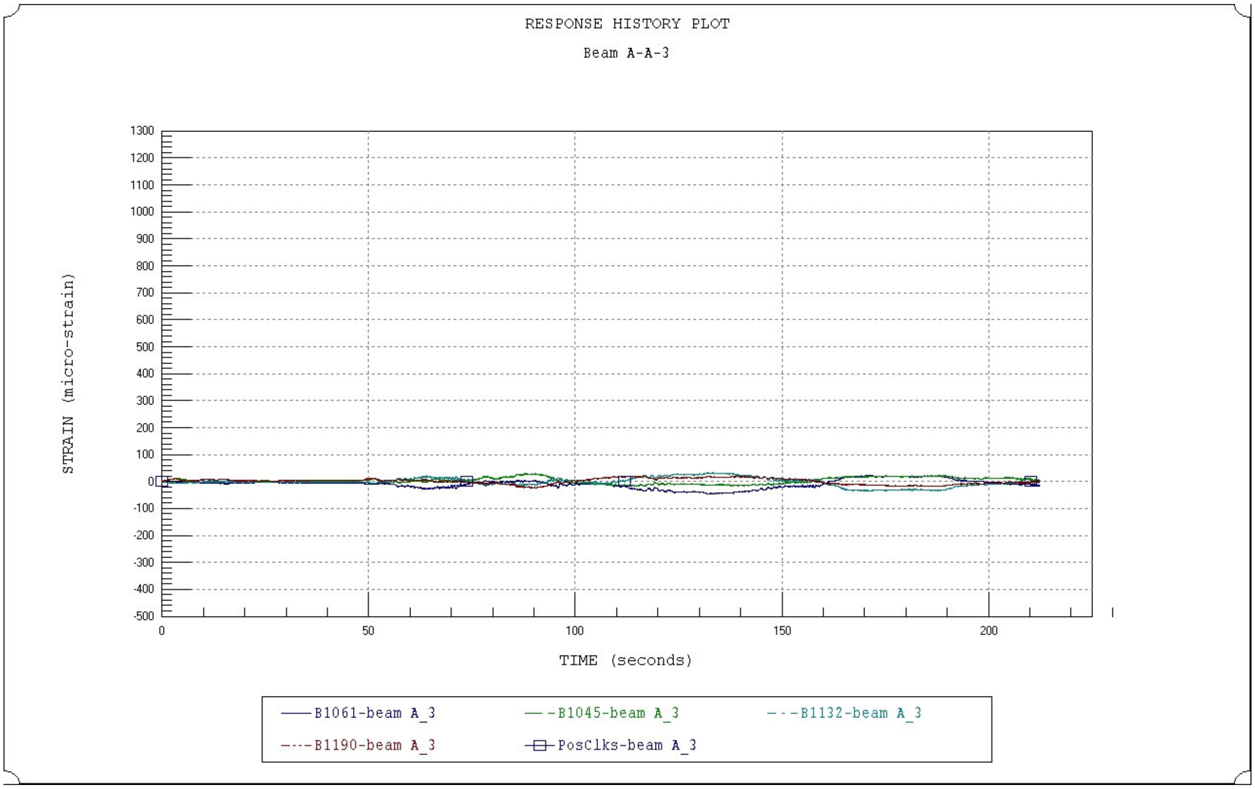

Figure 43 Girder A, Cross-Section A, File 3.

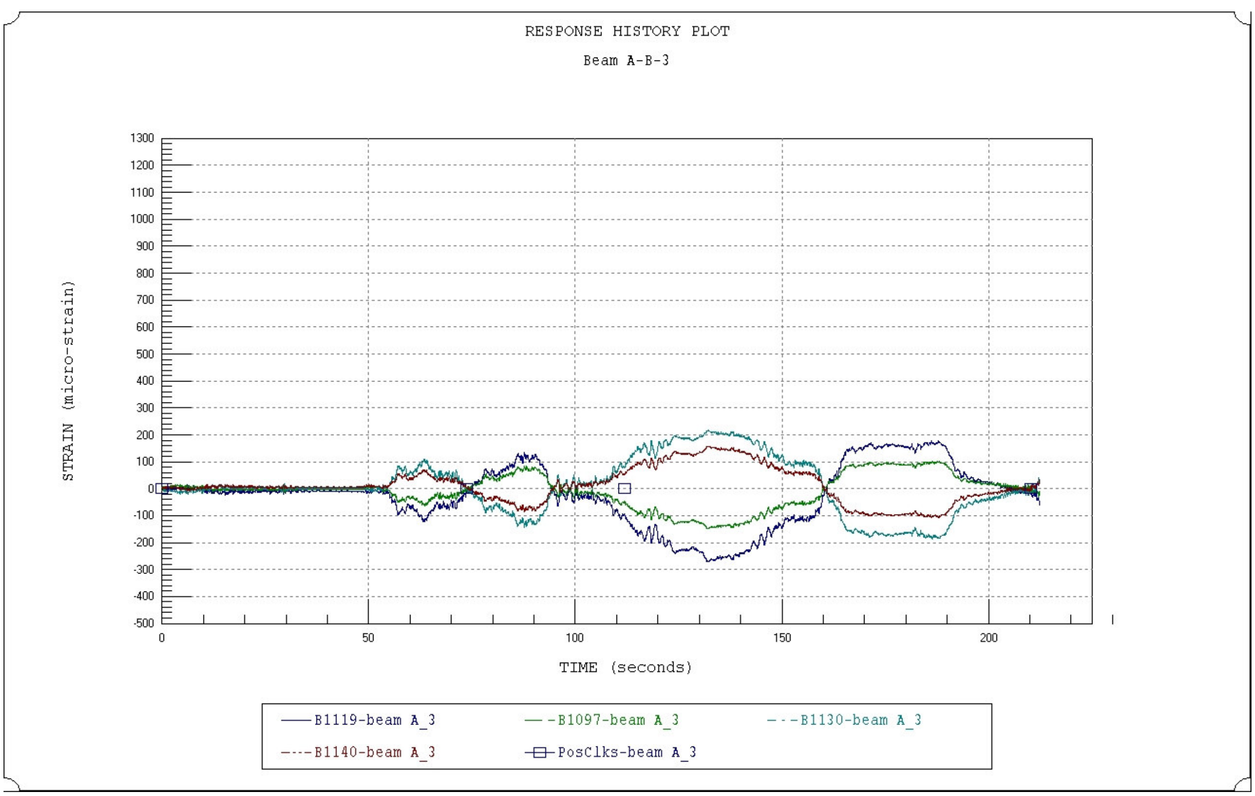

Figure 44 Girder A, Cross-Section B, File 3.

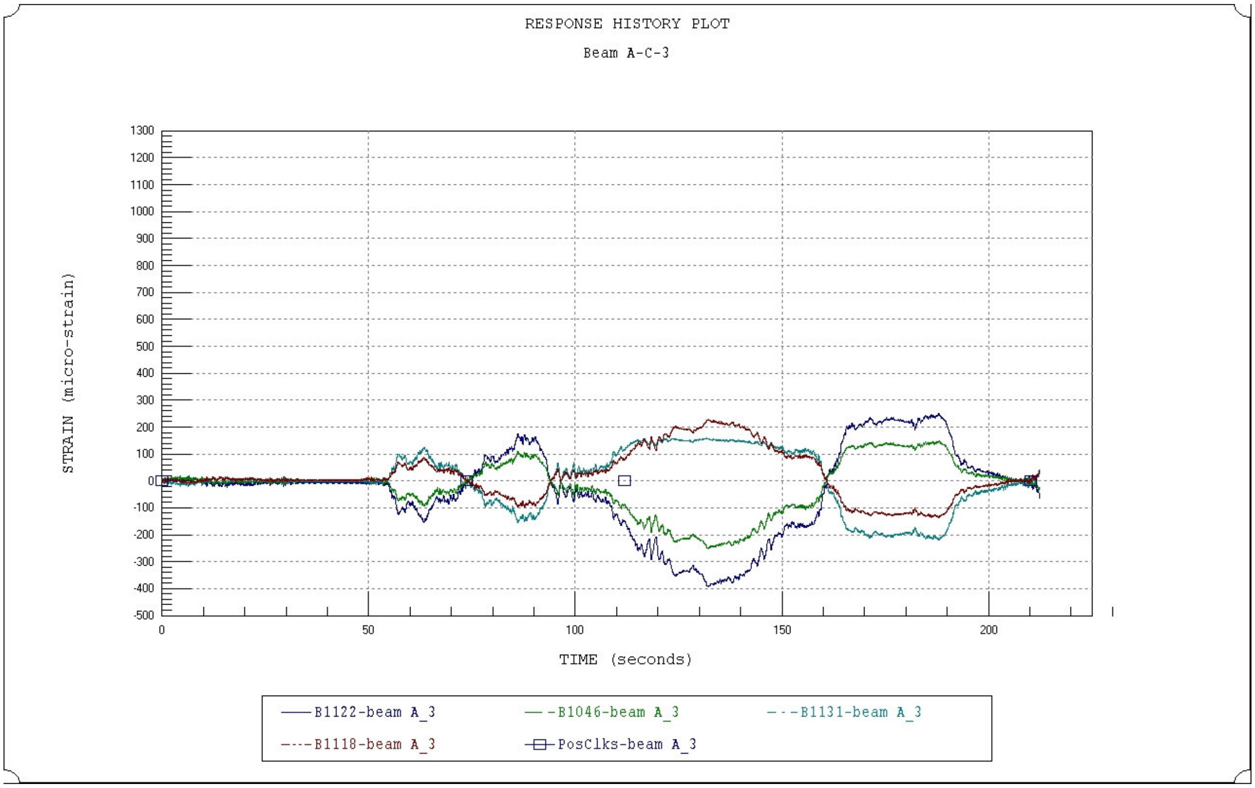

Figure 45 Girder A, Cross-Section C, File 3.

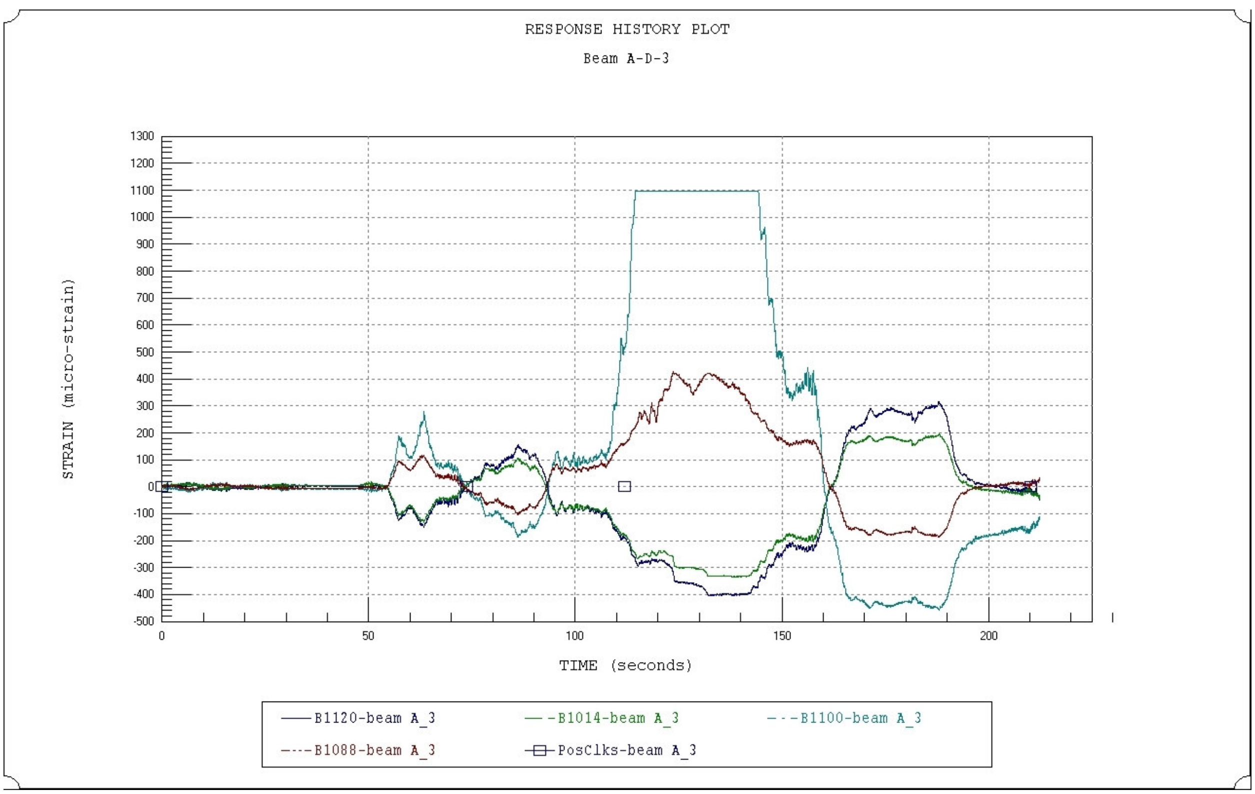

Figure 46 Girder A, Cross-Section D, File 3.

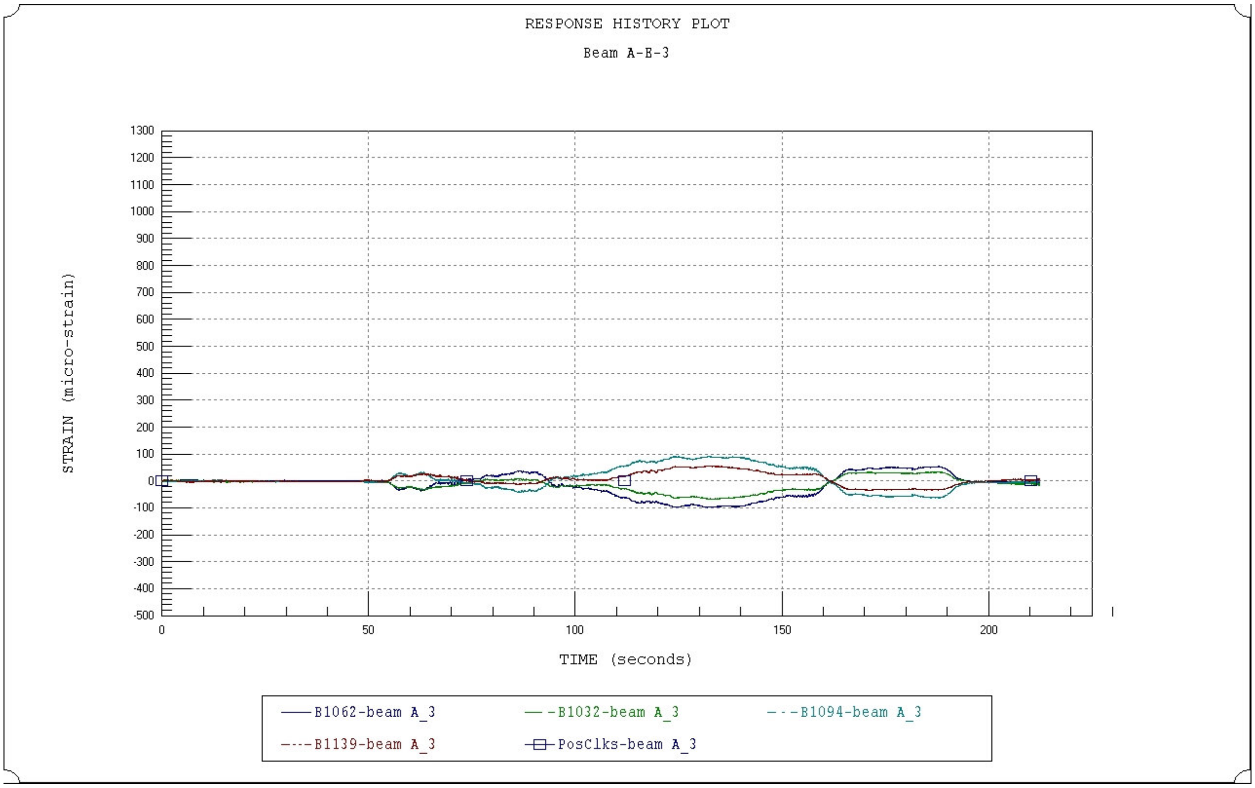

Figure 47 Girder A, Cross-Section E, File 3.

GIRDER B RESPONSES:

CLICKS: 1- start test

Table 12 Girder B turn onto HW-80 strain envelopes.

Beam B	*File Name:*	*Girder_B_3.dat*	
Cross-Section	Gage Number	Positive	Negative
A	B1128	38	-60
	B1127	19	-27
	5833	65	-47
	8688	34	-20
B	B1126	162	-300
	B1129	102	-203
	5690	363	-197
	6327	216	-121
C	B1087	196	-473
	B1125	111	-295
	4792	641	-324
	B1124	271	-117
D	B1095	194	-621
	B1133	110	-431
	8865	305	-196
	5567	456	-131
E	B1116	36	-119
	B1123	31	-85
	8860	125	-47
	9065	90	-34

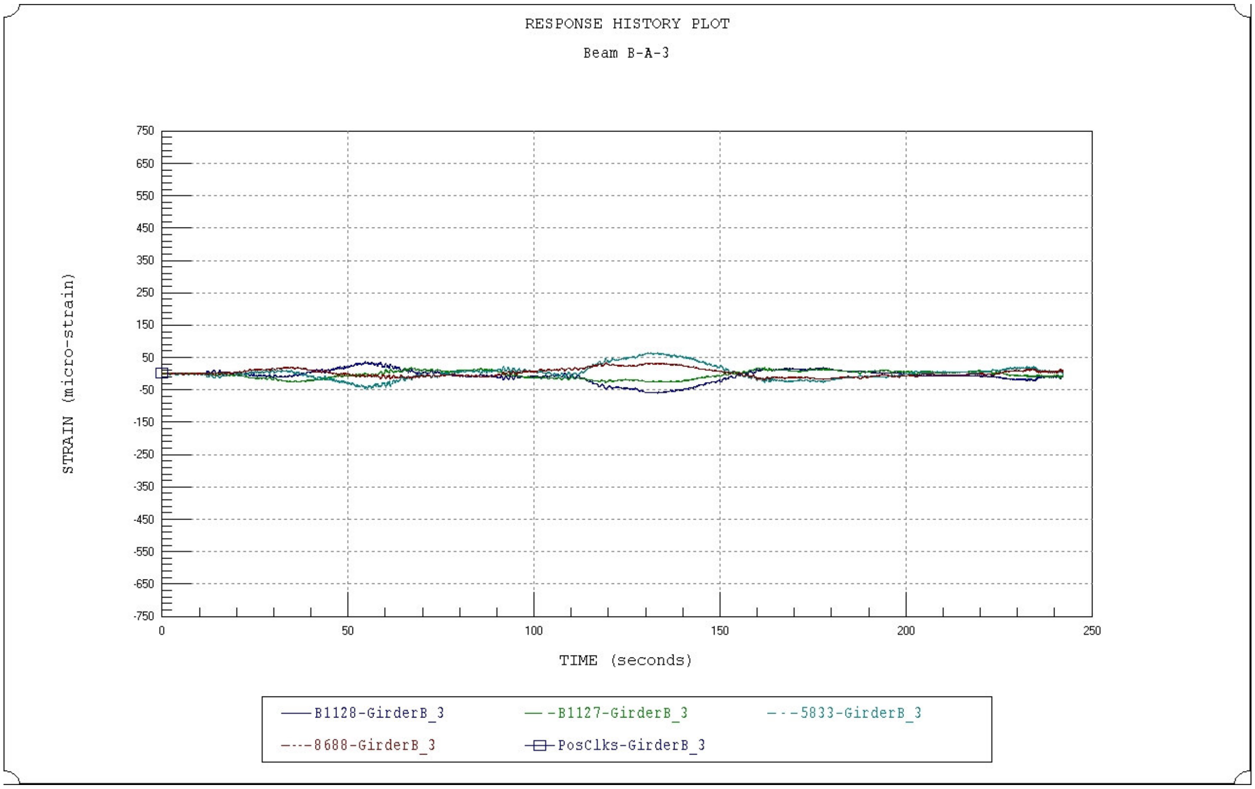

Figure 48 Girder B, Cross-Section A, File 3.

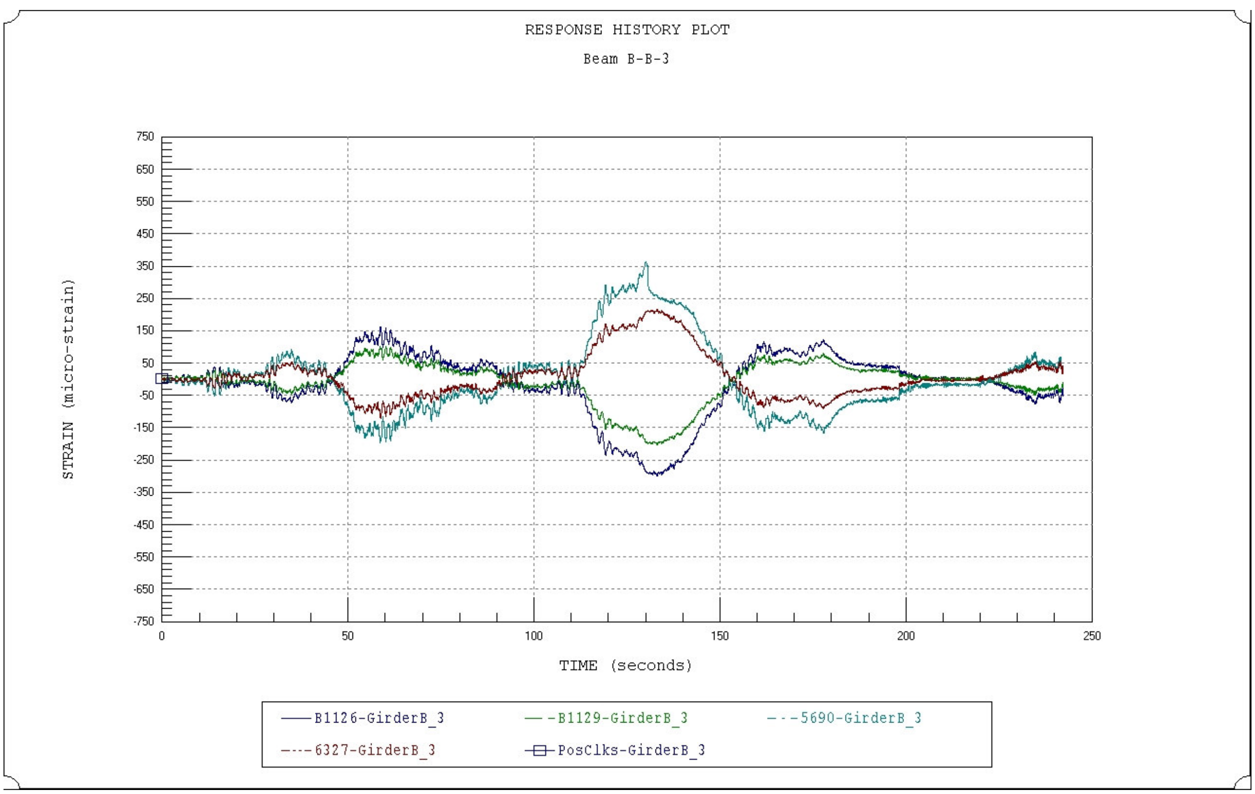

Figure 49 Girder B, Cross-Section B, File 3.

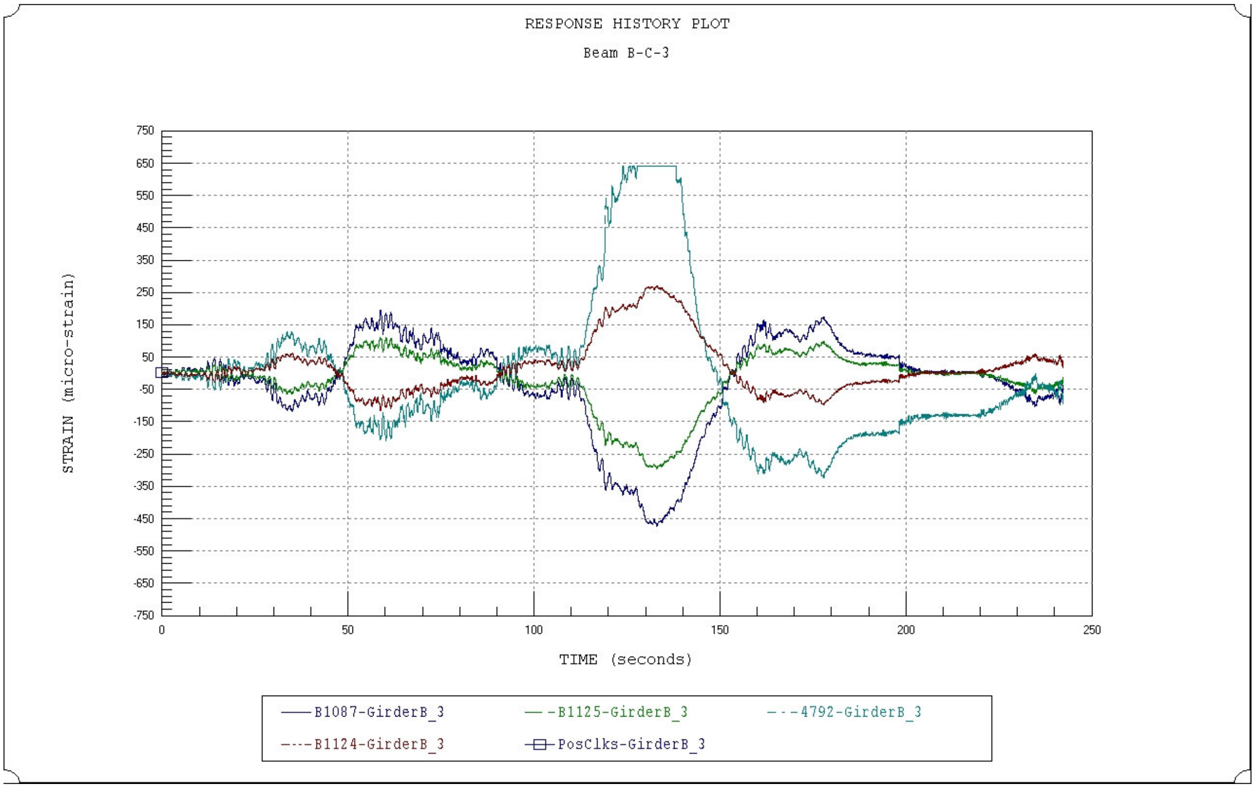

Figure 50 Girder B, Cross-Section C, File 3.

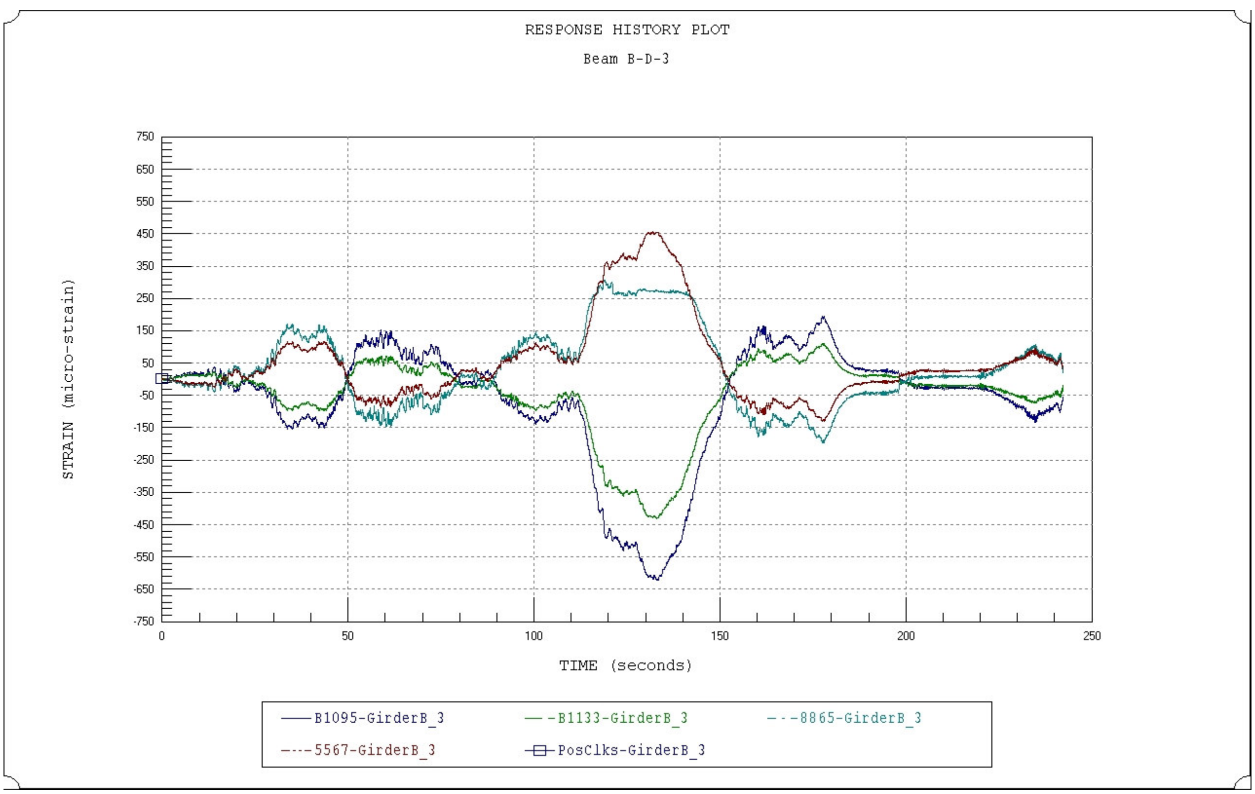

Figure 51 Girder B, Cross-Section D, File 3.

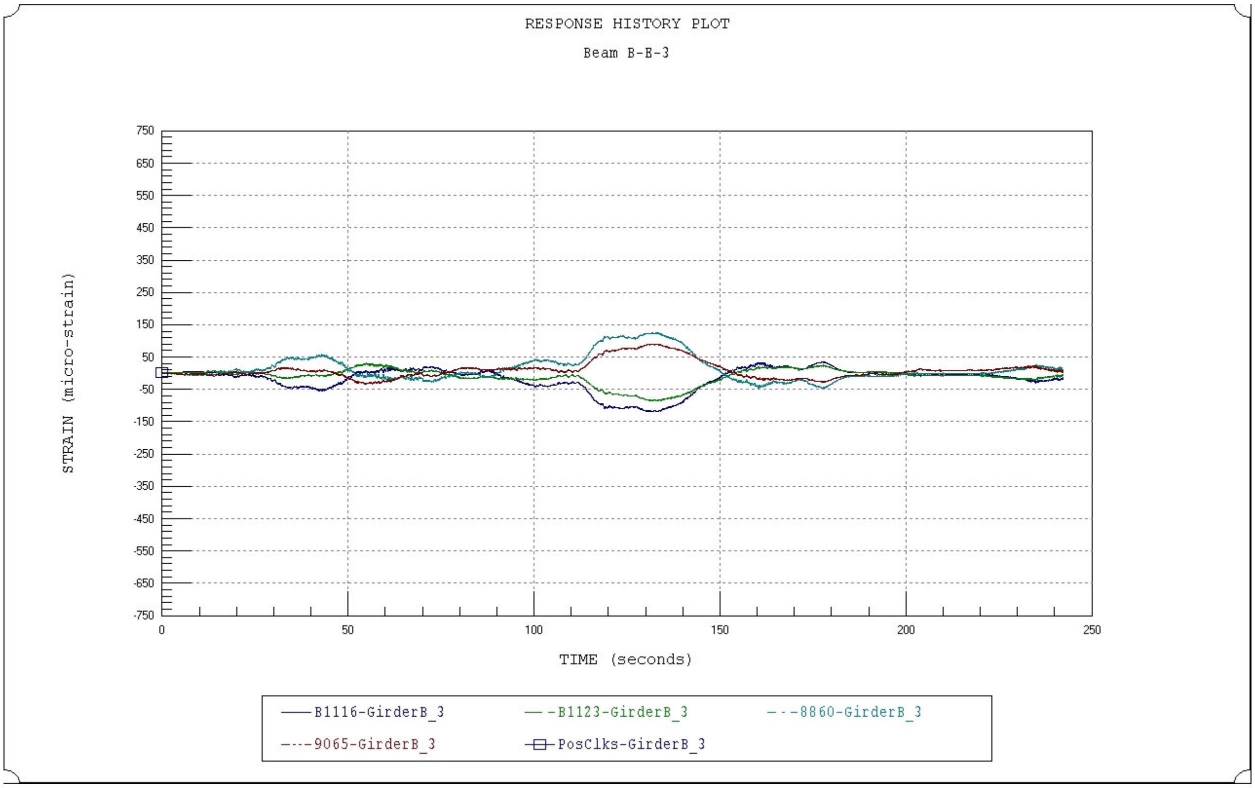

Figure 52 Girder B, Cross-Section D, File 3.

FEATURE: LEFT TURN TO GET TO I-20 (PR-117)

File Names: Beam_A_6.dat

Girder_B_6 & 7.dat

Details: Hard left turn onto PR-117. Both the tractor and the trailer had to use the dirt medians and drive over the center lane dividers in order to make this turn. This divider was concrete curbs containing a concrete slab. Pictures of the girders making this turn can be seen on the attached CD under “DOTD Picts”, files 473 thru 492.

Figure 53 Left turn onto PR-117.

GIRDER A RESPONSES:

CLICKS:
1- Start test
2- initiate turn
3- front tractor tires hitting curb
4- rear tractor tires hitting curb
5- trailer tires hitting curb
6- Rear trailer tires hitting curb

Table 13 Girder A left turn to get to I-20 (PR-117) strain envelopes.

Beam A *File Name:* *Beam_A_6.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1061	39	-37
	B1045	21	-18
	B1132	42	-46
	B1190	17	-25
B	B1119	206	-228
	B1097	122	-122
	B1130	173	-219
	B1140	136	-121
C	B1122	276	-344
	B1046	173	-216
	B1131	116	-250
	B1118	201	-154
D	B1120	322	-414
	B1014	211	-350
	B1100	1899	-303
	B1088	311	-189
E	B1062	56	-86
	B1032	44	-54
	B1094	86	-59
	B1039	51	-40

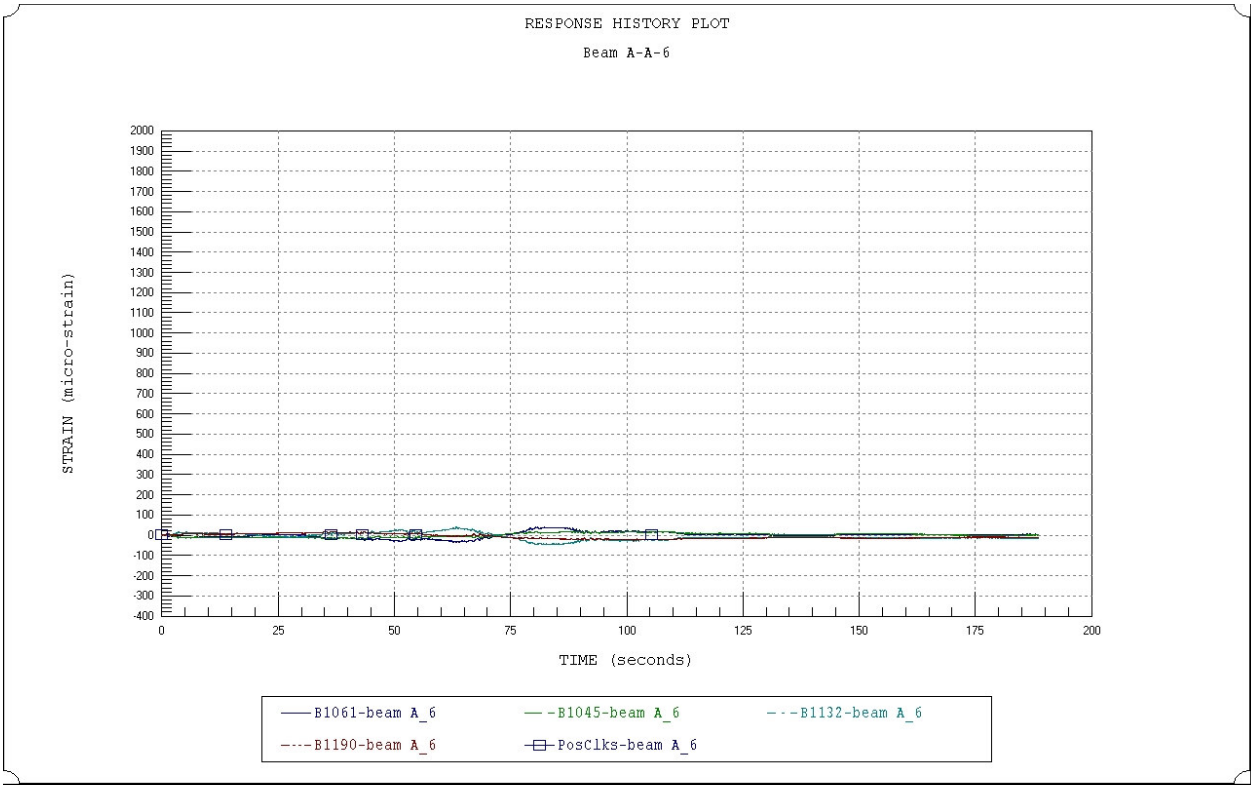

Figure 54 Girder A, Cross-Section A, File 6.

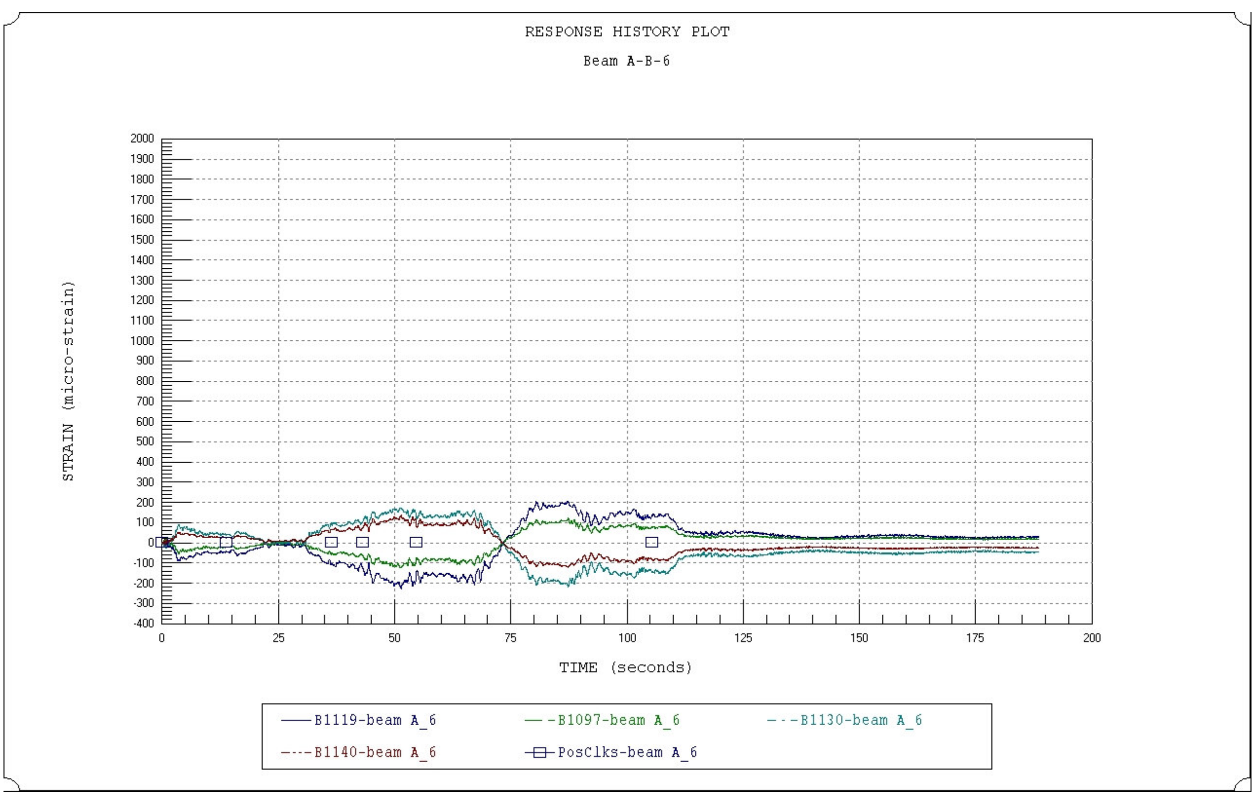

Figure 55 Girder A, Cross-Section B, File 6.

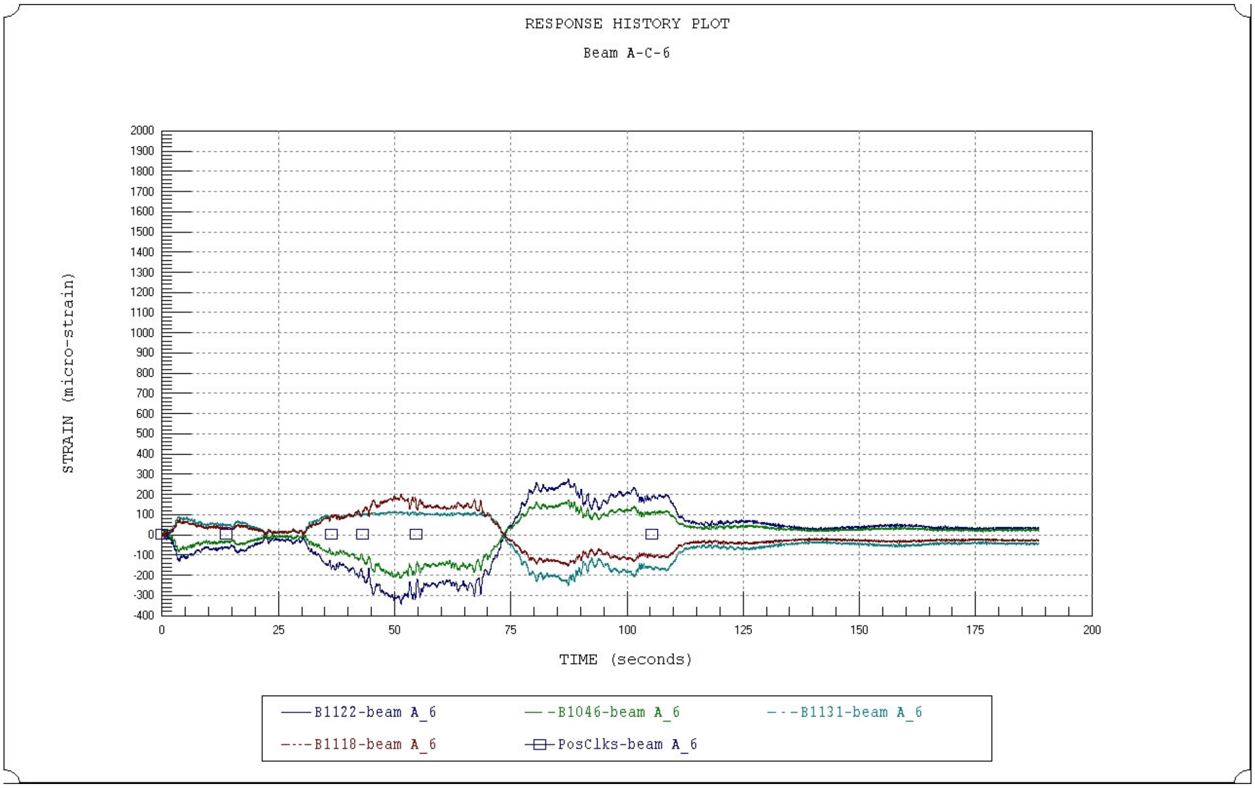

Figure 56 Girder A, Cross-Section C, File 6.

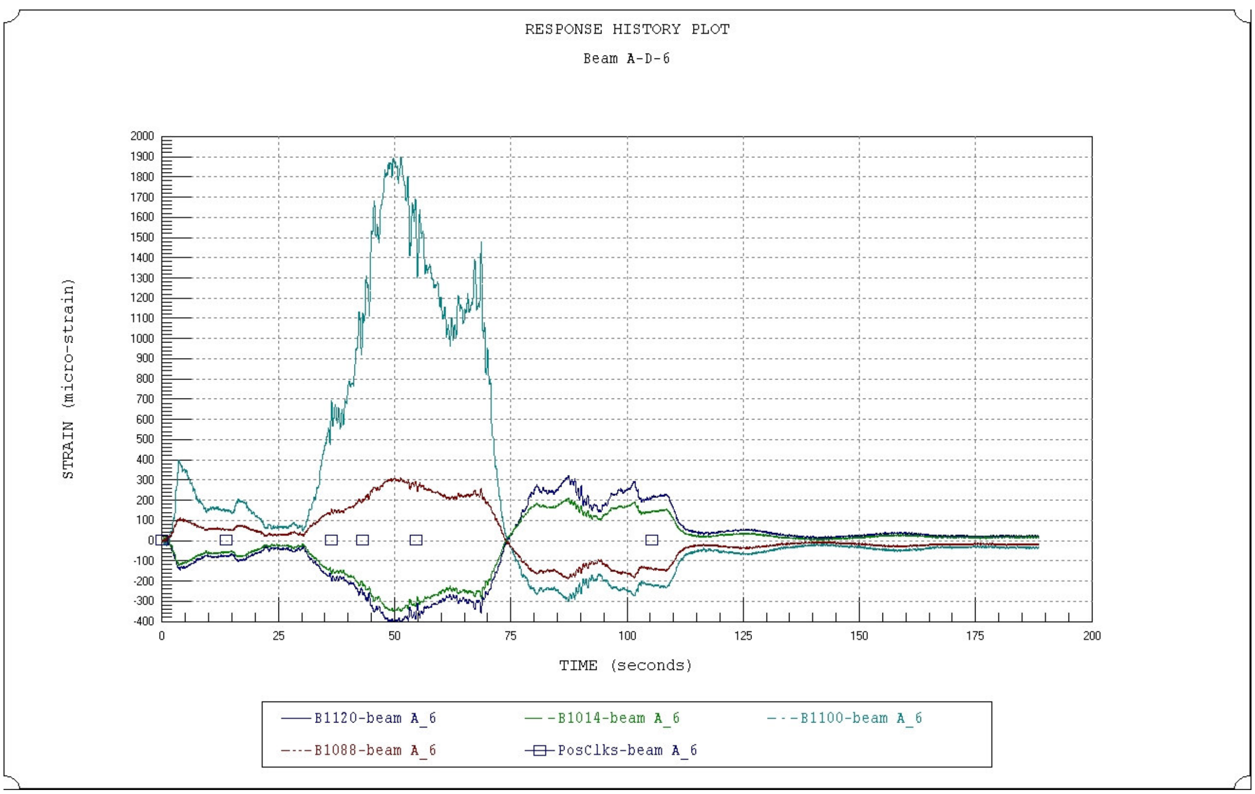

Figure 57 Girder A, Cross-Section D, File 6.

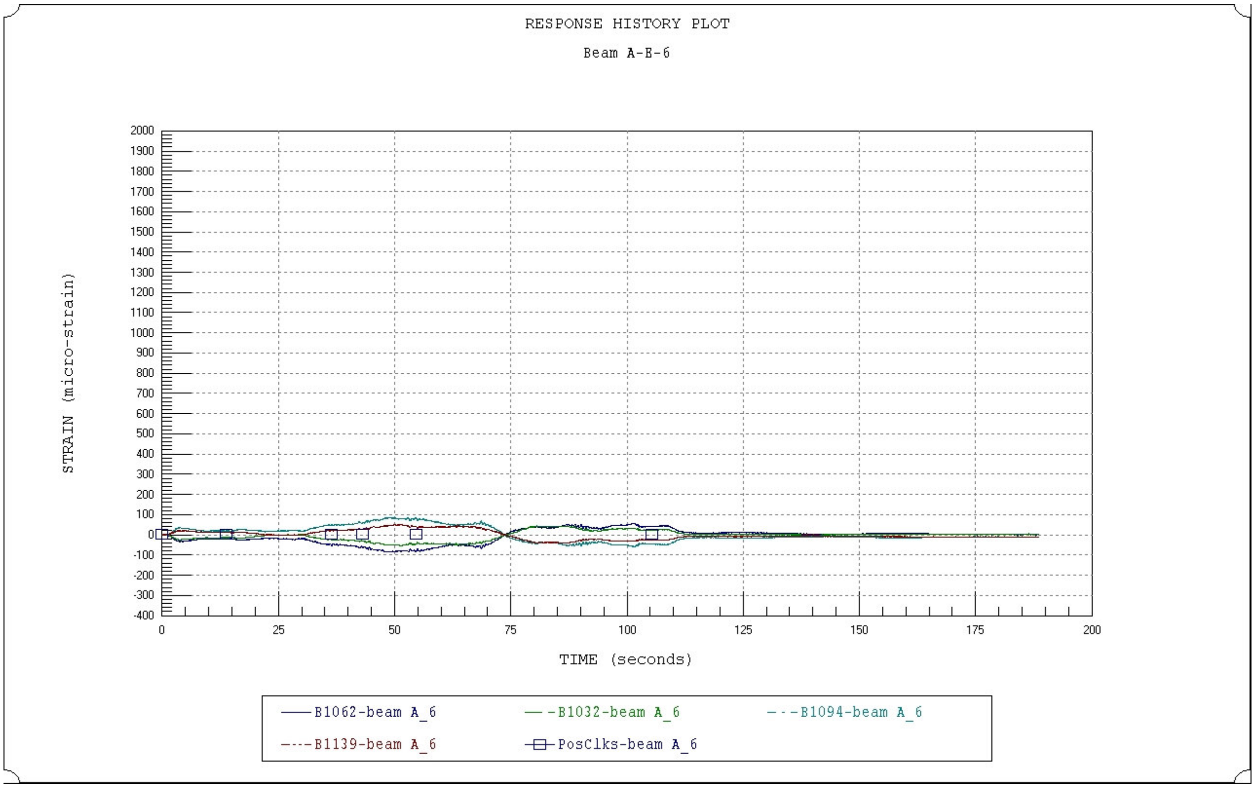

Figure 58 Girder A, Cross-Section E, File 6.

GIRDER B RESPONSES:

CLICKS:
1- Start test
2- tractor hitting curb
3- trailer tires hitting curb
4- rear trailer tires hitting curb

Table 14 Girder B left turn to get to I-20 (PR-117) strain envelopes.

Beam B *File Name: Girder_B_1.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1128	41	-37
	B1127	29	-16
	5833	48	-50
	8688	25	-31
B	B1126	175	-192
	B1129	113	-132
	5690	119	-234
	6327	143	-126
C	B1087	267	-318
	B1125	148	-207
	4792	736	-333
	B1124	186	-146
D	B1095	337	-448
	B1133	212	-312
	8865	120	-292
	5567	325	-244
E	B1116	80	-86
	B1123	47	-55
	8860	92	-89
	9065	62	-49

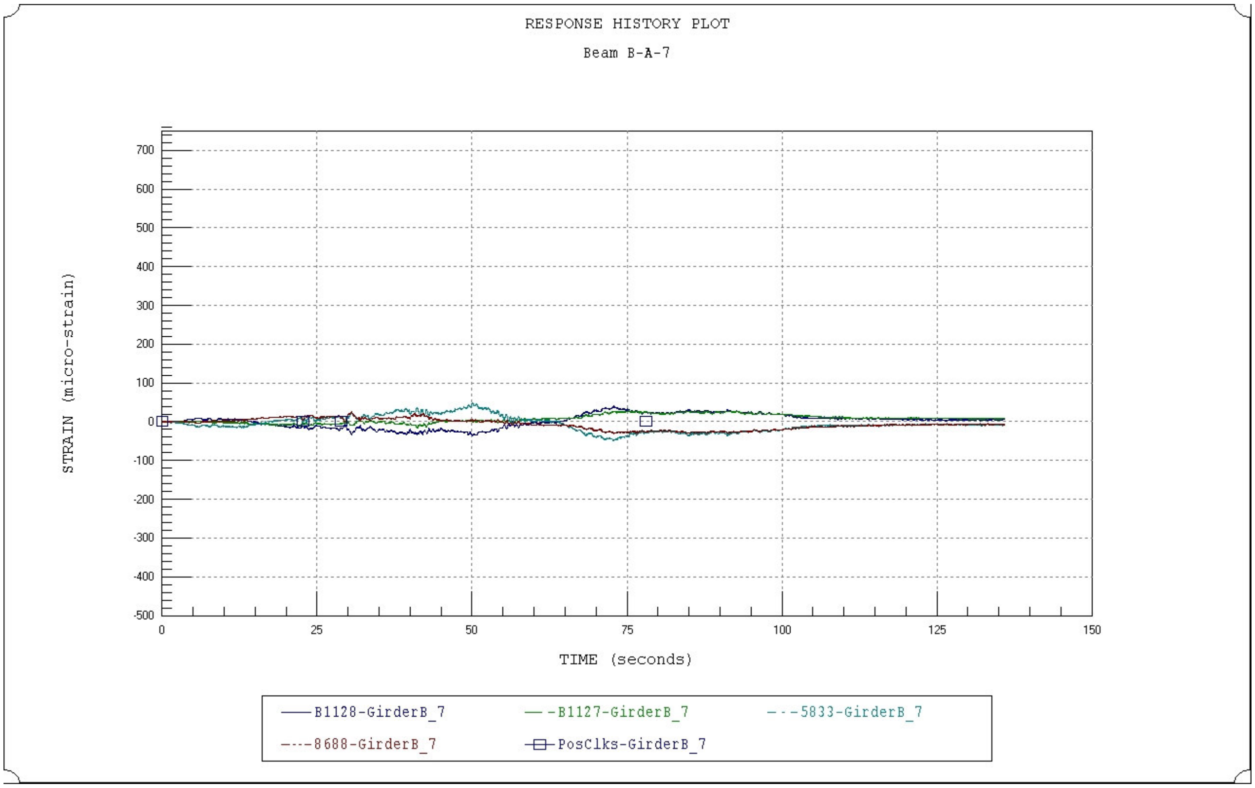

Figure 59 Girder B, Cross-Section A File 6.

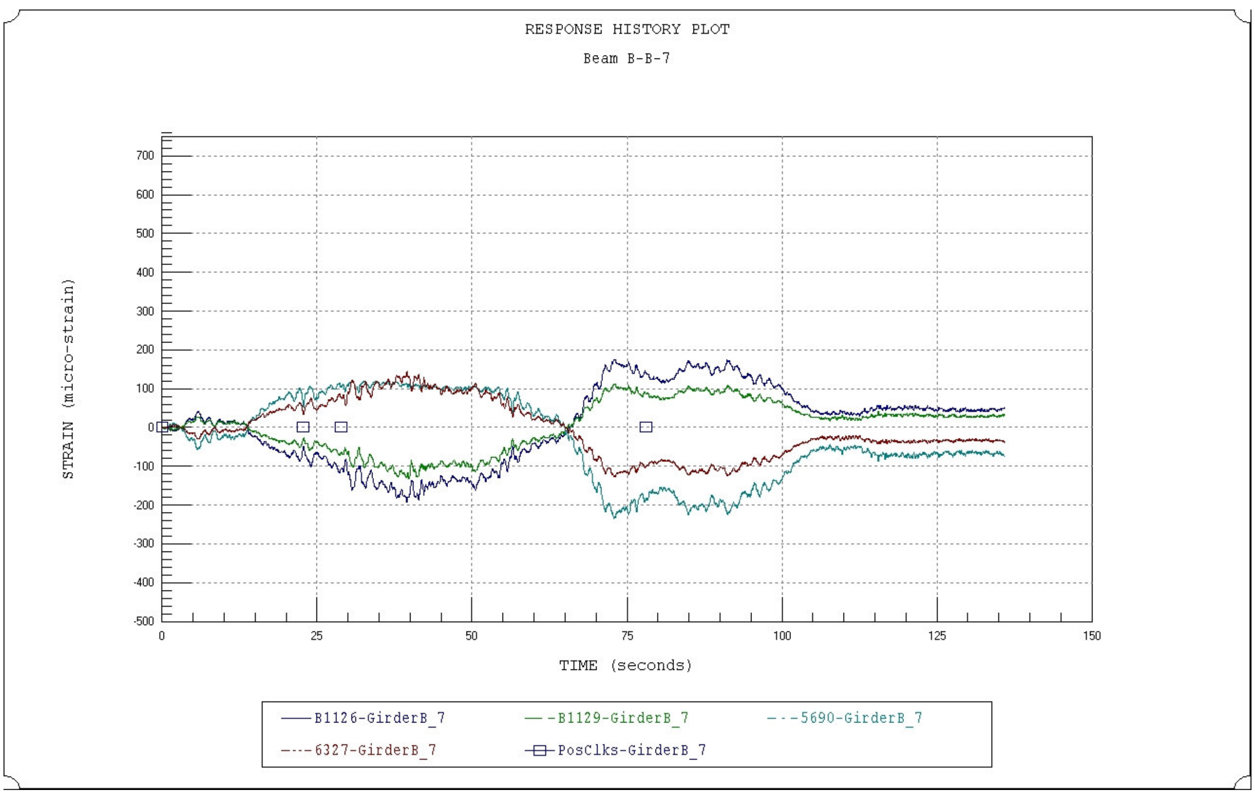

Figure 60 Girder B, Cross-Section B File 6.

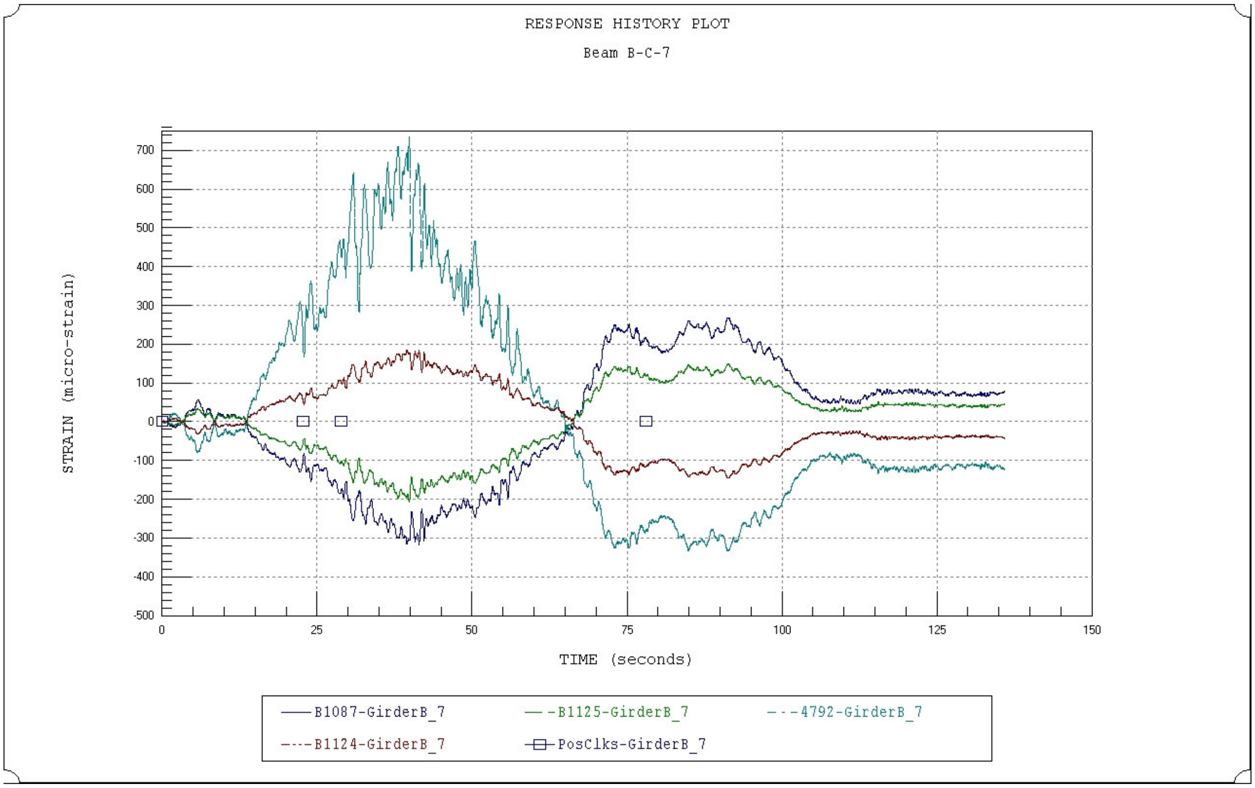

Figure 61 Girder B, Cross-Section C File 6.

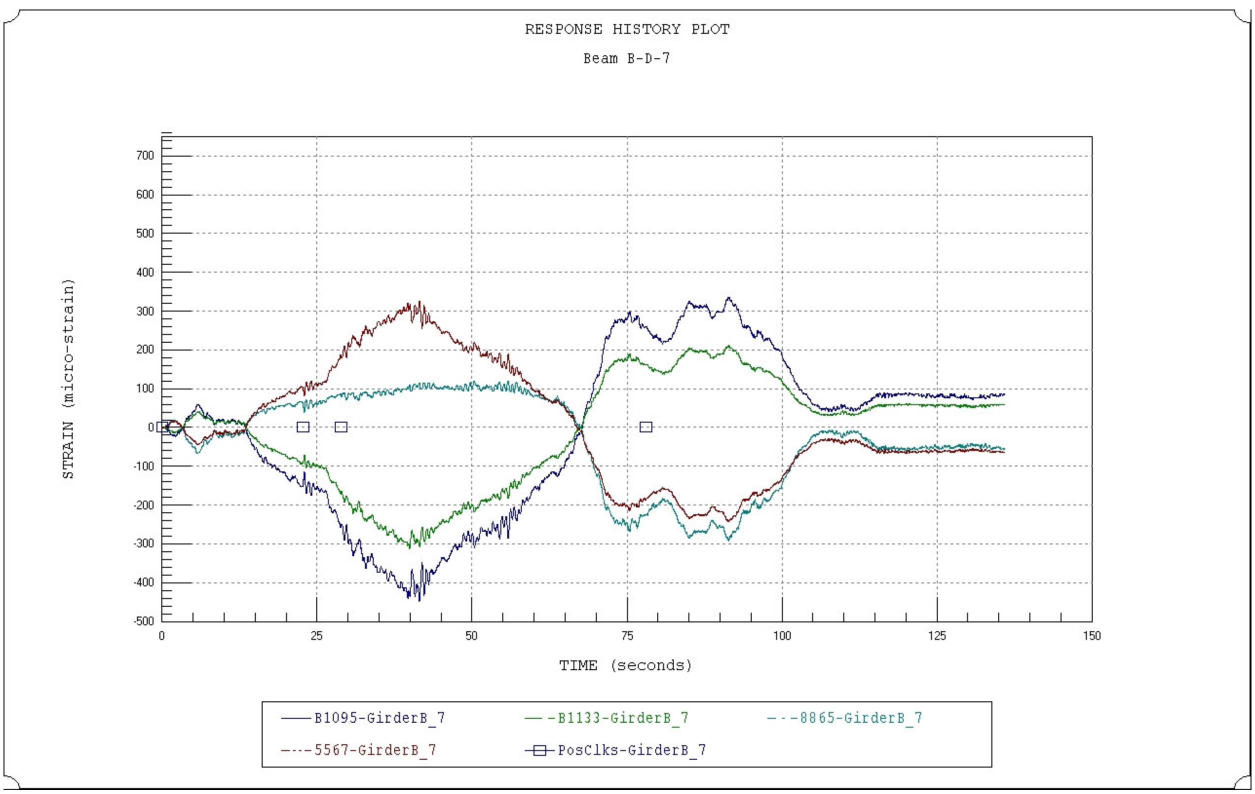

Figure 62 Girder B, Cross-Section D File 6.

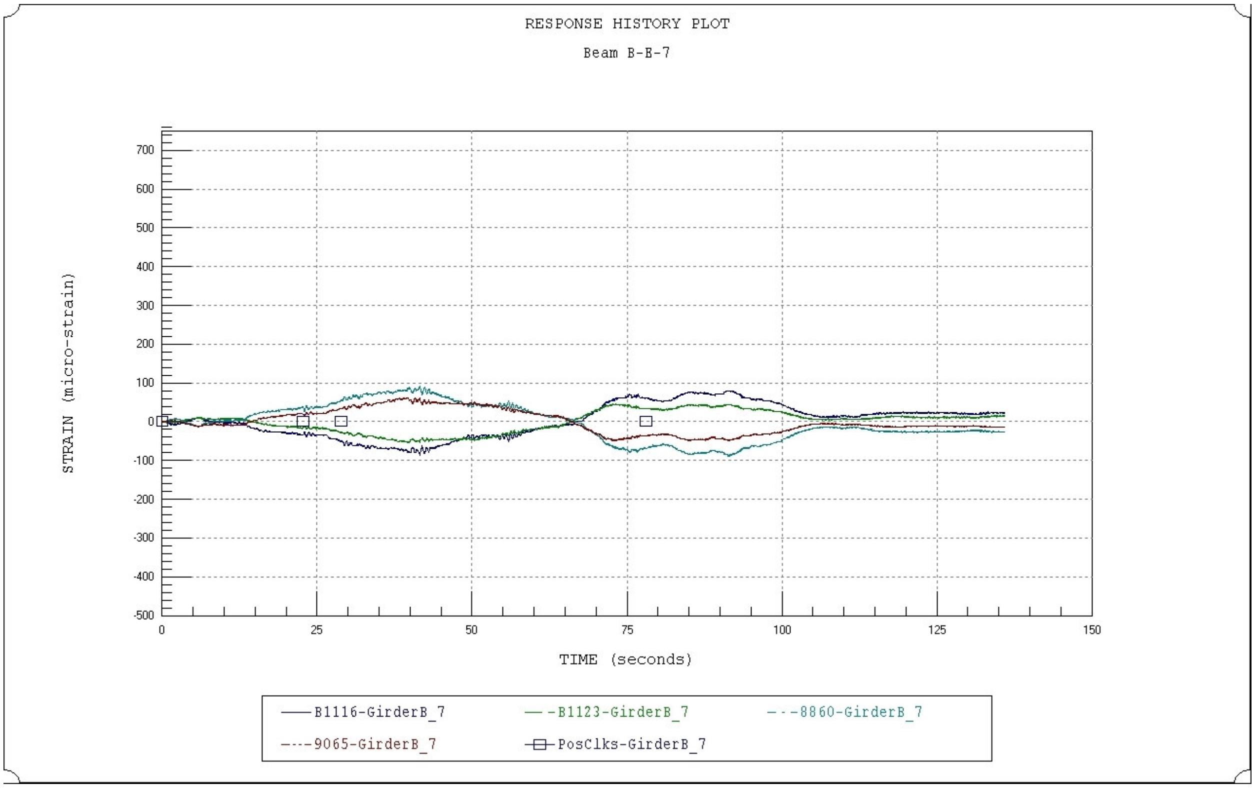

Figure 63 Girder B, Cross-Section E File 6.

FEATURE: RIGHT TURN ONTO I-20

File Names: Beam_A_8.dat

Girder_B_8.dat

Details: Hard right turn onto I-20. Both the tractor and the trailer had to use the dirt medians and drive over the center lane dividers in order to make this turn. This divider in this case was a concrete curb containing a grassy area. Pictures of the girders making this turn can be seen on the attached CD under "DOTD Picts", files 493 thru 504.

Figure 64 Right turn onto I-20.

GIRDER A RESPONSES:

CLICKS:
1- Start test
2- front tractor tires hitting curb
3- trailer tires hitting curb
4- Load straight

Table 15 Girder A right turn onto I-20 strain envelopes.

Beam A *File Name:* *Beam_A_8.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1061	11	-43
	B1045	4	-39
	B1132	30	-8
	B1190	27	-4
B	B1119	16	-230
	B1097	9	-127
	B1130	210	-18
	B1140	120	-12
C	B1122	26	-269
	B1046	15	-161
	B1131	215	-23
	B1118	139	-17
D	B1120	31	-266
	B1014	24	-201
	B1100	496	-35
	B1088	185	-26
E	B1062	9	-69
	B1032	4	-37
	B1094	60	-12
	B1039	28	-6

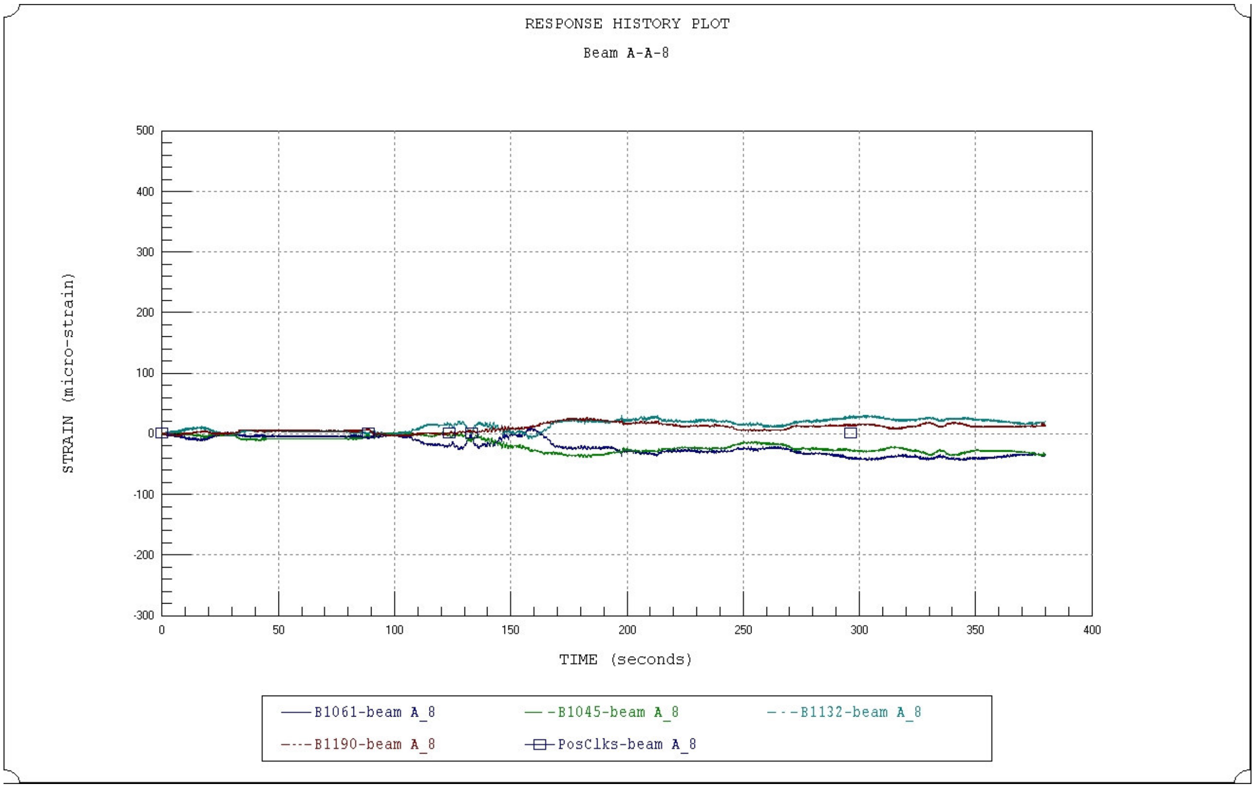

Figure 65 Girder A, Cross-Section A, File 8.

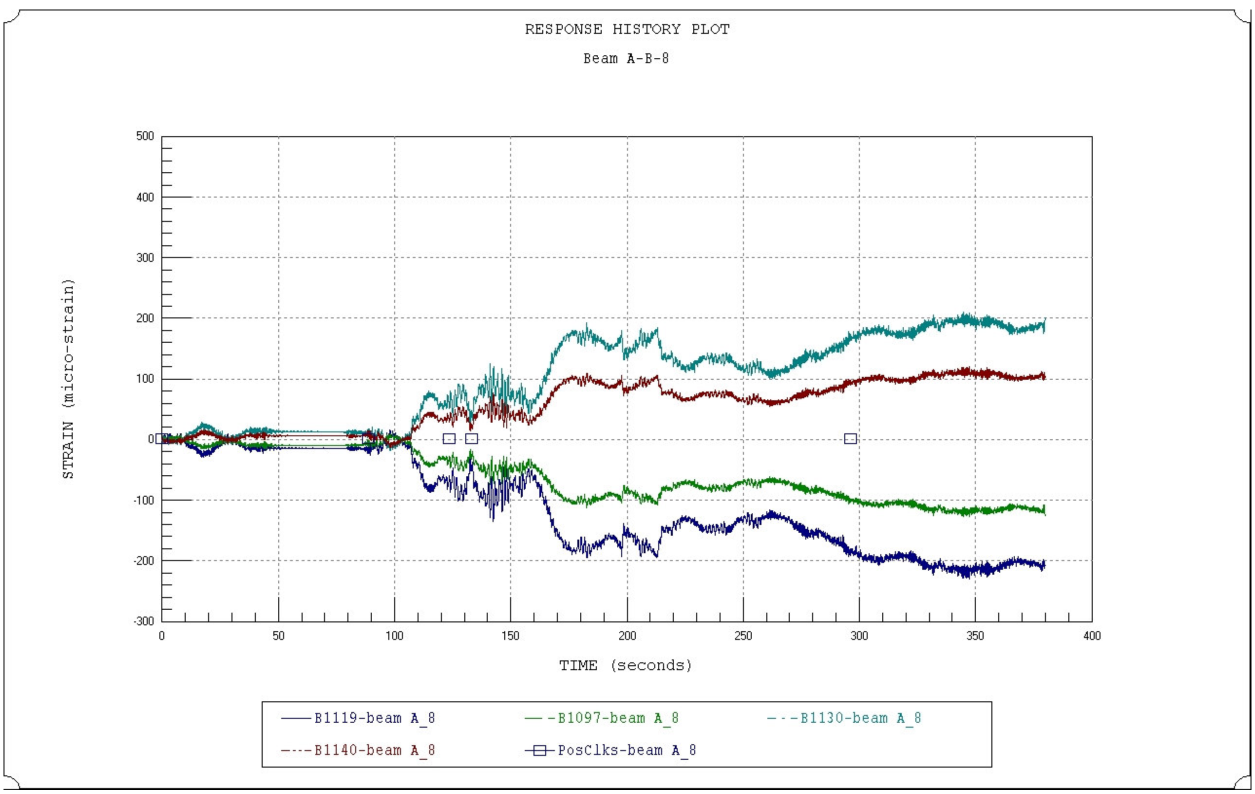

Figure 66 Girder A, Cross-Section B, File 8.

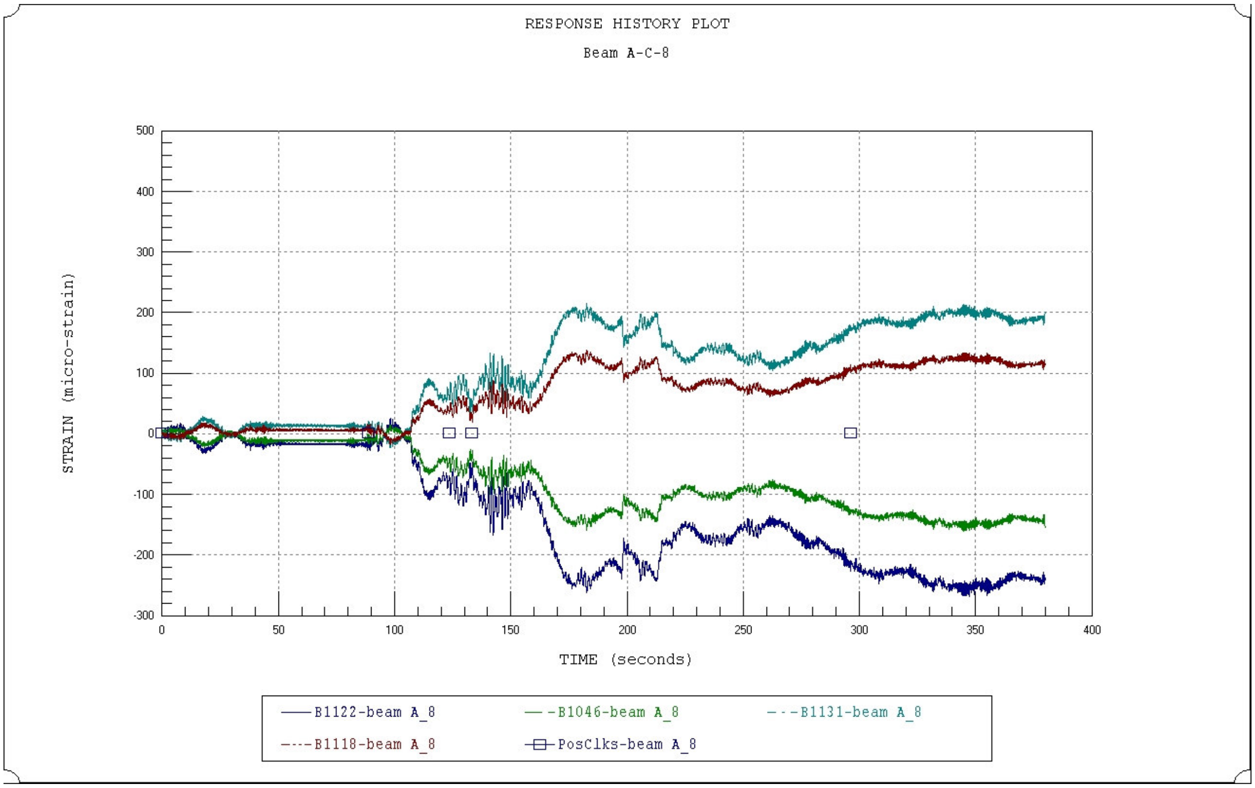

Figure 67 Girder A, Cross-Section C, File 8.

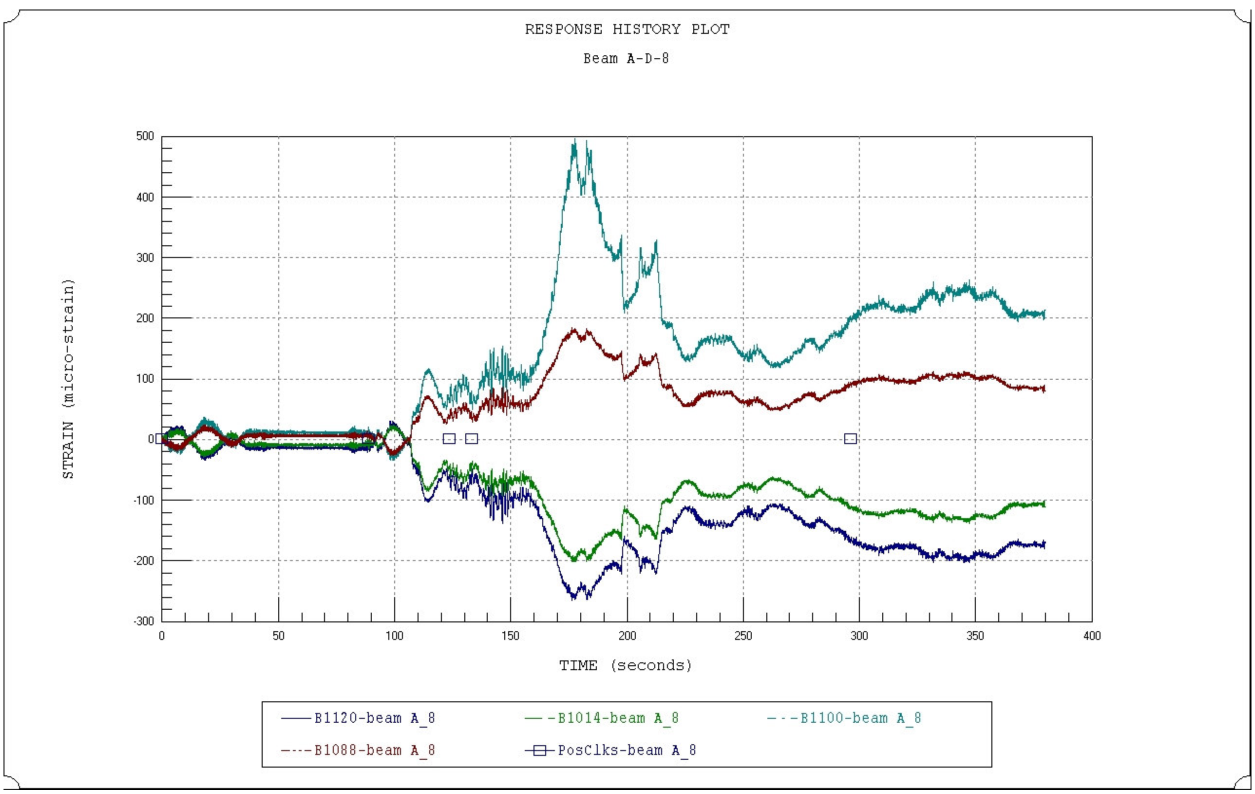

Figure 68 Girder A, Cross-Section D, File 8.

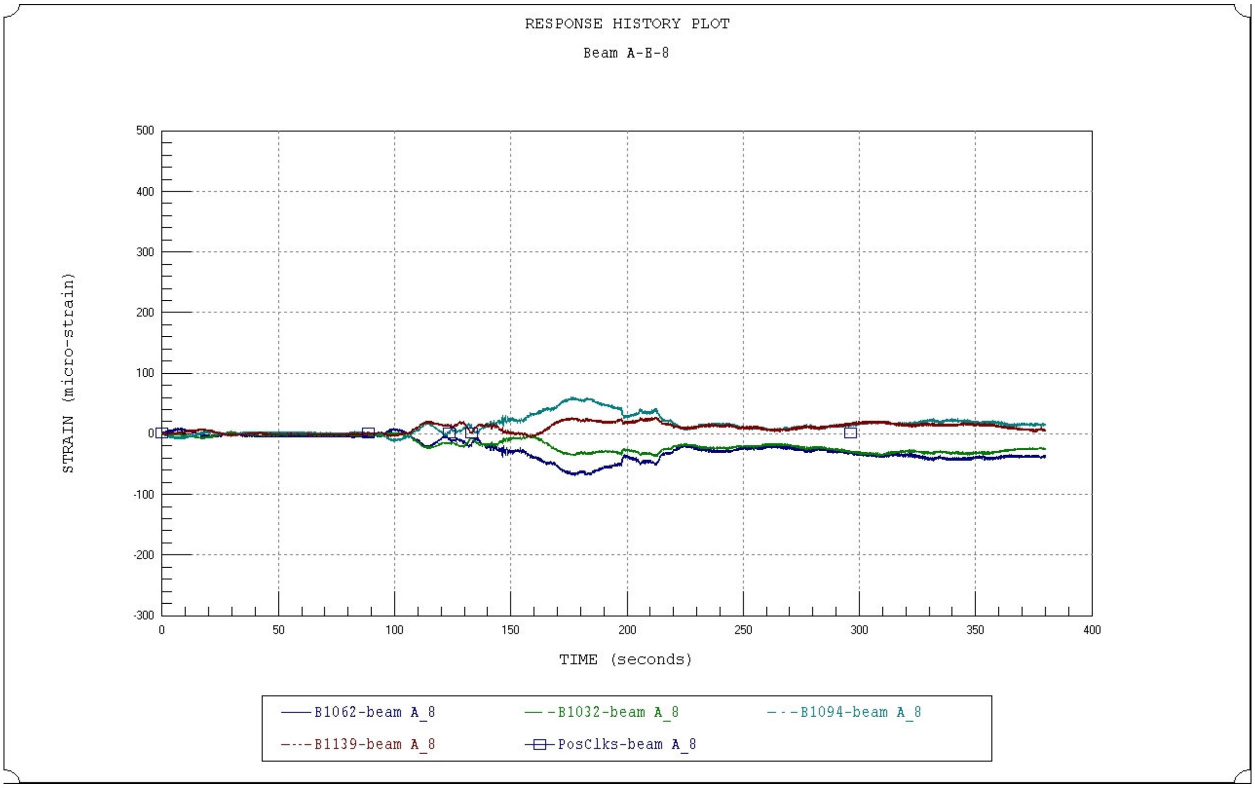

Figure 69 Girder A, Cross-Section E, File 8.

GIRDER B RESPONSES:

CLICKS:
1- Start test
2- front tractor tires hitting curb
3- trailer tires hitting curb
4- unknown (likely front trailer)
5- Load straight

Table 16 Girder B right turn onto I-20 strain envelopes.

Beam B *File Name:* *Girder_B_8.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1128	19	-37
	B1127	1	-42
	5833	37	-19
	8688	30	-6
B	B1126	21	-210
	B1129	13	-123
	5690	247	-24
	6327	151	-18
C	B1087	31	-310
	B1125	17	-167
	4792	413	-32
	B1124	169	-19
D	B1095	41	-361
	B1133	37	-218
	8865	275	-49
	5567	243	-52
E	B1116	8	-84
	B1123	16	-43
	8860	90	-9
	9065	45	-23

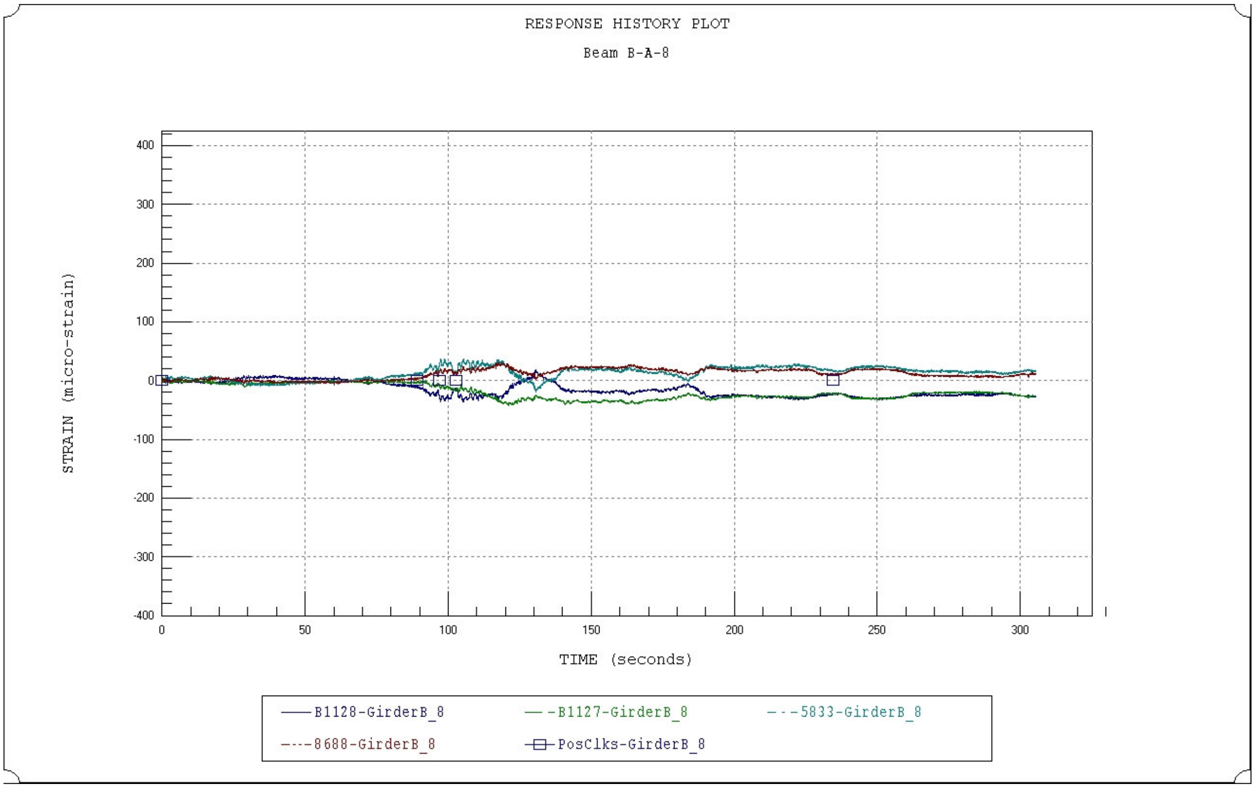

Figure 70 Girder B, Cross-Section A, File 8.

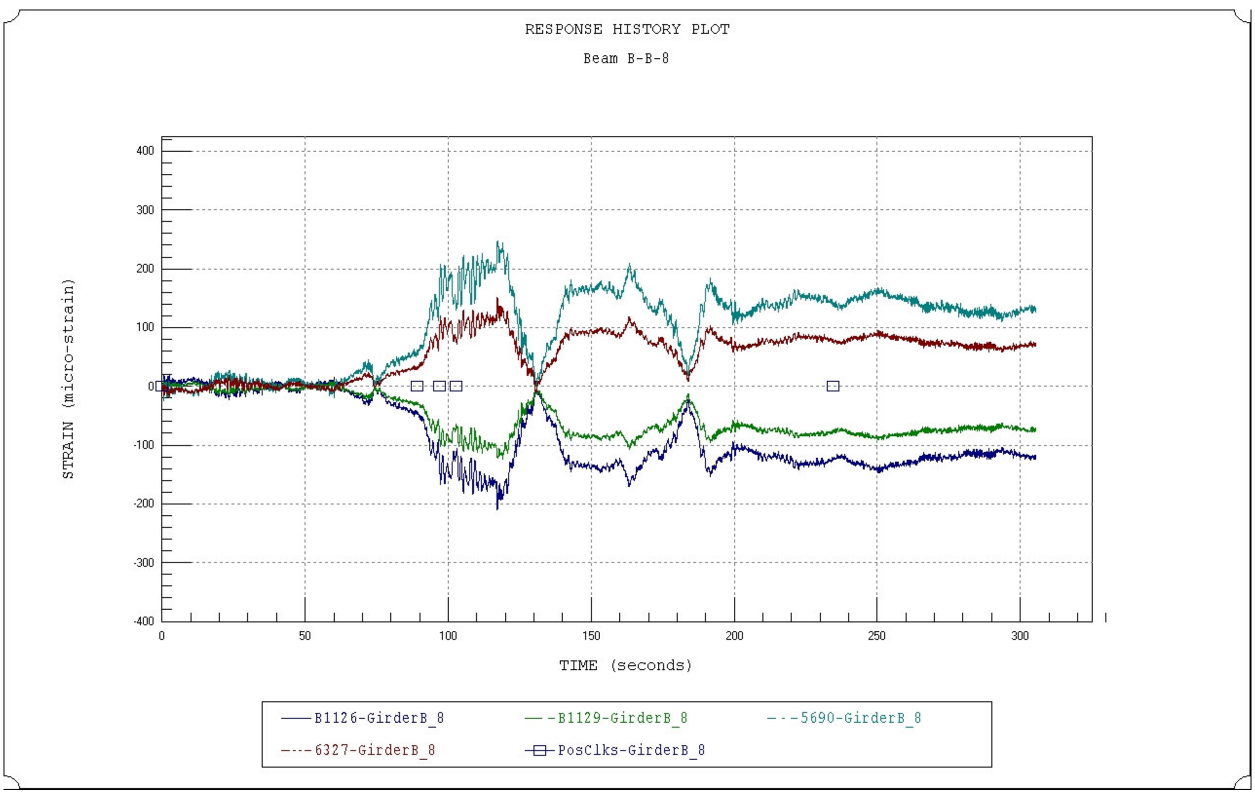

Figure 71 Girder B, Cross-Section B, File 8.

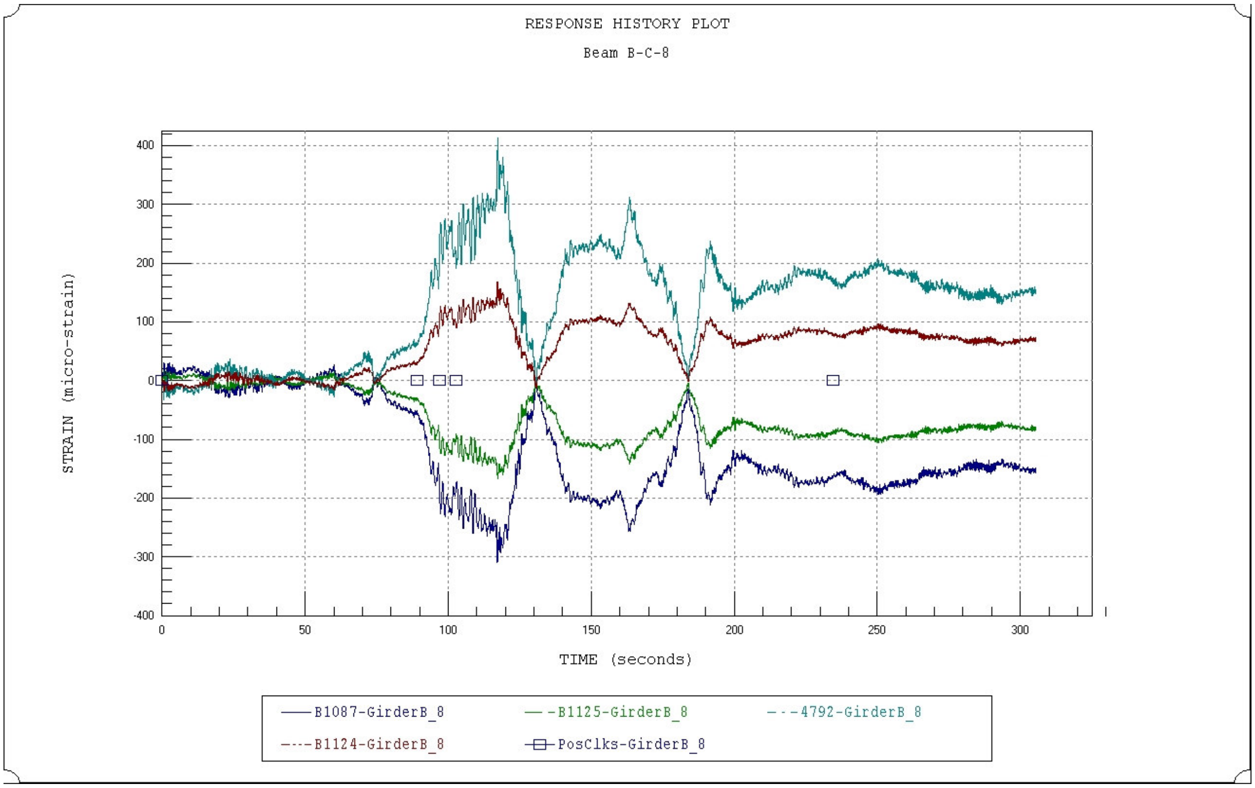

Figure 72 Girder B, Cross-Section C, File 8.

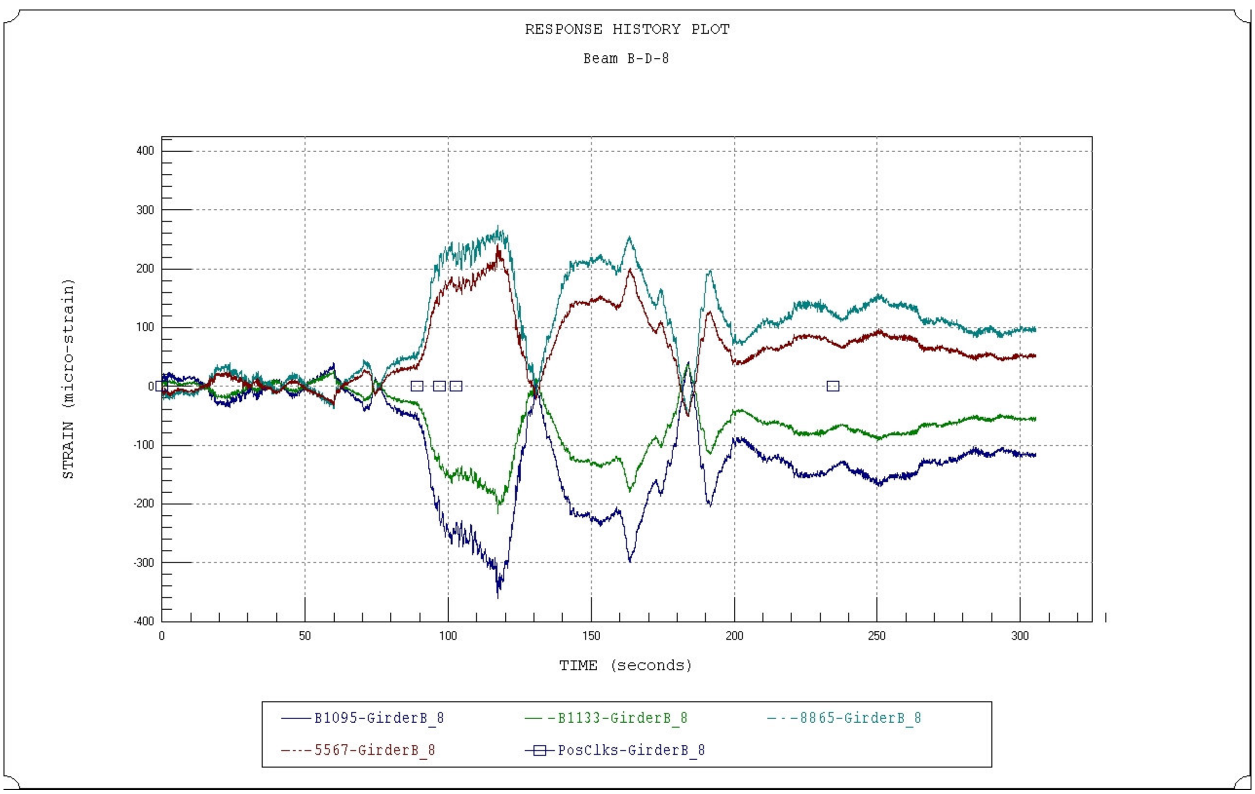

Figure 73 Girder B, Cross-Section D, File 8.

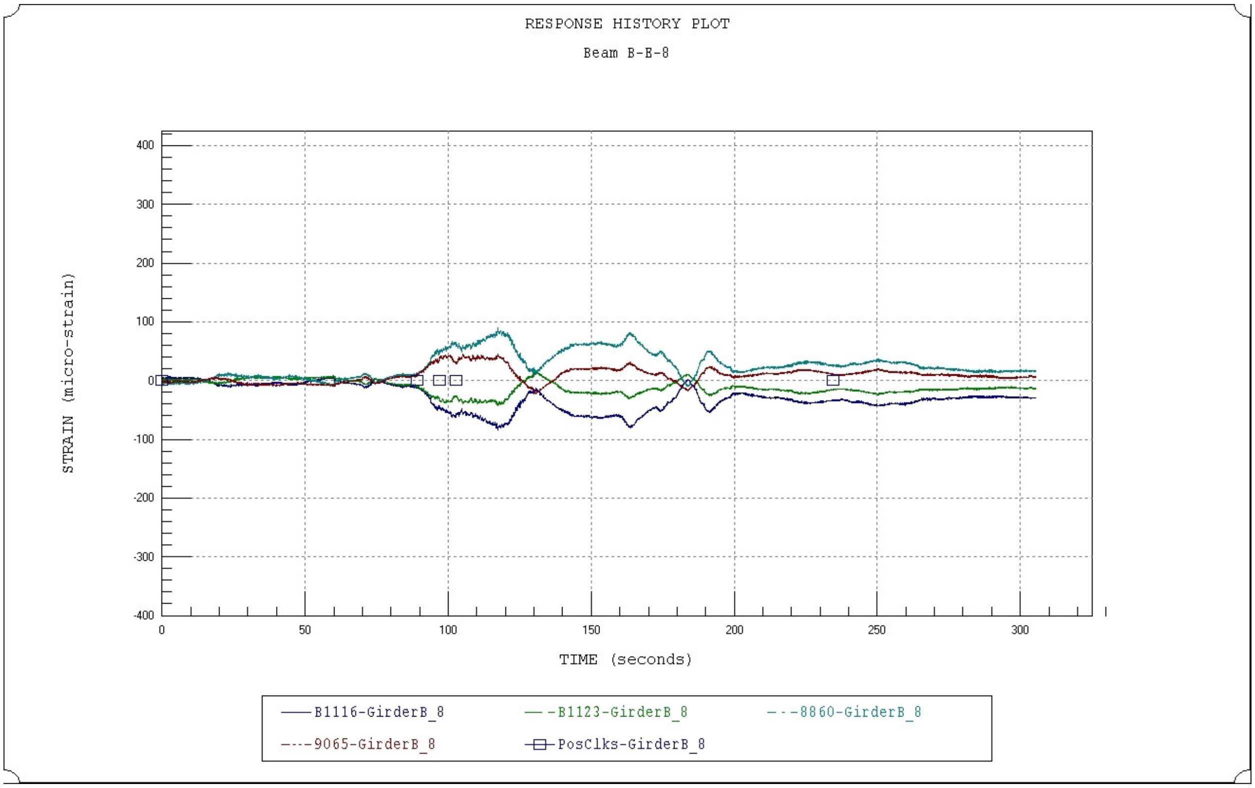

Figure 74 Girder B, Cross-Section E, File 8.

FEATURE: ENTER CITY

File Names: Beam_A_35.dat

Girder_B_columbia.dat

Details: Right U-turn from the highway to the side street leading to the construction site. Both the tractor and the trailer had to drive on uneven ground, curbs, and dirt in order to make this turn. Once the girders were on the job site, the tractor portion had to drive onto a dirt ramp (likely 7+ percent grade). Due to the muddy conditions at the job site, the trucks had to back down the ramp multiple times and reposition themselves in order to be in the correct locations for the cranes to pick the beams from the trailers. The long flat spots on the response histories coincide with the trucks being parked while coordination between the drivers and the foreman was going on. Pictures of the girders making this turn can be seen on the attached CD under "DOTD Picts", files 310 thru 319 and 516 thru 518.

Figure 75 U-turn in Columbia from the highway to the construction site.

GIRDER A RESPONSES:

CLICKS: 1- Start test

0 - ~550 sec: drive thru city

550 - ~900 sec: U-turn (flat spot from truck being stopped while moving obstacle from roadway

900 - ~1050 sec: Staging (rear wheels locked during this time)

1050 - ~1125 sec: 1st attempt at getting truck in position on dirt ramp

1125 - ~1250 sec: back down ramp

1250 - ~1400 sec: staging

1400 thru end of test: 2nd attempt at positioning truck on dirt ramp

Table 17 Girder A U-turn to construction site.

Beam A *File Name: Girder_A_Columbia.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1061	82	-43
	B1045	26	-27
	B1132	19	-100
	B1190	12	-39
B	B1119	776	-156
	B1097	280	-74
	B1130	97	-529
	B1140	71	-322
C	B1122	1990	-1893
	B1046	390	-122
	B1131	59	-604
	B1118	101	-409
D	B1120	839	-239
	B1014	564	-187
	B1100	1172	-790
	B1088	156	-564
E	B1062	121	-70
	B1032	100	-34
	B1094	47	-138
	B1039	27	-112

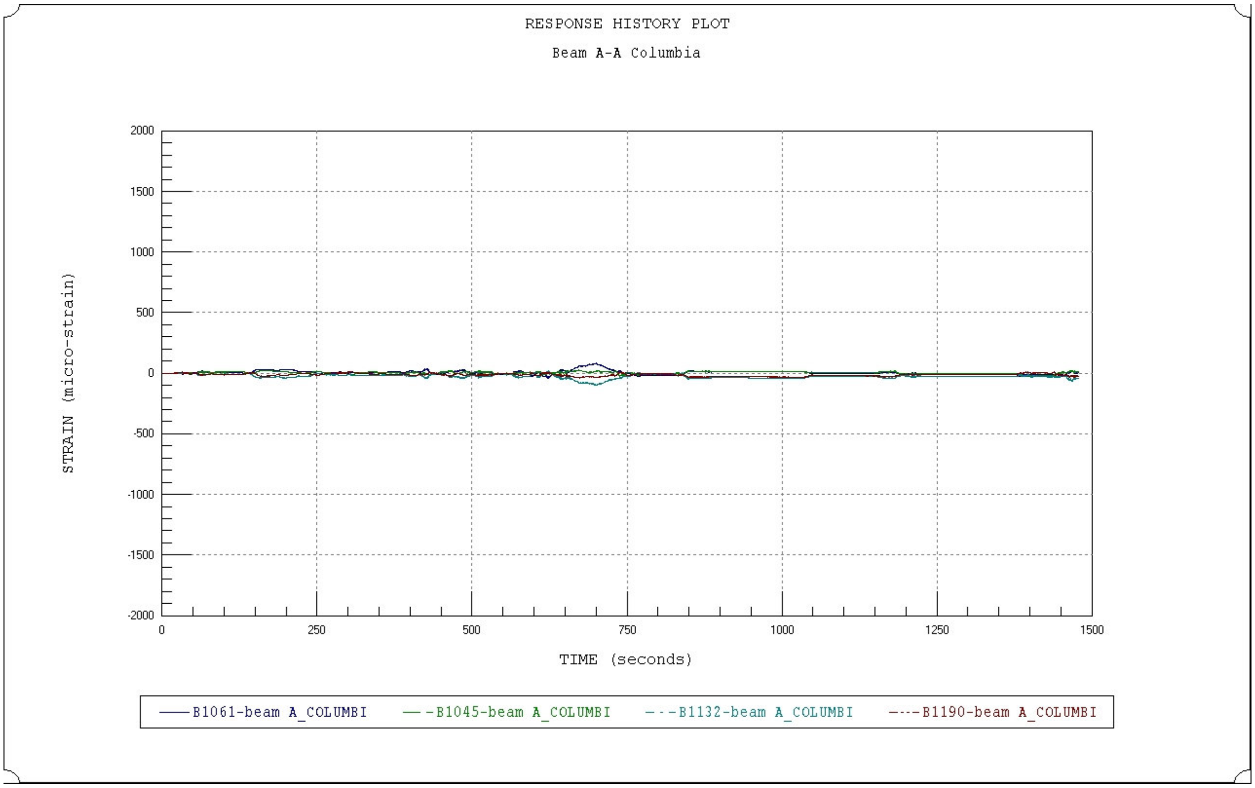

Figure 76 Girder A, Cross-Section A, File Columbia.

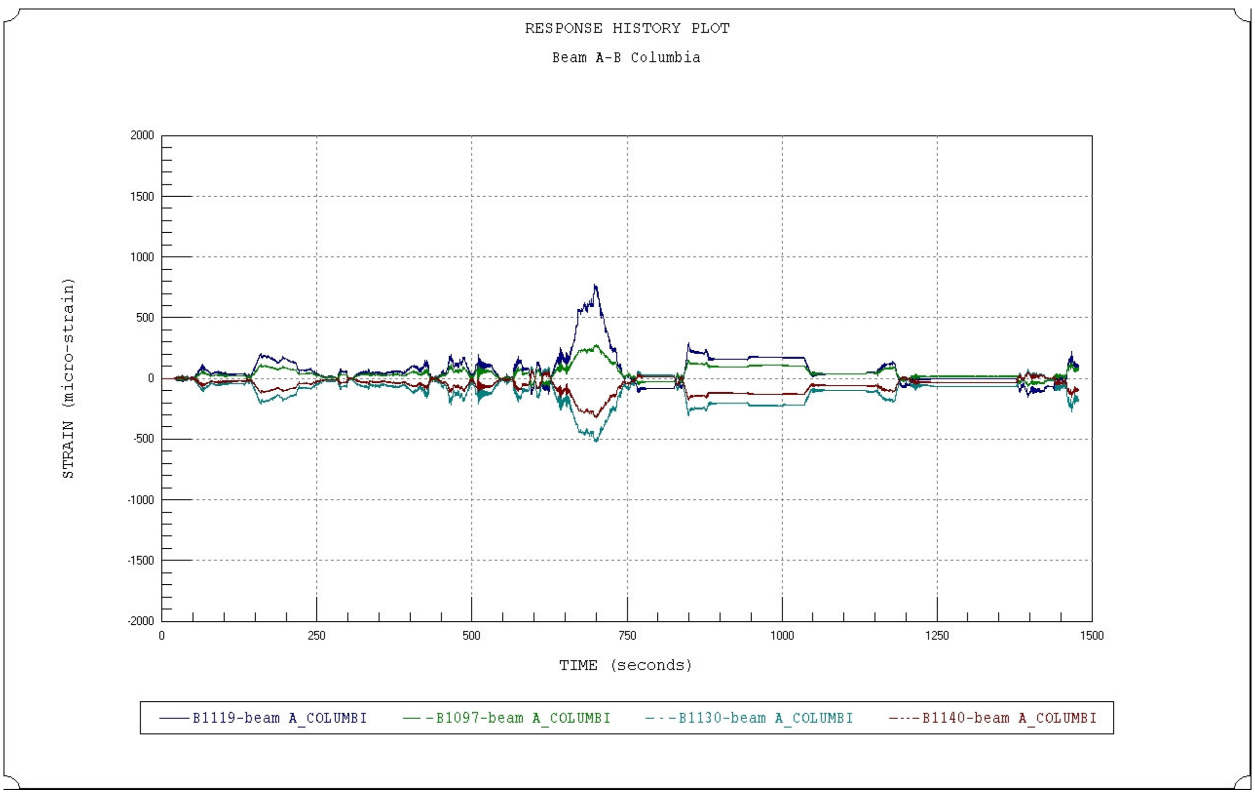

Figure 77 Girder A, Cross-Section B, File Columbia.

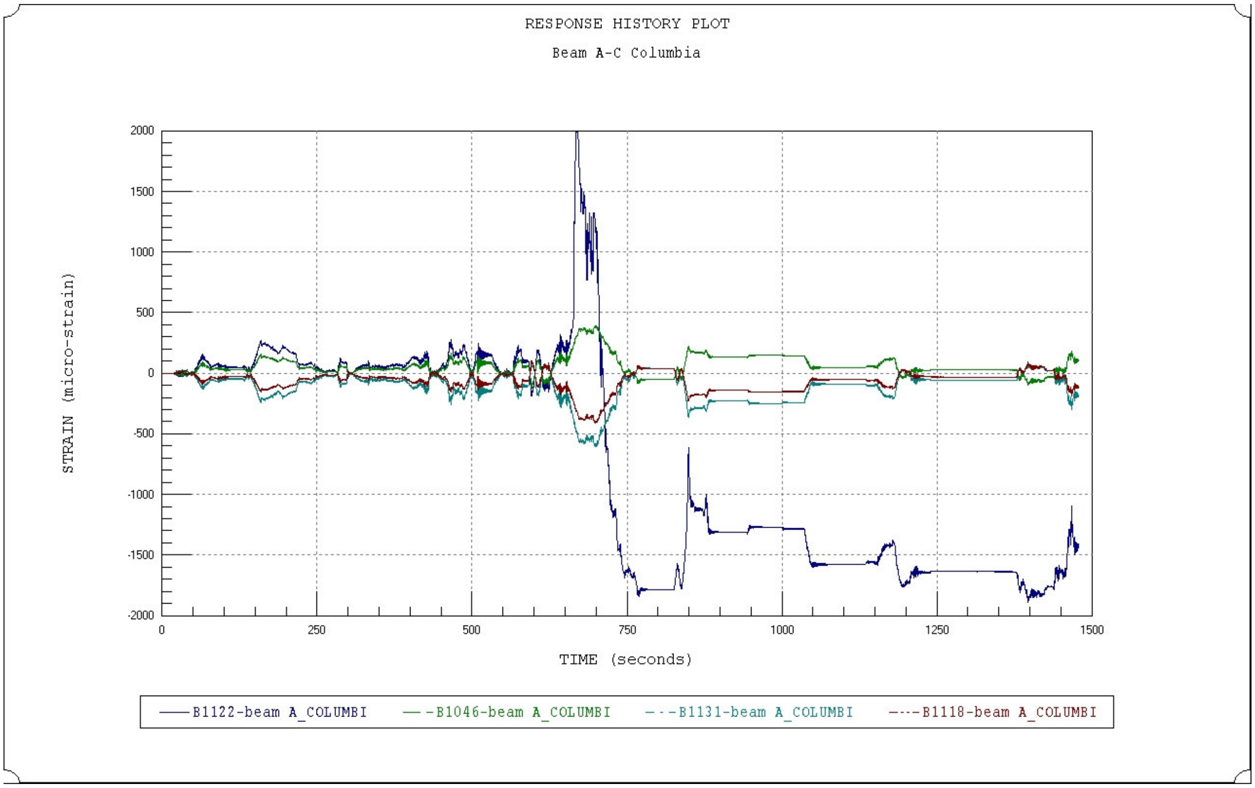

Figure 78 Girder A, Cross-Section C, File Columbia.

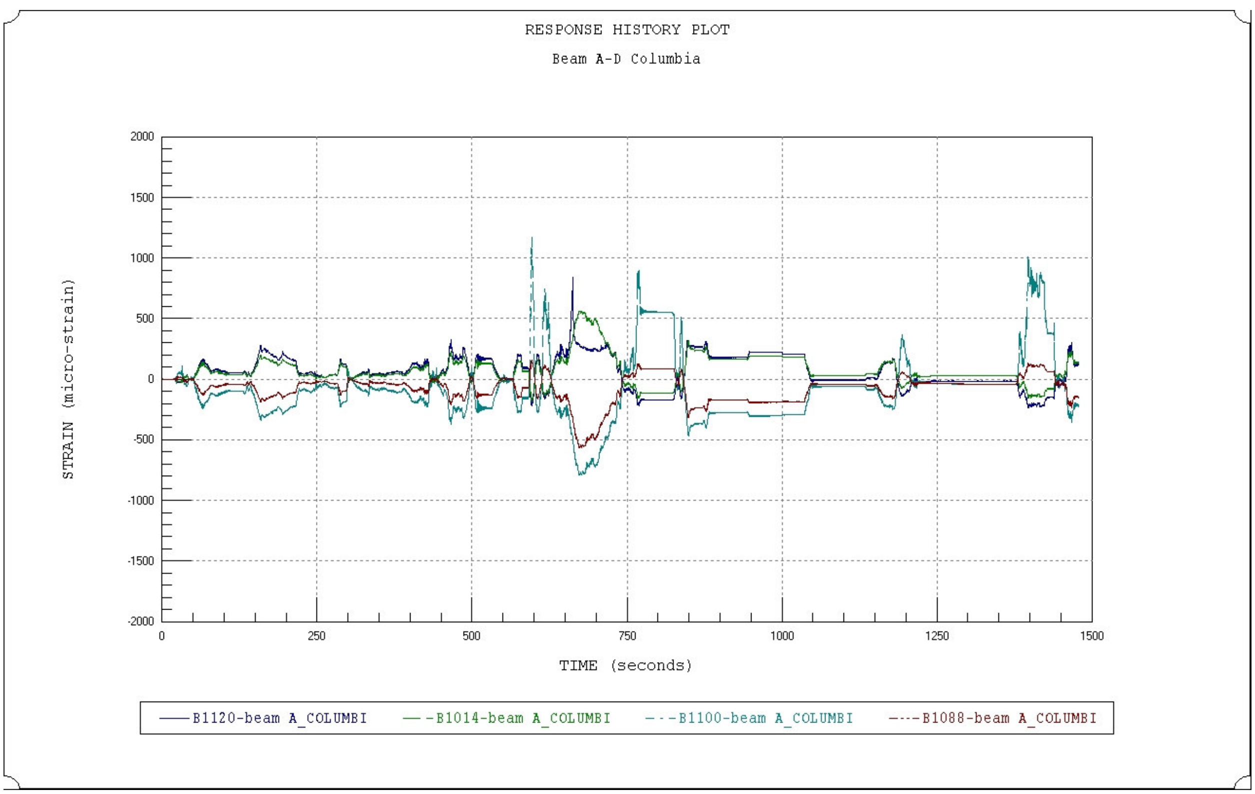

Figure 79 Girder A, Cross-Section D, File Columbia.

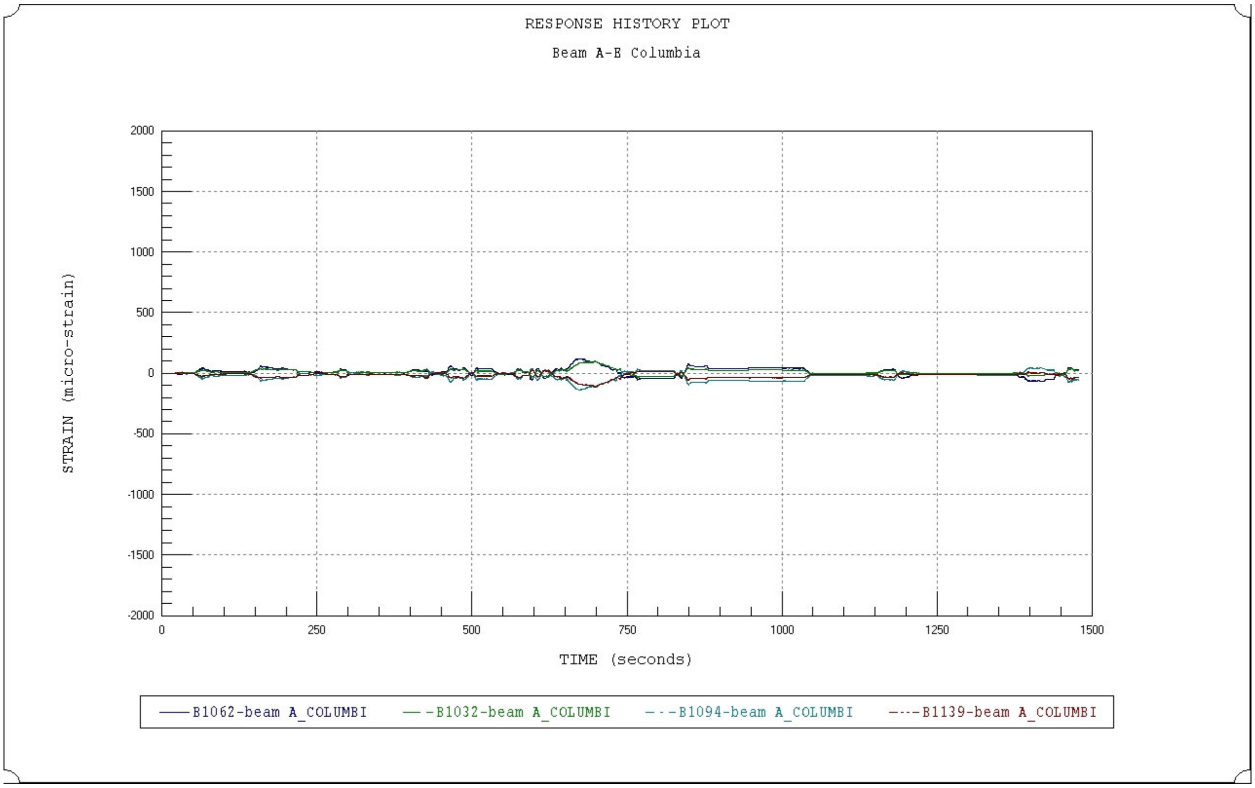

Figure 80 Girder A, Cross-Section E, File Columbia.

GIRDER B RESPONSES:

CLICKS: 1- Start test
0 - ~260 sec: drive thru city
260 - ~500 sec: U-turn
500 - ~ 780 sec: staging
780 thru end of test: drive onto dirt ramp

Table 18 Girder B U-turn to construction site.

Beam B *File Name: Girder_B_Columbia.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1128	93	-12
	B1127	41	-23
	5833	23	-93
	8688	24	-51
B	B1126	673	-68
	B1129	287	-49
	5690	97	-501
	6327	72	-307
C	B1087	717	-45
	B1125	398	-71
	4792	202	-660
	B1124	77	-414
D	B1095	1236	-146
	B1133	497	-120
	8865	113	-713
	5567	136	-565
E	B1116	132	-56
	B1123	106	-19
	8860	57	-131
	9065	21	-113

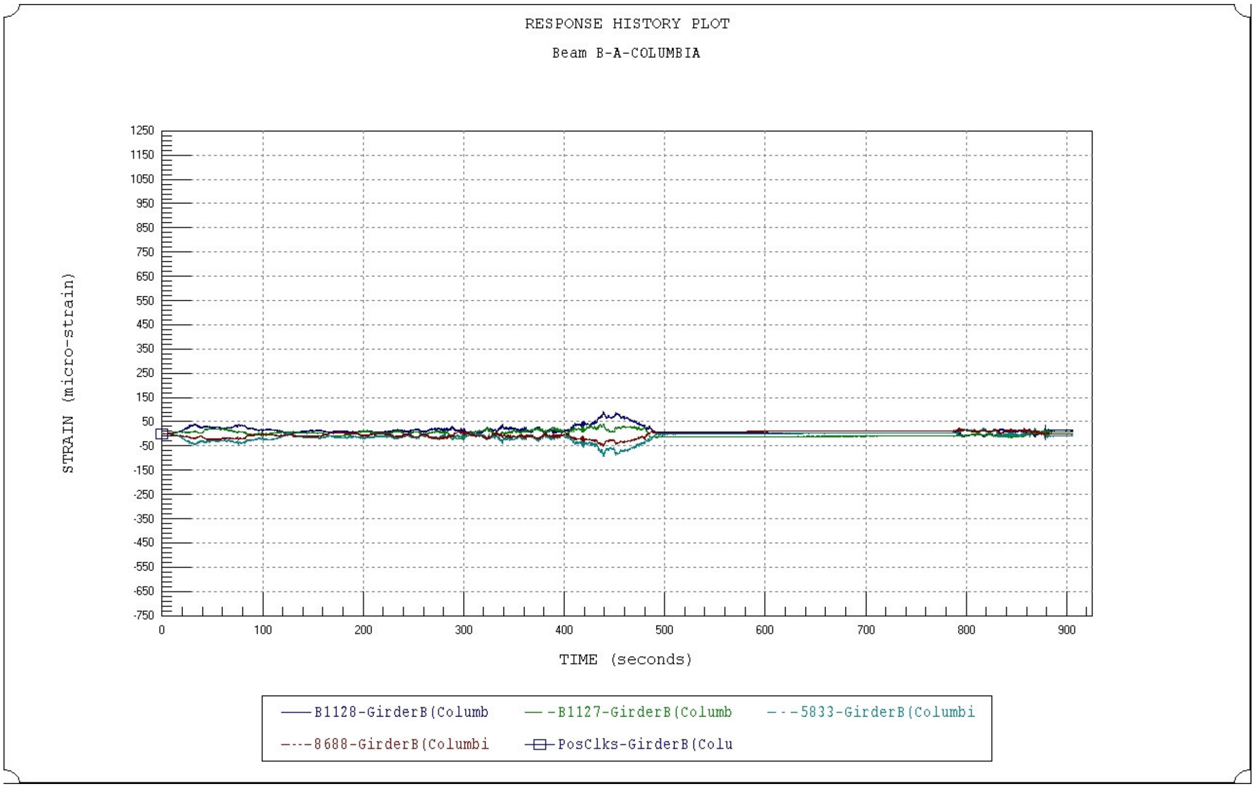

Figure 81 Girder B, Cross-Section A, File Columbia.

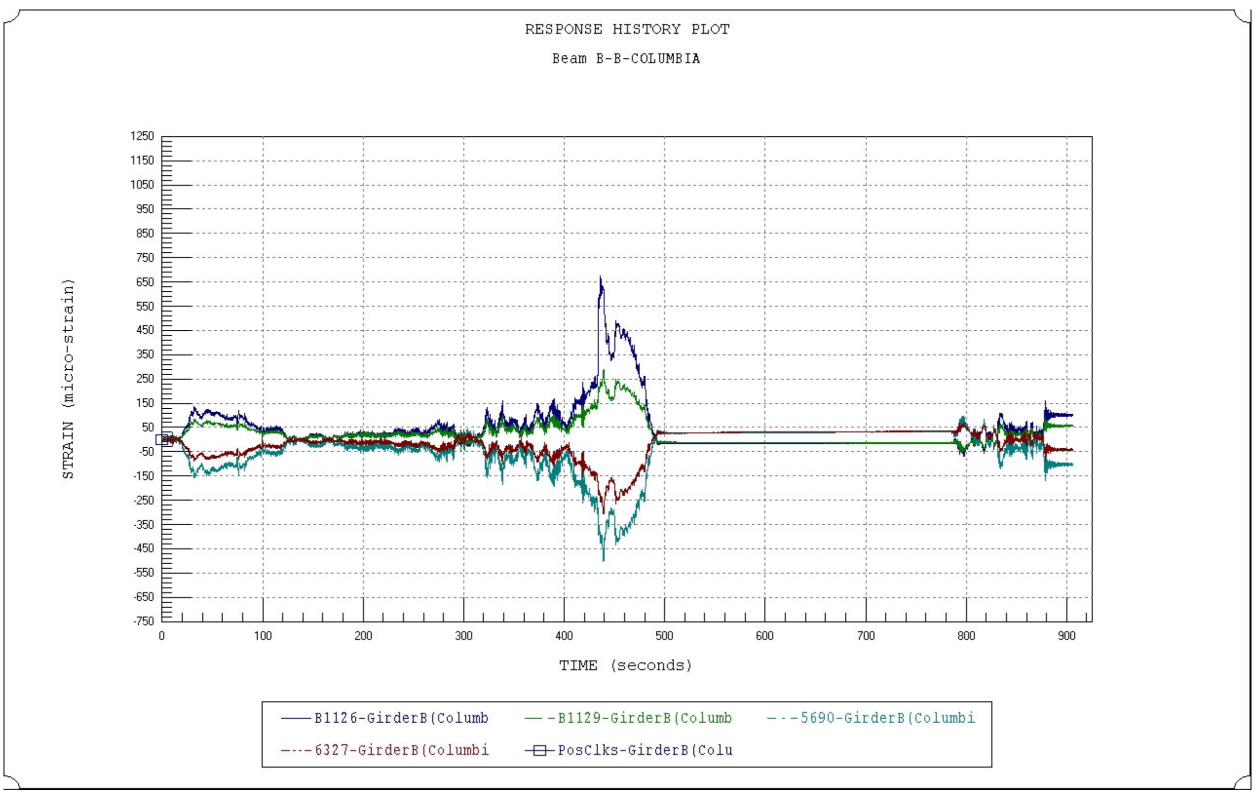

Figure 82 Girder B, Cross-Section B, File Columbia.

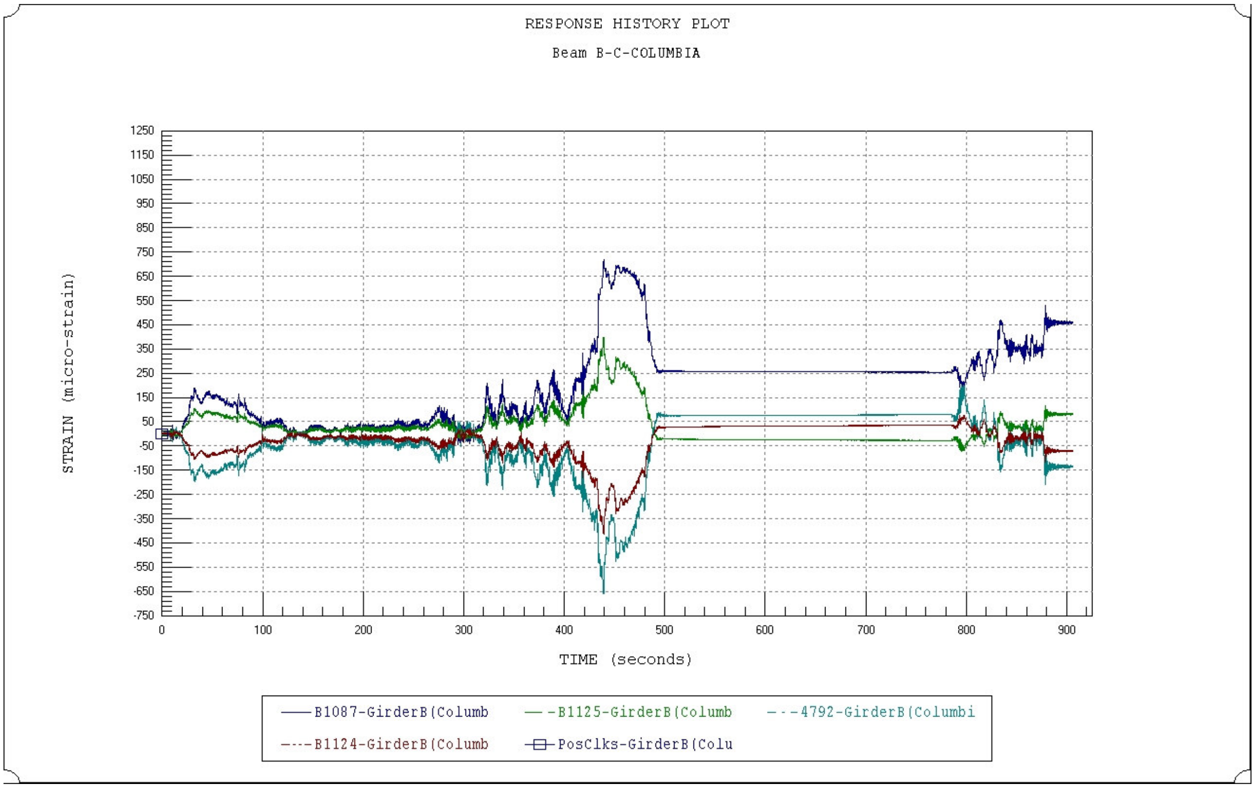

Figure 83 Girder B, Cross-Section C, File Columbia.

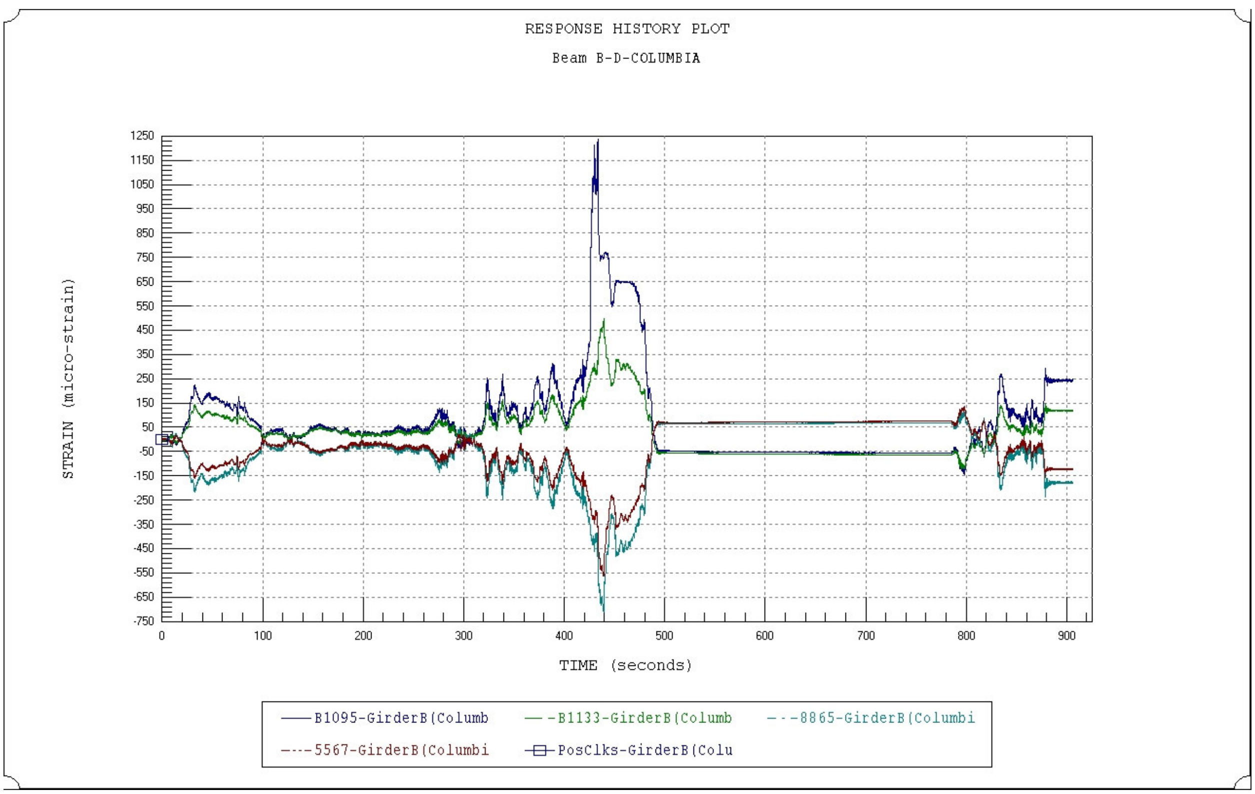

Figure 84 Girder B, Cross-Section D, File Columbia.

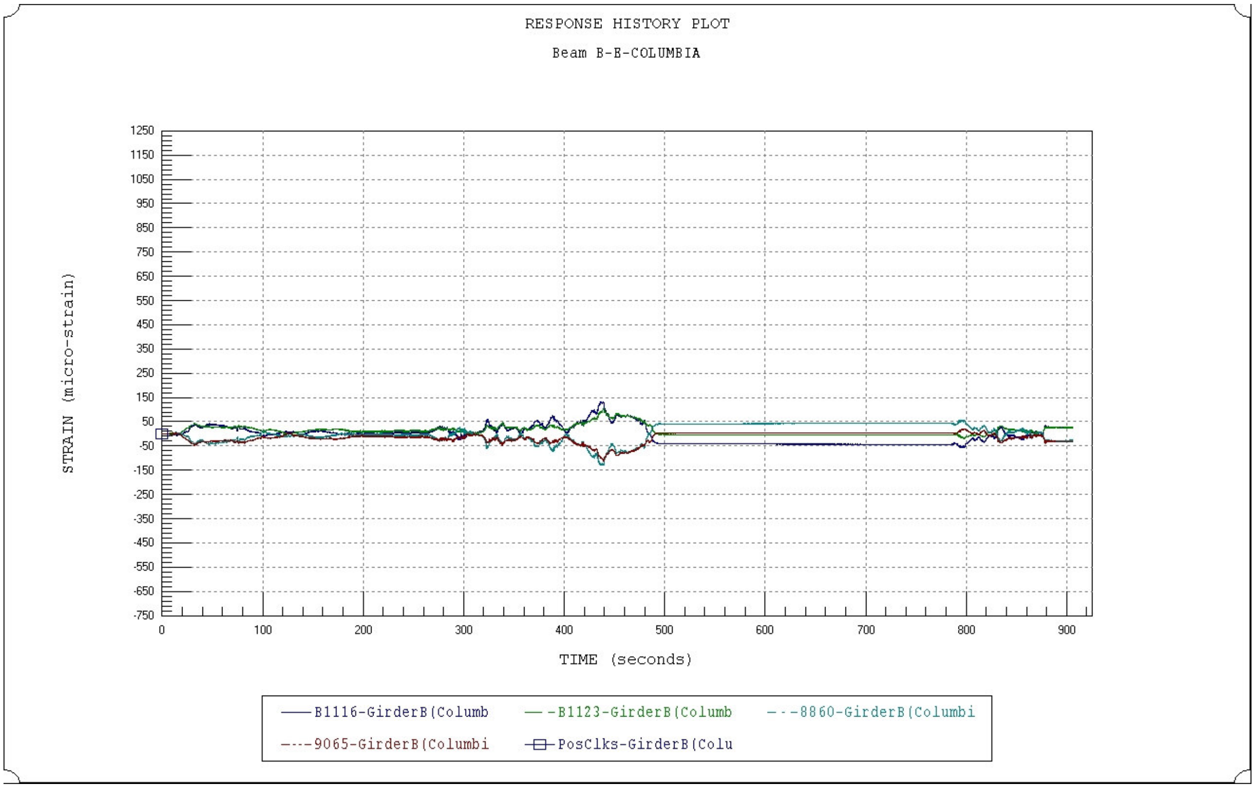

Figure 85 Girder B, Cross-Section E, File Columbia.

Standard Roadway conditions:

Several portions of the road were monitored as "controls" which included typical concrete and asphalt surfaces, areas that were considered to be rough due to a change in surface type, pot holes, ruts, etc.; construction zones; gradual turns; and bridge crossings. Many data files were collected for each of these categories and a representative response history was chosen for the report. Note that all of the data can be found on the provided CD if additional information about a specific feature type is needed.

Each subsection is labeled with the roadway feature and includes information pertaining to the specific file name given in this subsection. It also includes details and observations made during the monitoring and data review, a picture of each feature, load envelopes for each gage, and a representative response history of one of the midspan cross-sections. It is important to understand that the strains given in the envelope did not occur simultaneously; rather this was the maximum and minimum strain the cross-section experienced throughout this particular test. Also note that response histories for every cross-section for the files used in this subsection have been included on the CD under *Standard Roadway Conditions* in the *Additional Graphs* folder.

FEATURE: CONTROLS

File Names: Asphalt: Beam_A_5.dat

Girder_B_5.dat

Concrete: Beam_A_9.dat

Girder_B_22.dat

Details: The control testing was done on straight sections of roadway that that were considered "typical" roadway conditions.

Figure 86 Typical asphalt control roadway.

GIRDER A:

Table 19 Girder A asphalt (left) and concrete (right) control strain envelopes.

Asphalt Control *File Name:* *Beam_A_5.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1061	14.49	-25.39
	B1045	19.04	-25.48
	B1132	23.11	-18.96
	B1190	25.8	-15.27
B	B1119	76.81	-68.74
	B1097	53.16	-49.56
	B1130	78.39	-88.75
	B1140	43.53	-51.1
C	B1122	78.66	-78.95
	B1046	54.85	-58.33
	B1131	75.03	-74.31
	B1118	45.46	-47.71
D	B1120	52.87	-55.04
	B1014	43.32	-44.33
	B1100	86.22	-70.78
	B1088	37.31	-39.55
E	B1062	19.72	-17.14
	B1032	14.55	-15.72
	B1094	16.14	-23.03
	B1039	15.46	-17.41

Concrete Control *File Name:* *Beam_A_9.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1061	25.29	-7.782
	B1045	15.91	-12.5
	B1132	8.705	-23.21
	B1190	9.277	-17.78
B	B1119	118.9	-42.98
	B1097	56.47	-34.07
	B1130	51.62	-97.95
	B1140	25.1	-75.51
C	B1122	135.9	-54.13
	B1046	79.13	-39.86
	B1131	47.28	-106.8
	B1118	32.39	-81.76
D	B1120	86.33	-43.16
	B1014	66.74	-35.86
	B1100	70.12	-110
	B1088	33.02	-60.51
E	B1062	16.14	-13.74
	B1032	16.79	-7.617
	B1094	12.23	-18.34
	B1039	6.188	-16.05

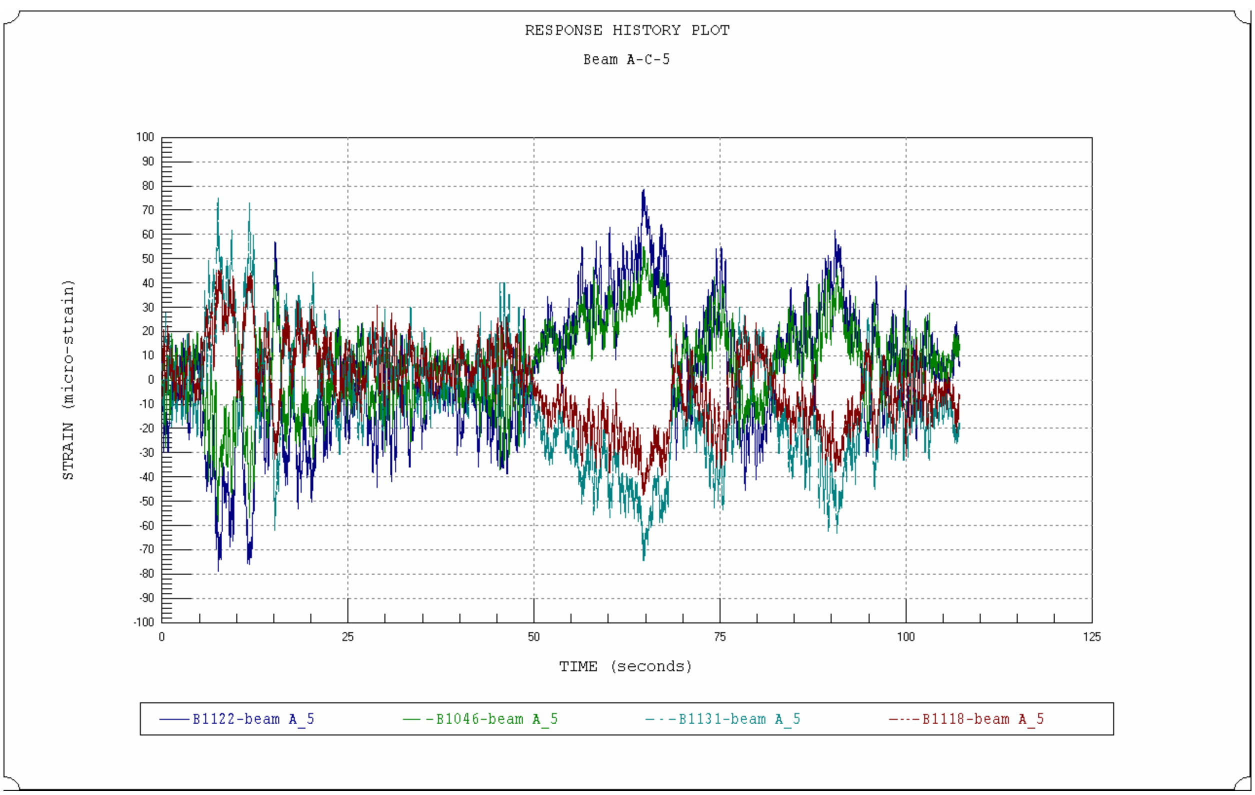

Figure 87 Girder A, File 5, Cross-Section C (asphalt control).

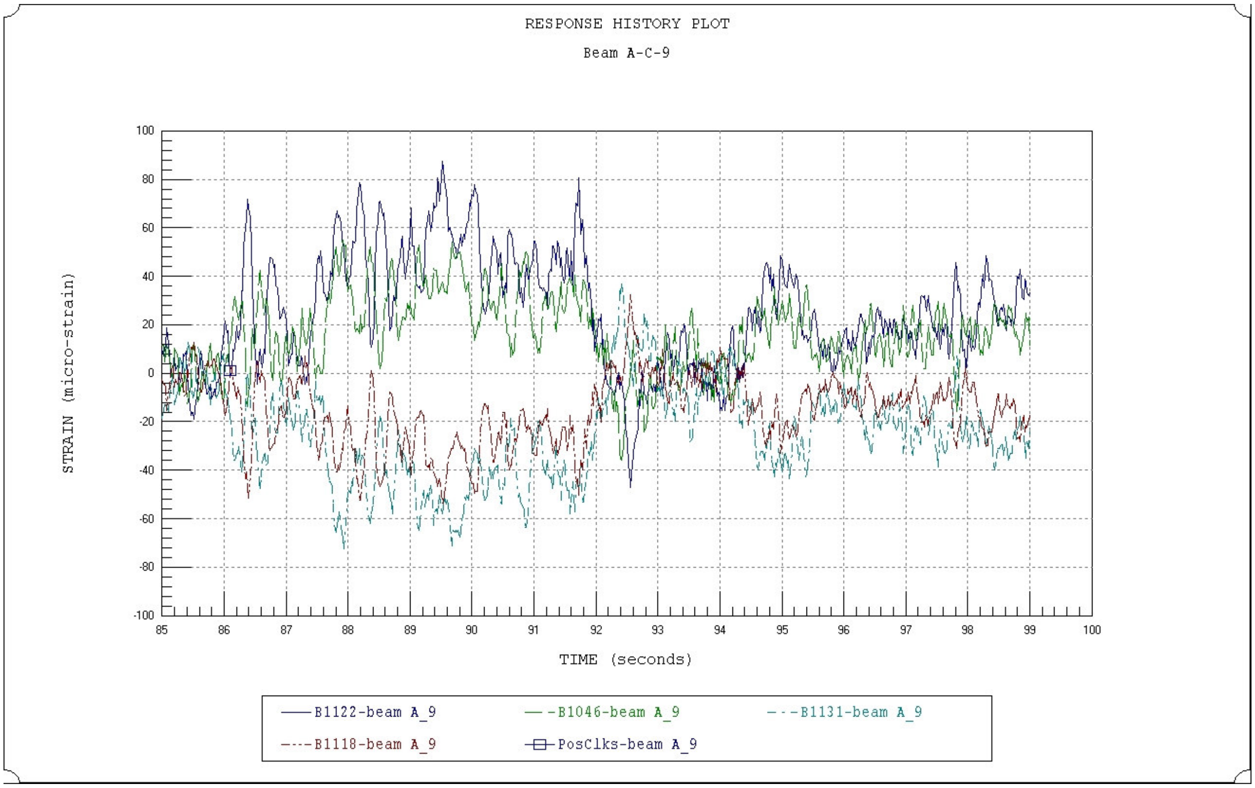

Figure 88 Girder A, File 9, Cross-Section C (concrete control).

GIRDER B:

Table 20 Girder B asphalt (left) and concrete (right) control strain envelopes.

Asphalt Control *File Name: Girder_B_5.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1128	4.856	-30.12
	B1127	10.74	-32.22
	5833	35.6	-4.976
	8688	32.4	-10
B	B1126	30.75	-116.3
	B1129	26.98	-71.99
	5690	147	-45.3
	6327	88.21	-27.72
C	B1087	49.24	-146.5
	B1125	32.41	-79.87
	4792	182.2	-57.31
	B1124	79.41	-29.33
D	B1095	51.95	-109.3
	B1133	33.46	-61.86
	8865	122.7	-57.43
	5567	73.53	-35.4
E	B1116	17.39	-32.45
	B1123	7.242	-18.21
	8860	34.8	-22.34
	9065	21.92	-5.806

Concrete Control *File Name: Girder_B_22.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1128	13.89	-7.972
	B1127	13.48	-5.563
	5833	9.881	-15.97
	8688	7.024	-14.81
B	B1126	46.12	-18.25
	B1129	37.36	-11.16
	5690	16.23	-64.31
	6327	16.58	-37.17
C	B1087	54.97	-28.58
	B1125	40.81	-14.85
	4792	18.1	-73.9
	B1124	20.35	-33.02
D	B1095	45.59	-30.55
	B1133	38.03	-14.01
	8865	18.85	-61.78
	5567	27.24	-34.69
E	B1116	10.07	-8.994
	B1123	11.06	-8.026
	8860	9.677	-16.63
	9065	9.733	-9.926

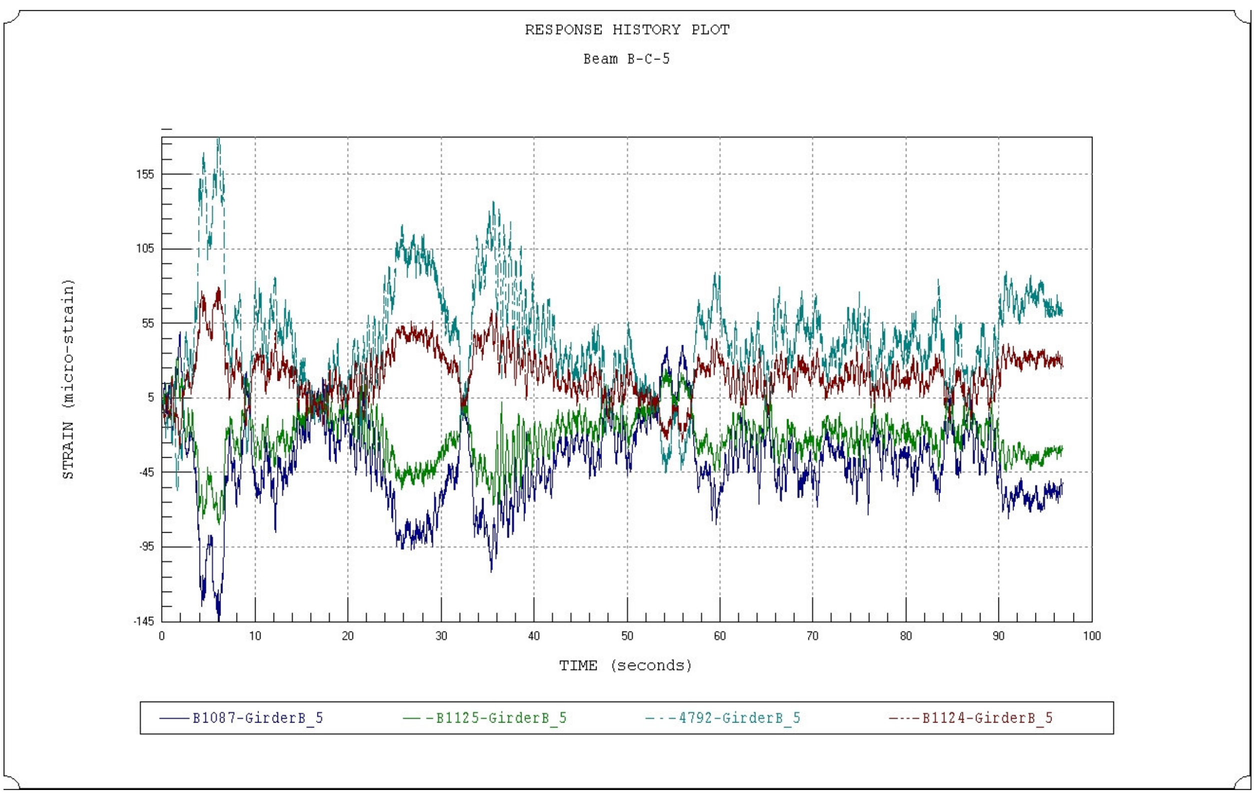

Figure 89 Girder B, File 5, Cross-Section C (asphalt control).

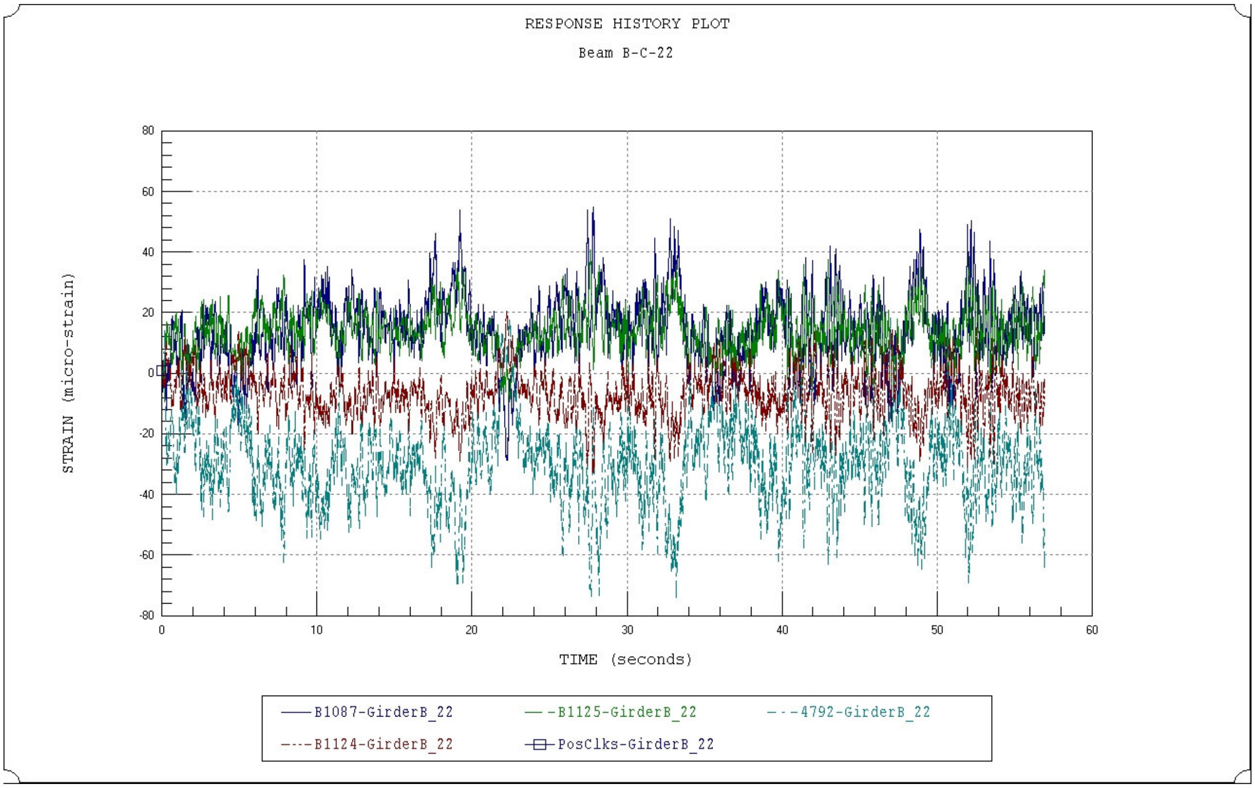

Figure 90 Girder B, File 9, Cross-Section C (concrete control).

FEATURE: ROUGH ROADWAY

File Names: Beam_A_25.dat

Girder_B_29.dat

Details: These portions of monitoring were areas where the road was in bad shape from things such as ruts, surface change from asphalt to concrete (or visa-versa), pot holes, or basically anything that caused the girders to bounce.

Figure 91 Example of rough road. Note the tar line on the right side of the picture.

GIRDER A:

Table 21 Girder A rough roadway strain envelopes.

Rough Roadway *File Name:* *Beam_A_25.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1061	28.01	-17.7
	B1045	19.7	-21.02
	B1132	18.18	-36.95
	B1190	10.05	-27.64
B	B1119	150.3	-53
	B1097	65.63	-59
	B1130	81.73	-132.6
	B1140	28.29	-105.2
C	B1122	186.8	-58.59
	B1046	89.74	-73.72
	B1131	82.69	-125
	B1118	33.36	-124.7
D	B1120	143.6	-37.87
	B1014	73.74	-61.76
	B1100	100.9	-135
	B1088	23.67	-109.9
E	B1062	26.5	-15.34
	B1032	19.53	-18.55
	B1094	20.25	-28.47
	B1039	8.895	-31.71

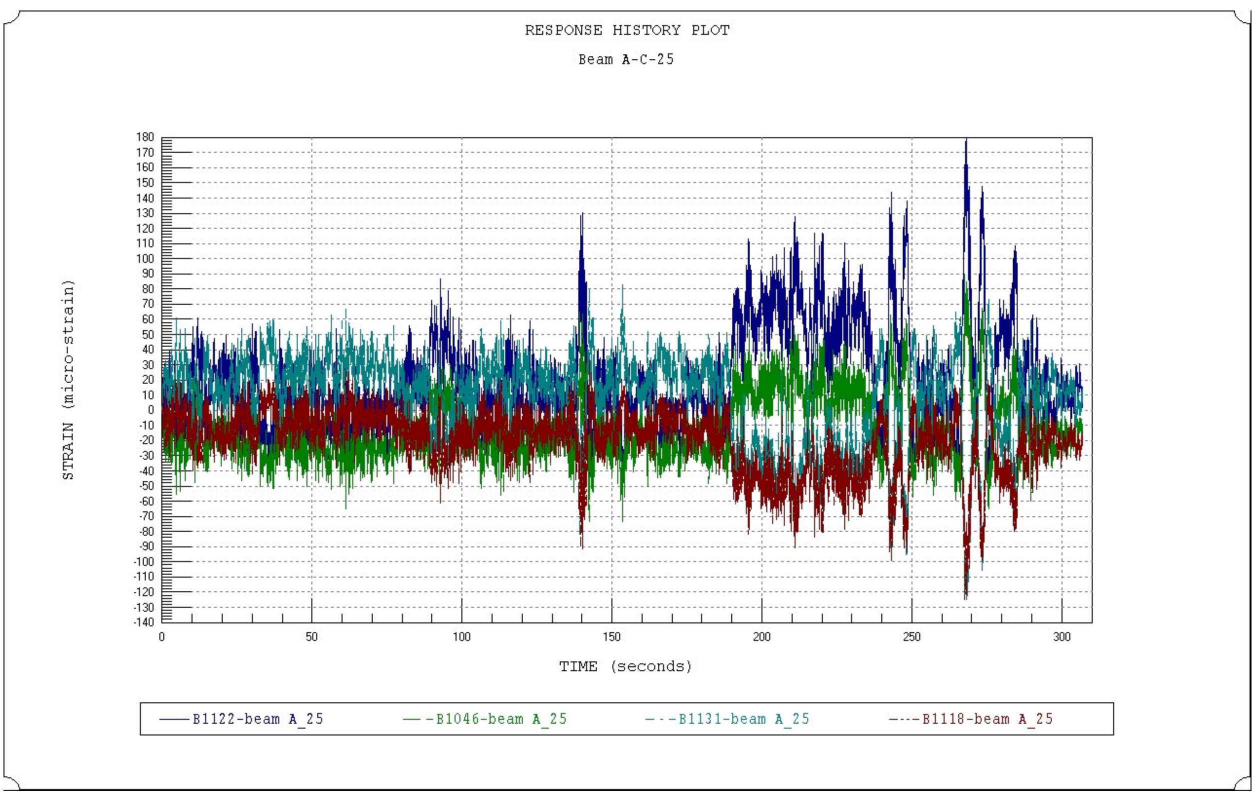

Figure 92 Girder A, File 25, Cross-Section C.

GIRDER B:

Table 22 Girder B rough roadway strain envelopes.

Rough Roadway *File Name:* *Girder_B_29.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1128	15.06	-22.35
	B1127	9.375	-21.87
	5833	25.46	-16.76
	8688	19.43	-13.16
B	B1126	65.72	-88.03
	B1129	40.85	-67.83
	5690	116.1	-79.4
	6327	66.51	-51.69
C	B1087	92.44	-108.3
	B1125	44.03	-72.15
	4792	222	-86.27
	B1124	63.95	-57.27
D	B1095	81.52	-89.18
	B1133	49.32	-55.24
	8865	78.04	-82.58
	5567	58.81	-63.74
E	B1116	17.88	-18.77
	B1123	14.68	-19.09
	8860	22.27	-19.61
	9065	16.83	-17.34

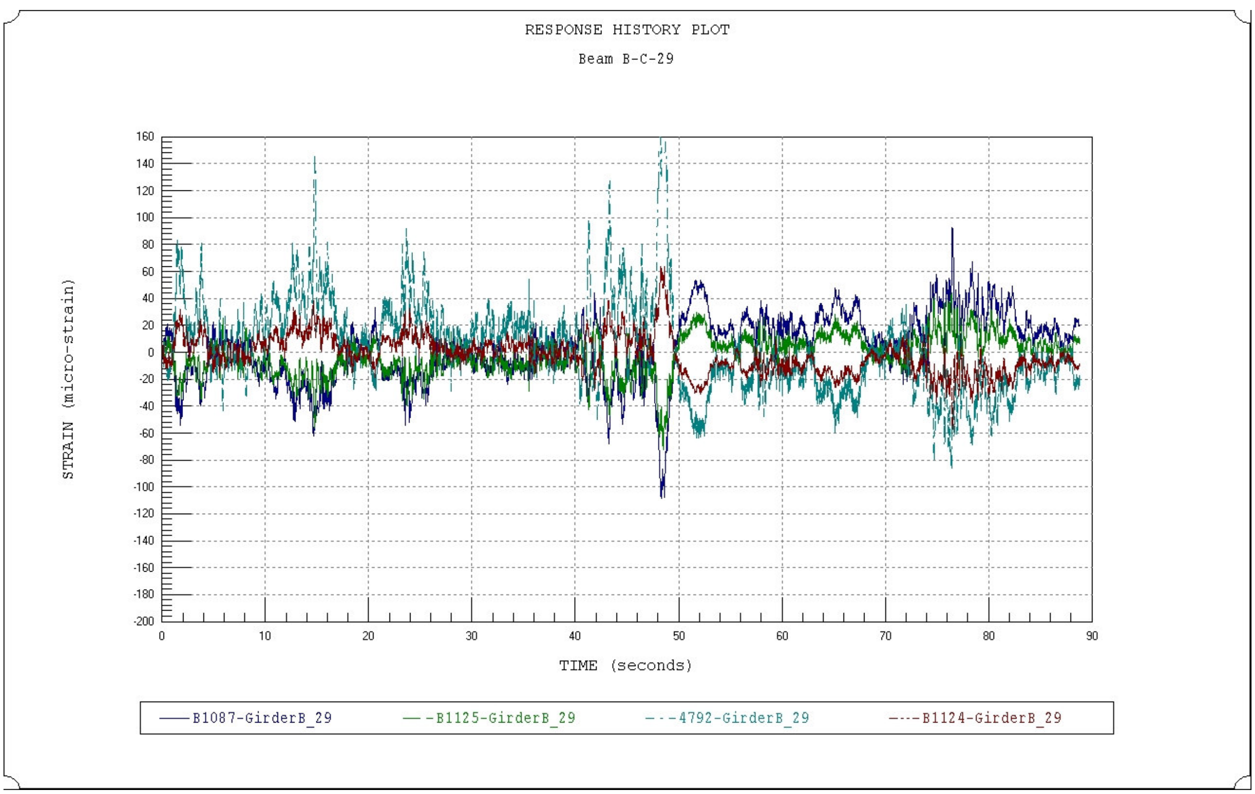

Figure 93 Girder B, File 29, Cross-Section C.

FEATURE: CONSTRUCTION ZONES

File Names: Beam_A_34.dat

Girder_B_37.dat

Details: Maybe instead: Construction zones are considered a separate feature from rough roads because in many of these areas there were very deep potholes and severe super-elevation changes. In many of these areas it was noted by BDI personnel that the ride became very rough and the bouncing of the beam could be felt in the cab of the semi tractor.

Figure 94 Sample construction zone picture. Median crossings, such as this one, had severe changes in super-elevation.

GIRDER A:

Table 23 Girder A construction zones strain envelopes.

Construction Zones *File Name: Beam_A_34.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1061	30.74	-52.91
	B1045	19.32	-44.13
	B1132	47.97	-36.18
	B1190	35.18	-23.77
B	B1119	91.93	-240.5
	B1097	57.83	-145.6
	B1130	227.7	-100
	B1140	152.2	-61.95
C	B1122	119.5	-285.9
	B1046	67.72	-172.2
	B1131	192	-100.8
	B1118	17.21	-73.75
D	B1120	126.9	-189.9
	B1014	90.44	-129.7
	B1100	360.8	-128.5
	B1088	124.1	-86.84
E	B1062	33.47	-46.22
	B1032	21.87	-33.79
	B1094	46.05	-38.02
	B1039	37.13	-28.61

Figure 95 Girder A, File 34, Cross-Section C.

GIRDER B:

Table 24 Girder B construction zones strain envelopes.

Construction Zones *File Name: Girder_B_37.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1128	33.04	-60.73
	B1127	12.21	-45.9
	5833	38.03	-23.67
	8688	61	-45.68
B	B1126	95.08	-248.4
	B1129	71.9	-156.6
	5690	246.3	-148.5
	6327	168.4	-75.06
C	B1087	126.2	-305.4
	B1125	84.26	-178.4
	4792	521.7	-164.9
	B1124	164.8	-77.62
D	B1095	131	-233.2
	B1133	74.31	-137.7
	8865	187.3	-141.7
	5567	149.1	-94.69
E	B1116	34.11	-57.27
	B1123	24.96	-42.09
	8860	48.64	-43.58
	9065	42.16	-34.24

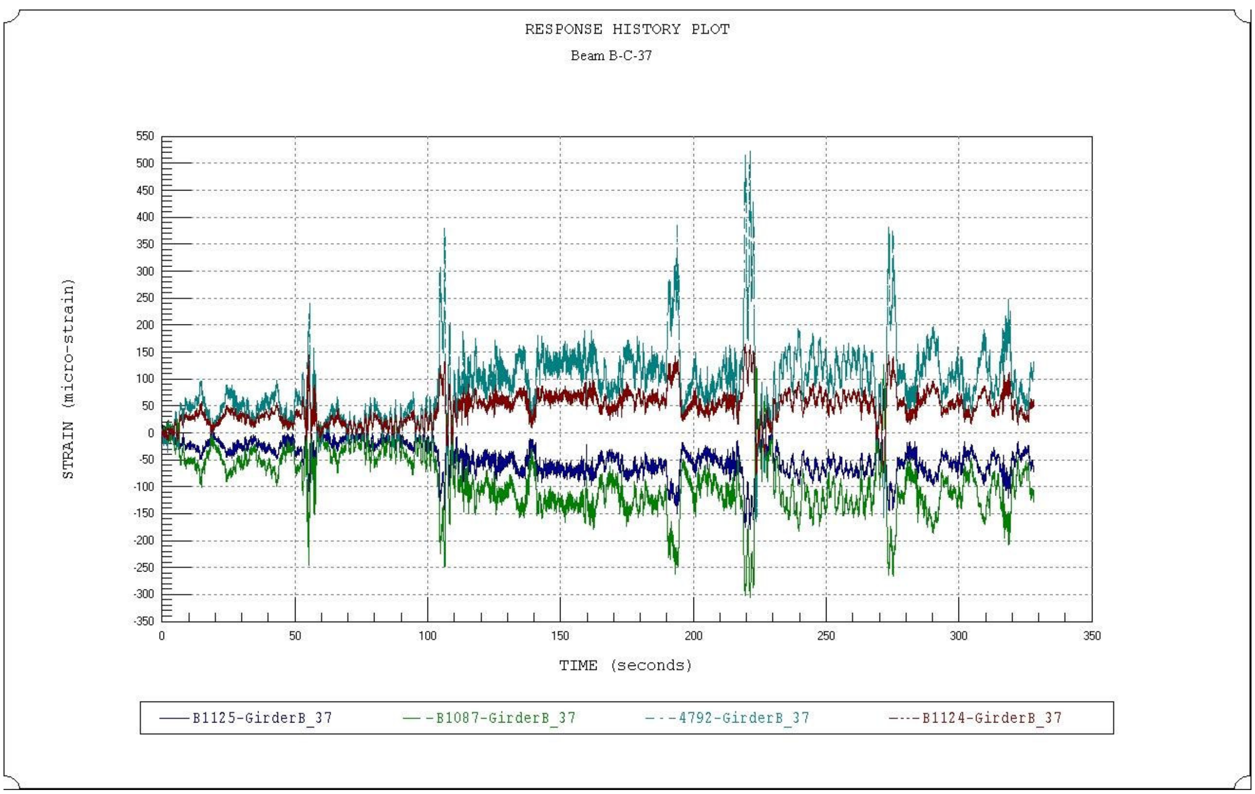

Figure 96 Girder B, File 34, Cross-Section C.

FEATURE: GRADUAL TURNS

File Names: Beam_A_27.dat

Girder_B_28.dat

Details: Gradual turns consisted of turns where the trailer wheels did not have to be manually operated. In some cases the semi had to slow down to make the turn, but no additional out-of-plane bending was induced by the turning of the rear trailer wheels. Note that in other cases some of these turns were taken at traveling speed.

Figure 97 Example of a gradual turn situation.

GIRDER A:

Table 25 Girder A gradual turns strain envelopes.

Gradual Turns *File Name: Beam_A_27.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1061	42.79	-35.99
	B1045	28.23	-36.18
	B1132	32.49	-47.78
	B1190	24.93	-34.99
B	B1119	206.8	-159.4
	B1097	116.8	-87.62
	B1130	136	-208.8
	B1140	98.61	-129.5
C	B1122	255.1	-182.3
	B1046	150	-109.9
	B1131	109.1	-223.9
	B1118	107.7	-149.8
D	B1120	319.8	-152.1
	B1014	211.6	-110.2
	B1100	388.8	-282.6
	B1088	100.4	-200.2
E	B1062	44.83	-38.85
	B1032	45.12	-31.06
	B1094	35.73	-55.98
	B1039	26.88	-53.37

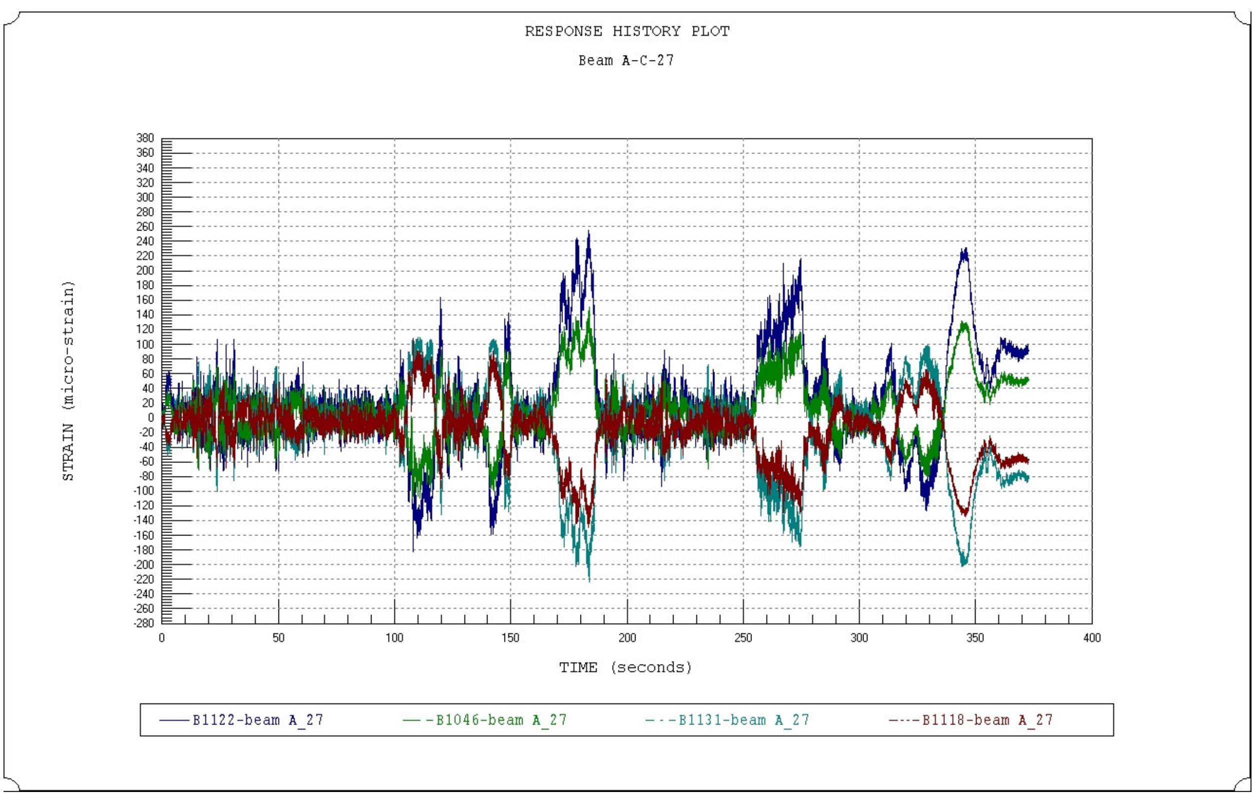

Figure 98 Girder A, File 27, Cross-Section C.

GIRDER B:

Table 26 Girder B gradual turns strain envelopes.

Gradual Turns *File Name:* *Girder_B_28.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1128	41.39	-39.75
	B1127	27.35	-35.15
	5833	46.53	-48.37
	8688	30.06	-34.8
B	B1126	177.9	-142
	B1129	103.4	-109.5
	5690	171.1	-196
	6327	104	-132.1
C	B1087	236.7	-193.3
	B1125	118.3	-132.6
	4792	429.4	-224
	B1124	106.8	-136
D	B1095	276.3	-183.6
	B1133	149.8	-121.6
	8865	147.5	-237.9
	5567	119.9	-194.3
E	B1116	44.18	-44.27
	B1123	40.12	-36.22
	8860	48.38	-51.31
	9065	35.4	-50.35

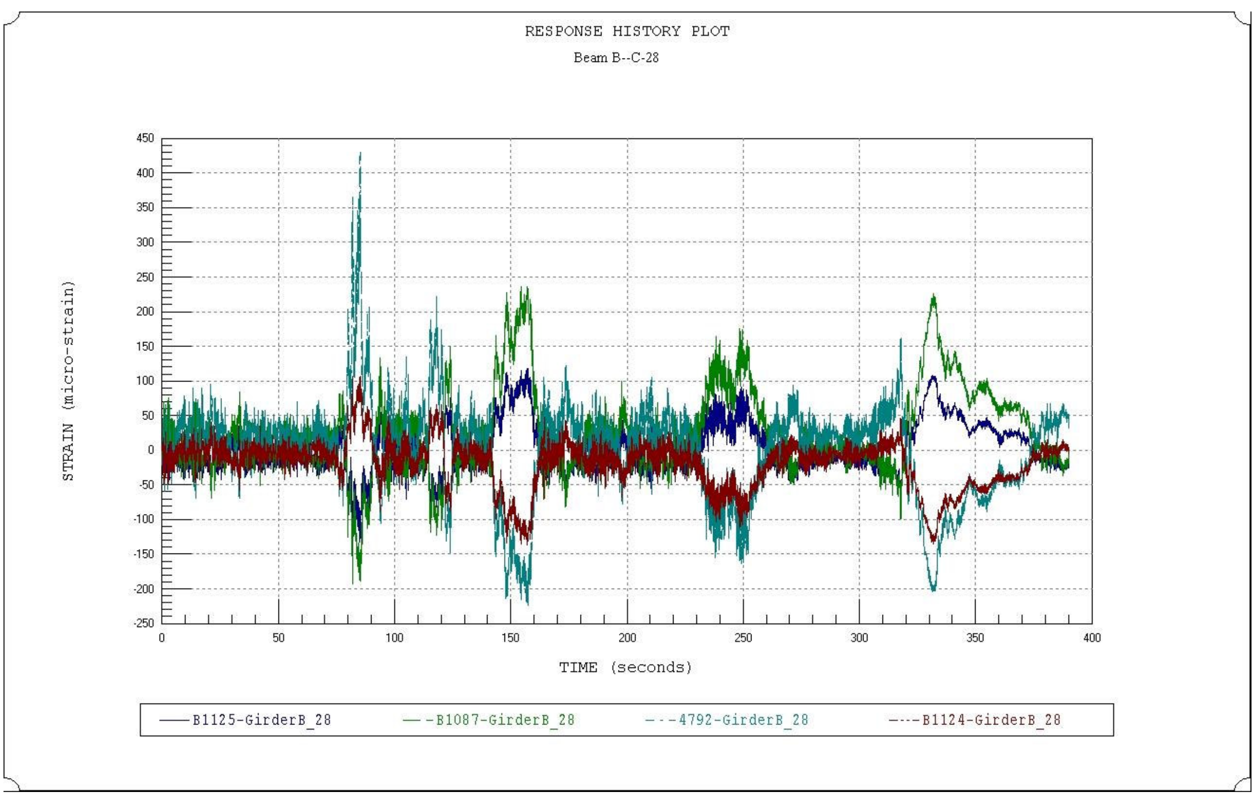

Figure 99 Girder B, File 28, Cross-Section C.

FEATURE: BRIDGE CROSSINGS

File Names: Beam_A_29.dat

Girder_B_30.dat

Details: The strains for these monitoring files varied drastically depending on the "smoothness" of the bridge approach spans, bridge deck condition, and expansion joint conditions. Both files below occurred when the girder crossed over an elevated bridge. There was a significant slope on both ends of the structure, which increased the strain magnitudes.

Figure 100 Example of a bridge crossing.

Girder A:

Table 27 Girder A bridge crossings strain envelopes.

Bridge Crossings *File Name:* *Beam_A_29.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1061	32.49	-33.65
	B1045	27.09	-38.26
	B1132	32.69	-36.94
	B1190	30.73	-24.35
B	B1119	195.1	-165.4
	B1097	98.53	-89.35
	B1130	122.1	-178.9
	B1140	105	-120.2
C	B1122	244.6	-198.7
	B1046	134.1	-124.2
	B1131	75.42	-189.7
	B1118	118	-138.6
D	B1120	190.3	-181.5
	B1014	133.3	-146.6
	B1100	770.1	-219.2
	B1088	130	-123.8
E	B1062	38.65	-42.03
	B1032	30.47	-32.03
	B1094	40.12	-43.95
	B1039	30.17	-30.74

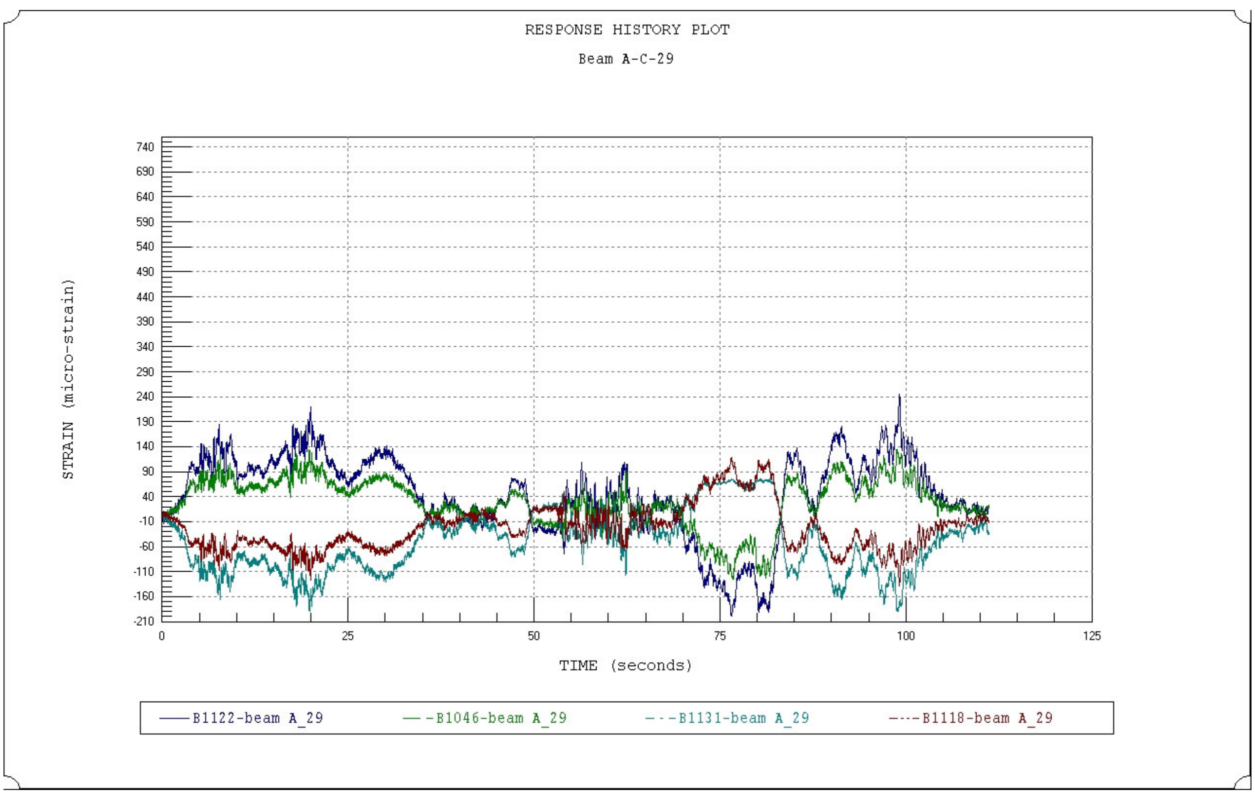

Figure 101 Girder A, File 29, Cross-Section C.

Girder B:

Table 28 Girder B bridge crossings strain envelopes.

Beam B *File Name:* *Girder_B_30.dat*			
Cross-Section	Gage Number	Positive	Negative
A	B1128	39	-31
	B1127	29	-37
	5833	33	-43
	8688	27	-29
B	B1126	180	-121
	B1129	106	-79
	5690	113	-198
	6327	90	-134
C	B1087	233	-169
	B1125	120	-95
	4792	364	-237
	B1124	99	-132
D	B1095	178	-176
	B1133	101	-102
	8865	102	-182
	5567	122	-114
E	B1116	38	-47
	B1123	30	-32
	8860	47	-40
	9065	37	-34

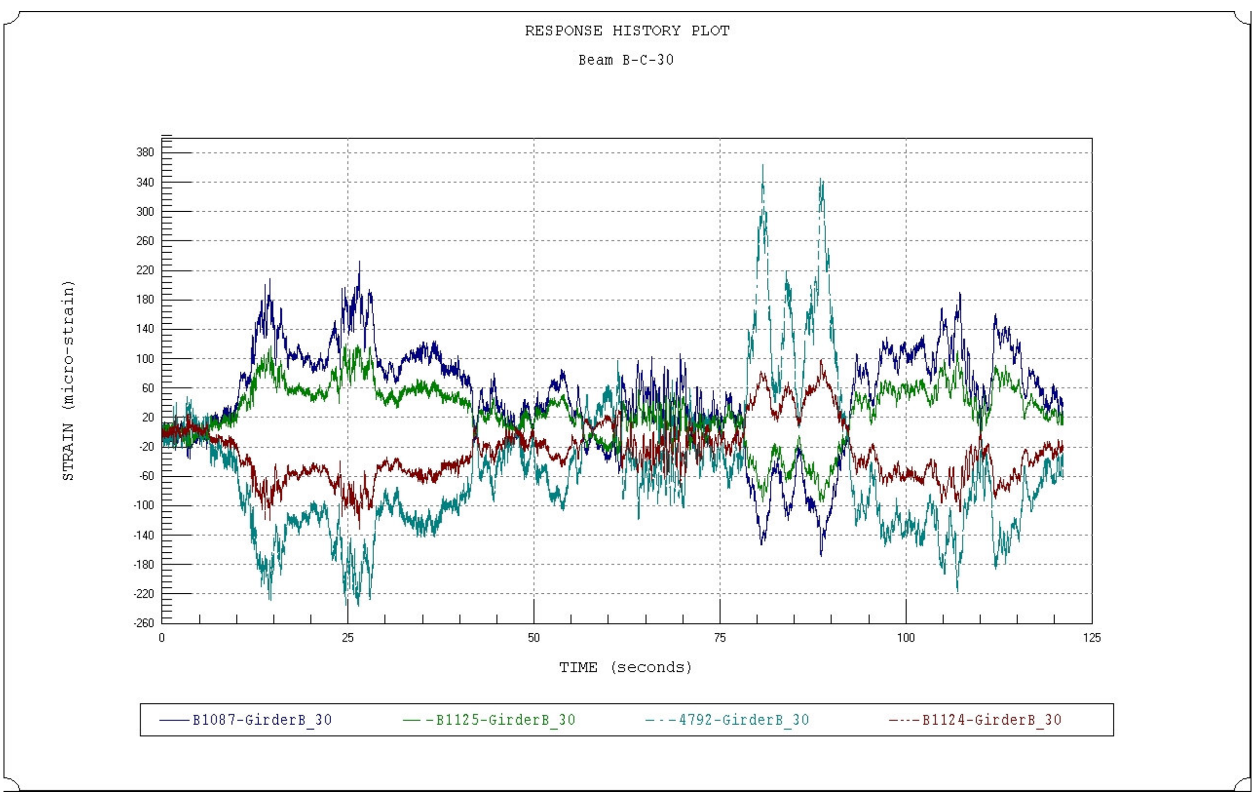

Figure 102 Girder B, File 30, Cross-Section C.

Unloading beams (Beam erection):

Once the trucks were in a position on the dirt ramp at the construction site, the beams were secured to the crane hooks and a test was started. Consecutive tests were run until the girder was secured to the bents. After the testing was complete the files were combined into a single file for easy data review.

FEATURE: BEAM ERECTION

File Names: Beam A_ (Erect-Full).dat

GirderB_(Erect-Full)_2.dat

Figure 103 Girder A being hoisted from trailer.

GIRDER A RESPONSES:

CLICKS: 1- Start test
~930sec crane cables tightened
~1200sec crane cables slacked
~1240sec girder picked from trailer
~3400sec girder placed on bearing locations
~3800sec cranes cables detached from beams.

Table 29 Girder A erection strain envelopes.

Beam A *File Name:* *GriderA_(Erect-full)*			
Cross-Section	Gage Number	Positive	Negative
A	B1061	49	-16
	B1045	12	-45
	B1132	64	-18
	B1190	9	-16
B	B1119	127	-119
	B1097	41	-86
	B1130	167	-50
	B1140	75	-56
C	B1122	205	-172
	B1046	57	-101
	B1131	154	-70
	B1118	87	-66
D	B1120	141	-103
	B1014	66	-74
	B1100	189	-83
	B1088	65	-82
E	B1062	58	-23
	B1032	19	-20
	B1094	44	-30
	B1039	20	-17

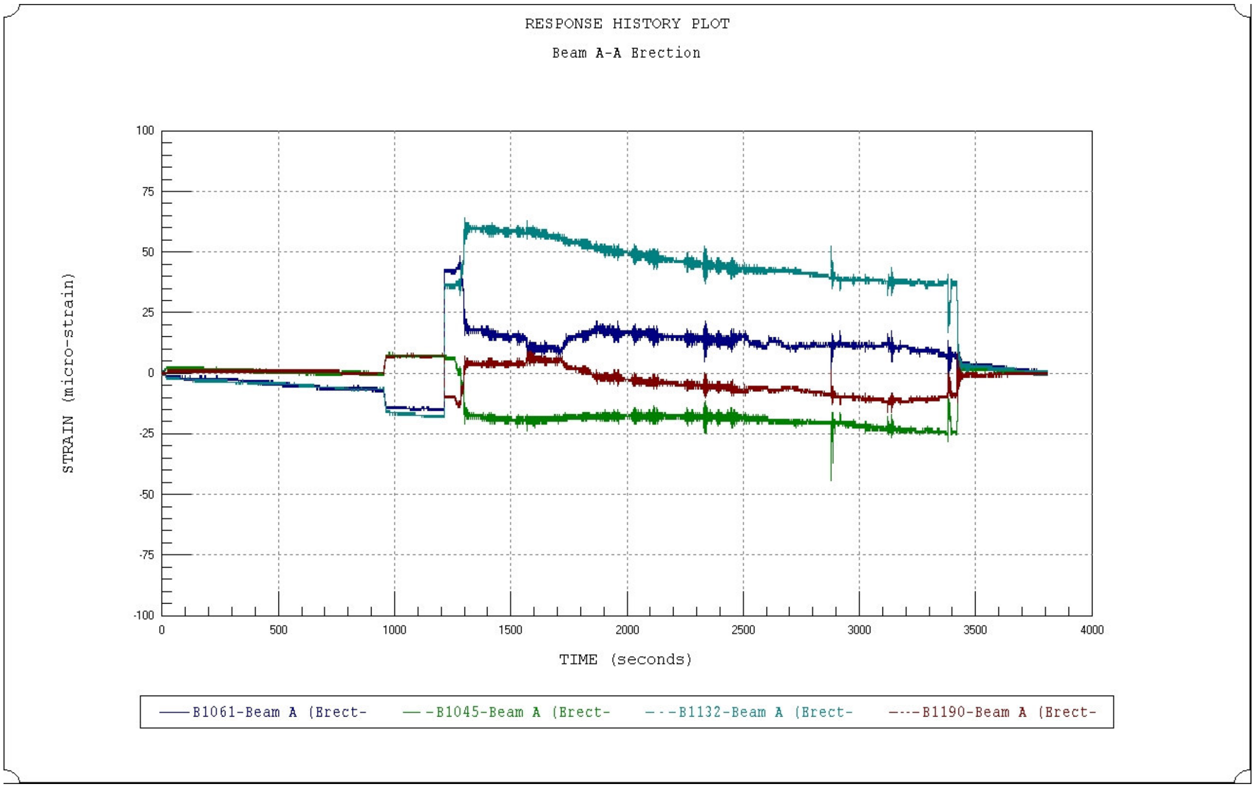

Figure 104 Girder A, File Erect-Full, Cross-Section A.

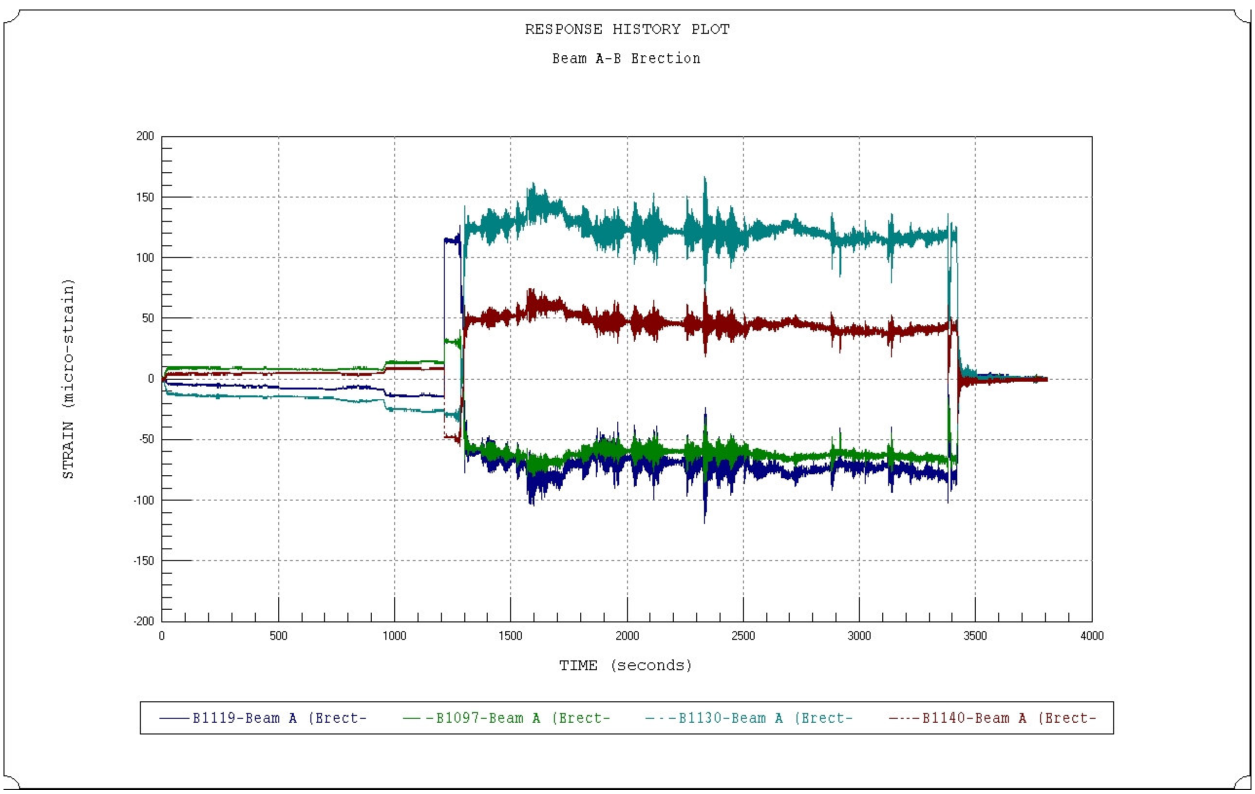

Figure 105 Girder A, File Erect-Full, Cross-Section B.

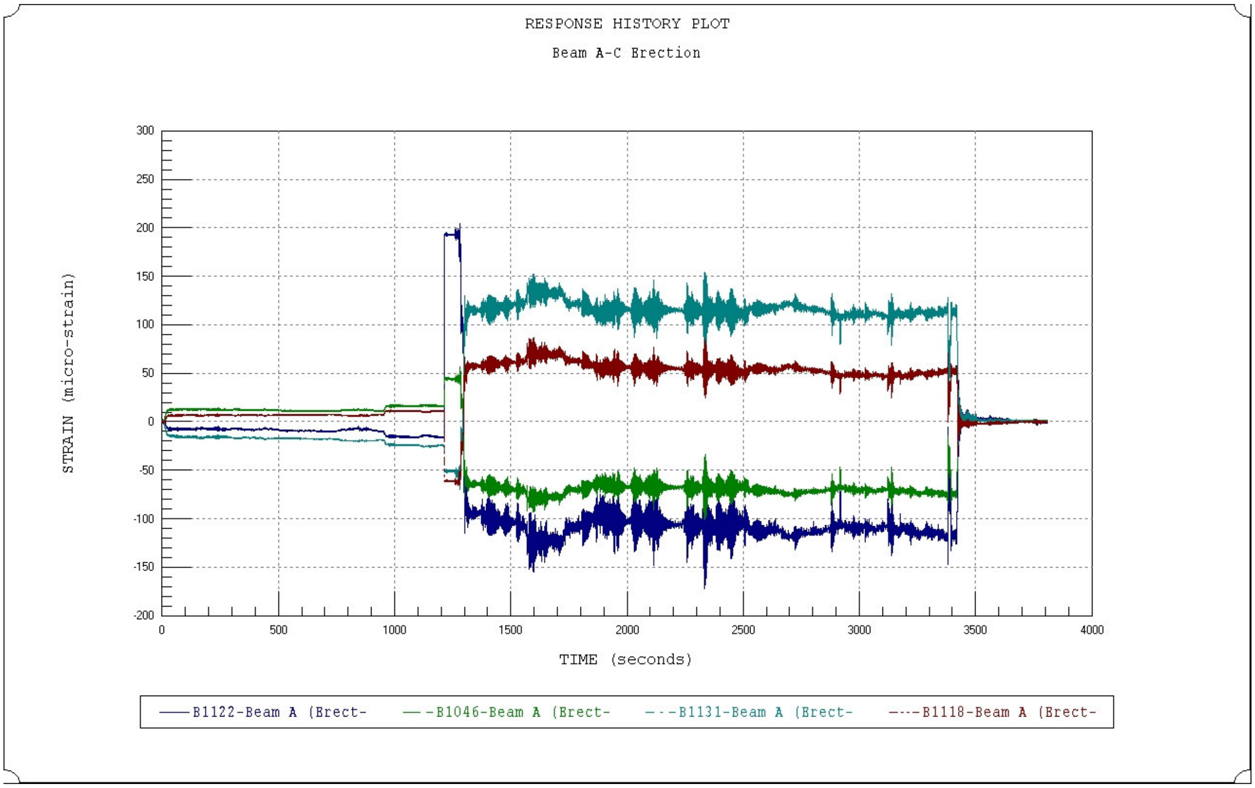

Figure 106 Girder A, File Erect-Full, Cross-Section C.

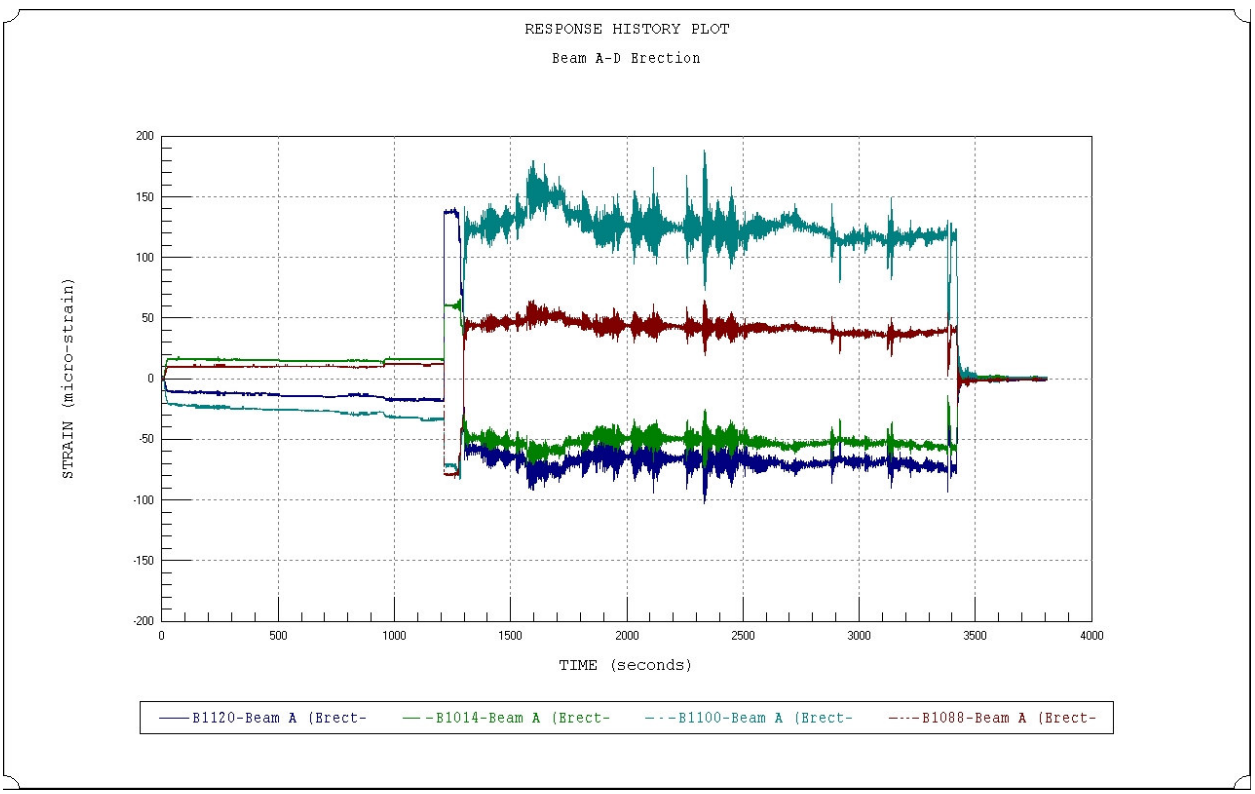

Figure 107 Girder A, File Erect-Full, Cross-Section D.

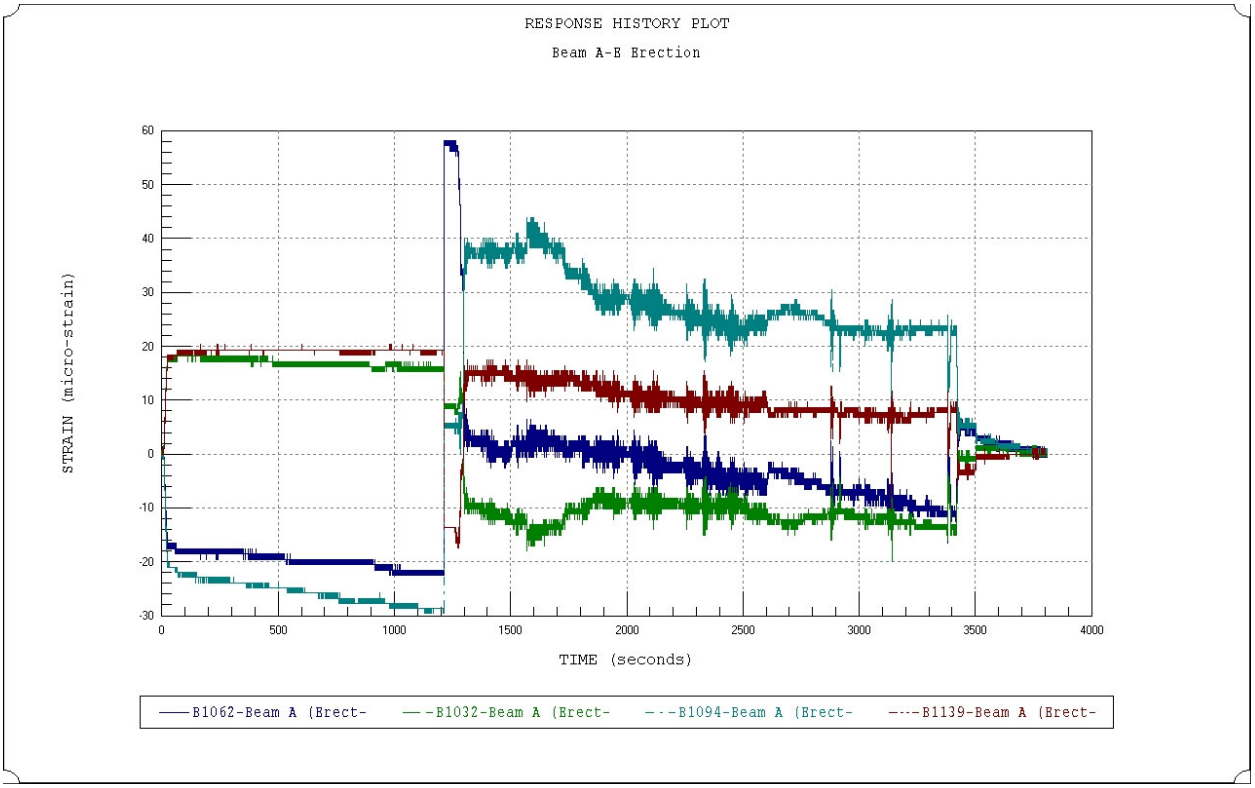

Figure 108 Girder A, File Erect-Full, Cross-Section E.

GIRDER B RESPONSES:

CLICKS: 1- start test
~50sec girder picked from trailer
~1000sec girder set onto bearing
~1075sec cables loosened slightly
~1200sec cables loosened slightly
~1400sec cables slacked and removed from girder

Table 30 Girder B erection strain envelopes.

Beam B *File Name: GriderB_(ecrect-full)_2*			
Cross-Section	Gage Number	Positive	Negative
A	B1128	6	-26
	B1127	35	-20
	5833	27	-19
	8688	33	-4
B	B1126	17	-129
	B1129	16	-82
	5690	151	-27
	6327	80	-10
C	B1087	21	-167
	B1125	17	-95
	4792	186	-30
	B1124	96	-9
D	B1095	15	-132
	B1133	14	-73
	8865	128	-24
	5567	80	-8
E	B1116	12	-27
	B1123	32	-13
	8860	18	-28
	9065	31	-2

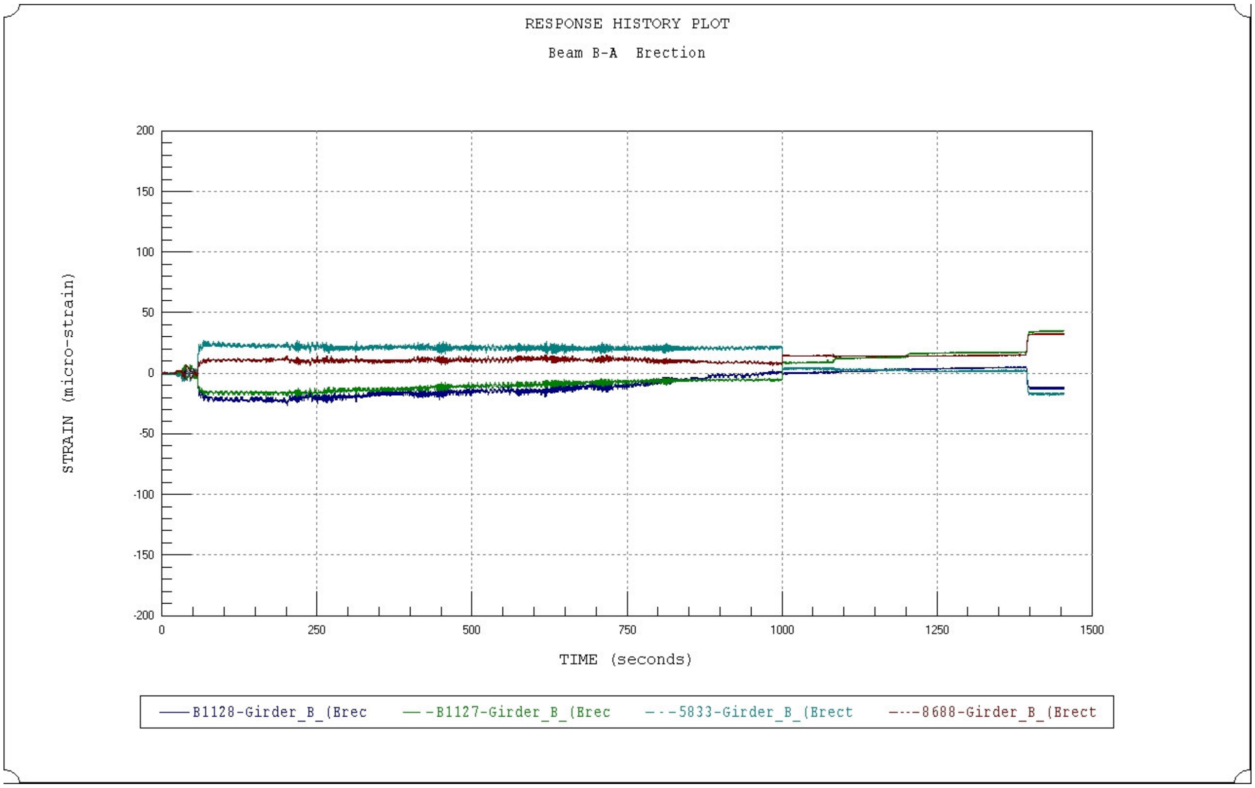

Figure 109 Girder B, File Erect-Full, Cross-Section A.

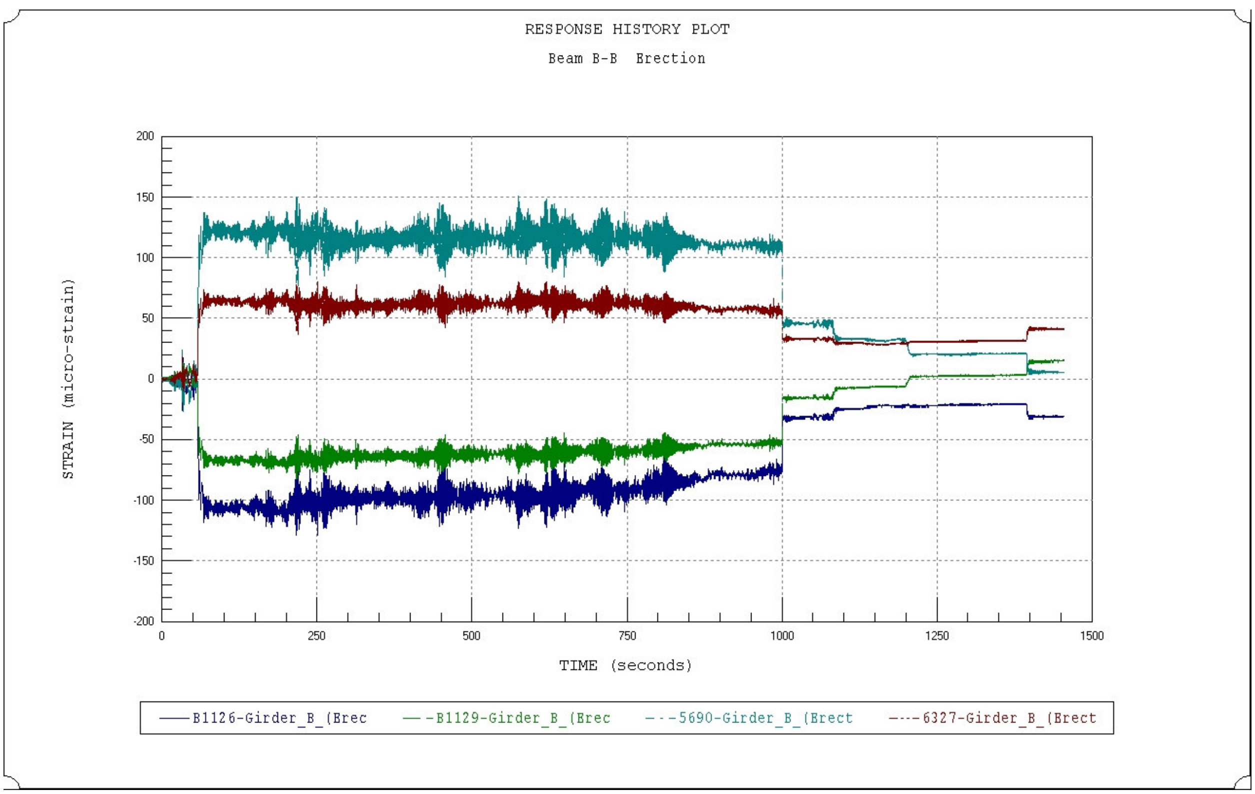

Figure 110 Girder B, File Erect-Full, Cross-Section B.

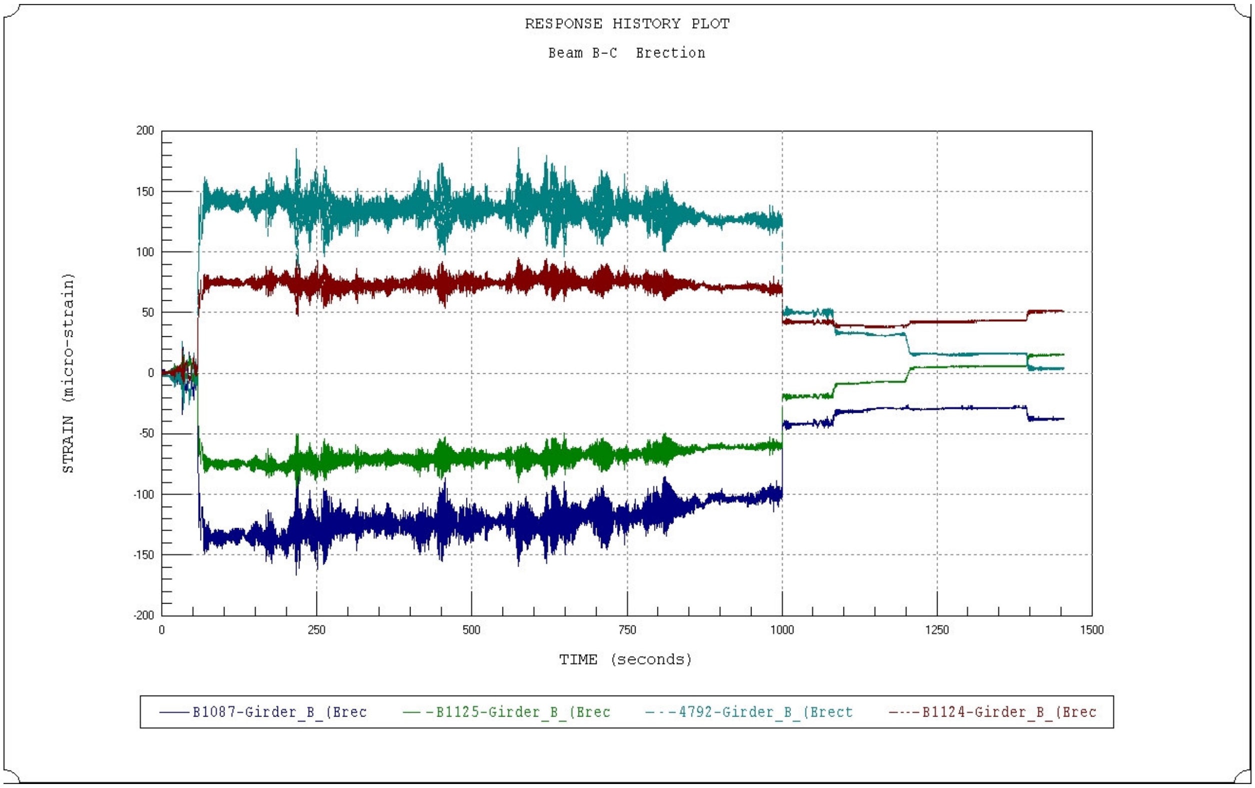

Figure 111 Girder B, File Erect-Full, Cross-Section C.

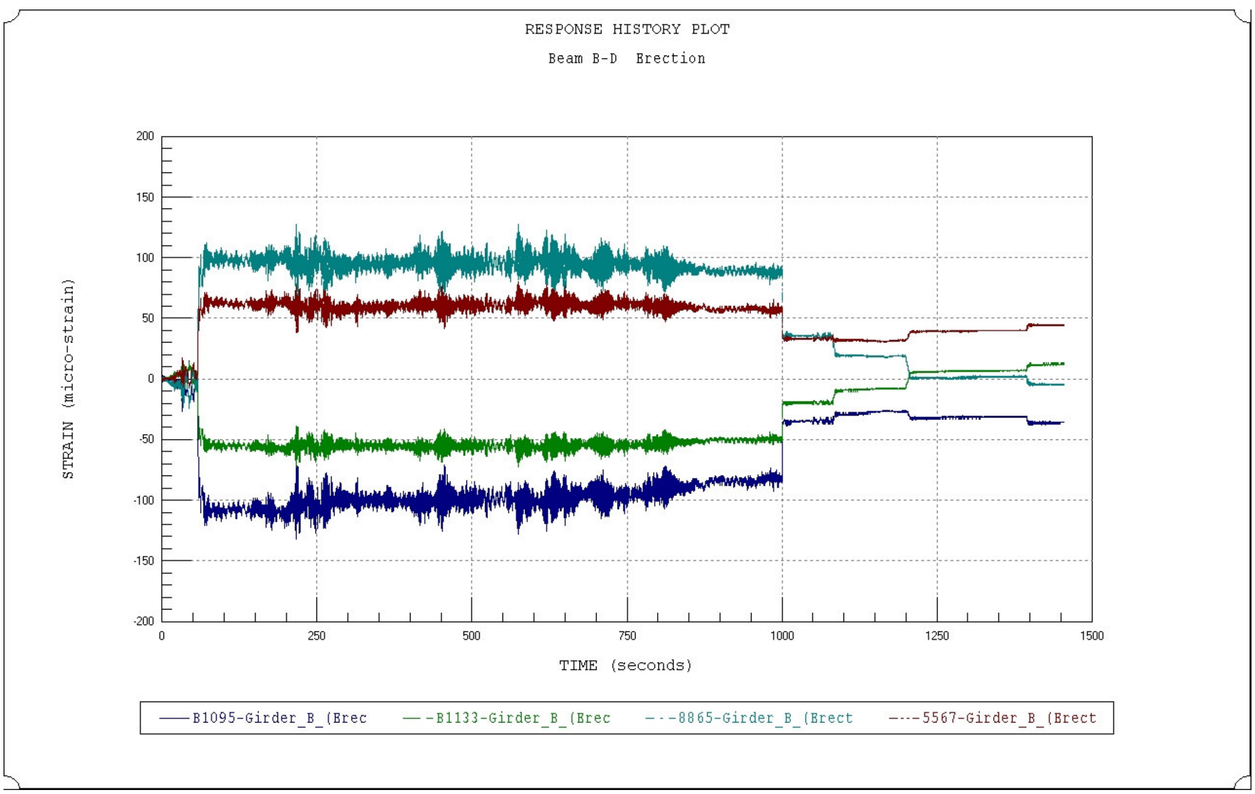

Figure 112 Girder B, File Erect-Full, Cross-Section D.

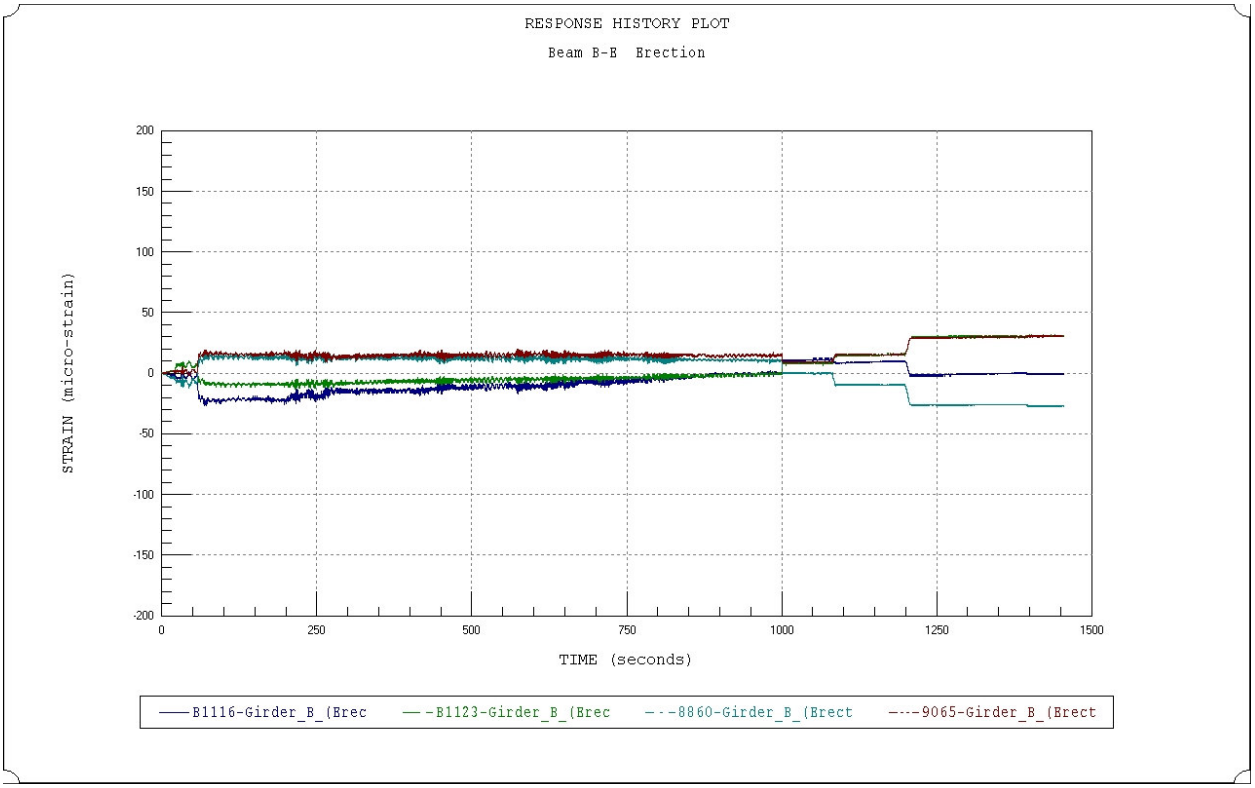

Figure 113 Girder B, File Erect-Full, Cross-Section E.

FURTHER TESTING

Due to the high strains seen during the transportation of the girders, it is recommended that this span of the structure be load tested and rated. It has also been noted within this report that the top flange of Girder A was severely cracked around midspan (see General Observations in the Test Results section of a better description). Due to these two observations it is unknown whether the integrity of the structure was compromised during the pour or transportation of the girders. By performing a simple, one day load test, the effects of the higher-than-expected strains can be evaluated. These results can then be compared to the overall design calculations and decide whether the current design criteria is sufficient for a pre-cast girder of this size.

Testing such as this is a good method of understanding the type of forces a girder is going to experience during its movement, but it is unclear how a beam analysis can be performed due to the number of unknown variables, such as bearing conditions, applied load, etc. As a result, a qualitative overview of the data will allow an engineer to decide if the beam's integrity has been compromised, while a load test will provide the quantitative aspect of the after effects of a movement such as this.

When collecting data with the BDI-STSII a simple text file was produced for each test. This data can be reviewed using BDI's proprietary Win-Graph software (WinGRF) or imported into Excel (or similar) and graphed manually. Below is an overview of the steps that should be taken to import and graph a WinSTS data file in Excel.

Opening a data file: In order to keep data files separated from other text files a suffix of ".dat" has been used in place of ".txt". If your computer does not recognize the ".dat" file, simply right click on the file to be opened and choose the open with -> choose program… button. This will open the window seen below in Figure 114. From this screen either Notepad or WordPad can be selected to open the file.

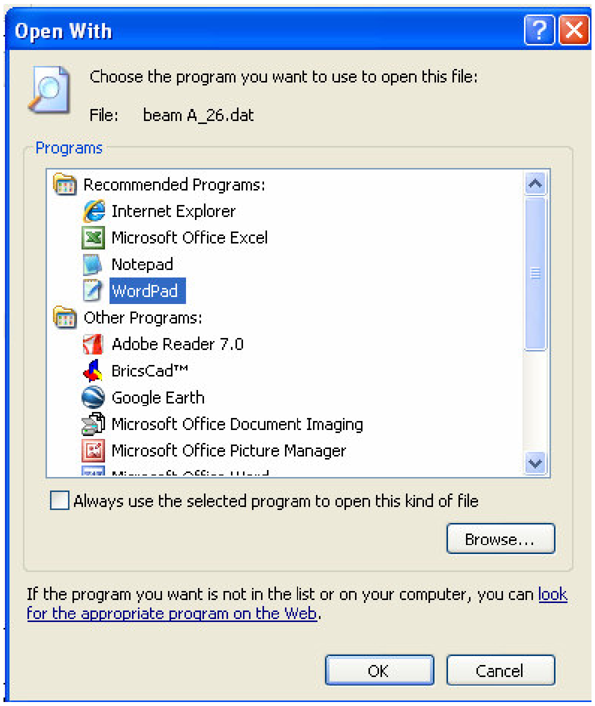

Figure 114 "Open With" window.

Once one of the programs has been chosen, the file will open as seen below in Figure 115. Note that most of the data has been disseminated from this file in order to show all of the important portions of the data file. At this point highlight the entire data file (cntrl+A), copy, and paste into Column B of a blank Excel worksheet.

Text to Columns: This operation is going to put all of the data into a single column. To separate the data into individual columns ensure the data column is highlighted and go to Data -> Text to Columns… and the screen in Figure 116 will open. From here follow these steps: choose delimitated, click the next button, uncheck all of the boxes except comma, click the next button, click the finish button. At this point each cell should contain a single piece of information, such as a strain value, ID number, etc. For this application most of this information is irrelevant, and can either be left alone or deleted. The same data file can be seen Figure 117 with the important information circled in red.

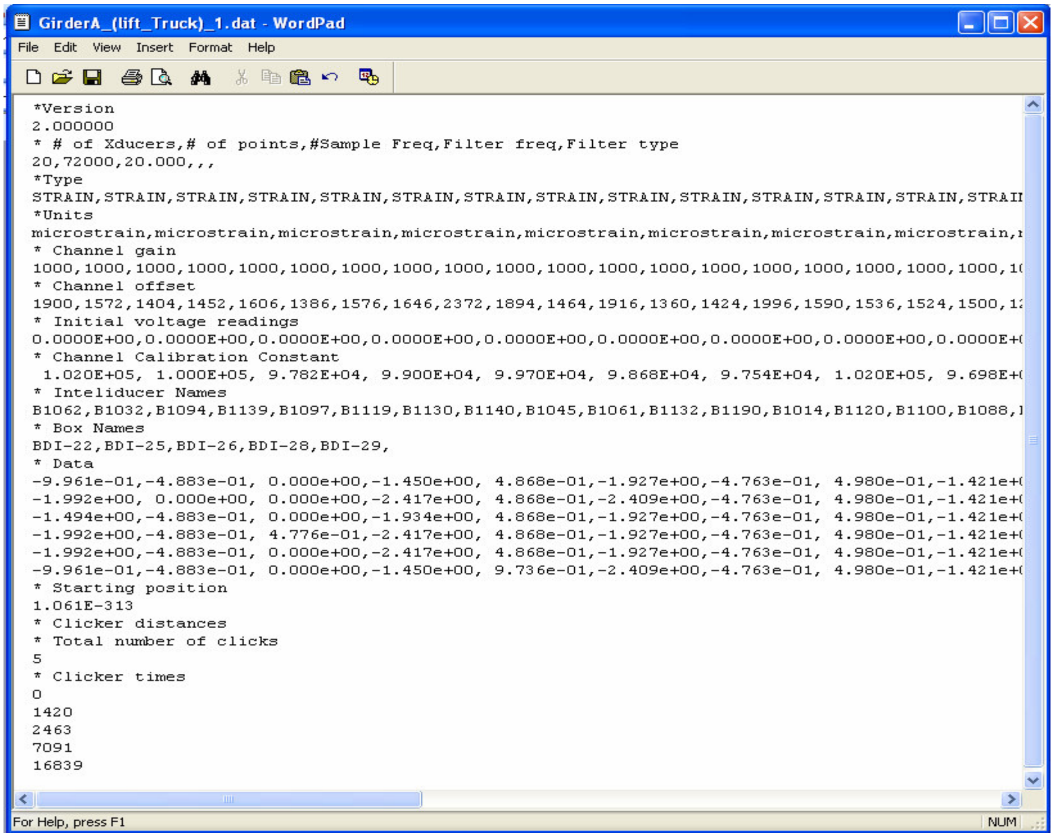

Figure 115 Example data file.

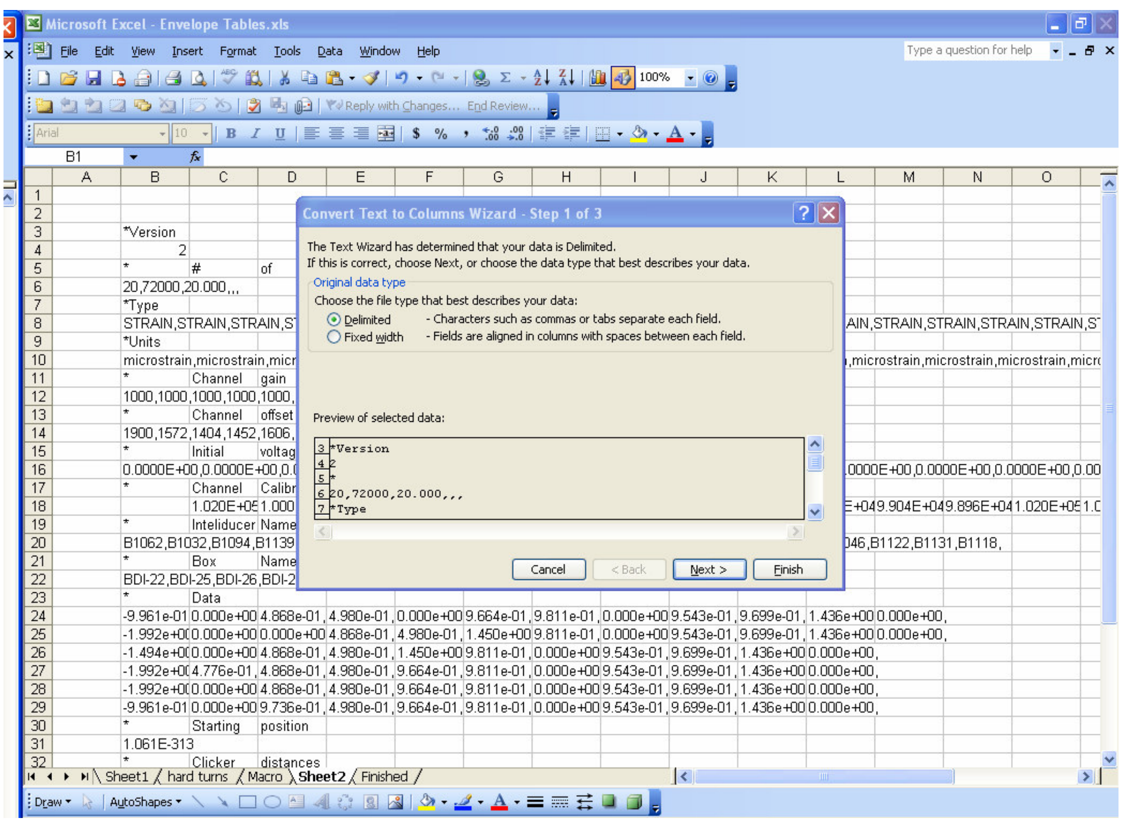

Figure 116 *Text to Columns* screen.

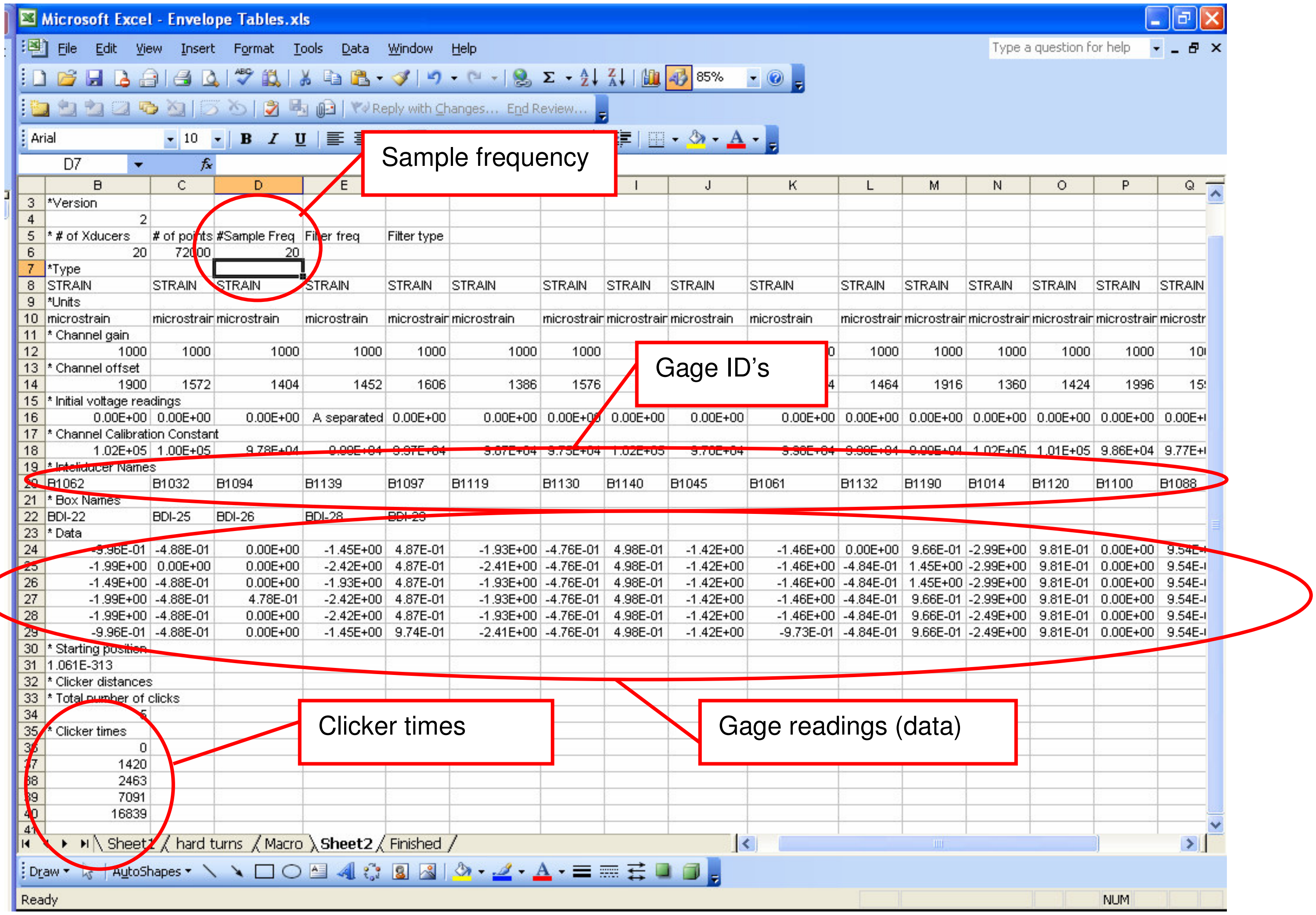

Figure 117 Separated data file.

Graphing: Each column has a gage ID and a string of data, so each gage ID corresponds to the data in the same column. In Column A, which should have been left blank when the data was imported into the spread sheet, time needs to be added. Next to the first data point (cell A24) enter "0". In cell A25 add the following equation: "=A24+ 1/sample frequency" (i.e. = 0 + 1 / 20). Copy this equation to all cells with a data point in Column B. To graph this data, highlight one of the column of data that is of interest, for example B1139. Click the graph button, select *XY (Scatter)* and under sub-type select *scatter with data points connected by smoothed lines without markers*. Click *Next* and under the Series tab, name the series by clicking the icon next to the entry box and selecting B1139 from the spreadsheet. Add the x values by highlighting the numbers in the time column (Column A). Other series can be added in this screen by clicking the *Add* button and highlighting the correct data column. Add the series name and time values as previously done. Once all of the series are selected click the Next button and enter the appropriate chart title and axis information. A competed example plot can be seen below in Figure 118.

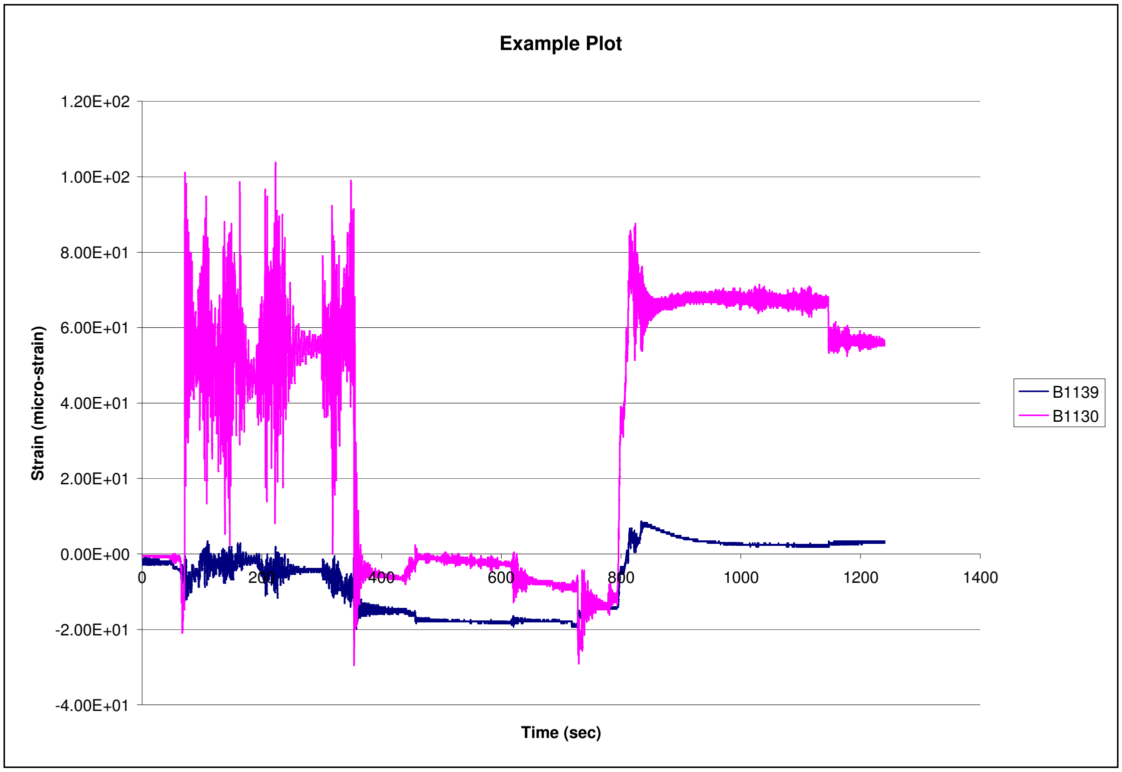

Figure 118 Example plot

Event markers: To add position markers the clicker information must be manipulated. As seen in Figure 117 the clicker times are simply a sample number. In other words, the numbers given in this field are the sample numbers in which a click was added to the data. To get this information in terms of time, simply divide the clicker time by the sample frequency. For example, clicker time 1420 occurred at 71 seconds (1420/20 = 71 seconds). These can be used in attempts to understand why a certain load was seen. These can be graphed, but it is quite tedious. First calculate all of the event times (clicks) and make two columns of this click information (see Figure 119). Next, find a good range to draw a vertical line from the example plot in Figure 118, say 0 to -60 in this case. Enter this information in cells near the click information (see Figure 119).

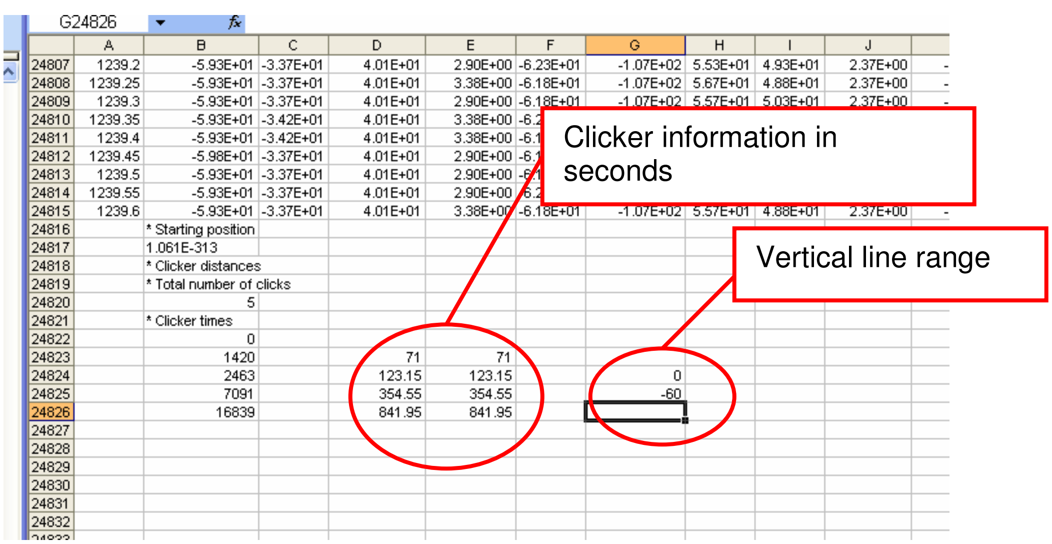

Figure 119 Click information on spreadsheet.

Right click on the chart and open *Source Data*. Click the *Add* button and for the X-values, highlight the click columns (e.g. 71, 71) and for the Y-values, highlight the vertical line range (0, -60) and give the series a relevant name. In Figure 120 below, the event markers can be seen as vertical lines. Note that the line width was increased to make the clicks stand out.

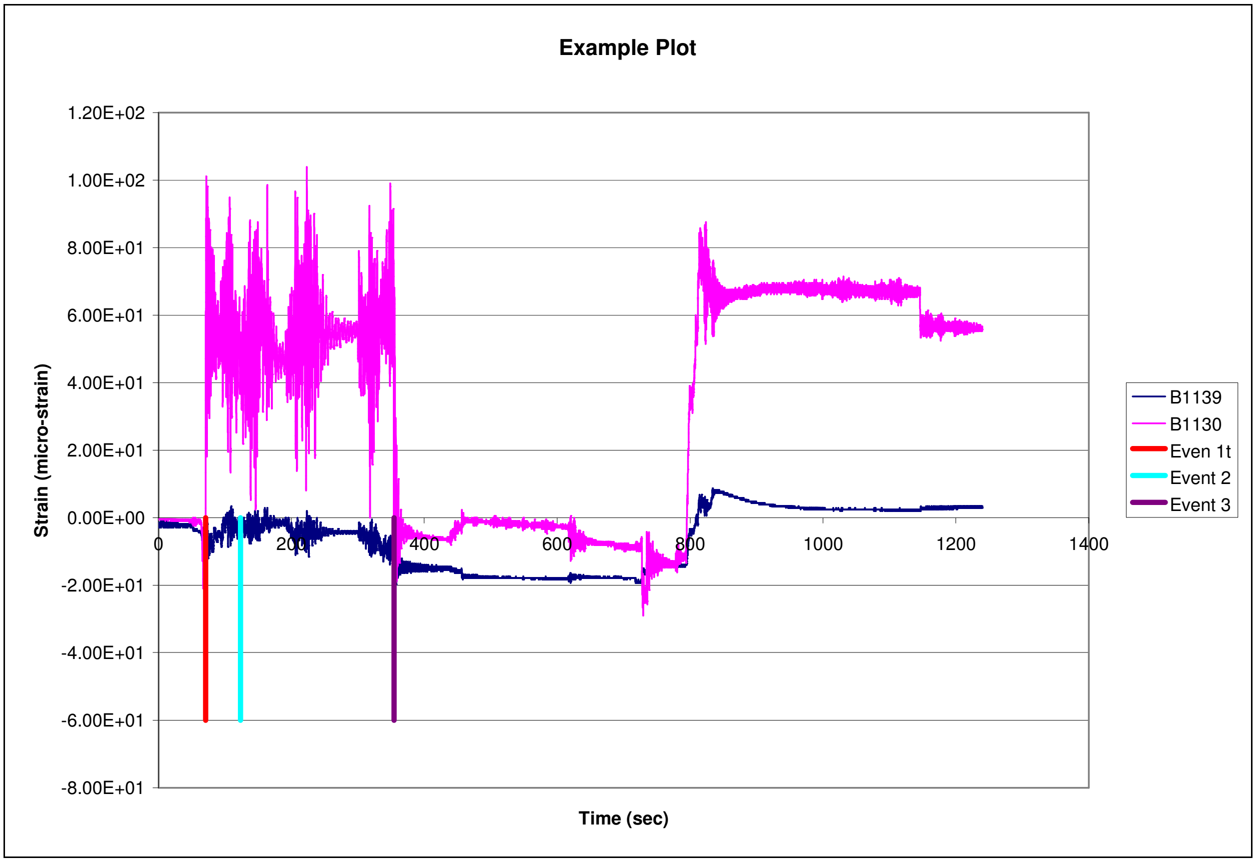

Figure 120 Example plot with clicks.

If a significant amount of data review is going to be performed on this supplied data it is highly recommended that WinGRF be used. Instead of spending hours on data preparation in Excel WinGRF will make these same graphs with a single button click.

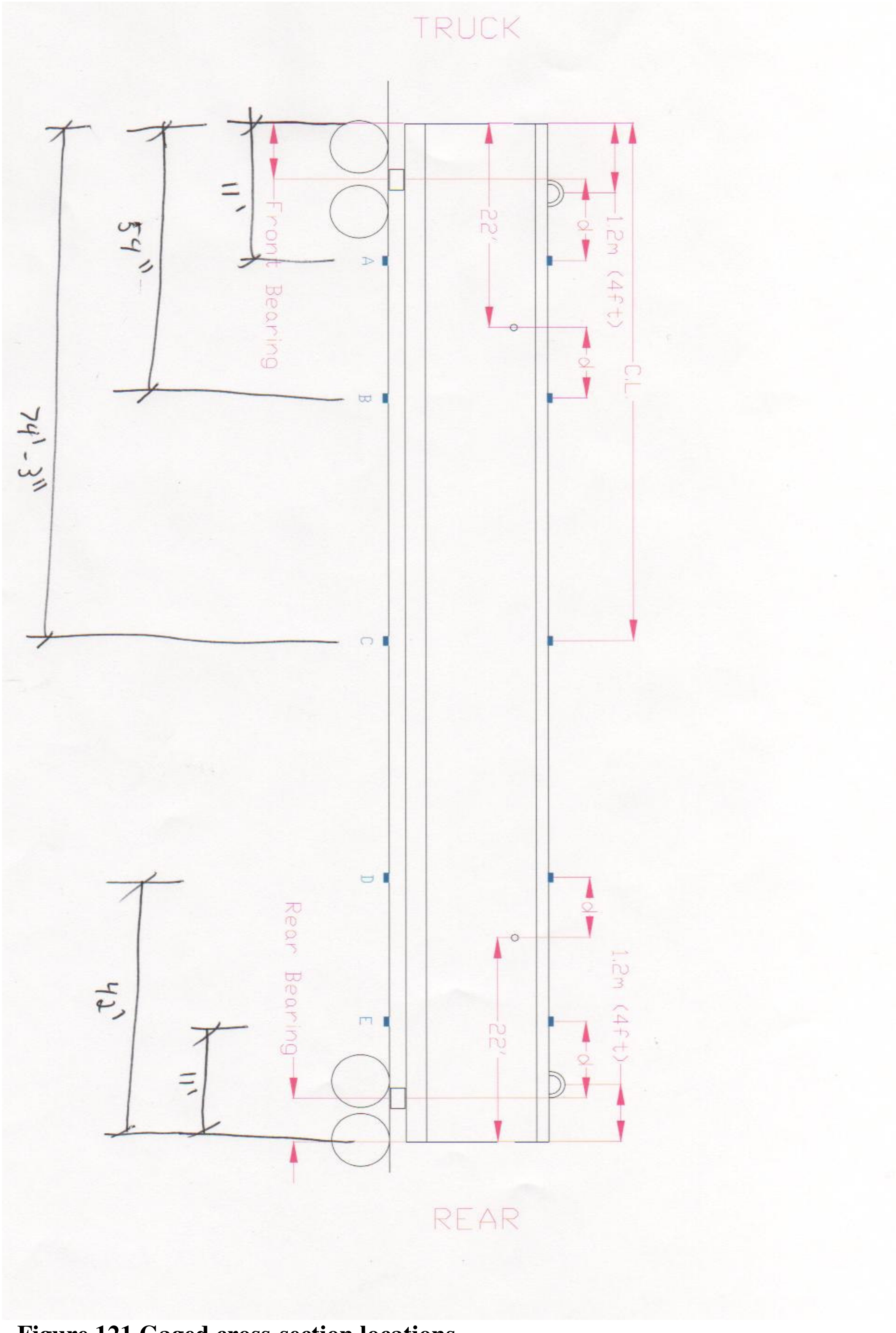

Figure 121 Gaged cross-section locations.

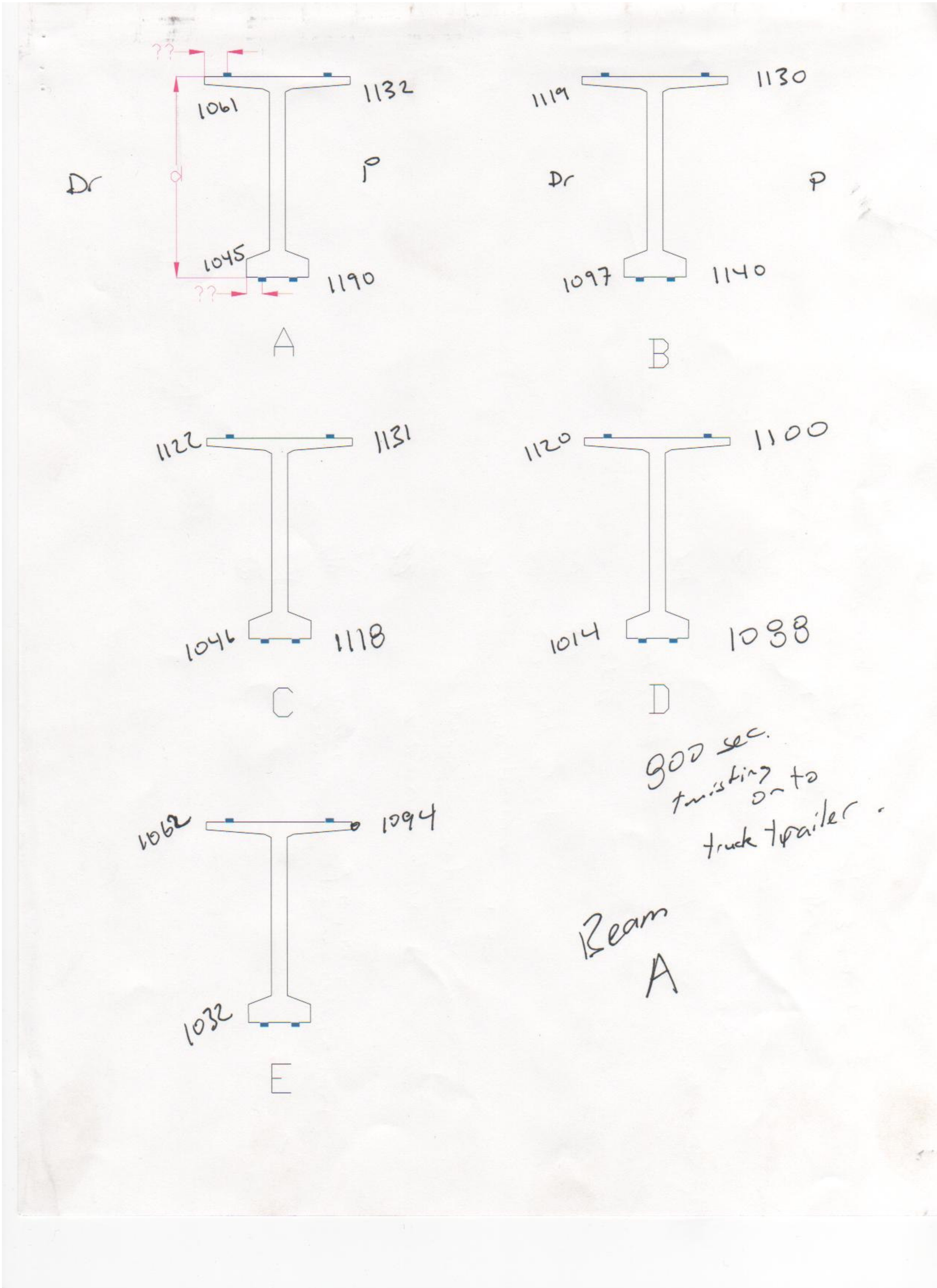

Figure 122 Beam A gage locations for each cross-section.

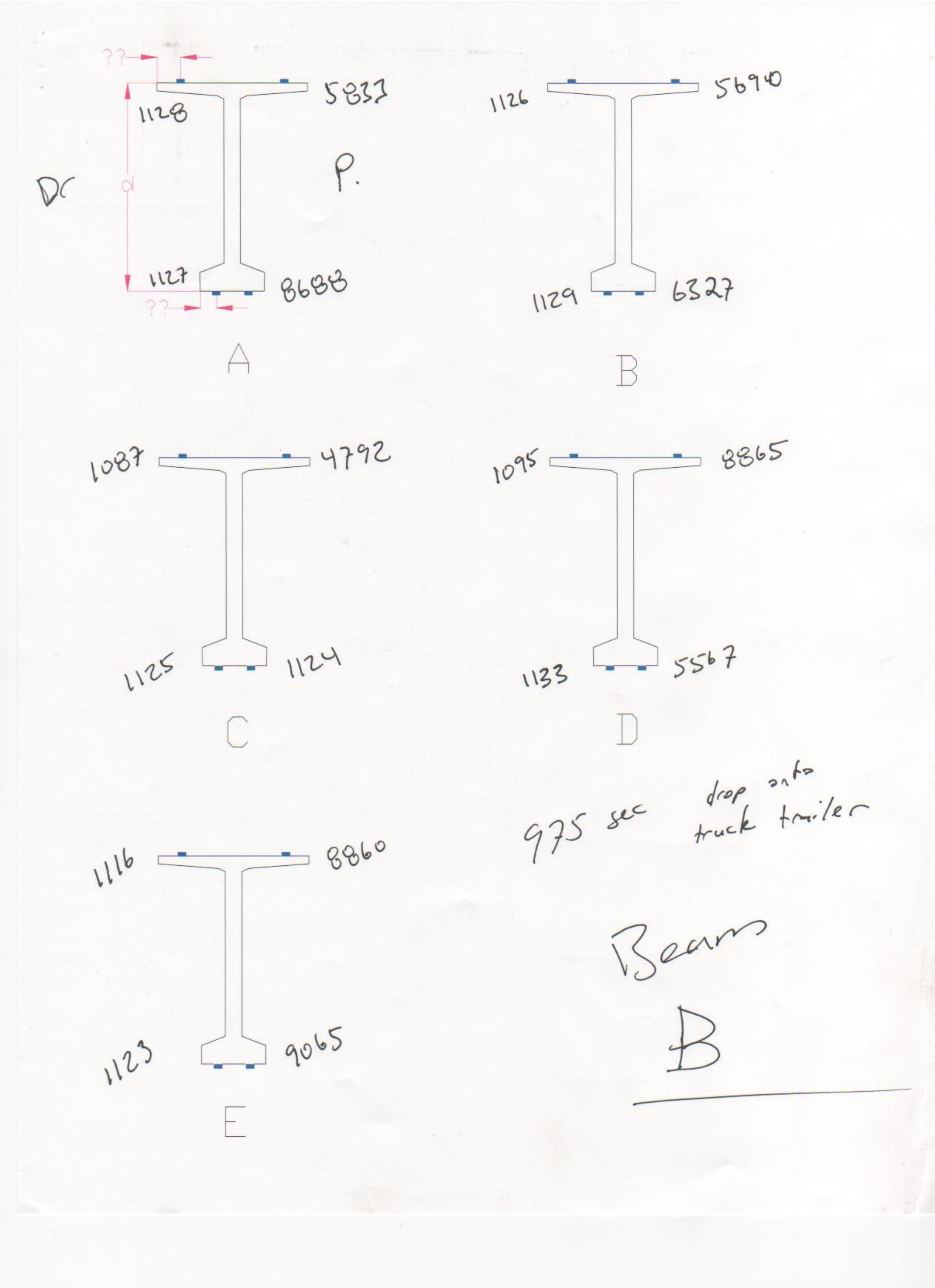

Figure 123 Beam B gage locations for each cross-section.

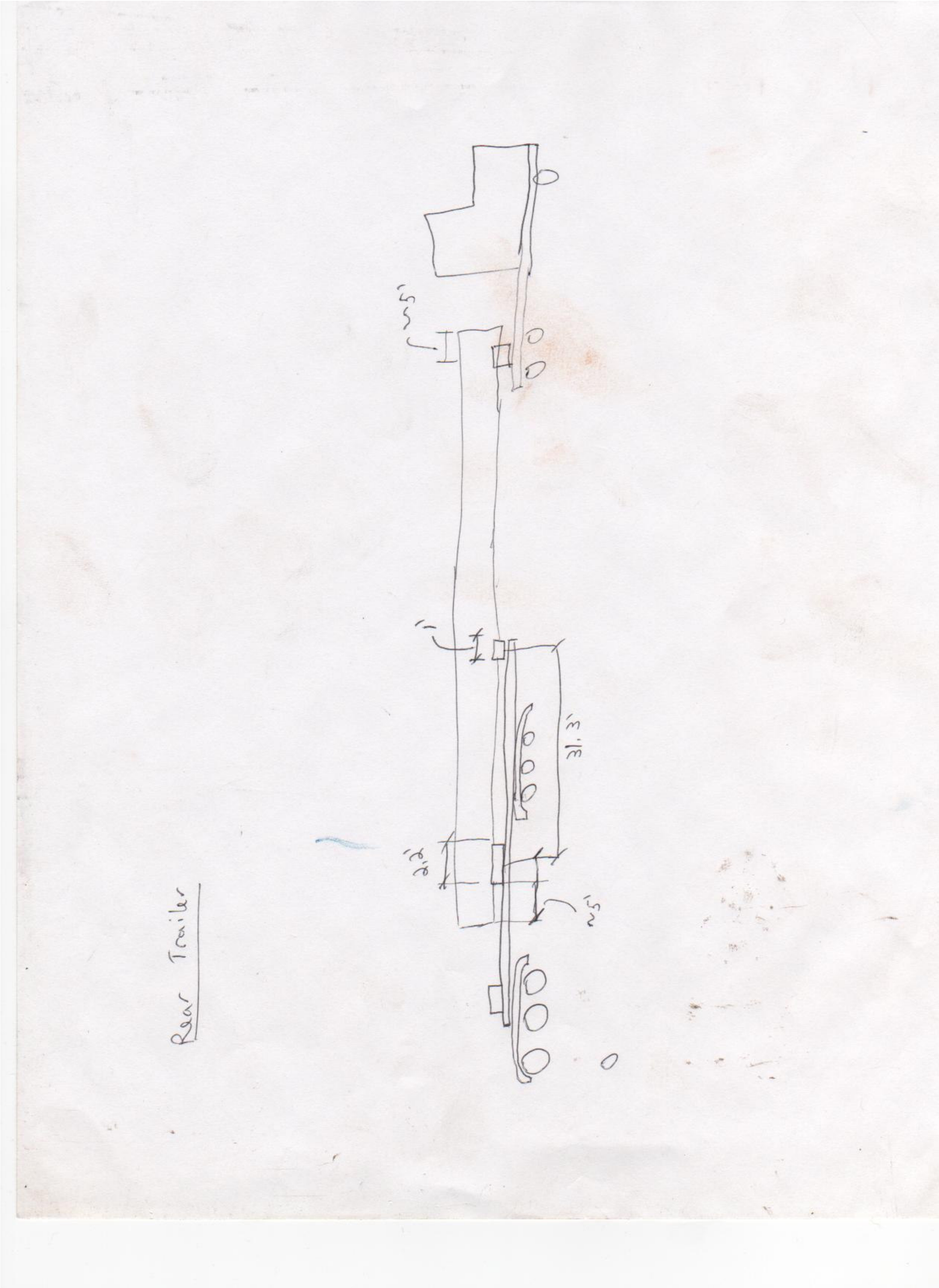

Figure 124 Truck and bearing dimensions.

Beam A

Feature	Est. Sample Rate	Mi #	Picture #	File Name	Speed	Clicks	
Turn out of yard	40	0	350, 351	1			
RR Tracks	50	0.2	352	4		#2 Truck hits tracks	
Asphalt Control	50	0.8	353	2	19	Hilly	
Left onto 80	50	1.8	354	3		2 start turn 3 truck straight 4 straight	1100 clip
Rough Asphalt	~~100~~ 50	2.1	355	4	8		
Asphalt Control	100	5.4	357	5	38		
Left turn to get to I-20 (PR-117)	50	6.8	358	6		Balanced 500gain truck went on curb clicks are @ wheels hitting curb	Gain 560
right onto I-20 (include on-ramp)	50	7.1	359, 360	8		click @ start Diff. in Load due to rd elev	
~~Asphalt Control~~	~~100~~	~~8.5~~	~~361~~	Skipped			
Overpass	50	9.4	362	9	42	2nd Tires hit Bridge	
Bump 1	100	9.8		1		#3	
Concrete control 1	100	10.6	363	1		#4	
Left turn 1	50	12.1	364	10			
Overpass 2	50	12.9	365	11	55		
Bridge 1	50	13.2	366	12			
Bridge 2	50	13.6	367	"			
Bridge 3	50	14		"			

Figure 125 Beam A data collection information.

Bridge 4	50	15.6	368	〃		
Bridge 5 ←	~~50~~	~~15.8~~		Missed		→
Dip in road	~~100~~ 50	18.2		13		
Bumps + Bridge 5 & 6	50	22		13	??	Balance clicks @ Bridges
Bridge 7 & 8	50	23.7	371, 372	14	60	clicks @ Bridges
Bridge 9, 10, 11	50	27	373, 374, 375	15	60	#2 rough!
Bridge 12	50	29	376	16		Missed 1/2
Bridge 13 + Concrete control	50	34.6	377	17	45-55	#2 Bridge #3 CCF
Left curve	50	41.8	378	18		Balance
Bridge 14 + some	50	54		19	60	
Concrete control 4	50	58	379	20	65	
Bridge 15 + Asphalt	50	62.3	380	21, 22	55	21 Bridge 22 Asphalt 32secs slowing down
Bridge 16, 17 : Bridges	50	66	383	24	57	#23 leaving rest area
Asphalt/ concrete control	100	67	384	24	58	85 sec As → Conc
Bump + Bridge 19	75	68.7-73.7		25	60	#2 Bridge #3 Very Bumpy #4 New Asphalt
Right curve	50	81.8		26		

Figure 126 Beam A data collection information (con't).

Transition + concrete+ overpass (include exit to 165)	75	83.4	389	27	55	#2 change to ... 3 @ Bridge; 4 rough Bridge 5 Stop
Bumpy	50	89	391	28	30-45	Balance
Bumpy + Bridge 20	50	89.7	392	28		#2 @ Bridge
Bridge 21, 22 + hill, br 23, left and right curve	100	91.8	393 thru 395	29		#2 start up hill Bridge round corner left, Round corner right
RR Tracks	100	94	396			Missed
Asphalt Control	50	95.5	397			Skip
Right curve to dbl lanes	50	99	398	30	40	
Right curve	50	99.5	399	30	50	2nd click
left thru const. + 1min (3.8 miles total)	100	103		31		2 superelevation 4 Bumps 3 Bumps
left turn + bridge 25 + bumps	100	109	405	32		150sec curve, hill, Bridge
Const.	100	109.8		33		2 superelev change
Right curve	50	110.7		33		
Left curve + big bump @ 112.5	50	111.9		34		Balance 2 start corner 3 Big Bump 4 grade change 5 hard right 6 superelev change
Bumps + left + right	50	113.2		34		
enter city	50	116.4	411, 412	35		

3) 982-0821

Figure 127 Beam A data collection information (con't).

Feature	Est. Sample Rate	Mi #	Picture #	File Name	Speed	Clicks
Turn out of yard	40	0	350, 351	[illegible]		[illegible]
RR Tracks	50	0.2	352	[illegible]		
Asphalt Control	50	0.8	353	[illegible]	[illegible]	
Left onto 80	50	1.8	354	[illegible]	[illegible]	[illegible]
Rough Asphalt	100	2.1	355	[illegible]	[illegible]	
Asphalt Control	100	5.4	357	[illegible]	[illegible]	
Left turn to get to I-20 (PR-117)	50	6.8	358	[illegible]		[illegible]
right onto I-20 (include on-ramp)	50	7.1	359, 360	[illegible]		[illegible]
Asphalt Control	100	8.5	361	[illegible]		[illegible]
Overpass	50	9.4	362	[illegible]		[illegible]
Bump 1	100	9.8		[illegible]	[illegible]	[illegible]
Concrete control-1	100	10.6	363			
Left turn 1	50	12.1	364	[illegible]	[illegible]	
Overpass 2	50	12.9	365	[illegible]	[illegible]	[illegible]
Bridge 1	50	13.2	366			[illegible]
Bridge 2	50	13.6	367			[illegible]
Bridge 3	50	14				[illegible]

Figure 128 Beam B data collection information.

Bridge 4	50	15.6	368	[illegible]	[illegible]	[illegible]
Bridge 5	50	15.8		[illegible]		[illegible]
Dip in road	100	18.2		[illegible]		[illegible]
Bumps + Bridge 5 & 6	50	22		[illegible]	[illegible]	
Bridge 7 & 8	50	23.7	371, 372	[illegible]	[illegible]	[illegible]
Bridge 9, 10, 11	50	27	373, 374, 375	[illegible]		[illegible]
Bridge 12	50	29	376	[illegible]		
Bridge 13 + Concrete control	50	34.6	377	[illegible]	[illegible]	[illegible]
Left curve	50	41.8	378	[illegible]		[illegible]
Bridge 14 + some	50	54		[illegible]		[illegible]
Concrete control 4	50	58	379	[illegible]		
Bridge 15 + Asphalt	50	62.3	380	[illegible]		[illegible]
Bridge 16, 17 [illegible]	50	66	383	[illegible]		[illegible]
Asphalt/ concrete control	100	67	384	[illegible]		[illegible]
Bump + [illegible]	75	68.7-73.7		[illegible]	[illegible]	[illegible]
Right curve	50	81.8		[illegible]		[illegible]

Figure 129 Beam B data collection information. (con't).

Transition + concrete+ overpass (include exit to 165)	75	83.4	389	[illegible]	[illegible]	[illegible]
Bumpy	50	89	391	[illegible]		[illegible]
Bumpy + Bridge 20	50	89.7	392	[illegible]		[illegible]
Bridge 21, 22 + hill, br 23, left and right curve	100	91.8	393 thru 395	[illegible]		[illegible]
RR Tracks	100	94	396	[illegible]		[illegible]
Asphalt Control	50	95.5	397			
Right curve to dbl lanes	50	99	398	[illegible]		[illegible]
Right curve	50	99.5	399			
left thru const. + 1min (3.8 miles total)	100	103		[illegible]		[illegible]
left turn + bridge 25 + bumps	100	109	405	[illegible]		[illegible]
Const.	100	109.8	[illegible]	[illegible]		[illegible]
Right curve [illegible]	50	110.7				
Left curve + big bump @ 112.5	50	111.9		[illegible]		[illegible]
Bumps + left + right	50	113.2				[illegible]
enter city	50	116.4	411, 412			

Figure 130 Beam B data collection information. (con't).

Effective gage length:	3.0 in (76.2 mm). Extensions available for use on R/C structures.
Overall Size:	4.4 in x 1.2 in x 0.5 in (110 mm x 33 mm x 12 mm).
Cable Length:	10 ft (3 m) standard, any length available.
Material:	Aluminum
Circuit:	Full wheatstone bridge with four active 350Ω foil gages, 4-wire hookup.
Accuracy:	± 2%, individually calibrated to NIST standards.
Strain Range:	Approximately ±4000 με.
Force req'd for 1000 με:	Approximately 9 lbs. (40 N).
Sensitivity:	Approximately 500 με/mV/V,
Weight:	Approximately 3 oz. (88 g),
Environmental:	Built-in protective cover, also water resistant.
Temperature Range:	-60°F to 250°F (-50°C to 120°C) operation range.
Cable:	BDI RC-187: 22 gage, two individually-shielded pairs w/drain.
Options:	Fully waterproofed, Heavy-duty cable, Special quick-lock connector.
Attachment Methods:	C-clamps or threaded mounting tabs & quick-setting adhesive.

APPENDIX D – SPECIFICATIONS: BDI STRUCTURAL TESTING SYSTEM

Channels	4 to 128, Expandable in multiples of 4
Hardware Accuracy	± 0.2% (2% for Strain Transducers)
Sample Rates	0.01 to 1,000 Hz sample rate. Internal over-sampling rate is 15 KHz.
Max Test Lengths	20 minutes at 100 Hz. 128K samples per channel maximum test length.
Gain Levels	1, 250, 500, 1000
Digital Filter	Fixed by selected sample rate
Analog Filter	200 Hz, -3db, 3rd order Bessel
Max. Input Voltage	±10V
Power	85 - 264 VAC, 47-440 Hz -25 to 55 degrees C
12VDC Power	External inverter included
Excitation Voltages: Standard: LVDT:	 5VDC @ 200mA ±15VDC @ 200mA
A/D Resolution	2.44 uV/bit (14-Bit ADC)
PC Requirements	Windows 2000, XP
PC Interface	USB 1.1 Port (Compatible with USB 2.0)
Self-Balancing Range	± 20 mV @ input with 350Ω Wheatstone bridge
Enclosures	Aluminum splash resistant
Cable Connections	All aluminum military grade, circular bayonet “snap” lock.
Vehicle Tracking:	See “AutoClicker” Specifications
Sensors	See “BDI Strain Transducer” Specifications Also supports LVDT’s, foil strain gages, accelerometers, various DC output sensors. Single RS232 serially-interfaced sensor.
Weights: Power Unit: STS Unit	 6.2 lbs (2.8 kg) 1.6 lbs (0.7 kg)
Dimensions: Power Unit: STS Unit:	 13.5” x 9.5” x 2.4” (343mm x 242mm x 61 mm) 11.8” x 3.4” x 1.7” (300mm x 87mm x 44mm)

Commander, B. (1989). "An Improved Method of Bridge Evaluation: Comparison of Field Test Results with Computer Analysis." Master Thesis, University of Colorado, Boulder, CO.

Gerstle, K.H. and Ackroyd, M.H. (1990). "*Behavior and Design of Flexibly-Connected Building Frames.*" Engineering Journal, AISC, 27(1),22-29.

Goble, G., Schulz, J., and Commander, B. (1992). "Load Prediction and Structural Response." Final Report, FHWA DTFH61-88-C-00053, University of Colorado, Boulder, CO.

Lichtenstein, A.G.(1995). "Bridge Rating Through Nondestructive Load Testing." Technical Report, NCHRP Project 12-28(13)A.

Schulz, J.L. (1989). "Development of a Digital Strain Measurement System for Highway Bridge Testing." Masters Thesis, University of Colorado, Boulder, CO.

Schulz, J.L. (1993). "In Search of Better Load Ratings." *Civil Engineering*, ASCE 63(9),62-65.