BONNER BRIDGE
Load Test of Spans 186 and 189

Bridge # 270011
Dare County, NC

Final Report
9 June 2006
WJE No. 2005.5426

Prepared for:
Bridge Maintenance Unit
North Carolina Department of Transportation

Prepared by:
WJE Engineers & Architects, PC

BONNER BRIDGE
Load Test of Spans 186 and 189

Bridge # 270011
Dare County, NC

Scott R. Canfield

Travis P. Green, P.E.

Mark Moore, P.E.

NORTH CAROLINA PROFESSIONAL SEAL 028047 ENGINEER MARK EDWARD MOORE
6-21-06

Final Report
9 June 2006
WJE No. 2005.5426

Prepared for:
Bridge Maintenance Unit
North Carolina Department of Transportation
4809 Beryl Road
Raleigh, NC 27606

Prepared by:
WJE Engineers & Architects, PC
4165 Shackleford Road, Suite 100
Norcross, Georgia 30093
770.923.9822 tel | 770.923.1966 fax

TABLE OF CONTENTS

BONNER BRIDGE
Load Test of Spans 186 and 189

Bridge # 270011
Dare County, NC

BACKGROUND

During the 2006 bi-annual routine inspection of the Bonner Bridge conducted by Alpha & Omega Group (A&O) in March and April 2006, severe deterioration was observed near mid-span of girder G3 (second girder from the west side) in Span 189. A&O reported approximately 11 broken or deteriorated prestressing strands at mid-span of the girder. The deteriorated area had been repaired with an epoxy-based repair material but the broken and/or partially broken prestressing strands had not been repaired. As part of the evaluation of the deteriorated condition observed in Span 189, a load test was conducted. The purpose of the load test was to assess the response of girder G3 to a controlled truck loading and evaluate the lateral distribution of the truck loading to adjacent girders. To allow for comparison with a span with no severely deteriorated girders, the load testing was repeated in Span 186. Spans 186 and 189 are located near the south end of the bridge and have fishing piers to the east and west. This report provides a summary of the load testing conducted and the behavior of the girders in spans 186 and 189 under the controlled truck loadings.

LOAD TEST SETUP

For spans 186 and 189, the cross-section of the bridge consists of four prestressed concrete girders spanning 59 ft. 7 in. between pile bents. The girders support a 7.25 in. cast-in-place reinforced concrete deck that forms the roadway surface. The total width of the bridge is 25 ft. 3 in. including a 20 ft. roadway. Details of the bridge girders and bridge cross section are shown in Figures 1 and 2.

Prior to application of the controlled truck loading, instrumentation and a data acquisition system were assembled in both spans. The instrumentation consisted of the following.

1. For girders G2, G3, and G4, a series of six strain gages were installed on the surface of the prestress concrete beams at the mid-span location. The location of the strain gages is shown in Figure 1a and 1b.
2. For girders G2, G3 and G4, a linear variable displacement transducer (LVDT) was installed at the north end of each girder to measure vertical displacement of the girder relative to the pile bent.
3. For girders G2, G3 and G4, a linear motion transducer (or string potentiometer) was installed at mid-span to measure the girder deflection under the truck loading.

The location and channel number for each strain gage, string pot, and LVDT are illustrated in Figures 1a and 1b. The string pots were used to collect mid-span deflections (Figure 4) while the LVDT's were used to measure bearing pad compression (Figure 5). Prior to installing the string pots, WJE installed galvanized reference wires between the bent caps. All data was collected using a Pacific Instruments 660-6000 data acquisition system capable of collecting up to 24 data channels simultaneously. The acquisition system was located on the west fishing pier.

SPAN LOADINGS

Three different truck positions were used to apply the test loadings in each span as illustrated in Figure 2. The three loadings were chosen to maximize the load on girder G3. The test truck load was applied to the bridge in two states; quasi-static and moving at 35 mph. A truck of known weight was provided by the NCDOT. The total weight of the test truck was 55,800 lbs with a front axle weight of 14,200 lbs and 20,850 lbs on each of the two rear drive axles. Detailed truck weight information is included in Attachment A.

For the first three loadings on each span, the truck speed was very slow in order to produce pseudo-static results. For the last three loadings on each span, the truck speed was increased to approximately 35 mph in an attempt to apply impact loadings to the girders. Table 1 provides a brief description of each span loading. Figures 6, 7 and 8 illustrate the three different truck positions.

Table 1. Truck position and speed for each span loading.

Loading No.	Span	Speed	Position of truck
1	189	5 mph or less	Left wheel over Girder No. 3
2		5 mph or less	Right wheel over Girder No. 3
3		5 mph or less	Truck centered over Girder No. 3
4		35 mph	Left wheel over Girder No. 3
5		35 mph	Right wheel over Girder No. 3
6		35 mph	Truck centered over Girder No. 3
7	186	5 mph or less	Left wheel over Girder No. 3
8		5 mph or less	Right wheel over Girder No. 3
9		5 mph or less	Truck centered over Girder No. 3
10		35 mph	Left wheel over Girder No. 3
11		35 mph	Right wheel over Girder No. 3
12		35 mph	Truck centered over Girder No. 3

LOAD TEST DATA

Load test results are provided in Figures 9-20. The field data used to create these graphs has been edited slightly. WJE edits include the following.

1. All data curves have been smoothed.
2. All strain gage values are an average of the top, middle, or bottom two strain gages on each girder.
3. The Span 186 data has been separated into static (loadings 7, 8, and 9) and dynamic (loadings 10, 11, 12) segments.
4. Drift was removed from the mid-span displacement curves for Span 186.
5. Drift was removed from the mid-span displacement curve for Girder 4, Span 189.

Edited and/or unedited data files are available upon request. Table 2 provides a summary of the maximum bottom flange strain and mid-span deflection for each loading.

Table 2. Maximum strain and deflection for each span loading.

Loading No.	Span	Max. mid-span strain at girder soffit (με) (average of gages 3&4)			Max. mid-span deflection (in.)*		
		G2	G3	G4	G2	G3	G4
1	189	No data due to download error from acquisition system.					
2							
3							
4		67	71	32	-0.010	-0.038	-0.024
5		57	69	43	-0.019	-0.025	0.030
6		48	59	32	-0.039	-0.045	-0.028
7	186	26	76	51	-0.012	-0.010	-0.009
8		53	87	35	-0.020	-0.012	-0.009
9		41	85	42	-0.017	-0.012	-0.009
10		29	77	53	-0.011	-0.013	-0.019
11		51	92	56	-0.017	-0.012	-0.008
12		44	51	32	-0.023	-0.008	-0.002

*Negative deflection is downward

A data acquisition error occurred during the transition from the pseudo-static and dynamic load tests in span 189. As a result of this error, data from the pseudo-static tests in span 189 were overwritten. Preliminary efforts to recover this data have not been successful. The data from the 35 mph truck speed tests for spans 186 and 189 have been used for the comparison of span performance.

OBSERVATIONS FROM LOAD TEST DATA

Based on a review of the load test data, the following observations are made.

1. Overall, the measured mid-span deflections of the girders were very small; typically ranging from 0.010 in. to 0.039 in. Measured mid-span deflections in Span 189 were larger than the measured mid-span deflections in Span 186.
2. The overall behavior of Span 189 was comparable to the behavior of Span 186 for each loading condition. For example, for the load cases of the test truck centered on girder G3 (loading 6 and 12), the measured strain at the bottom of girder G3 was 59 με in Span 189 and 51 με in Span 186.
3. The transverse distribution of the applied truck load was comparable for Span 189 and 186. For example, for the load cases of the test truck centered on girder G3 (loading 6 and 12), the measured strain at the bottom of girder G2 was 48 με in Span 189 and 44 με in Span 186.

Similarly, for the load cases of the test truck centered on girder G3 (loading 6 and 12), the measured strain at the bottom of girder G4 was 32 $\mu\varepsilon$ in Span 189 and 32 $\mu\varepsilon$ in Span 186.

From the load test data, the behavior of Span 189 compares favorably with the behavior of Span 186 for the applied truck loading. The measured strains are comparable for loadings in both spans and the measured mid-span deflections are very small.

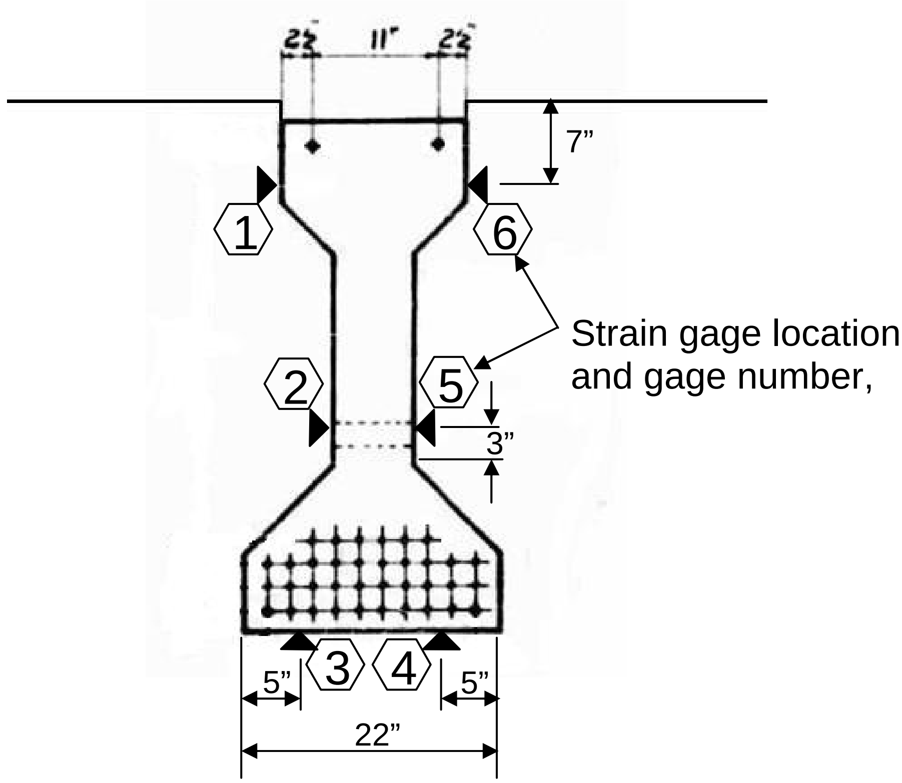
SUMMARY

As a follow up to our Load Test Summary dated May 31, 2006, we have reviewed the test data and computed live load distribution factors based on measured strains in the girders. From this review, we note the following.

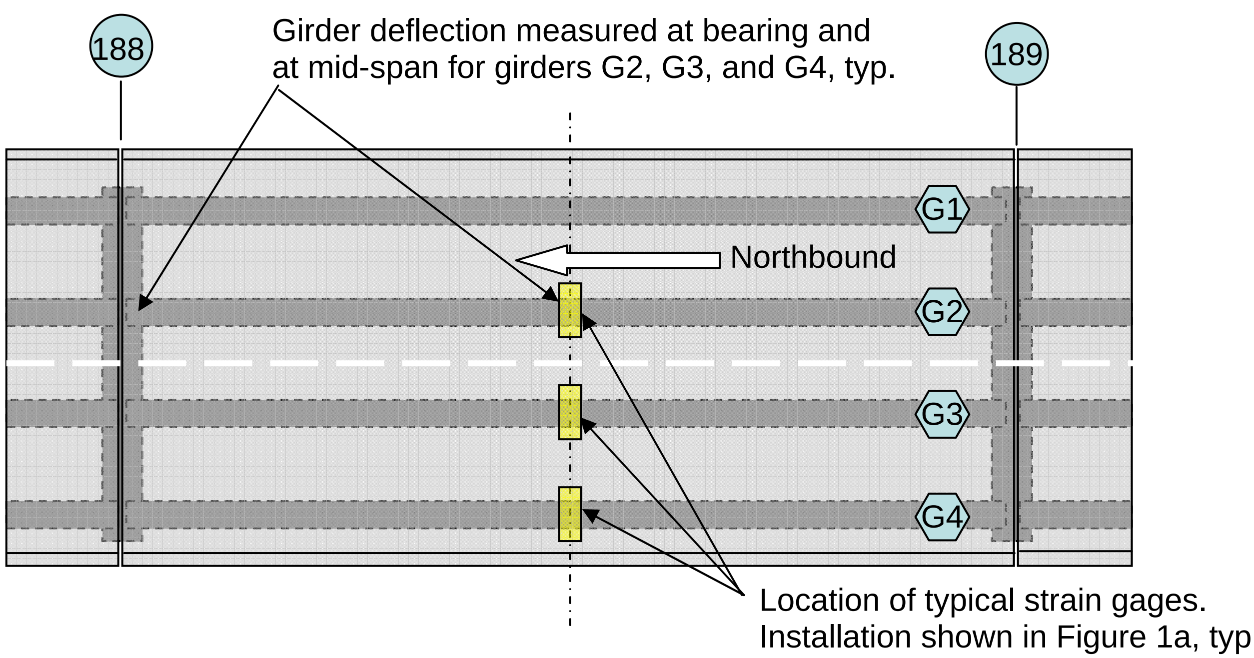
- For the dynamic tests, with the test truck centered over Girder G3, the measured strains at the bottom of girder G3 were 51 and 59 microstrain for Spans 186 and 189 respectively. Assuming the concrete in the prestressed girders has a compressive strength of 5,000 psi, these measured strains correspond to concrete stresses of approximately 205 and 237 psi.
- Using the test truck axle configuration and measured axle weights, the Live Load Moment and corresponding (from KO & Associates) mid-span bottom fiber girder stresses were computed for both the undamaged and damaged spans.
- The test truck used during the load test corresponds very closely to the NCOTTS3 standard truck.
- The bottom fiber girder stresses computed from the measured strain data were compared to the bottom fiber stresses calculated using the test truck weights and axle spacing. Distribution factors were then computed.
- The distribution factors computed using data from the load tests ranged from S/8.6 to S/15.5 depending on the position of the test truck relative to the girders.

From AASHTO, a distribution factor of S/5.5 would normally be used in rating the typical spans on the Bonner Bridge. From the load tests conducted in Spans 186 and 189 at the Bonner Bridge, the distribution of live loads from the test truck ranged from S/8.6 to S/15.5. The load tests also indicate that the significant localized damage to Girder G3 in span 189 has not significantly affected the lateral distribution of loads in the span. While the AASHTO "S-over" equations have been shown to be unsafe in some cases and too conservative in others, the load test data from the Bonner Bridge clearly indicates that the standard S/5.5 distribution factor is conservative compared to distribution factors derived from load test data. The 7.25 in. thick reinforced concrete deck and the cast-in-place diaphragms present in the typical spans of the bridge are clearly contributing to a more effective distribution of applied live loads to adjacent girders. In addition, there were no flexural cracks observed in the girders during the inspection and load testing. Further, based on load test data, the estimated mid-span stresses in the bottom fiber of the girders from the standard HS20 truck loading will be on the order of approximately 300-350 psi and well within the capacity of the existing girders.

FIGURES

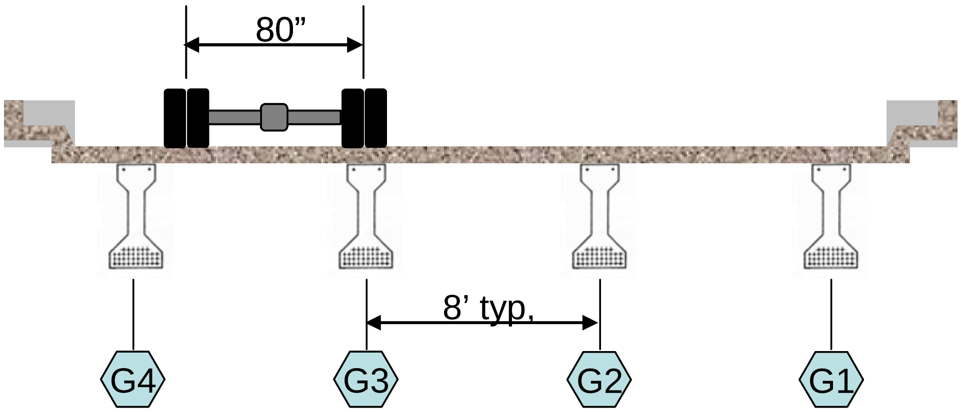


a) Location of strain gages at mid-span of typical 45" prestressed girder

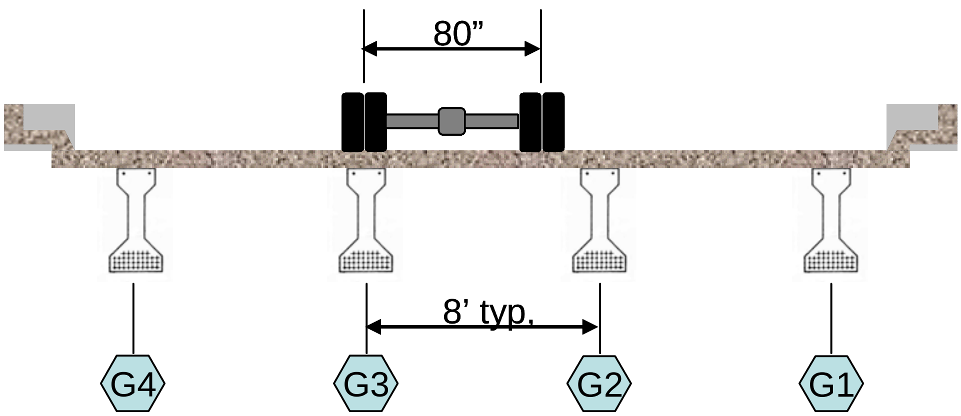


b) Plan view of Span 189 showing location of strain and deflection gages.
Note layout in Span 186 was similar.

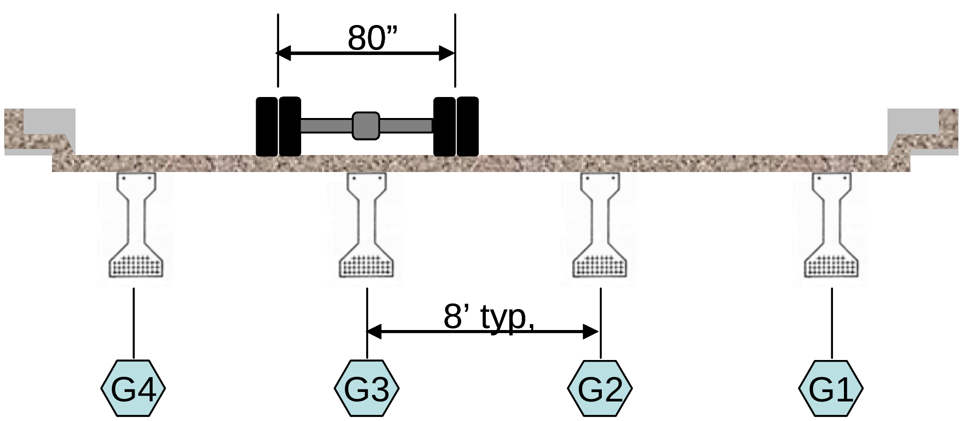
Figure 1. Location and channel numbering for strain gages, lvdt's, string pots.



a) Position of truck loading with left wheel over G3; Loading Nos. 1, 4, 7, and 10.



b) Position of truck loading with right wheel over G3; Loading Nos. 2, 5, 8 and 11.



b) Position of truck loading with right wheel over G3; Loading Nos. 3, 6, 9 and 12.

Figure 2. Position of truck wheel load for each load case (looking north).

Figure 3. Overall of instrumentation setup.

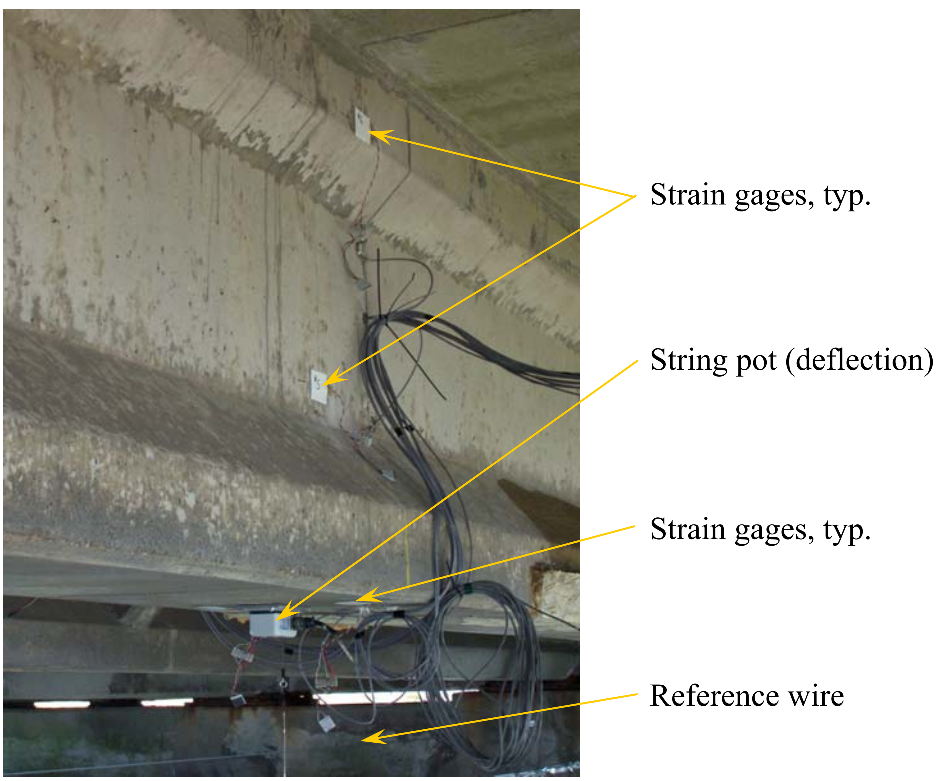


Figure 4. Overall of mid-span instrumentation (strain gages and string pot).

Figure 5. Typical LVDT installation at north end of each girder.

Figure 6. Truck positioned with left wheel over Girder No. 3 (looking north).

Figure 7. Truck positioned with right wheel over Girder No. 3 (looking north).

Figure 8. Truck centered over Girder No. 3 (looking north).

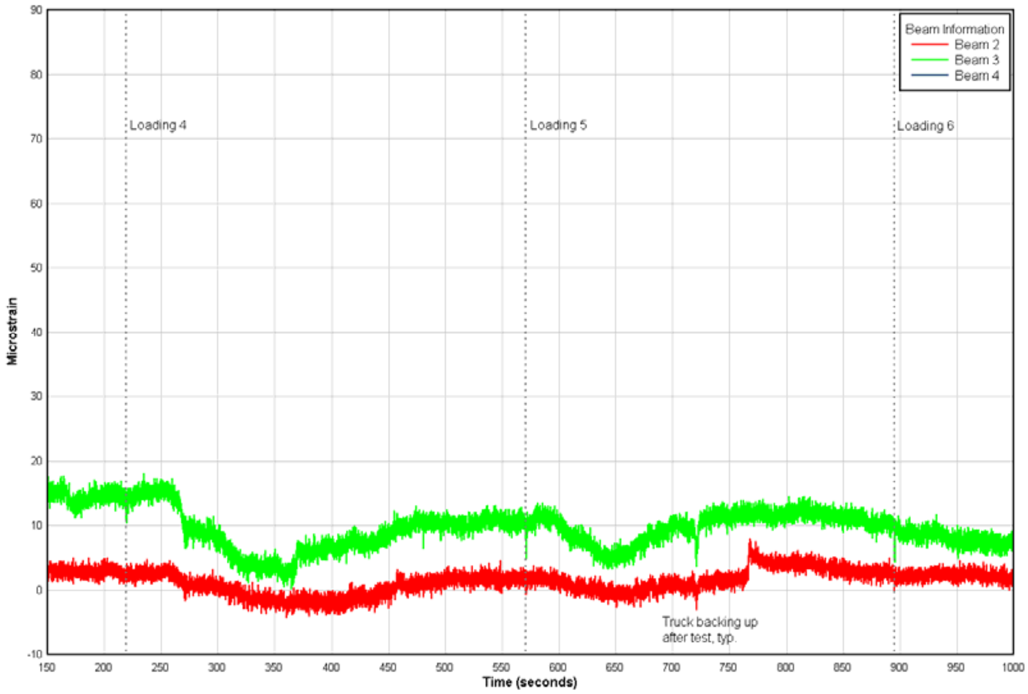


Figure 9. Span 189; loading nos. 4, 5, and 6; top strain gage data.

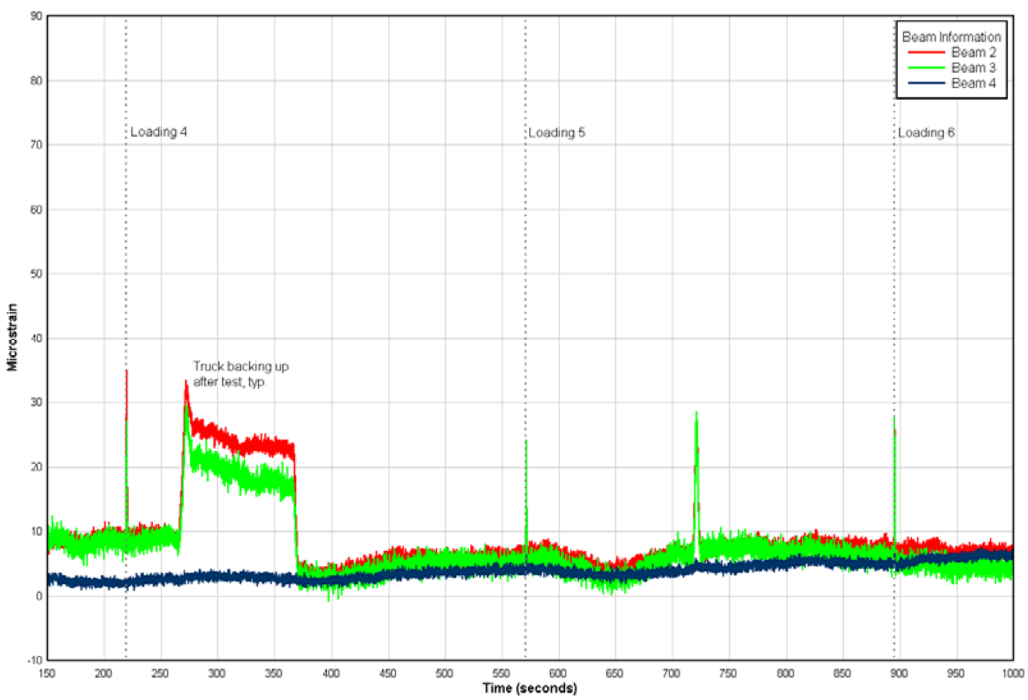


Figure 10. Span 189; loading nos. 4, 5, and 6; middle strain gage data.

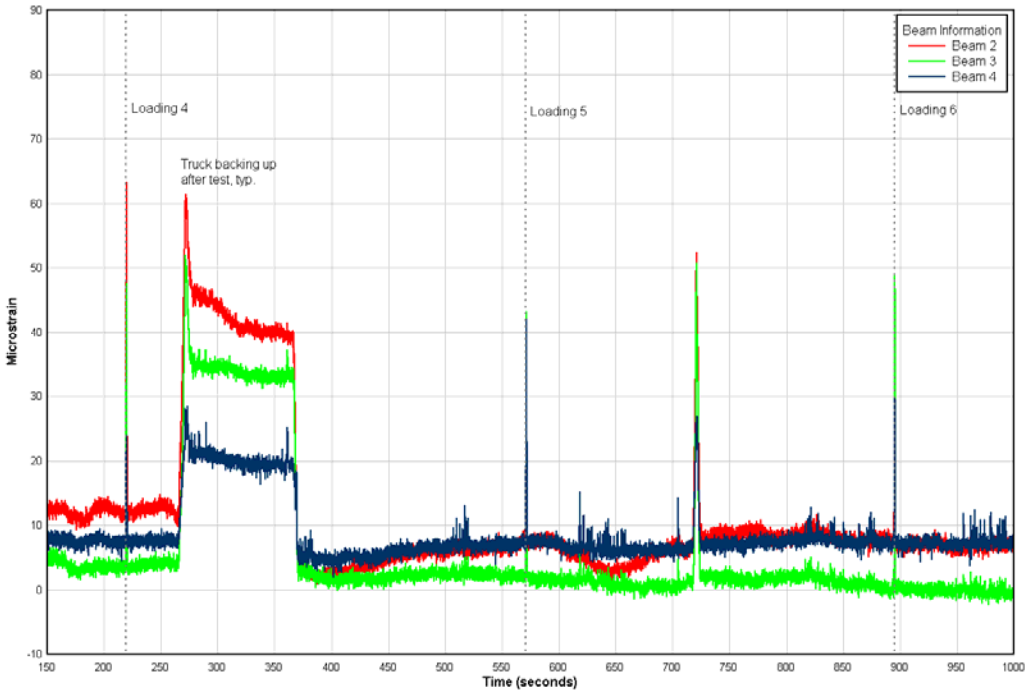


Figure 11. Span 189; loading nos. 4, 5, and 6; bottom strain gage data.

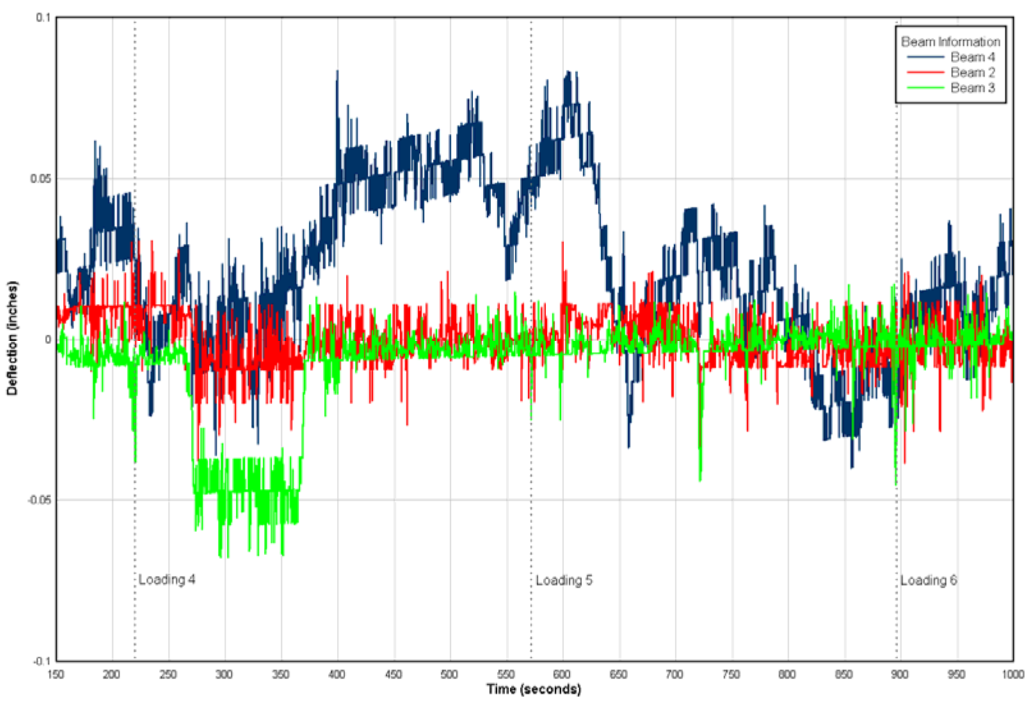


Figure 12. Span 189; loading nos. 4, 5, and 6; mid-span deflection data.

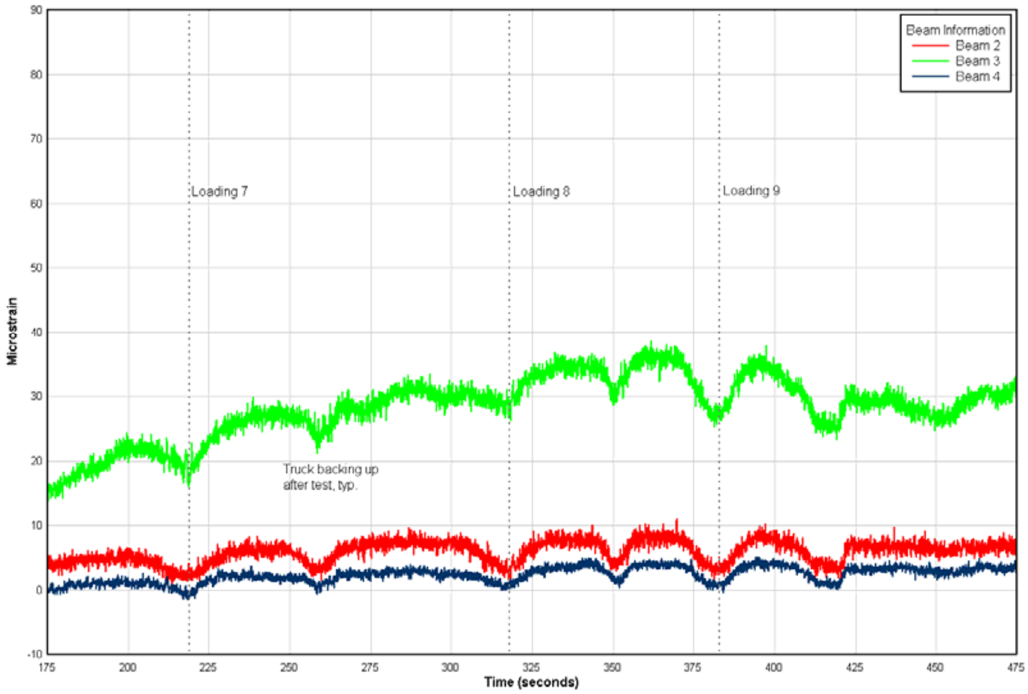


Figure 13. Span 186; loading nos. 7, 8, and 9; top strain gage data.

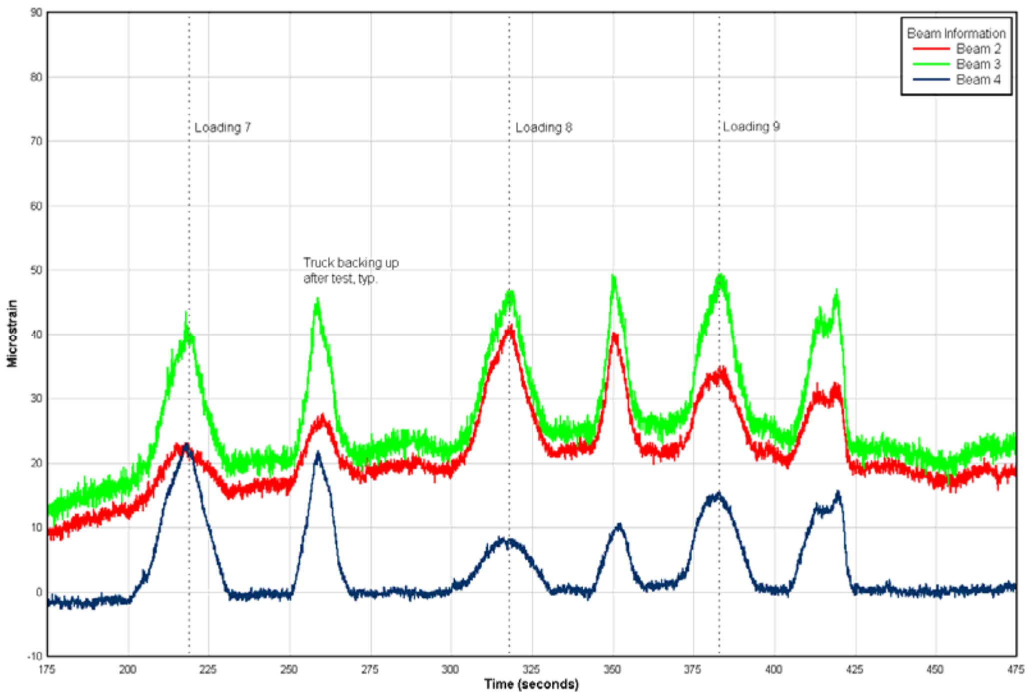


Figure 14. Span 186; loading nos. 7, 8, and 9; middle strain gage data.

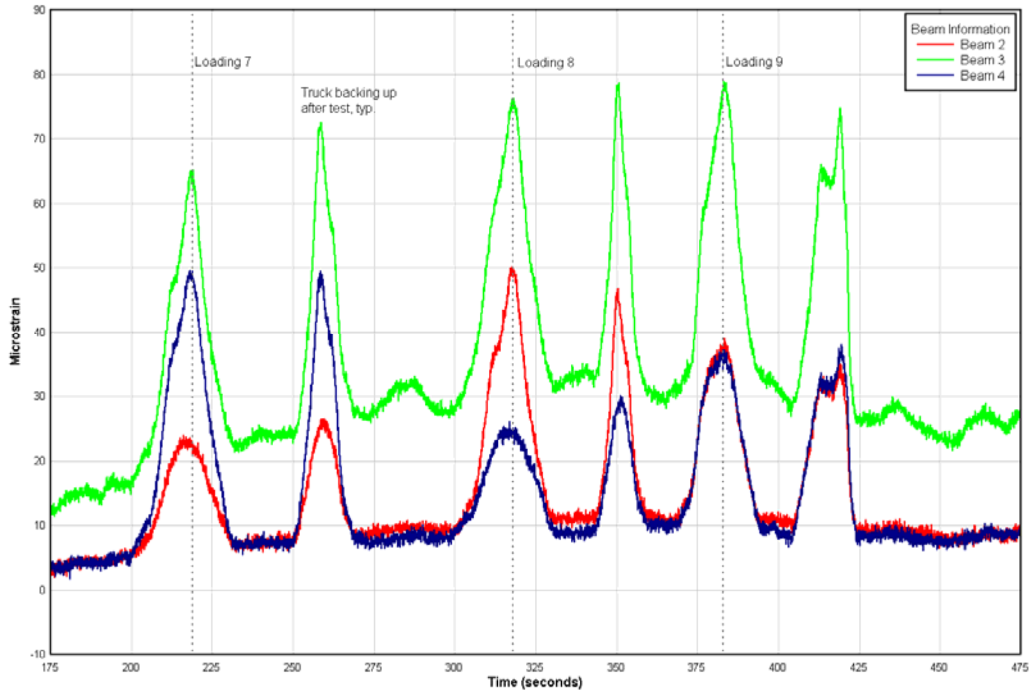


Figure 15. Span 186; loading nos. 7, 8, and 9; bottom strain gage data.

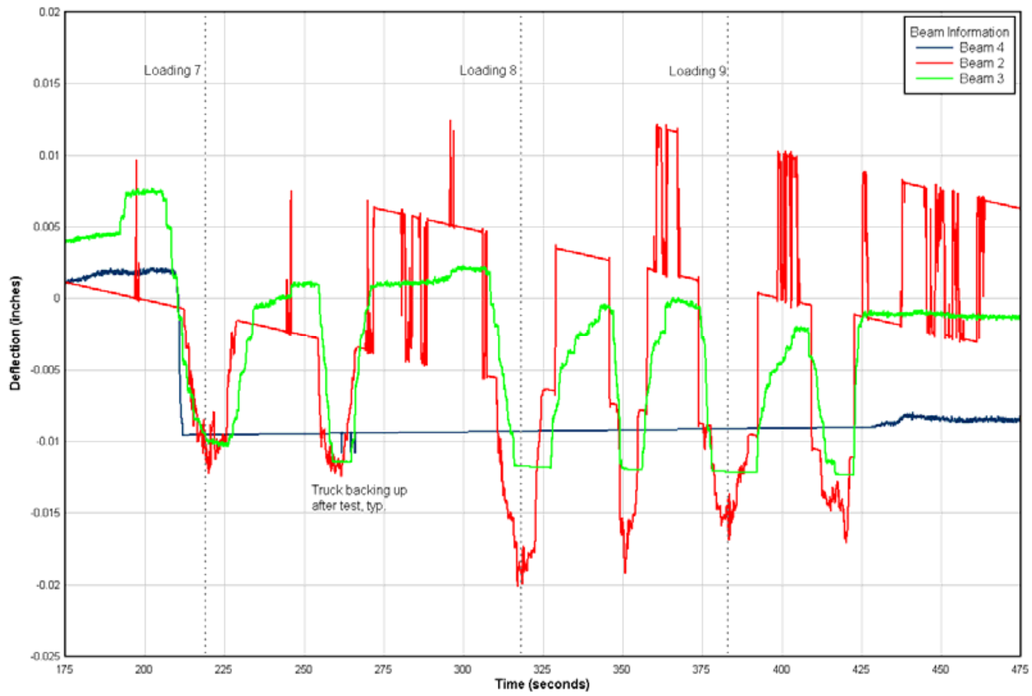


Figure 16. Span 186; loading nos. 7, 8, and 9; mid-span deflection data.(Note vertical axis plotted at different scale than scale used in Figure 11.)

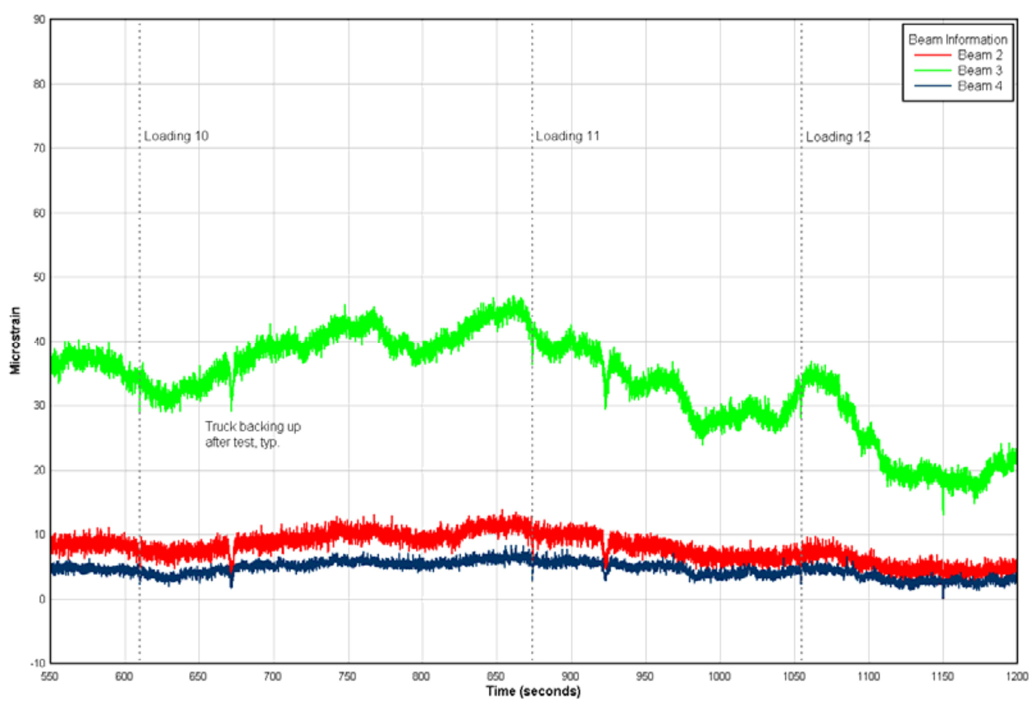


Figure 17. Span 186; loading nos. 10, 11, 12; top strain gage data.

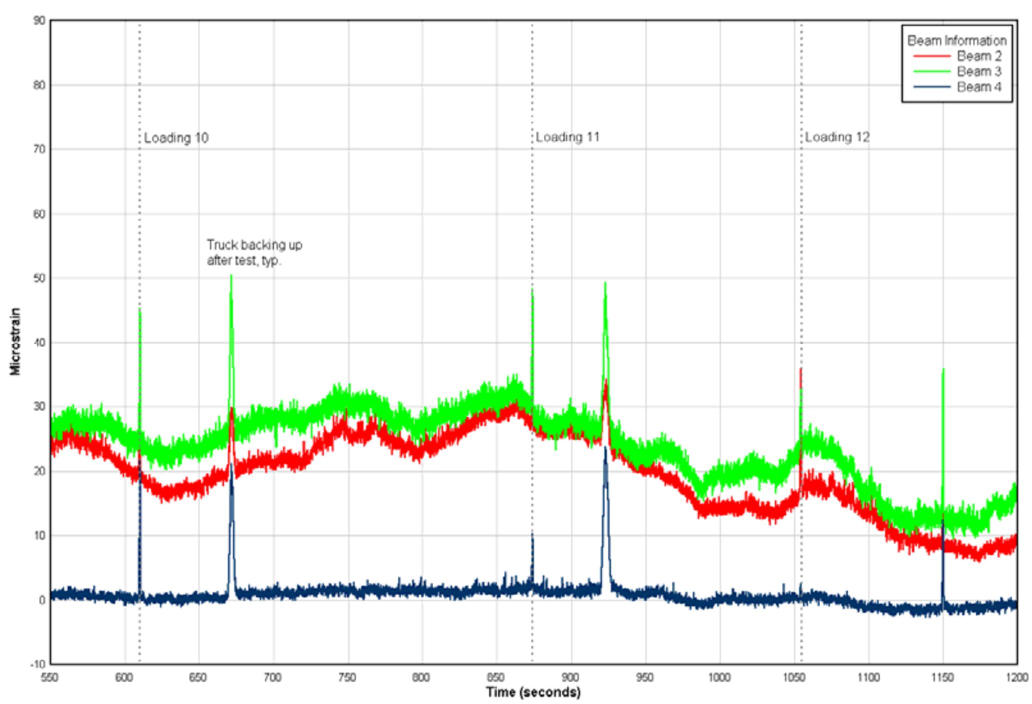


Figure 18. Span 186; loading nos. 10, 11, and 12; middle strain gage data.

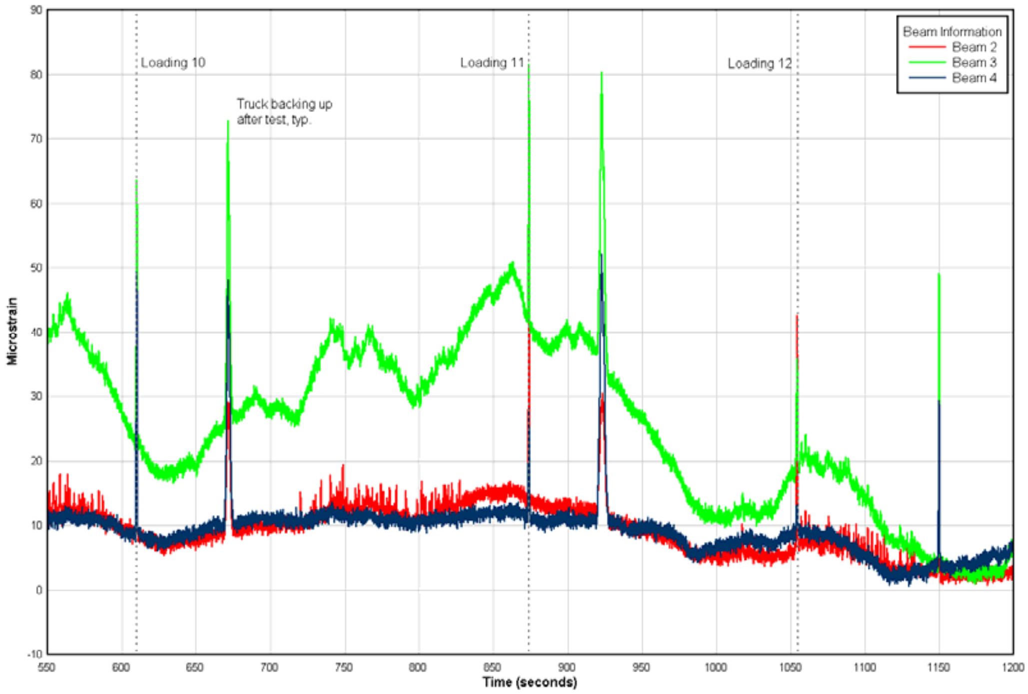


Figure 19. Span 186; loading nos. 10, 11, and 12; bottom strain gage data.

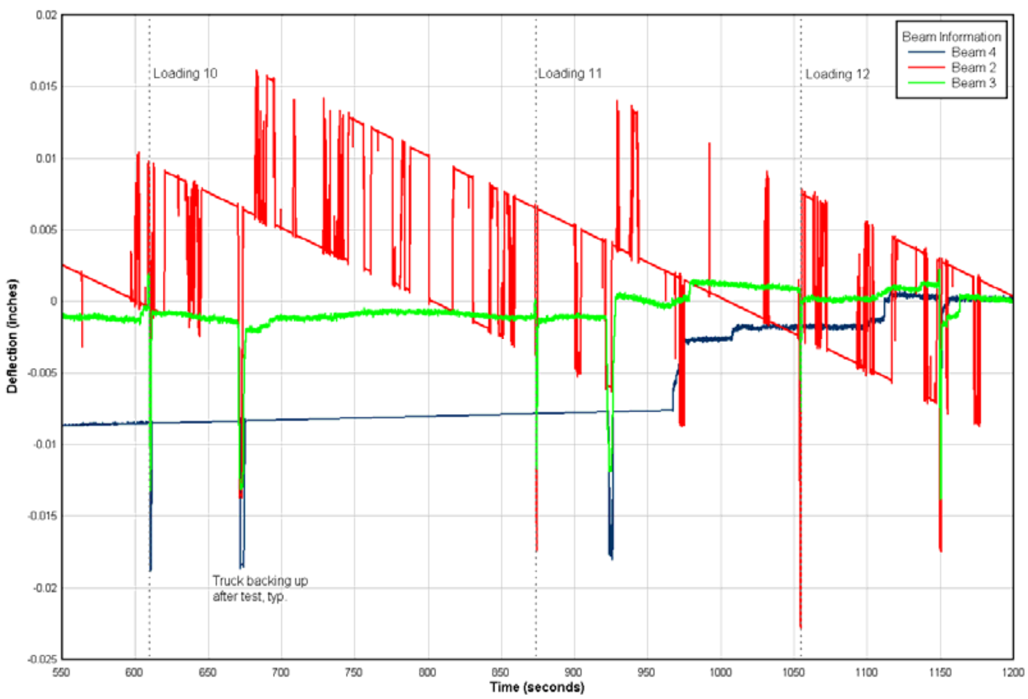


Figure 20. Span 186; loading nos. 10, 11, and 12; mid-span deflection data. (Note vertical axis plotted at different scale than scale used in Figure 11.)

ATTACHMENT A

ENF-020
(Rev. 5/98)

N. C. Department of Transportation
Division of Motor Vehicles
ENFORCEMENT SECTION

OWNER					DATE
MAKE		SERIAL NUMBER			
SCALE	1	2	3	4	LICENSED NUMBER
			LICENSE WEIGHT		LOAD

19'3"

AXLE NO. 1	14,100	7,000	9,700
AXLE NO. 2	20,850	7,100	9,500
AXLE NO. 3	20,850	14,100	11,300
AXLE NO. 4		Steering	11,200
AXLE NO. 5			41,700 Drive
AXLE NO. 6			
AXLE NO. 7			
TOTAL	55,800		

SIGNED ______________________

Figure A1. NCDOT truck weight information.

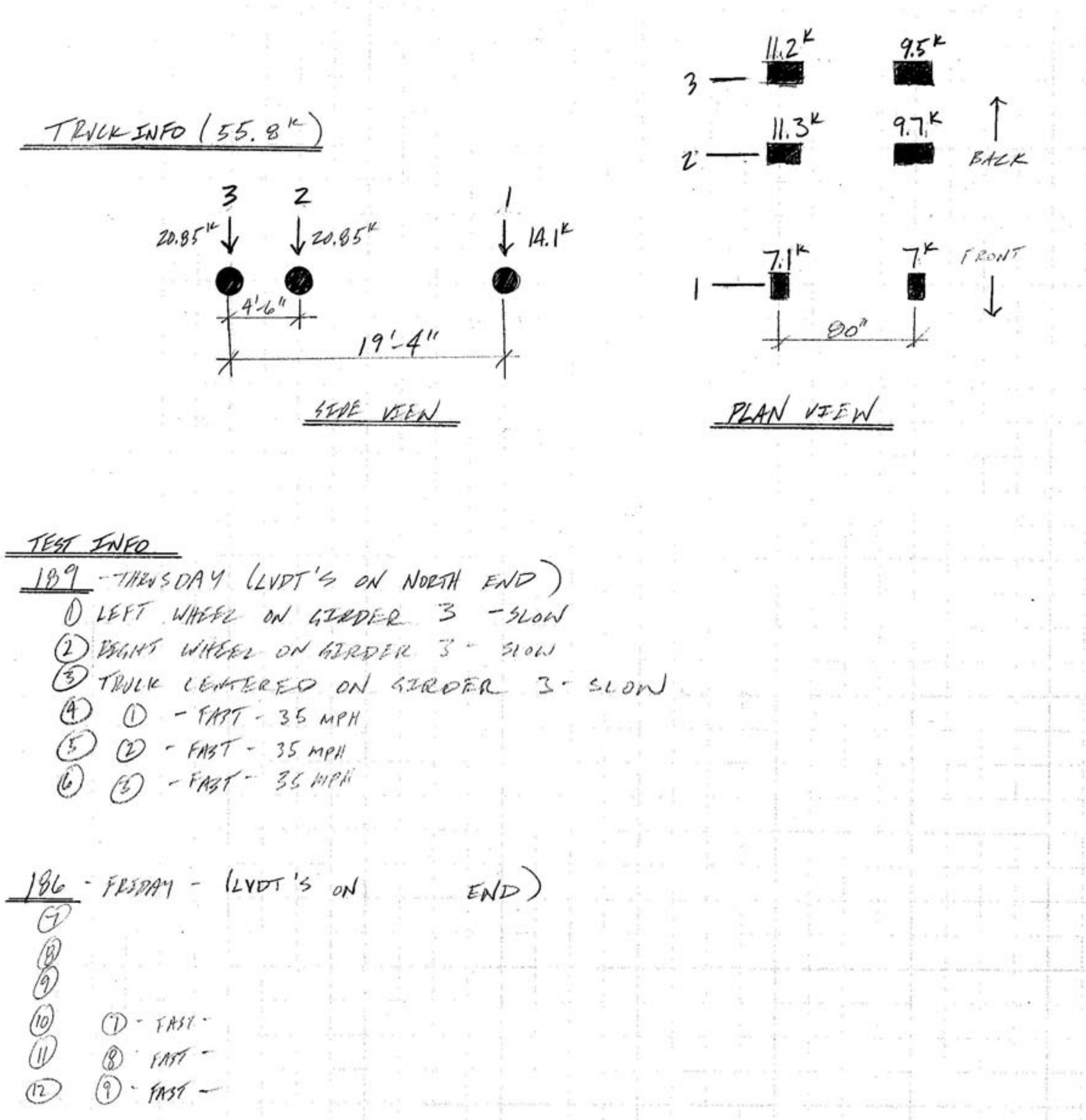


Figure A2. WJE field notes about NCDOT truck weight distribution.