FULL SCALE TEST OF HALF DEPTH GRID ON UPPER BUCKEYE BRIDGE TO DETERMINE EFFECTIVE FLANGE WIDTH, LIVE LOAD DISTRIBUTION, AND GRID DECK STRESSES

FOR

BRIDGE GRID FLOORING MANUFACTURING ASSOCIATION

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May 1996

ABSTRACT

A full scale test was performed on a 3-simple spans multi-girder steel bridge with 5" half-depth concrete filled steel grid deck. Steel girders and concrete were strain gaged for study of the effective flange width acting compositely with the girders and the live load distribution to the girders. Also, main bars of the steel grid deck were gaged to study the live load stresses in the grid. For the study of girder composite action and the live load distribution factor, one and two trucks were positioned at 4 different locations. For grid stresses a loaded two-axle truck was positioned at 9 different locations on the deck and measured strains were recorded. Actual stresses in the girders were computed using the recorded strains and compared to theoretical stresses computed assuming non-composite and composite with effective slab widths equal to the center-to-center distance of the girders. Also, compression in the deck was measured at different locations to show the participation of the deck in composite action with the girders. The results of this test show that composite action exists and the effective slab for composite action of this deck and girders is equal to center-to-center distance between the girders.

The distribution of wheel loads to girders, for single and multi-lane vehicle, was computed utilizing AASHTO Specifications for Highway Bridges (15th Edition) and AASHTO LRFD equations. Comparison of the test and computed stresses shows that measured stresses are smaller than the theoretical stresses of AASHTO Specifications for Highway Bridges and AASHTO LRFD.

Measured stresses in the deck were compared with the computed theoretical stresses utilizing Orthotropic plate equations developed for both full and half depth concrete filled steel grid decks. Results of this test shows that AASHTO LRFD, using proper section properties for stress computation, shows good correlation with the test results. However, deck test stresses in the negative moment region, top of the supporting members, are much smaller than AASHTO LRFD stresses or test stresses for positive moment region of the deck.

TABLE OF CONTENTS

LIST OF FIGURES

LISTS OF PHOTOS

INTRODUCTION

In the design of the superstructure components of bridges, such as girders, stringers and floorbeams, it is common to take advantage of the deck system by making the deck and superstructure elements act compositely. This is accomplished by use of a mechanical connection between the deck and superstructure, such as shear studs. The American Association of State Highway and Transportation Officials (AASHTO) "Standard Specifications for Highway Bridges, 15th Edition" covers effective flange width in Section 10.38.3.1, stating that "In composite girder construction the assumed effective width of the slab as a T-beam flange shall not exceed the following:

(1) One-fourth of the span length of the girder.
(2) The distance center to center of girders.
(3) Twelve times the least thickness of the slab."

Although AASHTO is clear in its statement and does not discriminate between different deck systems such as reinforced concrete and concrete-filled steel grid decks, some bridge owners and engineers do not take advantage of a grid deck's contribution when designing or analyzing the superstructure elements. Using common engineering principles it can be shown that a concrete-filled steel grid deck should contribute to the composite action at least as much as a reinforced concrete deck of equivalent thickness. For half-depth concrete filled steel grid deck the question is what thickness should be used, the overall deck thickness or just the thickness of the concrete component.

There have been a few tests performed on composite action of full-depth filled concrete steel grid decks (1, 2). However, there are no tests for half-depth concrete filled steel grid decks.

Another effect of grid decks on superstructure behavior is the live load distribution to the stringers. AASHTO covers live load distribution to longitudinal beams in Section 3.23.2. Table 3.23.1 contains several distribution factors for use with steel grid decks, based on various factors such as beam spacing, grid depth (thickness) and number of traffic lanes. However, this article does not differentiate between open grid, full depth concrete-filled grid deck, and half-depth concrete filled grid deck systems.

Also, to study live load stresses in the grid, main bars of the steel grid deck were gaged to measure stresses and compare them with the theoretical stresses computed modeling the deck as orthotropic plates.

OBJECTIVE

The objective of this project is to utilize field test results to develop the following items for half-depth concrete filled steel grid decks :

1. composite behavior of girder and deck;
2. the effective deck width (for composite design of stringers);
3. the live load distribution to the stringers;
4. live load stress in the half-depth concrete filled grid deck.

BRIDGE DESCRIPTION

The field testing was performed on the Upper Buckeye Bridge in Doddridge County, West Virginia. Figure 1. shows the bridge location. The bridge is owned and maintained by District 4 of West Virginia Department of Transportation.

The bridge was built in 1947 and consists of 3 simple span (45' c.-c. of bearings) steel multi-girders, rolled I-beams, carrying 2 traffic lanes (See Figure 2 for bridge floor plan). The girders supported a 7-1/4" conventional reinforced concrete deck.

In 1994, a rehabilitation project commenced, consisting of deck, superstructure, and bearing replacement (see photo No. 1) and substructure repairs. The existing reinforced concrete deck was replaced with a 5" half-depth concrete filled steel grid deck, grade 50 steel, main bars at 8" c.-c. w/ 2 supplementary bars, and 1-1/2" concrete overfill (see Figure 3 for typical grid cross section). The steel grid was Galvanized. The original simple-span rolled I-beams were also replaced, with similar depth but heavier rolled I-beams (see Figure 4 for typical deck cross section). Deck was attached to the new girders in spans 2 and 3 utilizing the detail shown in Figure 5; deck in span 1 utilized similar detail and shear studs (see Figure 6 for shear stud plan). However, all the girders were designed as non-composite.

TESTING PROGRAM

Strain Gage Installation

The test locations were selected at a center line of spans 1 and 3, 22.5' from each end. Since bridge is simple span and span length is 45' c.-c. of bearings, this location corresponds to the point of maximum moment in the girders when loaded properly.

A total of 31 and 32 gages were installed for span 1 and span 3 respectively: 12 steel strain gages (gage 1-12) on the girders (see photo No.2); 9 concrete gages (gage 21-29) in the concrete fill (see photo No. 3); 10 gages (13-20 and 30-31) for span 1 and

11 gages (13-20 and 30-32) for span 3 on the grid main bars (see Figure 7)(see photo Nos. 4 & 5). Both girder and grid gages were installed after erection.

Test Vehicles

One truck was used for the deck strain gages and two trucks for study of the composite behavior of the girders and live load distribution. The three test trucks were 2-axle dump truck (see photo No. 6 for typical truck), and furnished by Doddridge County, West Virginia Maintenance. The trucks gross vehicular weight and axle spacing are shown in Figure 8.

Test Procedure

The grid testing was performed on August 31, 1995 and girder composite action and live load distribution testing was performed on April 29, 1996. The bridge was closed to traffic, therefore, the test vehicles were the only live load in the vicinity of the strain gages. Photo numbers 7, 8, and 9 shows testing equipment and test trucks positioned on the bridge.

For the grid deck testing a truck was placed in 9 stationary positions. For the girder composite action and live load distribution study, 4 single and 4 double (multi) stationary truck positions were considered (see Figures 9 and 10 for locations) and the strain gage readings were recorded for each position. For girder composite action and live load distribution, first a single truck was positioned at a selected location and gage readings were recorded, then a second truck was moved into position and multi lane gage readings were recorded. In this study it was assumed that the traffic lane is 12' wide and truck should stay in the traffic lane with it's wheel at least 2' from the edge of the lane (see AASHTO Sections 3.6 and 3.7). Therefore, for multi lane truck position a minimum of 4 feet distance between two trucks was maintained at all time (see figure 8).

For gage calibration two unloaded readings were performed; one prior to loading, and one after loading. The average of these two numbers was used as the initial reading. Reading boxes were adjusted for the wire length and the gage factor.

TEST DATA EVALUATION

Calculation of Stresses

The actual stresses were calculated from the field data in the following manner. Initial reading was computed by averaging the gage readings prior to and after loaded condition. The net strain gage reading (loaded - initial), ie, strain in the component, was then multiplied by the modulus of elasticity to obtain the stress. Strain readings for girder composite action and live load distribution are summarized in Tables 1-16 and grid readings are shown in Tables 17-34 of Appendix A. Tables 1-8 and 9-16 are for single and multi lane girder tests for spans 1 and 3 respectively. Tables 1-4 and 9-12 present results of single truck and 5-8 and 13-16 present results of two trucks (multi-lane) for each span. Tables 17-25 and 26-34 are for grid test for spans 1 and 3 respectively.

The extreme fiber stresses, top and bottom flanges, in the girders were then calculated by using linear stress distribution from the gage locations and are shown in Tables 1-4 for spans 1 and 3. Concrete stresses are presented in Tables 5 and 6 for spans 1 and 3 respectively, and grid stresses in Tables 7-10.

Single lane live load distribution was studied utilizing the single truck gage readings and multi-lane live load distribution was based on the two truck gage readings.

From the gage reading of the grid main bar, maximum top and bottom stresses for the main bar of the grid deck were computed. These stresses are presented in Tables 7-10.

COMPARISON OF RESULTS - EFFECTIVE SLAB WIDTH AND LIVE LOAD DISTRIBUTION FACTORS

Theoretical Stress Calculation

Theoretical live load stresses in the top and bottom flanges of the girders were calculated as explained in the Appendix B. In this calculation it was assumed that the effective slab width for composite action is center-to-center of the girders, 8'-3". Note that this is greater than 12t, which is a conservative assumption for this study. Also, considering effective flange width of 12t versus center-to-center, the bottom flange section modulus, the governing location, would decrease by approximately 3%, which is not significant.

The stresses were calculated at the test location using the actual wheel loads, placed with the heavy axle at 0.5L, multiplied by the live load distribution factor based on AASHTO LRFD and AASHTO Standard Specification for Highway Bridges, 15th edition (which, for simplification will be referred to as AASHTO in the balance of the report) Table 3.23.1. Live load distribution factors are calculated in Appendix B and are summarized in Table 11. AASHTO LRFD live load distribution factors for interior girder shown in this table are based on thickness of 6.68" (from bottom of the main bar to the top of the deck). Stress computation was performed for single and multi lane live loads. AASHTO LRFD live load distribution factors, single and multi lane, were computed according to Tables 4.6.2.2.2b-1 and 4.6.2.2.2d-1. Since, girder spacing is greater than 6' according to footnote "f" of Table 3.23.1 of AASHTO, live load distribution factor is reaction of the wheel loads assuming the flooring between stringers acts as a simple beam. For multi lane live load, assumed distribution factor is (S/5.).

Stresses were computed assuming girders are non-composite, utilizing section modulus of the basic beam. Composite and non-composite stress calculation for interior and exterior girders based on single and multi lane live loads were performed and results are shown in Table 12.

Comparison of Results

A comparison of the non-composite theoretical values versus the measured values indicates that the measured stresses are much less than the theoretical stresses under all conditions (see Table 12). Single and multi-lane test stresses are less than theoretical values.

EFFECTIVE FLANGE WIDTH AND LIVE LOAD DISTRIBUTION FACTOR CONCLUSIONS

From the comparison of the stresses in Table 12 and concrete stresses from Tables 5 and 6, the following conclusions were made based on the results of this test:

- Composite action exists between deck and girders. This is evident from the comparison of the test stresses and the computed theoretical non-composite stresses, especially the top flange stresses;

- Test results show that center-to-center distance of girders could be used as the effective flange width. Theoretical stresses are computed based on this assumption (conservative for this study) and are larger than the measured stresses. Note that this is the effective flange width recommended by AISC code for composite girders;

- AASHTO LRFD live load distribution factor equations with the total depth (from bottom of the main grid bar to the top of the deck) as "T_s" can be used for single and multi lane live load distribution factors for the interior and exterior girders of the bridges with half-depth concrete grid decks. This is evident from the comparison of the test and theoretical AASHTO LRFD stresses.

- Test live load distribution factor is smaller than theoretical AASHTO and AASHTO LRFD. Therefore, upper limit of the live load distribution factor computed based on AASHTO LRFD should be S/5.5.

COMPARISON OF RESULTS - GRID DECK FORCES

Theoretical Stress Calculation

Appendix C presents theoretical stresses computed in the deck, based on utilizing the "exact" orthotropic plate equation. A simplified, approximate, form of this equation is presented in the first edition of AASHTO LRFD. This equation was used for computation of the maximum moment in the deck. Maximum stresses were computed utilizing two different methods of section modulus determination; 1.) assuming that entire concrete is uncracked, and 2.) utilizing section properties based on the transformed area method. Since computed theoretical stresses are going to be compared with the test results, assuming uncracked concrete is conservative. Also, live load stress levels are low and concrete may not have cracked. Grid main bar stresses based on AASHTO section 3.24.3.1 and transformed area method are also computed.

Comparison of Results

Grid deck live load stresses in the positive and negative moment regions for the top and bottom of the grid main bars are computed in Appendix C and tabulated in Table 13. Note that the transformed area method is utilized for computation of the stresses based on AASHTO. Since, AASHTO LRFD equation for grid decks deals with moments and not stresses, to make a comparison of the test results, both uncracked and transformed area method section properties were used to compute stresses.

GRID DECK LIVE LOAD FORCES: CONCLUSIONS

. Since test stresses in the top of the grid main bars in the positive moment region are much smaller than the bottom stresses in this region it can be concluded that the concrete overpour participates in the section properties;

. Smaller test stresses for the top of the grid main bar in the negative moment region indicates that neutral axis is closer to the top than bottom; therefore, part of the concrete is effective;

. Overall, AASHTO is conservative and AASHTO LRFD shows good correlation with test;

. Test negative moment stresses are much smaller than positive moment stresses. This might not effect strength design; however, it would be extremely important for fatigue considerations. Note that AASHTO and AASHTO LRFD assumes that moment of positive and negative regions are the same. This test shows this to be a very conservative assumption.

ACKNOWLEDGEMENT

This work is a result of much teamwork and was made possible by the efforts of many people. A few of these people are: Dr. Clark Mangelsdorf for his valuable comments and assistance; Technician Jim Swanson for gage installation; Messrs Randy Harris (Bridge Engineer) and Al Lipscomb (Assistant Bridge Engineer) from District 4 of the West Virginia Department of Transportation; Doddridge County Maintenance Supervisor Mike Hamilton and his crew, for their help and cooperation in providing traffic control and all test vehicles; and special thanks to Mr. Daniel H. Copeland, BGFMA Director, for his personal involvement, efforts, and support during the entire length of the project.

REFERENCES

1- "Test Data Showing Full Composite Action Between Concrete Filled Steel Grid Deck Supporting Stringers", U.S. Steel Corp., August 29, 1960.

2- "Full Scale Test of The Main Street Bridge", BGFMA, 1992.

Table 1: Span 1, girder top flange stresses (psi)

Truck Position		S1	S2	S3	S4
ONE TRUCK	1	99	-104	-114	-100
	2	55	-93	-56	38
	3	-7	-124	-151	21
	4	-142	-153	-51	3
TWO TRUCKS	1	-123	-218	-297	-189
	2	-196	-206	-210	-38
	3	-368	-241	-286	-46
	4	-503	-325	-184	-68

Table 2: Span 1, girder bottom flange stresses (psi)

Truck Position		S1	S2	S3	S4
ONE TRUCK	1	-134	304	1403	2059
	2	-43	471	1714	1749
	3	52	712	1949	1246
	4	91	1072	1923	742
TWO TRUCKS	1	577	2213	2581	2242
	2	640	2380	2921	1829
	3	1090	2656	2748	1257
	4	1636	2923	2461	788

Table 3: Span 3, girder top flange stresses (psi)

Truck Position		S1	S2	S3	S4
ONE TRUCK	1	30	-49	-181	--- *
	2	40	-88	-186	-365
	3	-52	-164	-213	---
	4	-80	-174	-203	-168
TWO TRUCKS	1	-87	-296	-413	--- *
	2	-106	-281	-336	-403
	3	-147	-310	-415	-347
	4	-265	-333	-328	-193

* No reading, Reading box was broken and was changed for next truck positions.

Table 4: Span 3, girder bottom flange stresses (psi)

Truck Position		S1	S2	S3	S4
ONE TRUCK	1	-106	126	1414	--- *
	2	-57	301	1584	2085
	3	25	770	1926	1088
	4	114	1109	1975	804
TWO TRUCKS	1	554	2057	2465	--- *
	2	574	2325	2756	2125
	3	1020	2684	2735	1306
	4	1563	2857	2434	741

Table 5: Span 1, stress (psi) in the concrete deck

Position	21	22	23	24	25	26	27	28	29
1	-15	-4	-10	-34	-15	-33	-29	-33	-59
2	-15	-33	-29	-50	-50	-61	-55	-44	-65
3	-23	-11	-27	-57	-67	-36	-40	-17	-84
4	-21	-10	-23	-75	-55	-54	-29	-21	-54
5	-48	-50	-40	-109	-105	-40	-11	4	-46
6	-69	-57	-75	-107	-105	-75	-29	-21	-40
7	-69	-75	-80	-124	-76	-73	-33	-21	-31
8	-80	-92	-55	-178	-75	-54	-36	-21	-19
9	-90	-101	-86	-141	-76	-67	-40	-25	-23

Table 6: Span 3, stress (psi) in the concrete deck

Position	21	22	23	24	25	26	27	28	29
1	-94	-33	11	40	128	325	67	-31	-13
2	21	-34	-8	-15	-46	-220	-44	-6	-109
3	0	-17	-13	-29	-33	-55	10	-54	-140
4	-17	-15	-11	-29	-67	-31	-63	-48	143
5	-42	-52	-6	-21	-113	-67	31	-42	206
6	-67	-52	19	-8	-82	-19	-15	-33	19
7	-88	-78	13	-27	-94	-50	-13	-36	-59
8	-117	-101	-2	-27	-78	-54	-25	-21	13
9	-138	-96	8	-4	-69	-46	-11	-13	-10

Table 7: Span 1, stress (psi) in the top of the grid deck main bars

Truck Position	13	15	17	19	30	31
1	89	265	317	800	0	334
2	274	763	-718	718	0	867
3	350	1239	-2134	1834	0	1151
4	486	491	-1118	84	0	51
5	-722	2201	-2949	1401	0	534
6	-2078	1338	-1367	918	0	251
7	-2168	145	-451	584	0	117
8	-1019	23	84	384	0	84
9	-1508	1083	251	151	0	-33

Table 8: Span 1, stress (psi) in the bottom of the grid deck main bars

Truck Position	14	16	18	20
1	-73	-218	0	-1276
2	-305	-1276	0	-3959
3	-421	-2291	0	-3596
4	-348	-841	0	73
5	1349	-4234	0	-1552
6	3379	-2755	0	-1073
7	4075	-305	0	-711
8	2480	392	0	-334
9	2552	-1726	0	-189

Table 9: Span 3, stress (psi) in the top of the grid deck main bars

Truck Position	13	15	17	19	30	31	32
1	93	190	181	551	-67	317	17
2	256	846	-382	584	884	600	33
3	256	946	-1155	1134	-334	600	0
4	389	791	-940	-217	767	33	33
5	-625	2342	-2392	1151	1301	400	300
6	-2240	1593	-1417	851	1451	184	484
7	-3141	186	-509	618	1134	117	667
8	-1426	-8	182	300	1251	17	1034
9	-2252	1406	470	167	634	33	984

Table 10: Span 3, stress (psi) in the bottom of the grid deck main bars

Truck Position	14	16	18	20
1	-116	-276	-1392	-1378
2	-290	-1160	870	-3103
3	-435	-1653	2552	-2813
4	-479	-2596	2190	798
5	885	-4350	6322	-1479
6	3089	-3799	3495	-1088
7	4771	-1871	1305	-827
8	2378	682	-203	-348
9	3060	-2045	-638	-102

Table 11: Live load distribution factors, Trucks

Code	Interior Girder		Exterior Girder	
	Single Lane	Multi Lane	Single Lane	Multi Lane
AASHTO LRFD	0.576	0.770	0.636	0.636
AASHTO	0.636	0.825	0.591	0.591

Notes:
. Presented AASHTO LRFD live load distribution factors are based on t = 6.68", total depth of deck (from bottom of the main bar to the top of the deck).

Table 12: Summary: theoretical and test girder stresses (ksi)

Code		Interior Girder				Exterior Girder			
		Single Lane		Multi Lane		Single Lane		Multi Lane	
		Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Composite	AASHTO LRFD	0.531	2.614	0.710	3.494	0.884	2.992	0.884	2.992
	AASHTO	0.586	2.886	0.761	3.744	0.821	2.780	0.821	2.780
Non-composite	AASHTO LRFD	3.741	3.741	5.000	5.000	4.130	4.130	4.130	4.130
	AASHTO	4.131	4.131	5.357	5.357	3.838	3.838	3.838	3.838
TEST		0.213	1.975	0.413	2.923	0.365	2.085	0.503	2.242

Notes:
. Single and multi-lane stresses shown in this table are the maximum stresses from Tables 1-4 (conservative);

Table 13: Summary: theoretical and test grid main bar stresses (ksi)

Code		Positive Moment Region		Negative Moment Region	
		Top	Bottom	Top	Bottom
AASHTO		3.093	5.661	6.328	7.307
AASHTO LRFD	TRANSFORMED AREA	7.237	8.356	3.537	6.474
	UNCRACKED	1.581	6.131	1.581	6.131
TEST		3.141	6.322	2.342	4.350

Note: In AASHTO LRFD, capacity and load for concrete filled steel grid decks are based on moment, not stresses. Also, loads are factored and capacity is based on moment capcity of composite plastic section. AASHTO LRFD stresses shown in this table are only to obtain range of stresses.

Table 3: Strains and stresses for span 1, position 3; Truck 1

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS	
1	3	3	3	3	0	-7	
2	4	5	5	4	-15		
3	3	4	4	5	44		52
4	2	2	2	1	-29	-124	
5	3	2	3	13	305		
6	2	3	3	23	595		712
7	0	0	0	3	87	-151	
8	4	4	4	35	899		
9	3	3	3	60	1653		1949
10	-8	-9	-9	-3	160	21	
11	334	342	338	354	464		
12	630	634	632	669	1073		1246

Table 4: Strains and stresses for span 1, position 4; Truck 1

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS	
1	3	5	4	0	-116	-142	
2	5	6	6	5	-15		
3	4	4	4	6	58		91
4	2	3	3	2	-15	-153	
5	2	2	2	19	493		
6	3	3	3	34	899		1072
7	0	0	0	6	174	-51	
8	4	4	4	36	928		
9	3	3	3	60	1653		1933
10	-9	-9	-9	-6	87	3	
11	342	348	345	357	348		
12	634	636	635	657	638		742

Table 5: Strains and stresses for span 1, position 1; Trucks 1 & 2

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE:	LOADED READING	STRESS psi	REMARKS
1	3	4	4	2	-44	-123
2	3	4	4	12	247	
3	2	3	3	19	479	577
4	2	2	2	4	58	-218
5	2	2	2	36	986	
6	0	1	1	65	1871	2213
7	0	0	0	1	29	-297
8	2	4	3	42	1131	
9	0	4	2	77	2175	2581
10	-8	-8	-8	-5	87	-189
11	337	339	338	374	1044	
12	631	630	631	696	1900	2242

Table 6: Strains and stresses for span 1, position 2; Trucks 1 & 2

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE:	LOADED READING	STRESS psi	REMARKS
1	4	3	4	0	-102	-196
2	4	4	4	12	232	
3	3	3	3	21	522	640
4	2	2	2	5	87	-206
5	2	3	3	39	1059	
6	1	2	2	71	2016	2380
7	0	0	0	5	145	-210
8	4	4	4	50	1334	
9	4	3	4	89	2480	2921
10	-8	-8	-8	-2	174	-38
11	339	334	337	370	972	
12	630	630	630	684	1566	1829

Table 7: Strains and stresses for span 1, position 3; Trucks 1 & 2

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
1	3	3	3	-4	-203	-368
2	4	5	5	18	392	
3	3	4	4	34	885	1090
4	2	2	2	5	87	-241
5	3	2	3	45	1233	
6	2	3	3	80	2248	2656
7	0	0	0	2	58	-286
8	4	4	4	46	1218	
9	3	3	3	83	2320	2748
10	-8	-9	-9	-5	102	-46
11	334	342	338	359	609	
12	630	634	632	669	1073	1257

Table 8: Strains and stresses for span 1, position 4; Trucks 1 & 2

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
1	3	5	4	-5	-261	-503
2	5	6	6	27	624	
3	4	4	4	50	1334	1636
4	2	3	3	4	44	-325
5	2	2	2	48	1334	
6	3	3	3	88	2465	2923
7	0	0	0	4	116	-184
8	4	4	4	43	1131	
9	3	3	3	75	2088	2461
10	-9	-9	-9	-8	29	-68
11	342	348	345	357	348	
12	634	636	635	658	667	788

Table 9: Strains and stresses for span 3, position 1; Truck 1

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
1	-2	-3	-3	-2	15	30
2	-2	-4	-3	-3	0	
3	0	0	0	-3	-87	-106
4	0	0	0	-1	-29	-49
5	1	0	1	3	73	
6	0	1	1	4	102	126
7	-2	-2	-2	-2	0	-181
8	-1	-2	-2	17	537	
9	-1	-1	-1	40	1189	1414
10	0	1	1	38	1088	---
11	320	27	174	262	--- *	
12	356	200	278	411	--- *	---

* No reading, Reading box was broken and was changed for next truck positions.

Table 10: Strains and stresses for span 3, position 2; Truck 1

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
1	-3	1	-1	0	29	40
2	-4	-1	-3	-4	-44	
3	0	3	2	0	-44	-57
4	0	1	1	-1	-44	-88
5	0	2	1	6	145	
6	1	0	1	9	247	301
7	-2	1	-1	0	15	-186
8	-2	0	-1	23	696	
9	-1	3	1	47	1334	1584
10	1	3	2	-1	-87	-365
11	27	27	27	65	1102	
12	200	200	200	260	1740	2085

Table 11: Strains and stresses for span 3, position 3; Truck 1

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
1	1	2	2	0	-44	-52
2	-1	-6	-4	-1	73	
3	3	0	2	2	15	25
4	1	3	2	0	-58	-164
5	2	3	3	12	276	
6	0	0	0	22	638	770
7	1	3	2	3	29	-213
8	0	0	0	28	812	
9	3	1	2	58	1624	1926
10	3	8	6	46	1175	1186*
11	27	26	27	48	624	
12	200	194	197	235	1102	1088

* From comparison of gages 10, 11, and 12 it is clear that this reading is not valid, and therefore was ignored.

Table 12: Strains and stresses for span 3, position 4; Truck 1

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
1	2	2	2	0	-58	-80
2	-6	-8	-7	-6	29	
3	0	2	1	4	87	114
4	3	5	4	3	-29	-174
5	3	4	4	20	479	
6	0	2	1	33	928	1109
7	3	4	4	5	44	-203
8	0	2	1	31	870	
9	1	2	2	59	1668	1975
10	8	6	7	5	-58	-168
11	26	21	24	34	305	
12	194	190	192	215	667	804

Table 13: Strains and stresses for span 3, position 1; Trucks 1 & 2

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
1	-2	-3	-3	-3	-15	-87
2	-2	-4	-3	6	261	
3	0	0	0	16	464	554
4	0	0	0	-1	-29	-296
5	1	0	1	32	914	
6	0	1	1	60	1726	2057
7	-2	-2	-2	-5	-87	-413
8	-1	-2	-2	32	972	
9	-1	-1	-1	70	2059	2465
10	0	1	1	3	73	---
11	320	27	174	255	--- *	
12	356	200	278	436	--- *	---

Table 14: Strains and stresses for span 3, position 2; Trucks 1 & 2

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
1	-3	1	-1	-2	-29	-106
2	-4	-1	-3	8	305	
3	0	3	2	18	479	574
4	0	1	1	1	15	-281
5	0	2	1	35	986	
6	1	0	1	68	1958	2325
7	-2	1	-1	0	15	-336
8	-2	0	-1	38	1131	
9	-1	3	1	81	2320	2756
10	1	3	2	-2	-116	-403
11	27	27	27	61	986	
12	200	200	200	261	1769	2125

PART II

TABLES 17-34 ARE DECK TEST RESULTS

Table 17: Strains and stresses for span 1, position 1; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
13	0	1	1	3	73	
14	0	-3	-2	-4	-73	
15	0	-1	-1	7	218	
16	0	7	4	-4	-218	
17	0	1	1	10	276	
18	0	0	0	0	0	
19	0	-2	-1	23	696	
20	0	0	0	-44	-1276	
21	0	2	1	-3	-15	
22	0	-2	-1	-2	-4	
23	0	3	2	-1	-10	
24	0	-6	-3	-12	-34	
25	0	2	1	-3	-15	
26	0	-1	-1	-9	-33	
27	0	-1	-1	-8	-29	
28	0	-5	-3	-11	-33	
29	0	-5	-3	-18	-59	
30	0	0	0	0	0	
31	0	-6	-3	7	290	

Table 18: Strains and stresses for span 1, position 2; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
13	1	0	1	8	218	
14	-3	-6	-5	-15	-305	
15	-1	0	-1	19	566	
16	7	5	6	-38	-1276	
17	1	-2	-1	-22	-624	
18	0	0	0	0	0	
19	-2	-1	-2	20	624	
20	0	-3	-2	-138	-3959	
21	2	6	4	0	-15	
22	-2	3	1	-8	-33	
23	3	6	5	-3	-29	
24	-6	-4	-5	-18	-50	
25	2	4	3	-10	-50	
26	-1	3	1	-15	-61	
27	-1	4	2	-13	-55	
28	-5	-2	-4	-15	-44	
29	-5	-3	-4	-21	-65	
30	0	0	0	0	0	
31	-6	-4	-5	21	754	

Table 19: Strains and stresses for span 1, position 3; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE:	LOADED READING	STRESS psi	REMARKS
13	0	-1	-1	9	276	
14	-6	-7	-7	-21	-421	
15	0	0	0	31	899	
16	5	3	4	-75	-2291	
17	-2	-4	-3	-67	-1856	
18	0	0	0	0	0	
19	-1	1	0	55	1595	
20	-3	-5	-4	-128	-3596	
21	6	0	3	-3	-23	
22	3	-7	-2	-5	-11	
23	6	0	3	-4	-27	
24	-4	-8	-6	-21	-57	
25	4	-1	2	-16	-67	
26	3	-6	-2	-11	-36	
27	4	-5	-1	-11	-40	
28	-2	-9	-6	-10	-17	
29	-3	-5	-4	-26	-84	
30	0	0	0	0	0	
31	-4	-1	-3	32	1001	

Table 20: Strains and stresses for span 1, position 4; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE:	LOADED READING	STRESS psi	REMARKS
13	-1	-1	-1	13	406	
14	-7	-7	-7	-19	-348	
15	0	-1	-1	12	363	
16	3	3	3	-26	-841	
17	-4	-3	-4	-37	-972	
18	0	0	0	0	0	
19	1	2	2	4	73	
20	-5	-7	-6	4	290	
21	0	1	1	-5	-21	
22	-7	-6	-7	-9	-10	
23	0	0	0	-6	-23	
24	-8	-7	-8	-27	-75	
25	-1	-4	-3	-17	-55	
26	-6	-4	-5	-19	-54	
27	-5	-2	-4	-11	-29	
28	-9	-8	-9	-14	-21	
29	-5	-5	-5	-19	-54	
30	0	0	0	0	0	
31	-1	-2	-2	0	44	

Table 21: Strains and stresses for span 1, position 5; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
13	-1	-3	-2	-20	-522	
14	-7	-6	-7	40	1349	
15	-1	2	1	55	1581	
16	3	3	3	-143	-4234	
17	-3	-2	-3	-91	-2567	
18	0	0	0	0	0	
19	2	4	3	45	1218	
20	-7	-4	-6	-59	-1552	
21	1	6	4	-9	-48	
22	-6	-2	-4	-17	-50	
23	0	7	4	-7	-40	
24	-7	4	-2	-30	-109	
25	-4	3	-1	-28	-105	
26	-4	3	-1	-11	-40	
27	-2	4	1	-2	-11	
28	-8	-2	-5	-4	4	
29	-5	-1	-3	-15	-46	
30	0	0	0	0	0	
31	-2	0	-1	15	464	

Table 22: Strains and stresses for span 1, position 6; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
13	-3	-6	-5	-58	-1552	
14	-6	-9	-8	109	3379	
15	2	3	3	35	943	
16	3	-1	1	-94	-2755	
17	-2	2	0	-41	-1189	
18	0	0	0	0	0	
19	4	7	6	33	798	
20	-4	-4	-4	-41	-1073	
21	6	4	5	-13	-69	
22	-2	-6	-4	-19	-57	
23	7	4	6	-14	-75	
24	4	4	4	-24	-107	
25	3	2	3	-25	-105	
26	3	0	2	-18	-75	
27	4	5	5	-3	-29	
28	-2	-3	-3	-8	-21	
29	-1	0	-1	-11	-40	
30	0	0	0	0	0	
31	0	1	1	8	218	

Table 23: Strains and stresses for span 1, position 7; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
13	-6	-6	-6	-60	-1566	
14	-9	-6	-8	133	4075	
15	3	4	4	7	102	
16	-1	-2	-2	-12	-305	
17	2	1	2	-12	-392	
18	0	0	0	0	0	
19	7	4	6	23	508	
20	-4	-5	-5	-29	-711	
21	4	0	2	-16	-69	
22	-6	-11	-9	-28	-75	
23	4	-4	0	-21	-80	
24	4	5	5	-28	-124	
25	2	-4	-1	-21	-76	
26	0	-4	-2	-21	-73	
27	5	0	3	-6	-33	
28	-3	-10	-7	-12	-21	
29	0	-4	-2	-10	-31	
30	0	0	0	0	0	
31	1	-2	-1	3	102	

Table 24: Strains and stresses for span 1, position 8; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
13	-6	-5	-6	-29	-682	
14	-6	-3	-5	81	2480	
15	4	7	6	8	73	
16	-2	1	-1	13	392	
17	1	4	3	5	73	
18	0	0	0	0	0	
19	4	7	6	17	334	
20	-5	-2	-4	-15	-334	
21	0	4	2	-19	-80	
22	-11	-5	-8	-32	-92	
23	-4	9	3	-12	-55	
24	5	12	9	-38	-178	
25	-4	1	-2	-21	-75	
26	-4	4	0	-14	-54	
27	0	5	3	-7	-36	
28	-10	-5	-8	-13	-21	
29	-4	2	-1	-6	-19	
30	0	0	0	0	0	
31	-2	-1	-2	1	73	

Table 25: Strains and stresses for span 1, position 9; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE:	LOADED READING	STRESS psi	REMARKS
13	-5	-6	-6	-44	-1117	
14	-3	-5	-4	84	2552	
15	7	7	7	35	812	
16	1	-2	-1	-60	-1726	
17	4	3	4	11	218	
18	0	0	0	0	0	
19	7	6	7	11	131	
20	-2	-5	-4	-10	-189	
21	4	-1	2	-22	-90	
22	-5	-8	-7	-33	-101	
23	9	6	8	-15	-86	
24	12	10	11	-26	-141	
25	1	-1	0	-20	-76	
26	4	1	3	-15	-67	
27	5	2	4	-7	-40	
28	-5	-10	-8	-14	-25	
29	2	-2	0	-6	-23	
30	0	0	0	0	0	
31	-1	-1	-1	-2	-29	

Table 26: Strains and stresses for span 3, position 1; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE:	LOADED READING	STRESS psi	REMARKS
13	0	3	2	4	73	
14	0	0	0	-4	-116	
15	0	-4	-2	3	145	
16	0	1	1	-9	-276	
17	0	-8	-4	-3	29	
18	0	-52	-26	-74	-1392	
19	0	-7	-4	13	479	
20	0	5	3	-45	-1378	
21	0	-41	-21	-45	-94	
22	0	25	13	4	-33	
23	0	14	7	10	11	
24	0	3	2	12	40	
25	0	-7	-4	30	128	
26	0	104	52	137	325	
27	0	19	10	27	67	
28	0	8	4	-4	-31	
29	0	13	7	3	-13	
30	1225	1235	1230	1228	-58	
31	0	1	1	10	276	
32	0	1	1	1	15	

Table 27: Strains and stresses for span 3, position 2; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
13	3	3	3	10	203	
14	0	2	1	-9	-290	
15	-4	-5	-5	18	653	
16	1	3	2	-38	-1160	
17	-8	-12	-10	-19	-261	
18	-52	-52	-52	-22	870	
19	-7	-6	-7	11	508	
20	5	7	6	-101	-3103	
21	-41	-48	-45	-39	21	
22	25	11	18	9	-34	
23	14	14	14	12	-8	
24	3	3	3	-1	-15	
25	-7	-49	-28	-40	-46	
26	104	13	59	1	-220	
27	19	-6	7	-5	-44	
28	8	9	9	7	-6	
29	13	8	11	-18	-109	
30	1235	1258	1247	1273	769	
31	1	3	2	20	522	
32	1	3	2	3	29	

Table 28: Strains and stresses for span 3, position 3; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
13	3	2	3	9	189	
14	2	2	2	-13	-435	
15	-5	-7	-6	18	696	
16	3	5	4	-53	-1653	
17	-12	-9	-11	-38	-798	
18	-52	-50	-51	37	2552	
19	-6	-4	-5	29	986	
20	7	9	8	-89	-2813	
21	-48	-46	-47	-47	0	
22	11	16	14	9	-17	
23	14	17	16	12	-13	
24	3	2	3	-5	-29	
25	-49	-44	-47	-55	-33	
26	13	2	8	-7	-55	
27	-6	-7	-7	-4	10	
28	9	11	10	-4	-54	
29	8	13	11	-26	-140	
30	1258	1206	1232	1222	-290	
31	3	5	4	22	522	
32	3	5	4	4	0	

Table 29: Strains and stresses for span 3, position 4; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
13	2	3	3	13	305	
14	2	3	3	-14	-479	
15	-7	-9	-8	8	464	
16	5	6	6	-84	-2596	
17	-9	-13	-11	-33	-638	
18	-50	-49	-50	26	2190	
19	-4	-5	-5	-11	-189	
20	9	10	10	37	798	
21	-46	-51	-49	-53	-17	
22	16	14	15	11	-15	
23	17	17	17	14	-11	
24	2	3	3	-5	-29	
25	-44	-45	-45	-62	-67	
26	2	6	4	12	31	
27	-7	-10	-9	8	63	
28	11	10	11	-2	-48	
29	13	8	11	48	143	
30	1206	1208	1207	1230	667	
31	5	5	5	6	29	
32	5	7	6	7	29	

Table 30: Strains and stresses for span 3, position 5; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
13	3	0	2	-15	-479	
14	3	6	5	35	885	
15	-9	-8	-9	50	1697	
16	6	8	7	-143	-4350	
17	-13	-12	-13	-66	-1552	
18	-49	-45	-47	171	6322	
19	-5	-2	-4	31	1001	
20	10	12	11	-40	-1479	
21	-51	-51	-51	-62	-42	
22	14	15	15	1	-52	
23	17	14	16	14	-6	
24	3	-4	-1	-6	-21	
25	-45	-56	-51	-80	-113	
26	6	-3	2	-16	-67	
27	-10	-14	-12	-4	31	
28	10	10	10	-1	-42	
29	8	12	10	64	206	
30	1208	1204	1206	1245	1131	
31	5	7	6	18	348	
32	7	7	7	16	261	

Table 31: Strains and stresses for span 3, position 6; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
13	0	-1	-1	-60	-1726	
14	6	5	6	112	3089	
15	-8	-10	-9	28	1073	
16	8	8	8	-123	-3799	
17	-12	-11	-12	-44	-943	
18	-45	-42	-44	77	3495	
19	-2	-1	-2	24	740	
20	12	13	13	-25	-1088	
21	-51	-56	-54	-71	-67	
22	15	14	15	1	-52	
23	14	14	14	19	19	
24	-4	-4	-4	-6	-8	
25	-56	-59	-58	-79	-82	
26	-3	1	-1	-6	-19	
27	-14	-12	-13	-17	-15	
28	10	11	11	2	-33	
29	12	14	13	18	19	
30	1204	1209	1207	1250	1262	
31	7	6	7	12	160	
32	7	6	7	21	421	

Table 32: Strains and stresses for span 3, position 7; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
13	-1	-1	-1	-83	-2378	
14	5	8	7	171	4771	
15	-10	-7	-9	-9	-15	
16	8	11	10	-55	-1871	
17	-11	-10	-11	-22	-334	
18	-42	-44	-43	2	1305	
19	-1	-2	-2	17	537	
20	13	16	15	-14	-827	
21	-56	-58	-57	-80	-88	
22	14	15	15	-6	-78	
23	14	13	14	17	13	
24	-4	-6	-5	-12	-27	
25	-59	-58	-59	-83	-94	
26	1	-7	-3	-16	-50	
27	-12	-7	-10	-13	-13	
28	11	14	13	3	-36	
29	14	19	17	1	-59	
30	1209	1207	1208	1242	986	
31	6	5	6	9	102	
32	6	4	5	25	580	

Table 33: Strains and stresses for span 3, position 8; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
13	-1	0	-1	-37	-1059	
14	8	8	8	90	2378	
15	-7	-8	-8	-5	73	
16	11	14	13	36	682	
17	-10	-8	-9	-4	145	
18	-44	-42	-43	-50	-203	
19	-2	0	-1	8	261	
20	16	18	17	5	-348	
21	-58	-57	-58	-88	-117	
22	15	14	15	-12	-101	
23	13	16	15	14	-2	
24	-6	-2	-4	-11	-27	
25	-58	-55	-57	-77	-78	
26	-7	3	-2	-16	-54	
27	-7	-10	-9	-15	-25	
28	14	13	14	8	-21	
29	19	10	15	18	13	
30	1207	1218	1213	1250	1088	
31	5	4	5	5	15	
32	4	8	6	37	899	

Table 34: Strains and stresses for span 3, position 9; live load

GAGE NO.	INITIAL READING	FINAL READING	AVERAGE	LOADED READING	STRESS psi	REMARKS
13	0	0	0	-60	-1740	
14	8	9	9	114	3060	
15	-8	-8	-8	29	1073	
16	14	15	15	-56	-2045	
17	-8	-9	-9	4	363	
18	-42	-44	-43	-65	-638	
19	0	-2	-1	4	145	
20	18	19	19	15	-102	
21	-57	-61	-59	-95	-138	
22	14	14	14	-11	-96	
23	16	16	16	18	8	
24	-2	-2	-2	-3	-4	
25	-55	-55	-55	-73	-69	
26	3	-11	-4	-16	-46	
27	-10	-12	-11	-14	-11	
28	13	14	14	10	-13	
29	10	15	13	10	-10	
30	1218	1214	1216	1235	551	
31	4	4	4	5	29	
32	8	5	7	36	856	

1) AASHTO LRFD

I) INTERIOR BEAM:

Single and multi lane distribution factors for interior girder (S2 & S3): AASHTO LRFD Table 4.6.2.2.2b-1

Single Lane

D.F. = $0.06 + (S/14.)^{0.4} (S/L)^{0.3} (K_g/12.LT_s^3)^{0.1}$

Multi Lane

D.F. = $0.075 + (S/9.5)^{0.6} (S/L)^{0.2} (K_g/12.LT_s^3)^{0.1}$

where;

K_g = $n(I+Ae_g^2)$
A = stringer area
e_g = distance from center of beam to the center of deck.
T_s = deck thickness
S = stringers spacing
L = Stringers span length

Girders for the tested bridge are W36 x 170 @ 8'-3" c/c spacing and simple span of 45'-0" long. Deck is 5" half depth concrete-filled steel grid deck with 1-1/2" concrete overfill.

a) Assume thickness is equal to total concrete depth including overpour
t = 2.5 + 1.5 = 4.
e_g = 36.17/2. + 3.875 + 4./2. = 23.96 inches
assumed 3.875" haunch, includes 1 3/8 " bar that was welded to the top of girder and 2.5" to the bottom of the concrete.
$K_g = 8(10500 + 50 \times 23.96^2) = 313633$

Single Lane Distribution Factor:

D.F. = $0.06 + (8.25/14)^{0.4} (8.25/45.)^{0.3} (313633/(12.x45.x4.^3))^{0.1}$
= 0.667 Trucks

Multi Lane Distribution Factor:

D.F. = $0.075 + (8.25/9.5)^{0.6} (8.25/45.)^{0.2} (313633/(12.x45.x4.^3))^{0.1}$
= 0.891 Trucks

b) Assume thickness is equal to total deck depth including overpour
t = 5.187 + 1.5 = 6.68"
e_g = 36.17/2. + 1.375 + 6.68/2. = 22.8 inches
assumed 1.375" haunch
$K_g = 8(10500 + 50 \times 22.8^2) = 291936$

Single Lane Distribution Factor:

D.F. $= 0.06 + (8.25/14)^{0.4}\ (8.25/45.)^{0.3}\ (291936/(12.\mathrm{x}45.\mathrm{x}6.68^3))^{0.1}$
$= 0.576$ Trucks

Multi Lane Distribution Factor:

D.F. $= 0.075 + (8.25/9.5)^{0.6}\ (8.25/45.)^{0.2}\ (291936/(12.\mathrm{x}45.\mathrm{x}6.68^3))^{0.1}$
$= 0.770$ Trucks

Computation of theoretical moment:

As is indicated in the text, strain gage measurements were taken at the centerline, 0.5L, of girders with truck axle at this location. Therefore, compute moment for a simple-span beam with 45' span length and 23.17 kips load, first axle of Truck 1, at the center of the beam and 9.8 kips load, second axle, at 12'-5" from center of the beam:

M = 310.071 k-feet due to Truck 1 (D.F. = 1)

Note: since Truck 2 axle weights are nearly the same as Truck 1, for simplicity assume that moment due to Truck 2 is the same.

Compute theoretical stresses for multi and single lane trucks:

Distribution factor based on total concrete including overpour t=4"

M(single lane) = 0.576 x 310.071 = 178.601 k-feet
M(multi lane) = 0.770 x 310.071 = 238.755 k-feet

Composite section properties of the girders, based on center-center of deck as effective flange width, is as follow: Note that this effective flange width, 99", is greater than 12t (total thickness of 6.68), 80", and this is a conservative assumption for this calculation.

Composite section properties of the interior beam (S2 & S3):

```
TOP    FLANGE= 12.030 IN. X  1.1000 IN.
BOTTOM FLANGE= 12.030 IN. X  1.1000 IN.
WEB PLATE    = 33.970 IN. X   .6800 IN.
DECK:
  EFFECTIVE WIDTH= 99.000 IN.
  THICKNESS      =  4.000 IN.
  HAUNCH         =  4.975 IN.  which is from top of web to the
bottom of the concrete.

AREA OF STEEL= 49.57 IN.2
```

SECTION PROPERTIES

```
IX=     10361.67 in4; (STEEL ONLY)
N/A AT  18.09 in FROM BOTT. OF SECTION

IX=     17490.28 in4;  (3N=  24)
N/A AT  24.07 in FROM BOTT. OF SECTION

IX=     24645.60 in4;  ( N=   8)
N/A AT  30.06 in FROM BOTT. OF SECTION
S(top) = 4033.65 in3
S(bottom) = 819.88 in3
```

<u>Top flange stress</u>

f(single lane) = 178.601 x 12 / 4033.65 = 0.531 ksi
f(multi lane) = 238.755 x 12 / 4033.65 = 0.710 ksi

<u>Bottom flange stress</u>

f(single lane) = 178.601 x 12 / 819.88 = 2.614 ksi
f(multi lane) = 238.755 x 12 / 819.88 = 3.494 ksi

II) EXTERIOR BEAM:

Single and multi lane distribution factors for exterior girder (S2 & S3): AASHTO LRFD Table 4.6.2.2.2d-1

Single Lane Distribution factor:

Lever Rule:
Assume first wheel on top of the exterior girder and second girder 6' apart.

D.F. = (1 + 2.25/8.25) = 0.636 trucks

Multi Lane Distribution Factor:

D.F. = e(D.F. of single lane)

where;

$e = 0.77 + d_e/9.1 >= 1.0$ $-1.0 =< d_e <= 5.5$
d_e = Distance between the center of exterior beam and interior edge of the curb or traffic barrier (FT)

d_e = 1' - 7 1/2" = 1.625'
e = 0.77 + 1.625/9.1 = 0.949 therefor; e = 1.0
D.F. = 1(D.F. of single lane) = 0.636 trucks

Computation of theoretical moment:

The same as interior girder.

M = 310.071 k-feet due to Truck 1 (D.F. = 1)

Compute theoretical stresses for multi and single lane trucks:

M(single & multi lane) = 0.636 x 310.071 = 197.205 k-feet

Composite section properties of the girders, based on effective deck width from edge of the deck to the center of spacing between the exterior and first interior girder, is as follows: This effective flange width is 69".

Composite section properties of the exterior beam (S1 & S4):

```
TOP    FLANGE=  12.030 IN. X  1.1000 IN.
BOTTOM FLANGE=  12.030 IN. X  1.1000 IN.
WEB PLATE    =  33.970 IN. X   .6800 IN.
DECK:
  EFFECTIVE WIDTH=  69.000 IN.
  THICKNESS      =   4.000 IN.
  HAUNCH         =   4.975 IN.
AREA OF STEEL=  49.57 IN.2
```

SECTION PROPERTIES

```
IX=     10361.67 in4; (STEEL ONLY)
N/A AT  18.09 in FROM BOTT. OF SECTION

IX=     15735.65 in4;  (3N=  24)
N/A AT  22.60 in FROM BOTT. OF SECTION

IX=     22085.30 in4;  ( N=   8)
N/A AT  27.92 in FROM BOTT. OF SECTION
S(top) = 2677.00 in3
S(bottom) = 791.02 in3
```

<u>Top flange stress</u>

f(single & multi lane) = 197.205 x 12 / 2677.00 = 0.884 ksi

<u>Bottom flange stress</u>

f(single & multi lane) = 197.205 x 12 / 791.02 = 2.992 ksi

2) AASHTO Standard Specification for Highway Bridges, 15th Edition Table 3.23.1

I) Interior beam

Single Lane:

Since girder spacings are greater than 6' use footnote "f".

D.F. = (1. + 2.25/8.25)/2. = 0.636 trucks

Multi Lane:

From AASHTO Table 3.23.1; S/5.

D.F. = 8.25 / 5. = 1.65 wheel, 0.825 trucks

II) Exterior beam

Assume first wheel 2' from curb:

D.F. = (7.875 + 1.875) / 8.25 = 1.182 wheels, 0.591 trucks

Stresses can computed by multiplying the AASHTO LRFD stresses by the ratio of live load distribution factors of AASHTO over AASHTO LRFD.

COMPUTATION OF LIVE LOAD MOMENT IN STEEL GRID DECK

I) AASHTO LRFD

Since live load is known, live load moment was computed with multiple presence factor "m" of 1. for one lane, γ of 1., and impact factor of 0%.

Tire contact area equation is:

$$l = m\gamma\left(1 + \frac{IM}{100}\right)\frac{P}{2.5} \qquad 3.6.1.2.5 \qquad (Eq.1)$$

where;

l = Tire length in direction of traffic;
width = 20 inches;
P = 10 kips
IM (impact factor) = 0%

Live load moment equation is:

Note that this equation is exact solution of the equation presented in section 4.6.2.1.8 of the AASHTO LRFD.

$$M_L = \frac{4CqS^2}{\pi^3}\left[\Sigma_{m=1,2,3,..}\frac{1}{m^3}SIN\frac{m\pi\xi}{S}Sin\frac{m\pi u}{2S}SIN\frac{m\pi x}{S}\right]\left[1-\left(1+\frac{vm\pi}{4\lambda S}\right)\left(e^{\frac{-vm\pi}{2\lambda S}}\right)\right] \qquad (Eq.2)$$

where;

C = 1 for simple span and 0.8 for 3 or more continuous spans.
P = wheel load
q = P / (uv)
u = tire contact dimension in direction of main bars
v = tire contact dimension in direction of cross bars
(Note that one of these could be assumed 20" and the other one "l" as defined above)
S = span
ξ = location of center of patch load in direction of main bars
x = location of computed moment
$\lambda = (D_y/D_x)^{0.25} = (1/D)^{0.25}$
D_x = flexural rigidity in direction of main bars
D_y = flexural rigidity in direction of cross bars

Values of "D" from test; otherwise if not available, based on the LRFD AASHTO:

D = 2.0 fully filled grid decks with ≥ 1.5 in. monolithic overfill
D = 2.5 all other fully filled grid decks
D = 8.0 half filled grid decks with ≥ 1.5 in. monolithic overfill
D = 10.0 all other half filled grid decks

Using equation 2 compute live load moment

By moving one truck by small increments over 8.25' span it was determined that the maximum moment occurs under the first wheel at the center of the span.

Therefore;
C = .8
P = (wheel)(1+Impact)(m)(γ) = 10.x1.x1.x1.= 10.0 kips
u = 20 inches
v = 1 as defined in equation 1
  = (1.)(1.)(1 + 0.)10./2.5 = 4 inches
q = P/(uv) = 10.0/(4x20) = .125 k/sqft
$\lambda = (D_y / D_x)^{.25} = (1 / D)^{.25} = (1/8)^{.25} = 0.5946$
D = 8. from AASHTO LRFD 4.6.2.1.8

M_{LL} = 2.931 k-ft/ft

Since level of stresses is low assume that concrete is not cracked and compute section properties of the section with entire concrete.

I = 23.66 in^4 /ft

N.A. = 4.124" from bottom

S_t = 22.247 IN^3 /FT

S_b = 5.737 IN^3 /FT

f(top) = 2.931 x 12. / 22.247 = 1.581 ksi
f(bottom) = 2.931 x 12. / 5.737 = 6.131 ksi

Also, stresses computed utilizing the transformed area method section properties.

<u>Negative moment regions:</u>

f(top) = 2.931 x 12. / 4.86 = 7.237 ksi
f(bottom) = 2.931 x 12. / 4.209 = 8.356 ksi

<u>Positive moment regions:</u>

f(top) = 2.931 x 12. / 9.943= 3.537 ksi

f(bottom) = 2.931 x 12. / 5.433 = 6.474 ksi

II) AASHTO, Standard Specification for Highway Bridges, 15th Edition

Based on AASHTO equation (3.24.3.1):

M_{LL} = 0.8((S+2)/32)P = 0.8((8.25+2)/32)10 = 2.563 k-ft/ft

Note that this is service load moment and should not be compared with AASHTO LRFD moment shown above.

Section modulus based on transformed area method:

Positive moment region:

S_t = 9.943 IN^3 /FT

S_b = 5.433 IN^3 /FT

Negative moment region:

S_t = 4.860 IN^3 /FT

S_b = 4.209 IN^3 /FT

Stresses:

Positive moment region:

f(top) = 2.563 x 12. / 9.943 = 3.093 ksi
f(bottom) = 2.563 x 12. / 5.433 = 5.661 ksi

Negative moment region:

f(top) = 2.563 x 12. / 4.860 = 6.328 ksi
f(bottom) = 2.563 x 12. / 4.209 = 7.307 ksi

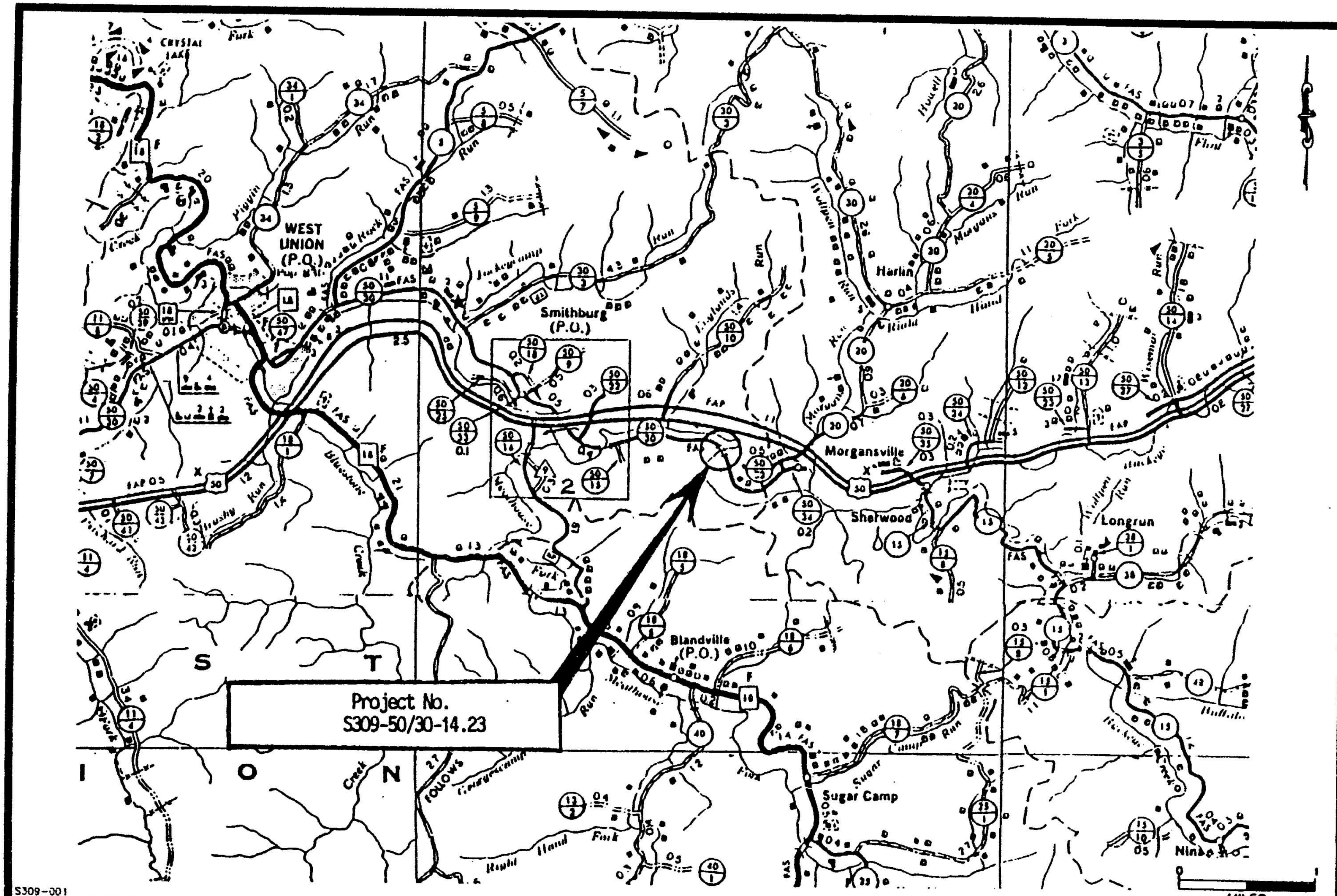


FIGURE 1
BRIDGE LOCATION

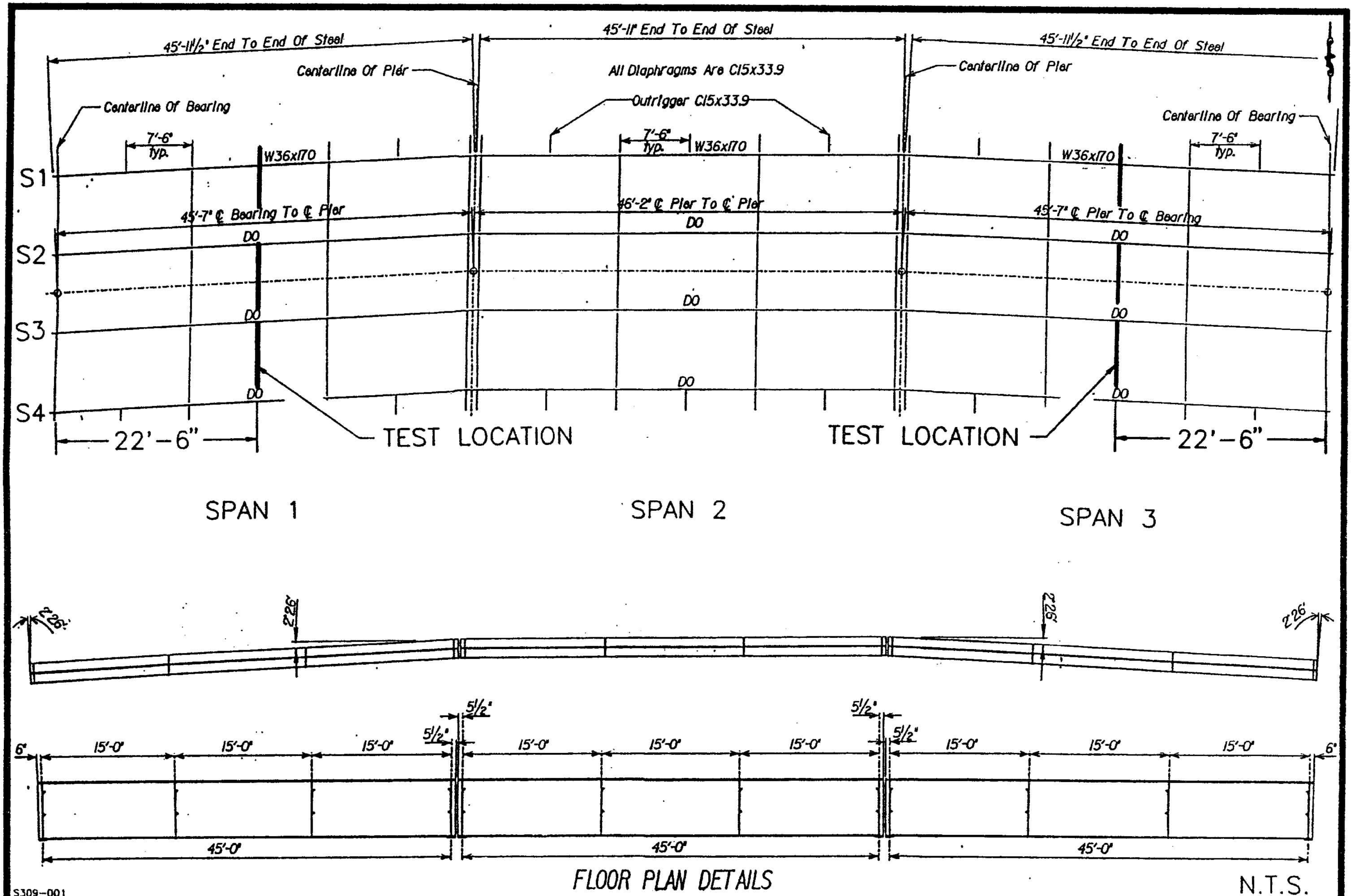
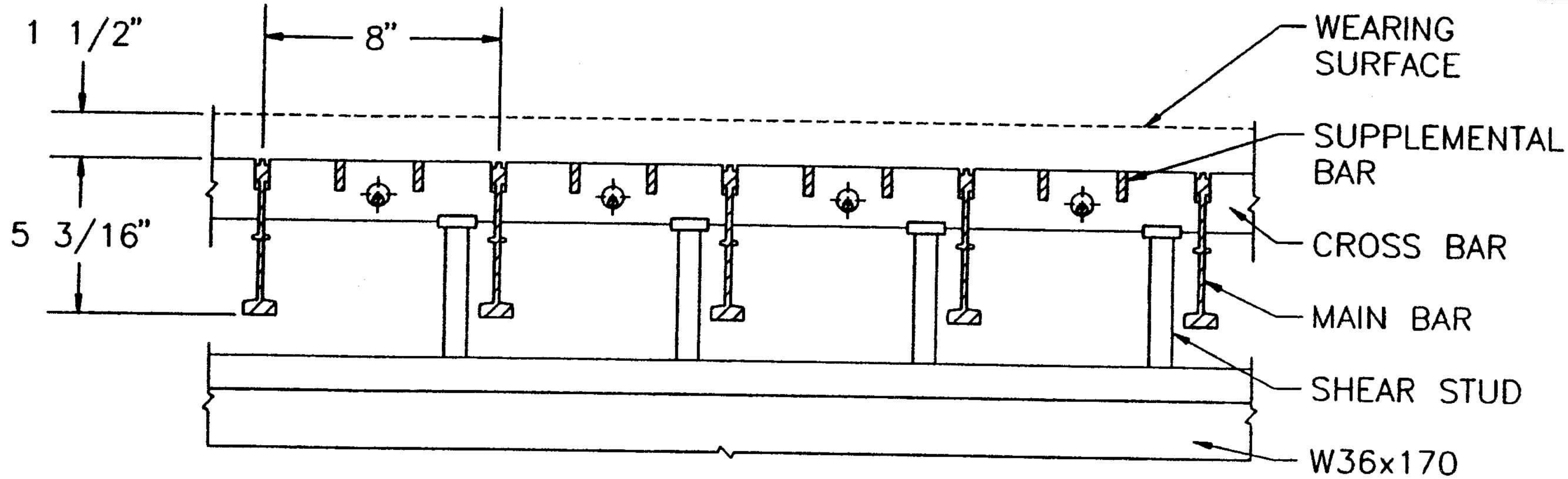
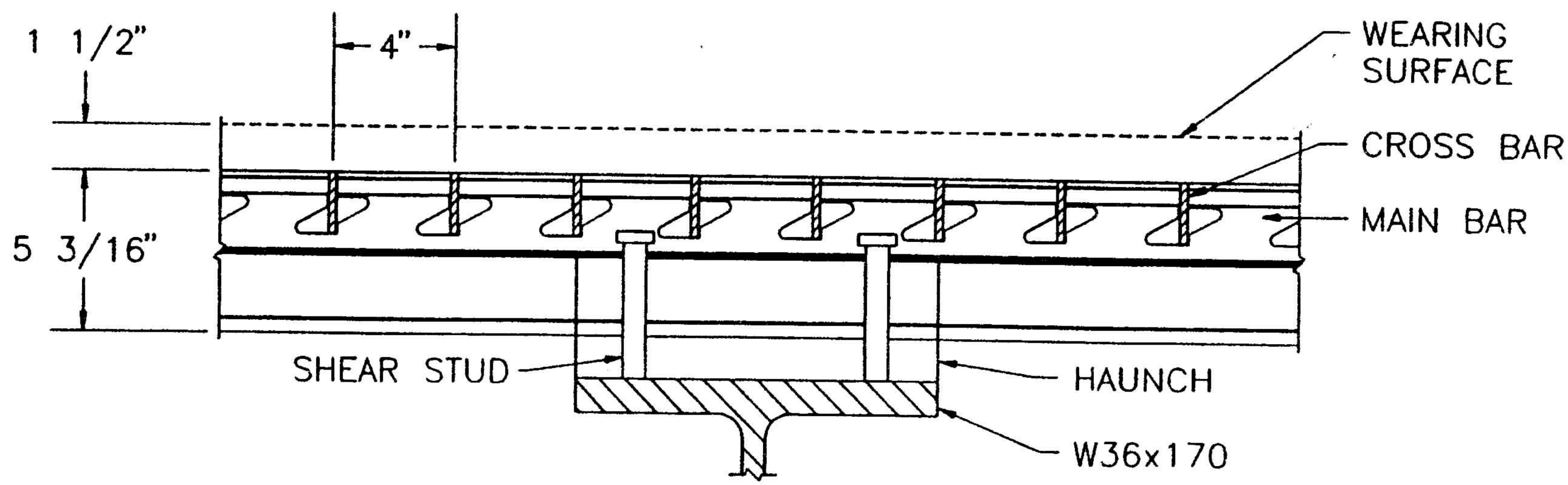


FIGURE 2
BRIDGE FRAMING PLAN



LOOKING NORTH

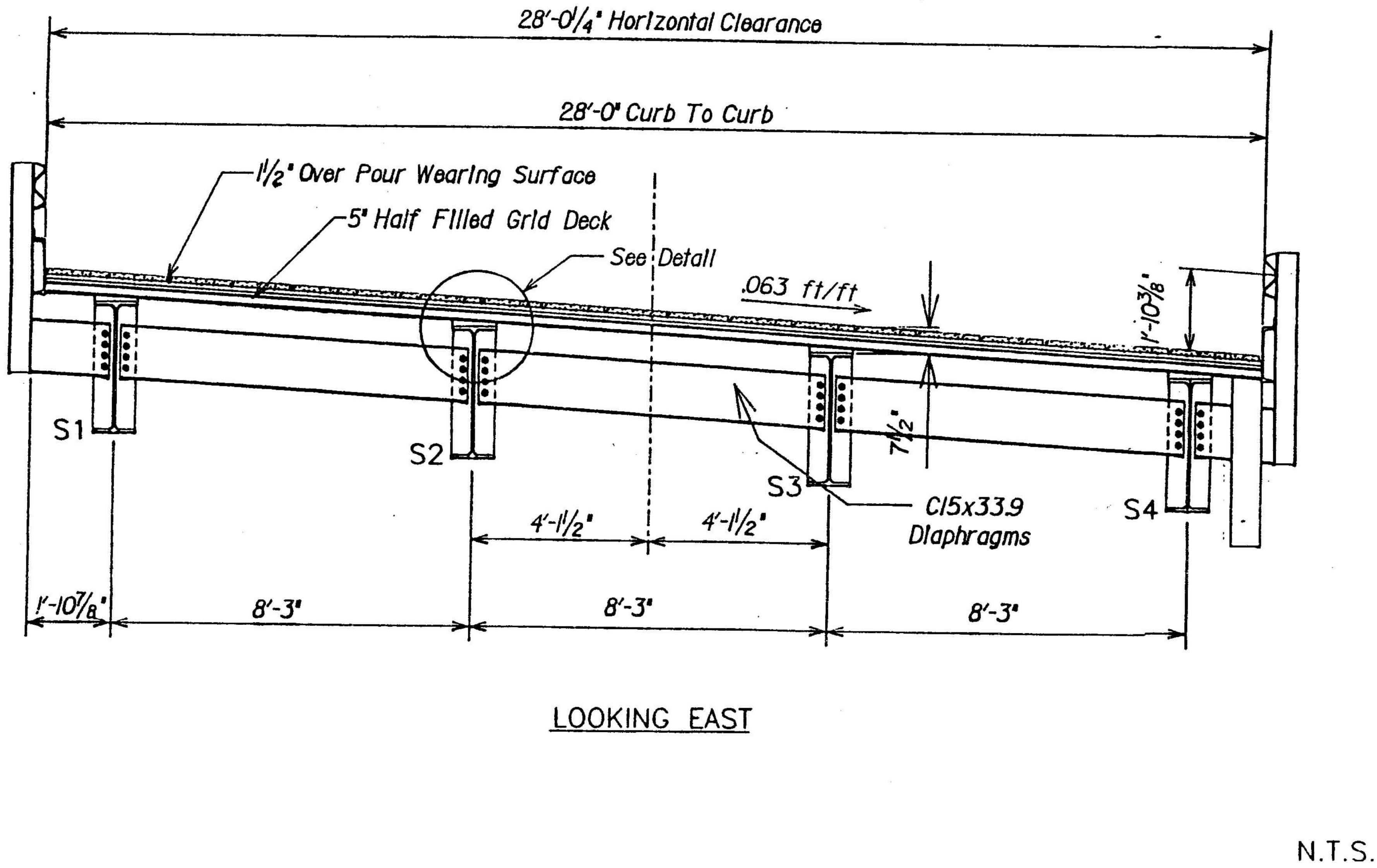


LOOKING EAST

S309-002

N.T.S.

FIGURE 3
TYPICAL GRID CROSS-SECTION



S309-001

FIGURE 4
TYPICAL DECK CROSS-SECTION

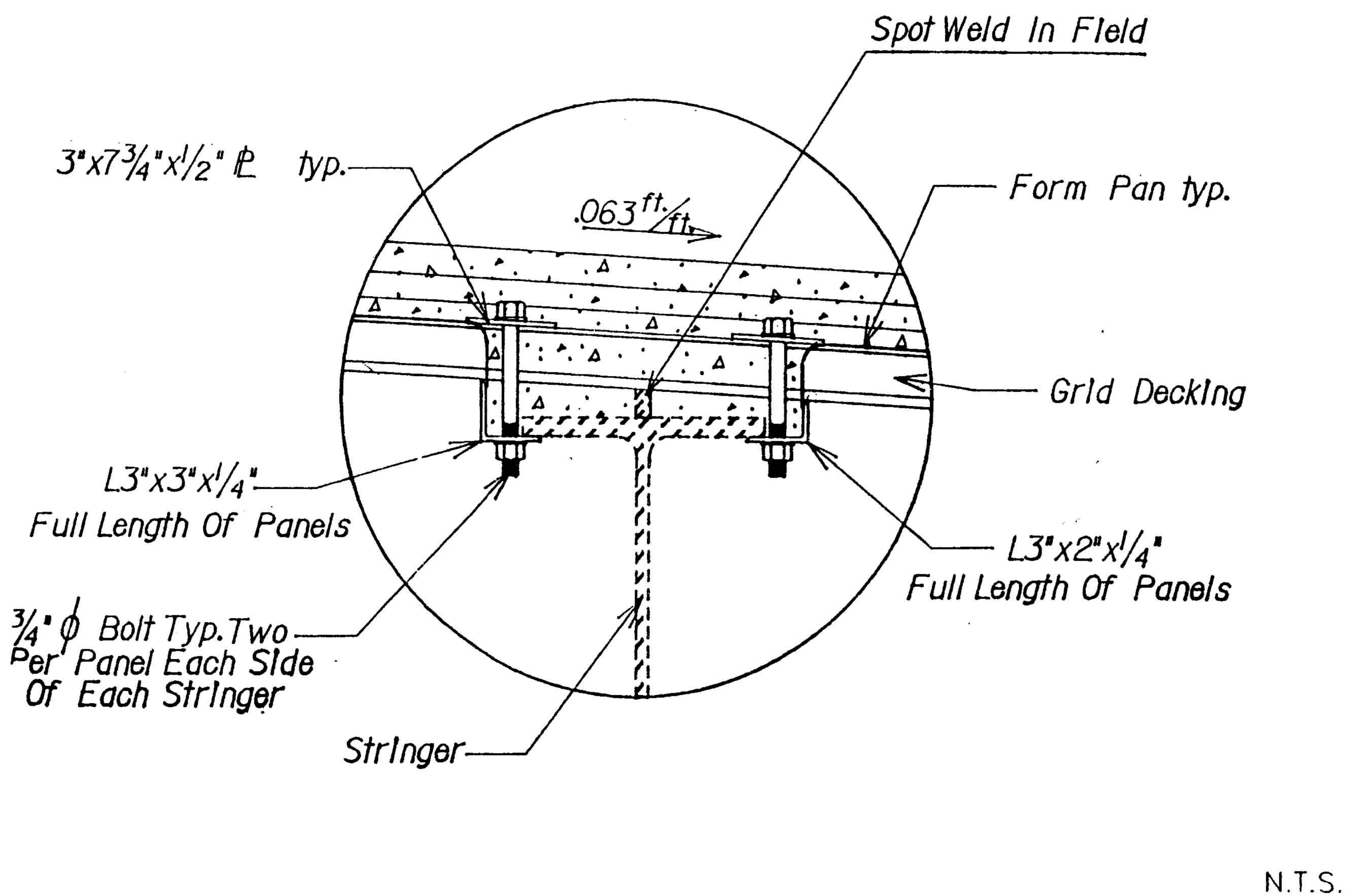


FIGURE 5
TYPICAL ATTACHMENT DETAIL, SPANS 2 AND 3

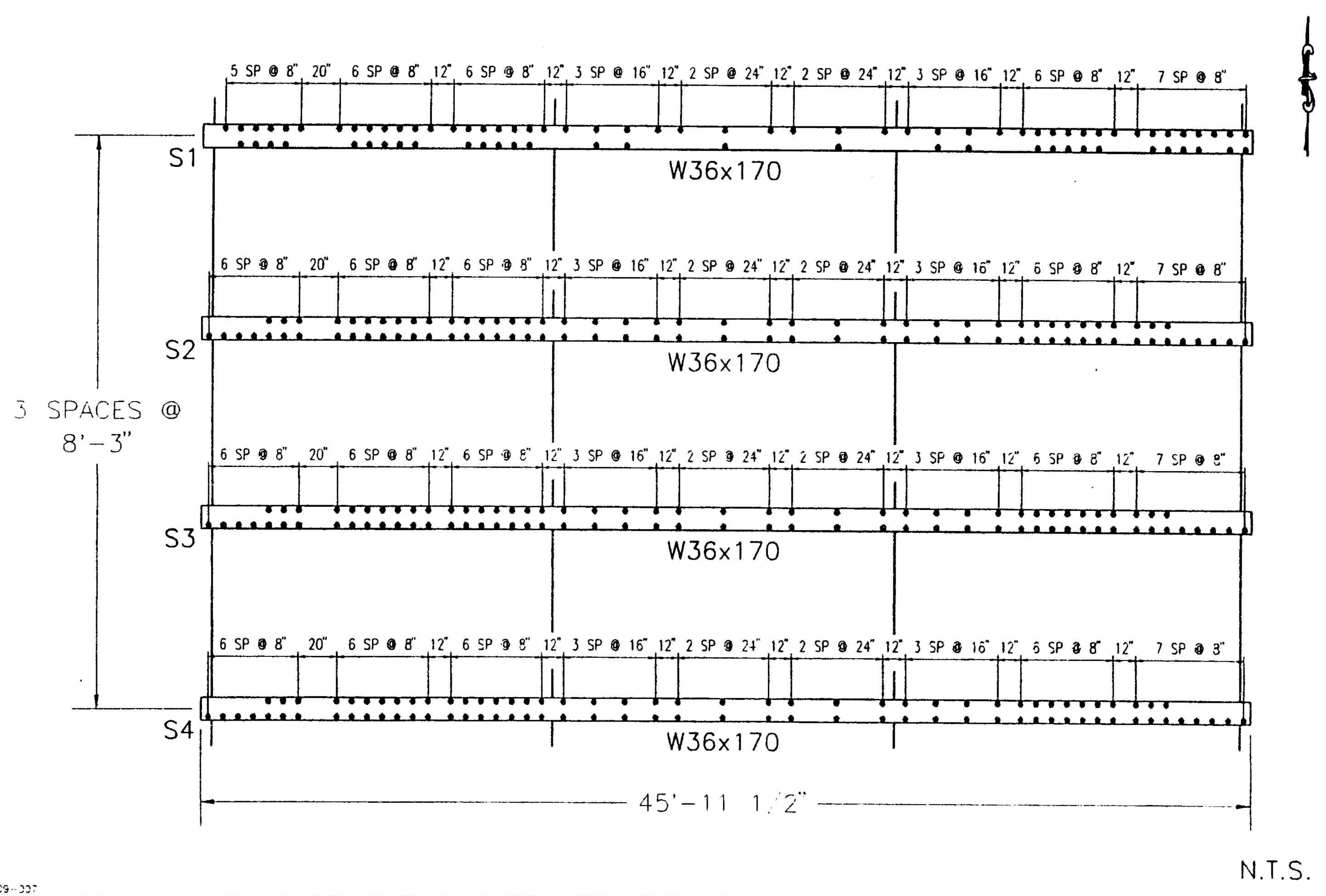
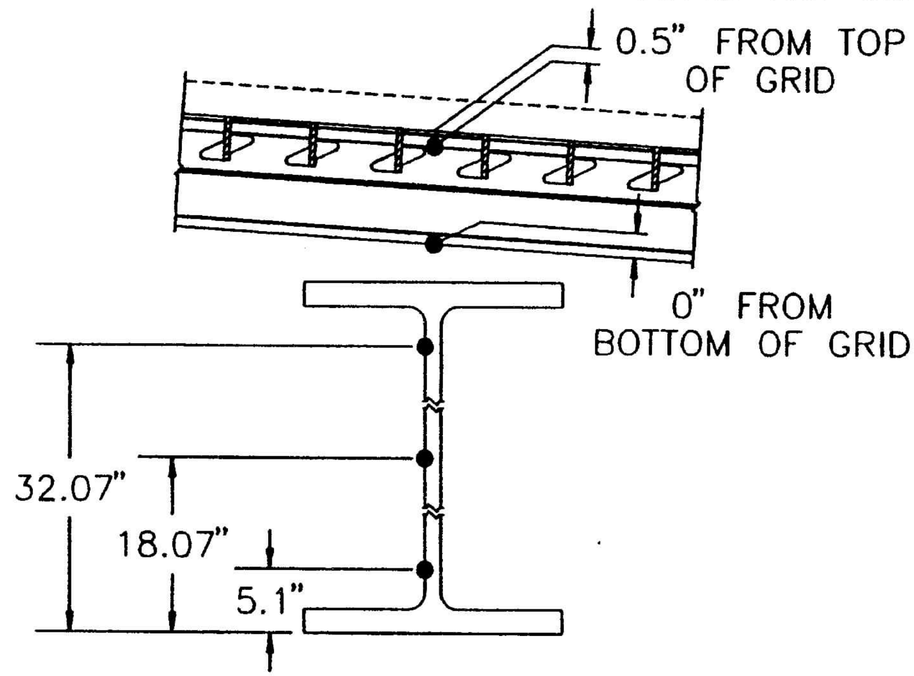


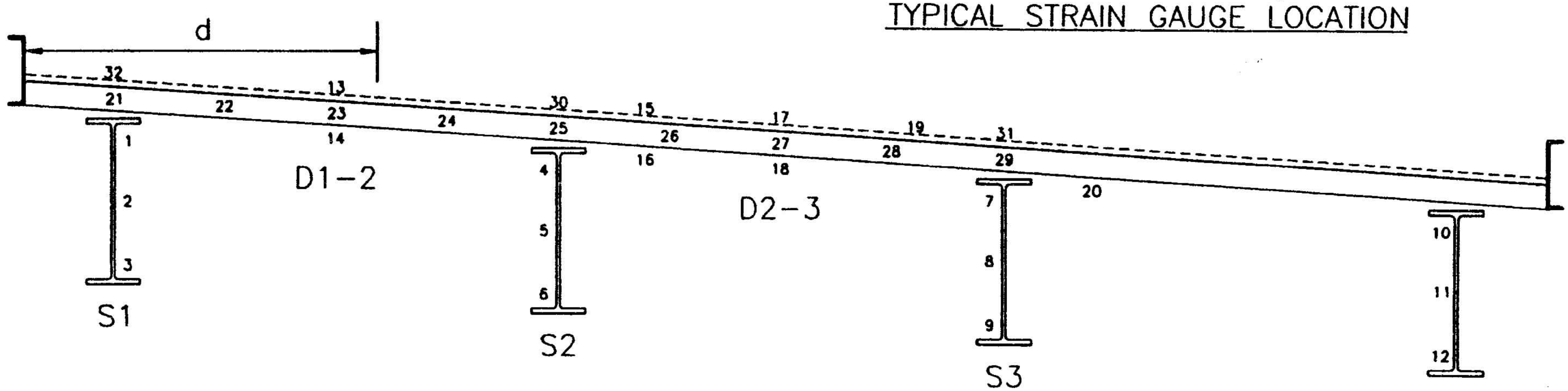
FIGURE 6
PLAN OF HEADED SHEAR STUDS, SPAN 1

GAUGE NUMBER	d
13	72"
14	72"
15	132"
16	132"
17	172"
18	172"
19	204"
20	228"
21	20"
22	48"

GAUGE NUMBER	d
23	72"
24	96"
25	120"
26	144"
27	172"
28	196"
29	216"
30	120"
31	216"
32	20"



TYPICAL STRAIN GAUGE LOCATION

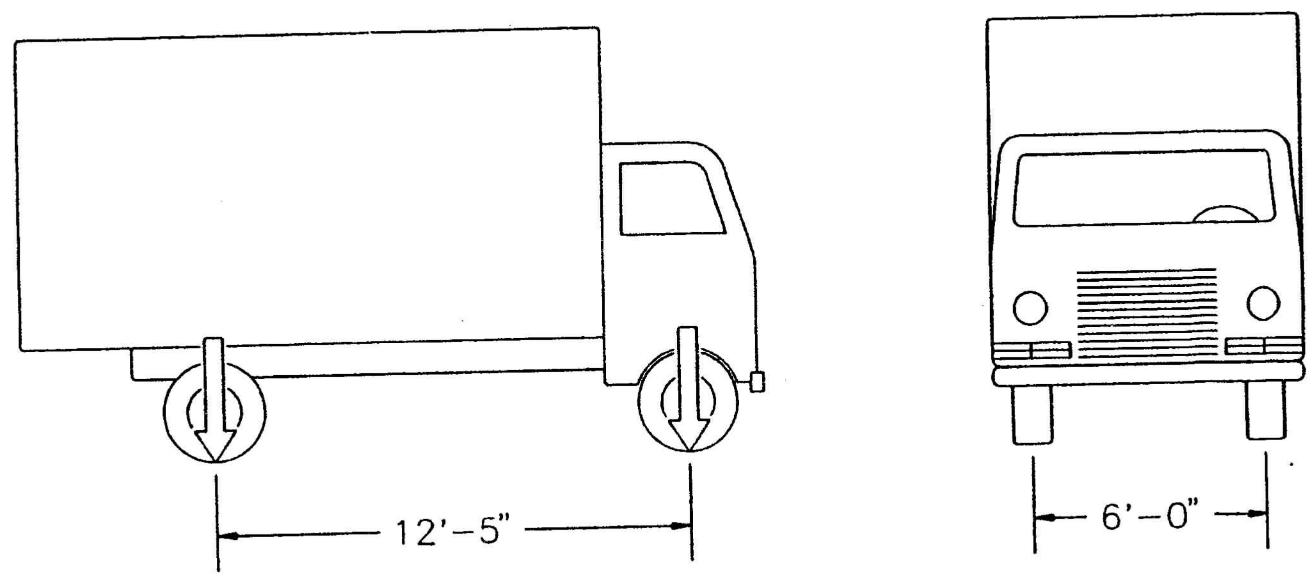


TYPICAL DECK CROSS-SECTION LOOKING EAST

N.T.S.

S309-003

FIGURE 7
STRAIN GAUGE LOCATIONS

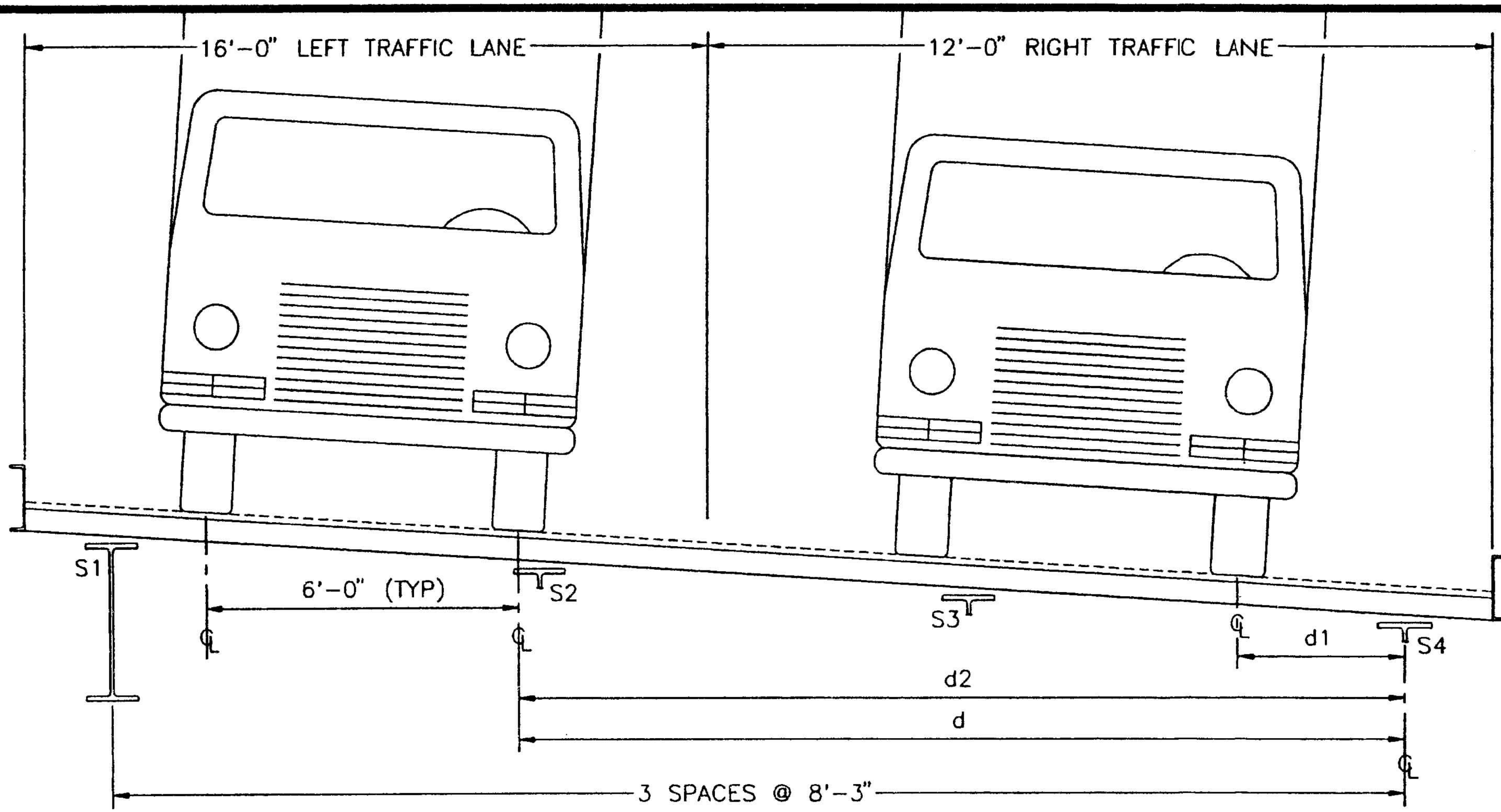


TRUCK		FRONT AXLE lbs	REAR AXLE lbs
DECK GAUGES		10,500	20,000
GIRDER GAUGES	T1	9,800	23,170
	T2	10,150	23,200

N.T.S.

S309-004

FIGURE 8
DIMENSIONS OF TEST TRUCK



DECK GAUGES			
POSITION NUMBER	d	POSITION NUMBER	d
1	0"	6	13'-6"
2	4'-1 1/2"	7	14'-7 1/2"
3	5'-3"	8	16'-6"
4	8'-3"	9	18'-9"
5	12'-4 1/2"		

TYPICAL DECK CROSS-SECTION
LOOKING EAST

GIRDER GAUGES		
POSITION NUMBER	TRUCK 1 d1	TRUCK 2 d2
1	0"	12'-4 1/2"
2	2'-3"	12'-4 1/2"
3	4'-3"	14'-3"
4	6'-3"	16'-6"

S309-006

FIGURE 10
TRUCK POSITIONS

Photo 3: Concrete strain gages

Photo 4: Strain gages attached to main grid bars

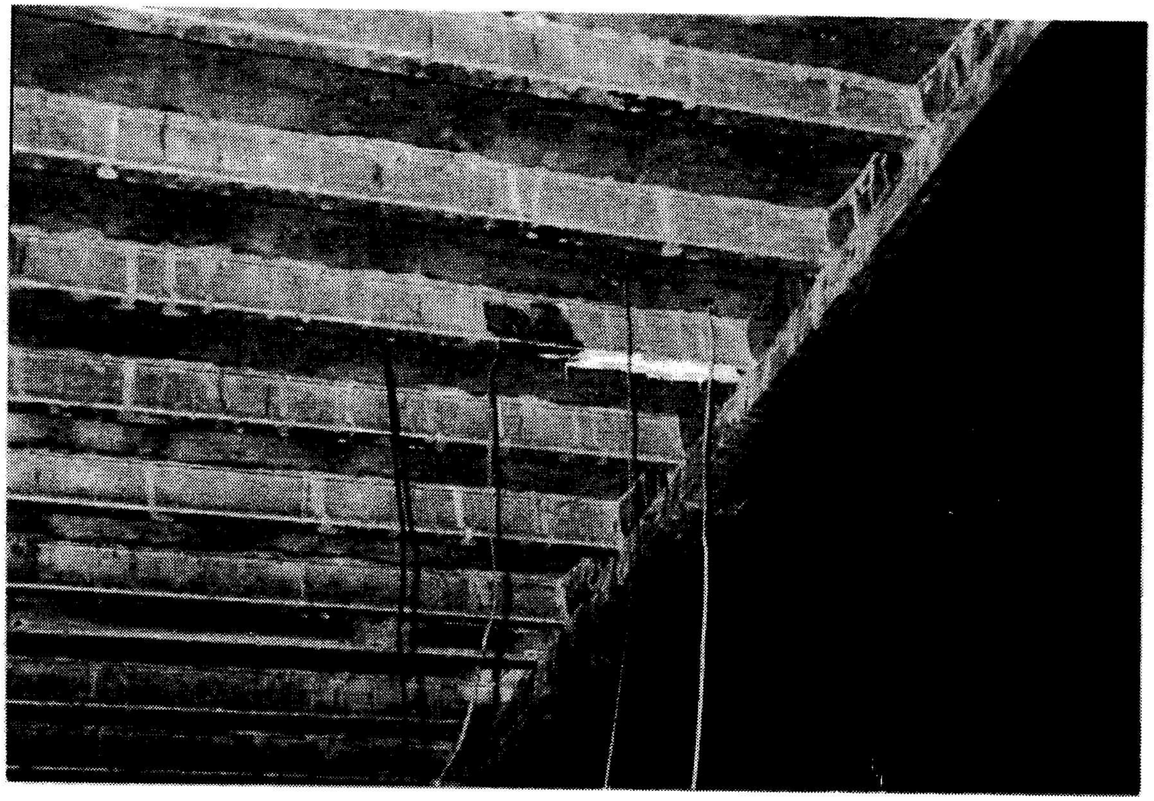


Photo 5: Strain gages attached to main grid bars

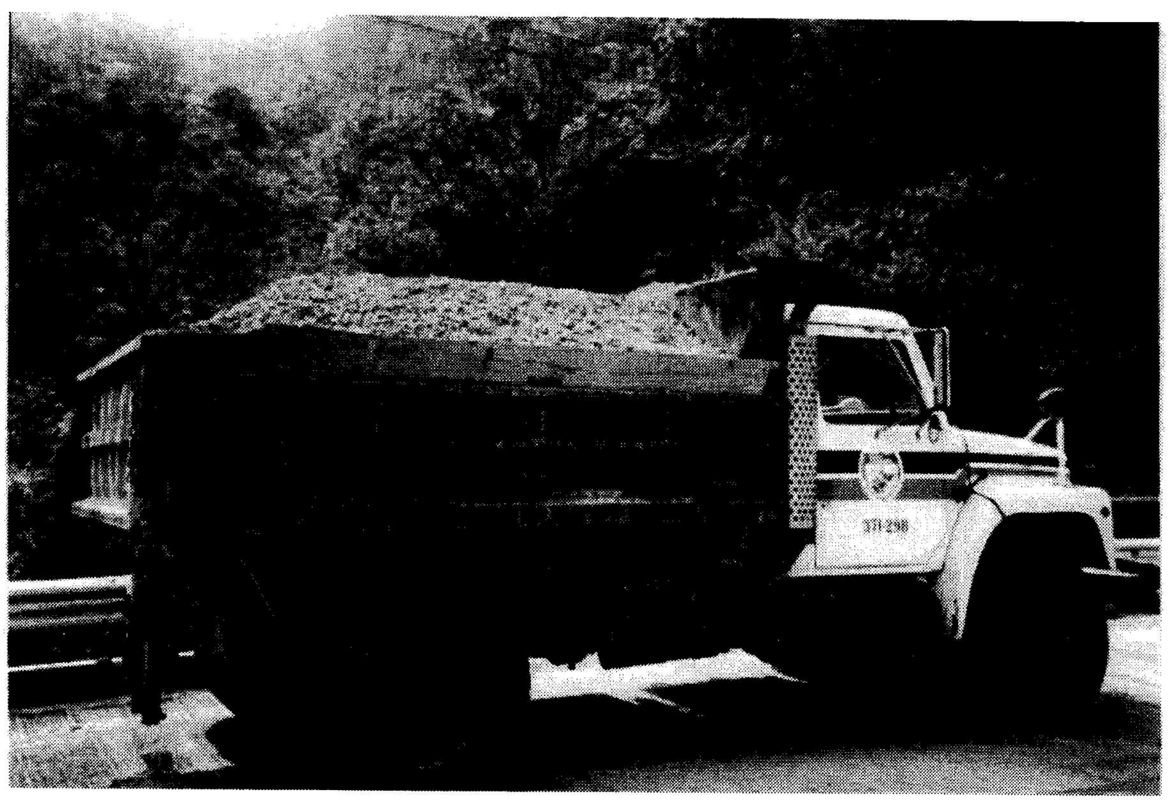


Photo 6: Test vehicle

Photo 9: Two test vehicles positioned on bridge