DTI 138

Bridge Load Testing

Bridge 3-437
SR 54 Over Assawoman Bay
Part II

by

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June 2002

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Delaware Center for Transportation
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Bridge Load Testing

BRIDGE 3-437
SR 54 OVER ASSAWOMAN BAY

Final Report

Report Prepared by:

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Executive Summary

A diagnostic load test of Delaware Bridge 3-437 was conducted on May 19, 1999. The purpose of the test was primarily to quantify the transverse load distribution of the superstructure.

The bridge, which carries State Rt. 54 traffic over Assawoman Bay, was built in 1957. It's superstructure is made up of eleven simple spans, with each span consisting of thirteen adjacent prestressed box-beam (or voided slabs). Each box beam has a cross section of 36 inches wide by 21 inches deep and contains two circular voids. A typical plan view and one of the bridge cross-section are shown in sketches SK1 and SK2.

The bridge was tested using two pre-weighed 3-axle trucks. The two trucks weighed 67.1 kips and 63.6 kips respectively. A total of six load passes were conducted (each pass consisted of two trucks crossing the bridge either individually or simultaneously). Five of the load passes were semi-static, while one was dynamic. Two spans of the bridge (spans 1 and 4) were instrumented. These spans were selected by Whitman, Requardt and Associates based upon visual inspections. Span 1 was thought to be representative of the more deteriorated spans, while span 4 was felt to be representative of the spans that were in better condition. The bridge was instrumented with 22 strain transducers. The transducers were mounted to the beam soffits primarily at the 4/10 point (the location that governed in terms of load rating). The peak tensile strain recorded during the test was $43\mu\varepsilon$. As expected, this occurred during the pass in which the two trucks crossed side-by-side. Based on the strains measured, multiple vehicle distribution factors were found to range from 0.48 to 0.51 for span 1 and 0.49 to 0.50 for span 4. Impact effects measured during the test were less than predicted by AASHTO by roughly 50%. Computed peak strains due to the two test trucks are on the order of $140\mu\varepsilon$, meaning that the measured peak strains were roughly 1/3 of the theoretically predicted values.

This report presents the details of the diagnostic load test and results.

Test Setup

The diagnostic test was conducted using the Bridge Diagnostics Inc. Structural testing System (STS) and two 3-axle trucks. Two spans of the bridge (spans 1 and 4) were instrumented with strain transducers. These spans were selected by Whitman, Requardt and Associates based upon visual inspections. Span 1 was thought to be representative of the more deteriorated spans, while span 4 was felt to be representative of the spans that were in better condition. The bridge was instrumented with 22 strain transducers. The transducers were mounted to the beam soffits primarily at the 4/10 point (the location that governed in terms of load rating). Sketches SK3 and SK4 show the layout of strain transducers. Strain transducers are identified by a three-digit number. Because of the damp weather, it was not possible to get the transducers to bond to some of the northern most beams.

Two pre-weighed 3-axle trucks were used to load the bridge during the tests. The trucks were weighed at the site using Intercorp portable scales (+/- 10 lbs). The gross weight of the two trucks was 67.1 kips (Truck 2921) and 63.6 kips (Truck 2739) respectively. Sketches SK5 and SK6 give the axle spacings and wheel loads for each truck.

A total of six load passes were conducted. Five of the load passes were semi-static , while one was dynamic. Semi-static tests involve having the trucks cross the bridge at a slow roll of approximately 2 to 5 mph (no impact effects) and recording data during the entire truck crossing at 20 Hz. The dynamic test, aimed at measuring impact effects, involved having the truck cross the bridge at full speed (approximately 25 mph) and recording data during the entire truck crossing at 60 Hz. Each pass consisted of the trucks moving in the eastbound direction. In the various passes, the trucks were positioned in different transverse locations (paths). A total of four different load paths were used (Paths A, B, C, and D). The load path locations are described below with sketches SK7 through SK10 show the location of the four different load paths (Paths A, B, C, and D).

Path A-Wheel on passenger side front axle on white line of eastbound lane.
Path B-Truck centered in eastbound lane.
Path C-Truck centered in westbound lane.
Path D-Truck straddling center yellow line.

In five of the passes, one truck crossed the bridge followed by the other truck (both trucks passed along the same transverse location). For each of these passes except pass 5, Truck 2921 (67.1

kips) was the first to cross the bridge. In one pass, the two trucks crossed side-by-side. The table that follows describes each of the six passes (referred to as Passes 1-6).

Pass	Loading	Trucks	Load Path
1	Semi-static	One truck at a time	Path A
2	Semi-static	One truck at a time	Path B
3	Semi-static	One truck at a time	Path C
4	Semi-static	Two trucks simultaneously	Path B&C
5	Semi-static	One truck at a time	Path D
6	Dynamic	One truck at a time	Path B

Results

The 22 strain transducers recorded longitudinal strains on the beam soffits due to the loaded trucks during each of the six passes. The peak tensile strain recorded during the test was 43$\mu\varepsilon$, which was recorded by transducer 317 during Pass 4 (side-by-side trucks). Table 1 shows the peak strains (positive meaning tension) for all gages for each of the six passes.

Repeatability of Data

By comparing the data from simultaneous trucks of semi-static Passes 1, 2, 3, and 5 one sees a high degree of repeatability of the data (similar strain time histories due to the similar weight vehicles). The same type of comparison can be made by comparing the distribution of strains across the cross-section of the bridge for Passes 2 and 3 (reflections about centerline). Finally, the superposition of strains from Passes 2 and 3 are nearly identical as for Pass 4. The repeatability of the data indicates that the transducers are giving consistent data.

Transverse Load Distribution

The transverse distribution of strains across the cross-section of spans 1 and 4 for each pass and due to each truck are shown in Figures 1 through 6. These strains are recorded at the same time, and are plotted when the peak strain in the cross-section is measured. To get an idea of the Distribution Factor (DF) for each beam for multiple loaded lanes, we can either look at the results for Pass 4, or the superposition of results for Passes 2 and 3. These results are shown in Figures 7 and 8. Also shown in these figures is the distribution using the peak strains for each gage. Comparing the set of peak strains for each gage lying along the 4/10 point of the span, as compared to the strains recorded at a single time when the single largest peak strain occurs, we can see that the set of peak values do occur at virtually the same time. As a result, the peak values found in Table 1 can be used to evaluate the DF.

From the data, and filling in for missing gages using information gained from symmetric passes, we find that regardless of the location of the path (A, B, C, or D), the sum of the strains across the cross-section due to the heavier truck (Truck 2921) is roughly 175$\mu\varepsilon$ for span 1 and roughly 165$\mu\varepsilon$ for span 4. This summation of strains is proportional to the summation of moments. The summation of strains due to both trucks (Pass 4) is 335$\mu\varepsilon$ for span 1. This values is consistent with the result from superimposing passes 2 and 3, and are roughly twice the amount of strain due to a single truck (the two trucks have fairly similar gross weights). From this we can conclude that the strain due to one wheel line would be approximately 1/4 of the total summation. With a maximum recorded strain of 43$\mu\varepsilon$, we get a DF of approximately 0.5. Figures 7 and 8 show that by considering the different passes and spans, multiple vehicle distribution factors are found to range from 0.48 to 0.51 on span 1 and 0.49 to 0.50 on span 4.

Impact Effects

By comparing peak strains from Passes 2 and 6, we can get some idea about the impact factor. The ratio of the peak strain during the dynamic pass (Pass 6) to the peak strain recorded during the semi-static pass (Pass 2) is $36\mu\varepsilon/31\mu\varepsilon = 1.16$ for span 1 and $25\mu\varepsilon/26\mu\varepsilon = 0.96$ for span 4. While only limited data exists, it appears that the first span has higher impact effects than span 4 (the measured data shows no measurable impact effects on span 4). This is expected since the approach to the bridge has an incline, and trucks are likely to bounce more on the first span. It should be noted that the impact effects measured on span 1 are only 16% which is lower than AASHTO's recommended value of 30% for the span lengths of this bridge. However, variation in truck speed, truck suspension, and condition of the wearing surface could cause the impact effects to be higher (i.e. closer to the AASHTO value).

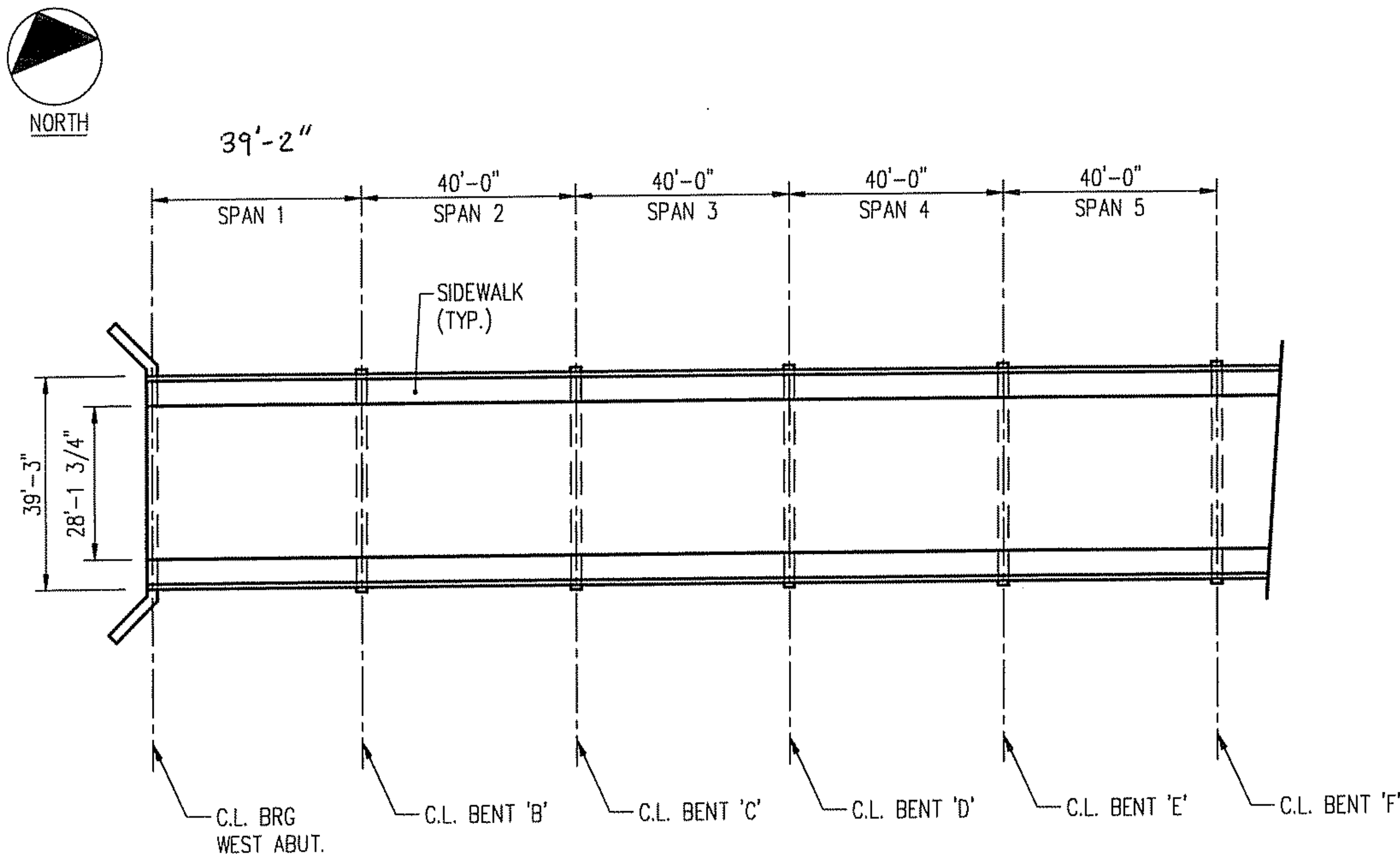
Theoretical Peak Strain

Often it is found that the peak recorded strain is lower than the theoretically predicted peak strain. If we use Truck 2921 for a live load and use a distribution factor (DF) equal to 0.5, set impact effects to zero (to be consistent with the semi-static test), use a moment of inertia value for the cross-section of 25,473 in^4 (uncracked section), a location of the centroid at 10.41 inches above the beam soffit, and a modulus of elasticity for the concrete of $E = 4{,}287$ ksi ($f'c = 5$ ksi), we get a peak tensile strain at the 4/10 point on the 40 foot span 4 of 138$\mu\varepsilon$. This is roughly 3 times greater than the peak measured strain. The differences may in part be attributed to partially restrained supports, higher strength concrete than assumed, load being carried by the thicker concrete sidewalk sections and the parapet/guardrail system.

Summary

Bridge 3-437 was instrumented with 22 strain transducers and tested using two pre-weighed 3-axle trucks. The transducers were mounted to the beam soffits of spans 1 and 4. These spans were selected by Whitman, Requardt and Associates based upon visual inspections. Span 1 was thought to be representative the more deteriorated spans, while span 4 was felt to be representative of the spans that were in better condition. The transducers were located primarily at the 4/10 point because that location governs for the load rating. The peak tensile strain recorded during the test was 43$\mu\varepsilon$. Based on the strains measured, multiple vehicle distribution factors were found to be roughly 0.50 for both spans tested. Impact effects measured during the test were less than predicted by AASHTO by roughly 50%. Theoretically computed peak strains due to the two test trucks were roughly 1/3 of the theoretically predicted values.

A.1 APPENDIX - SKETCHES



P L A N   V I E W

N.T.S.

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DEPT. OF CIVIL ENGINEERING
NEWARK, DELAWARE 19716

PROJECT: BRIDGE 3-437 STATE ROUTE 54 OVER ASSAWOMAN BAY

TITLE:

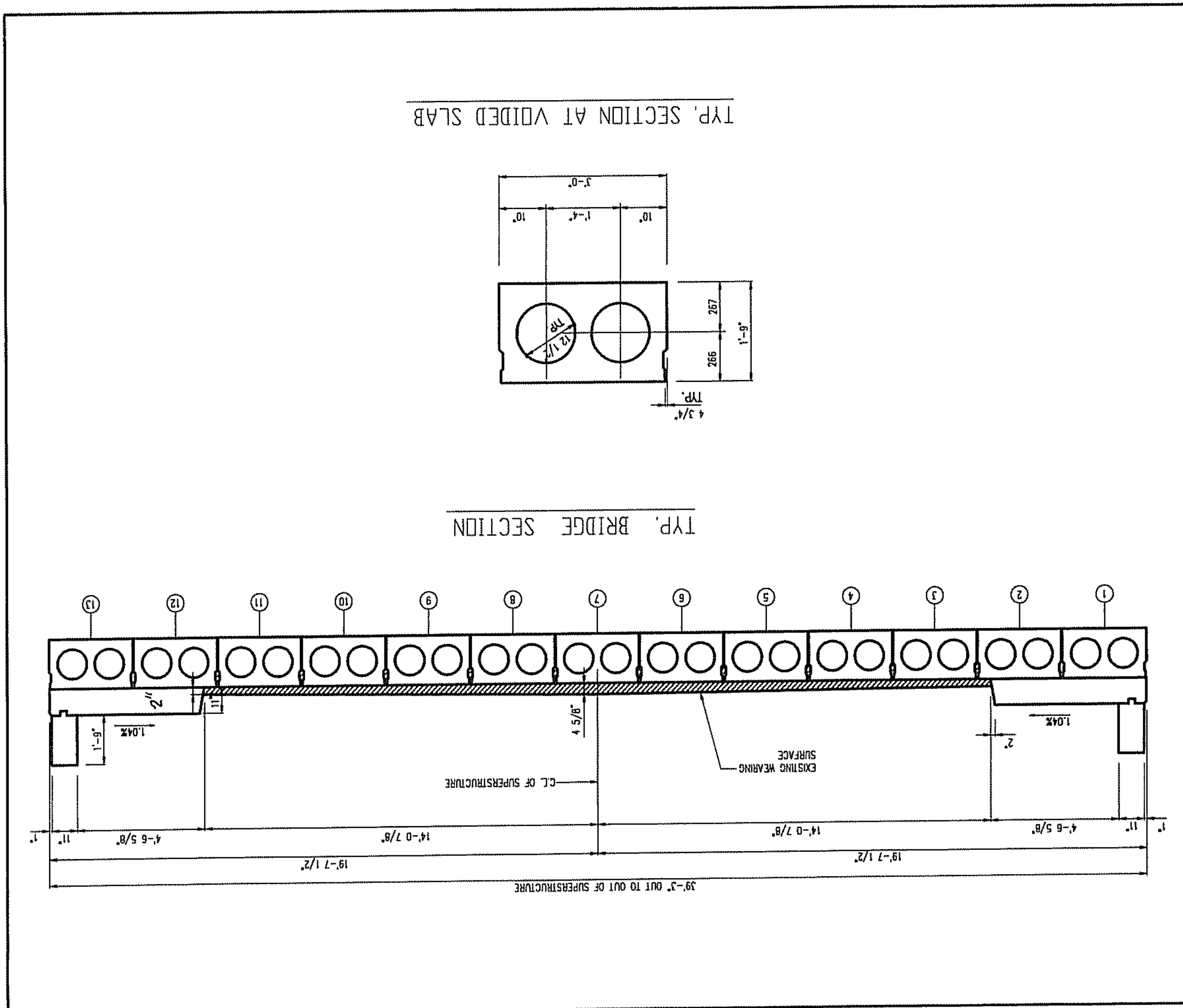
DRAWN BY: B.W.D.

APPROVED BY: W. W. FINCH, JR.

SCALE: N.T.S.

DATE: 06-01-99

DWG NO. SK1



DWG NO. SK2

TITLE:

DRAWN BY: B.W.D.

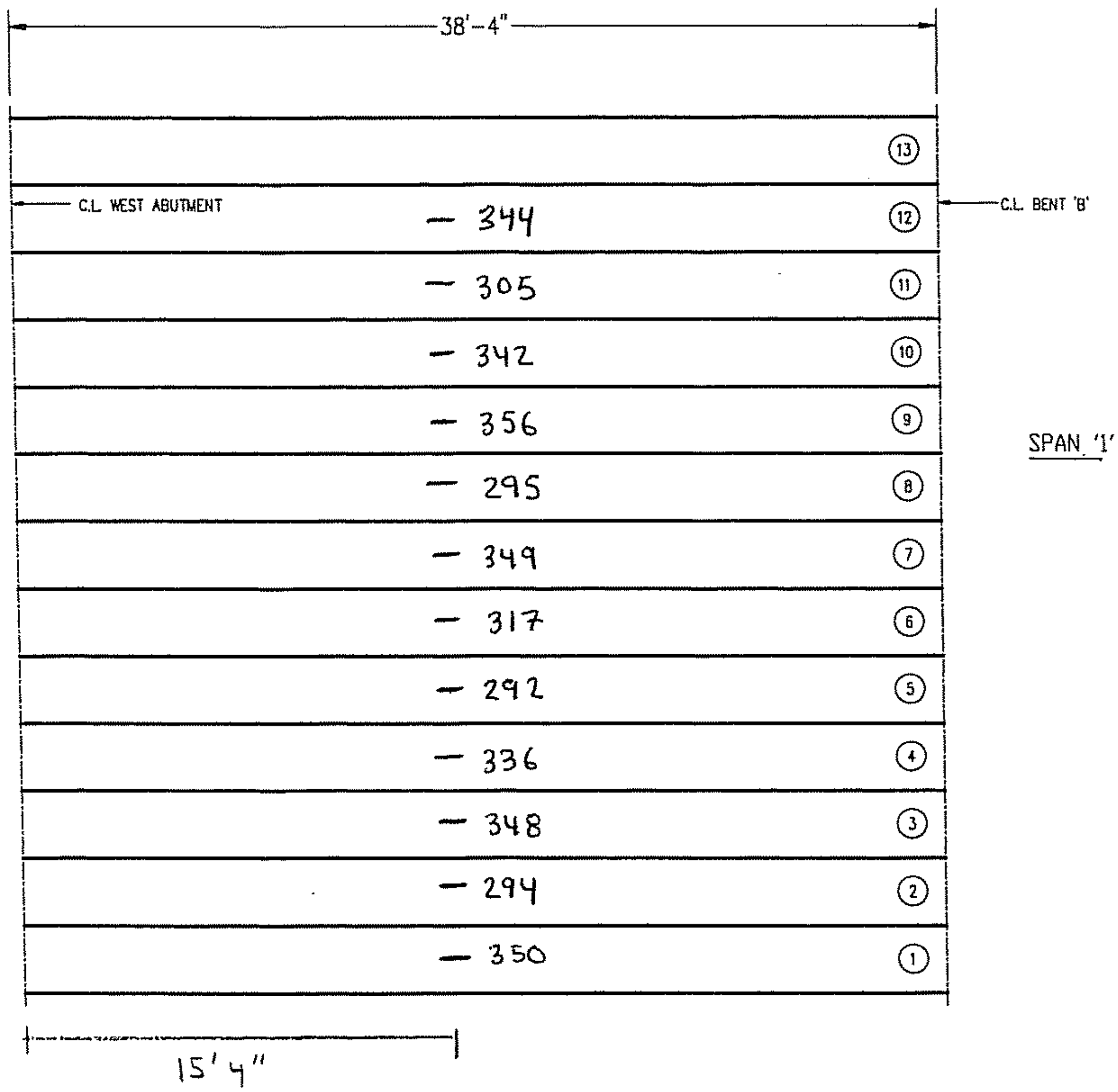
APPROVED BY: W. W. FINCH, JR.

DATE: 06-01-99

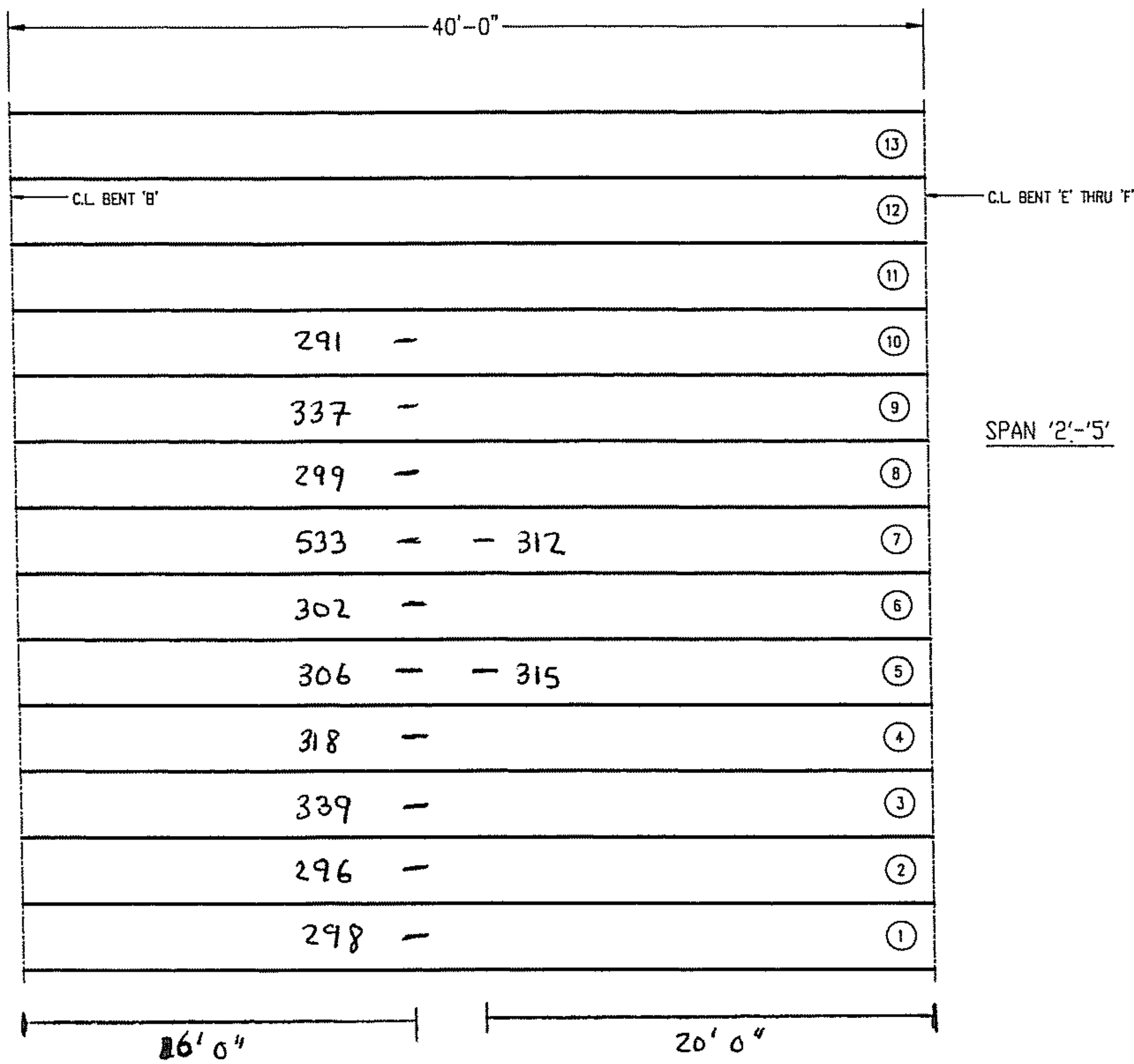
SCALE: N.T.S.

PROJECT: **BRIDGE 3-437**
STATE ROUTE 54 OVER ASSAWOMAN BAY

UNIVERSITY OF DELAWARE
DEPT. OF CIVIL ENGINEERING
NEWARK, DELAWARE 19716



UNIVERSITY OF DELAWARE DEPT. OF CIVIL ENGINEERING NEWARK, DELAWARE 19716	PROJECT: BRIDGE 3–437 STATE ROUTE 54 OVER ASSAWOMAN BAY	TITLE: DRAWN BY: B.W.D. APPROVED BY: W. W. FINCH, JR. SCALE: N.T.S. DATE: 06-01-99	DWG NO. SK3



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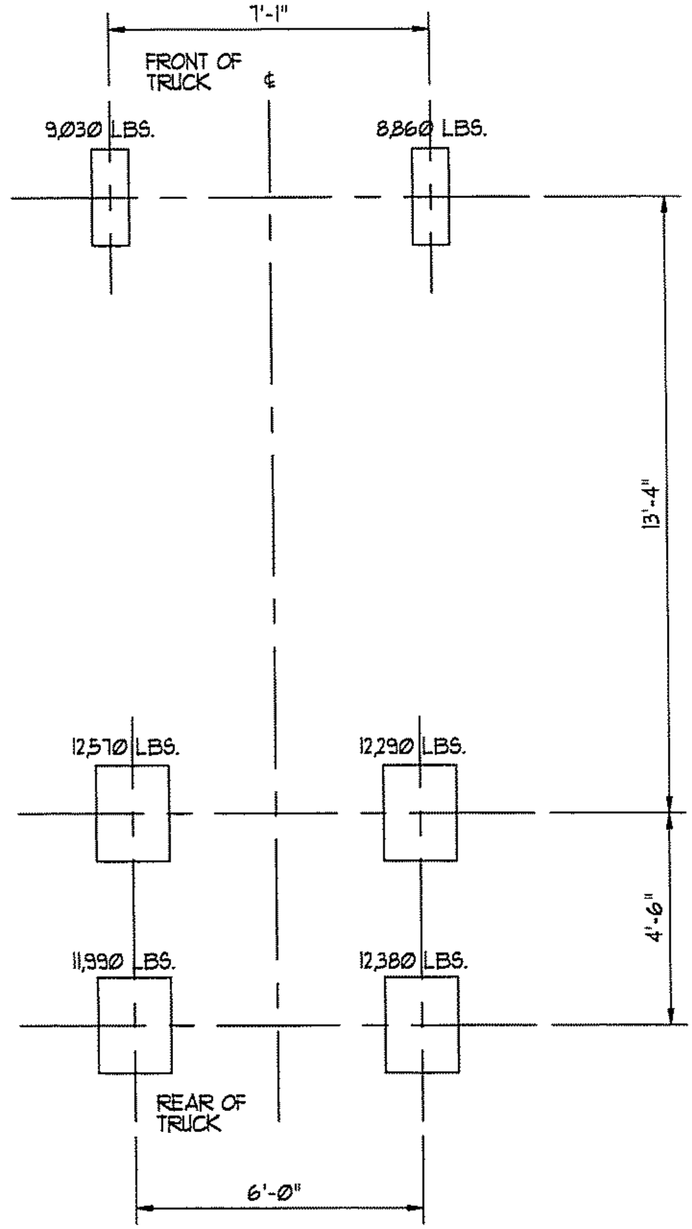

PLAN VIEW OF WEIGHED "TEN WHEEL" TRUCK NO. 2921

N.T.S.

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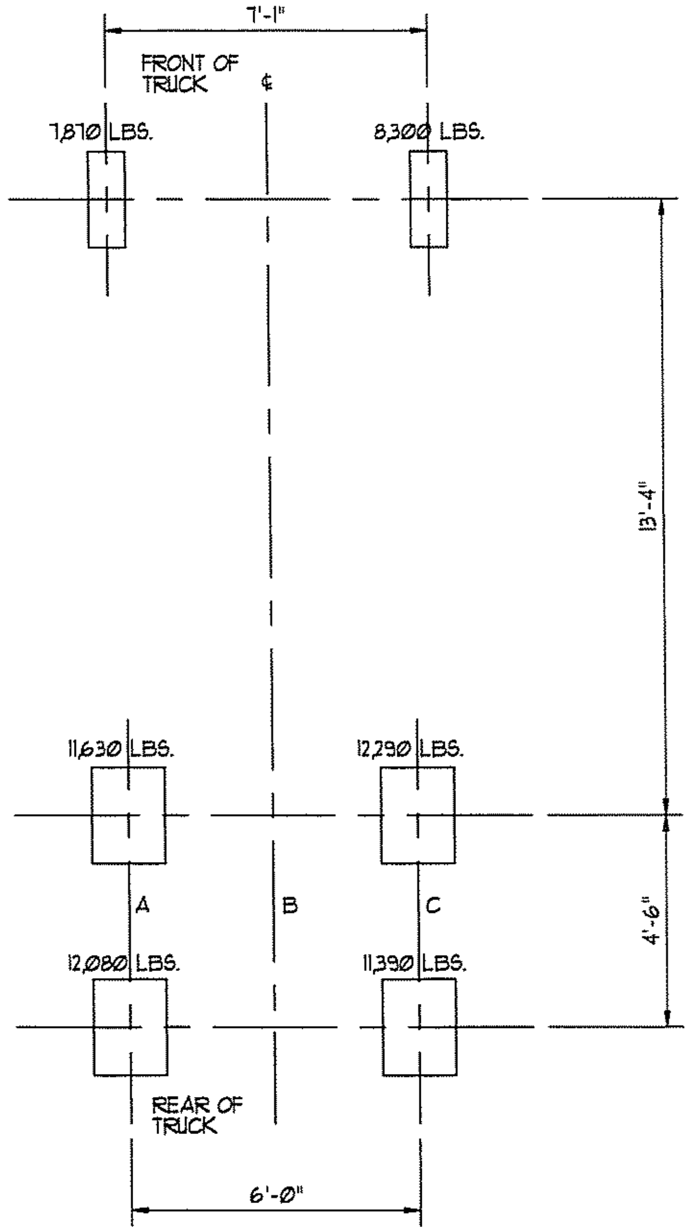

PLAN VIEW OF WEIGHED "TEN WHEEL" TRUCK NO. 2739

N.T.S.

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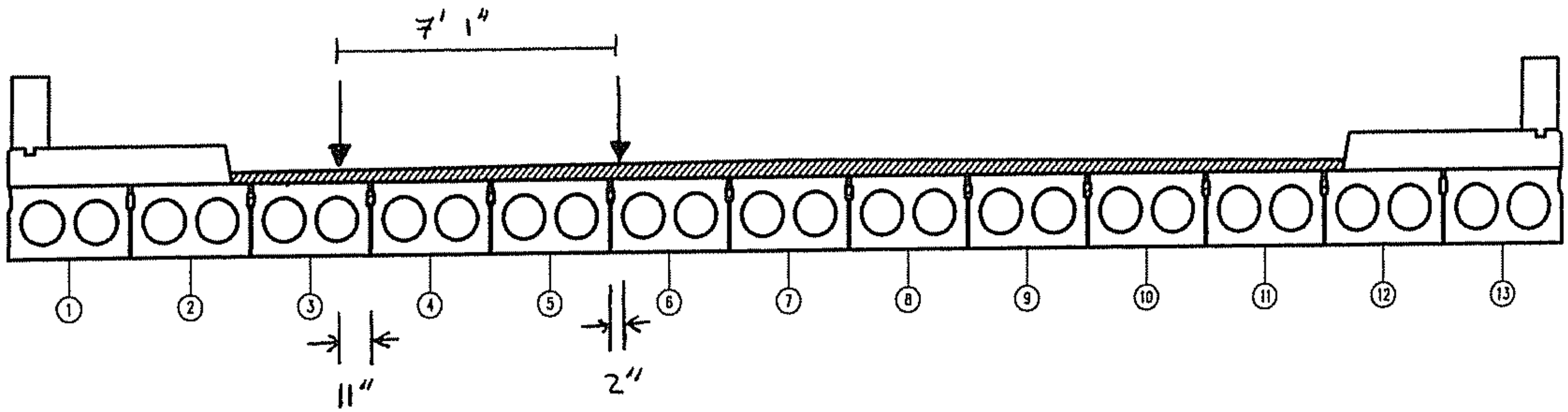

LOCATION OF TRUCK PASSES

PATH A (Front tires)

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NEWARK, DELAWARE 19716

PROJECT: BRIDGE 3-437
STATE ROUTE 54 OVER ASSAWOMAN BAY

TITLE:

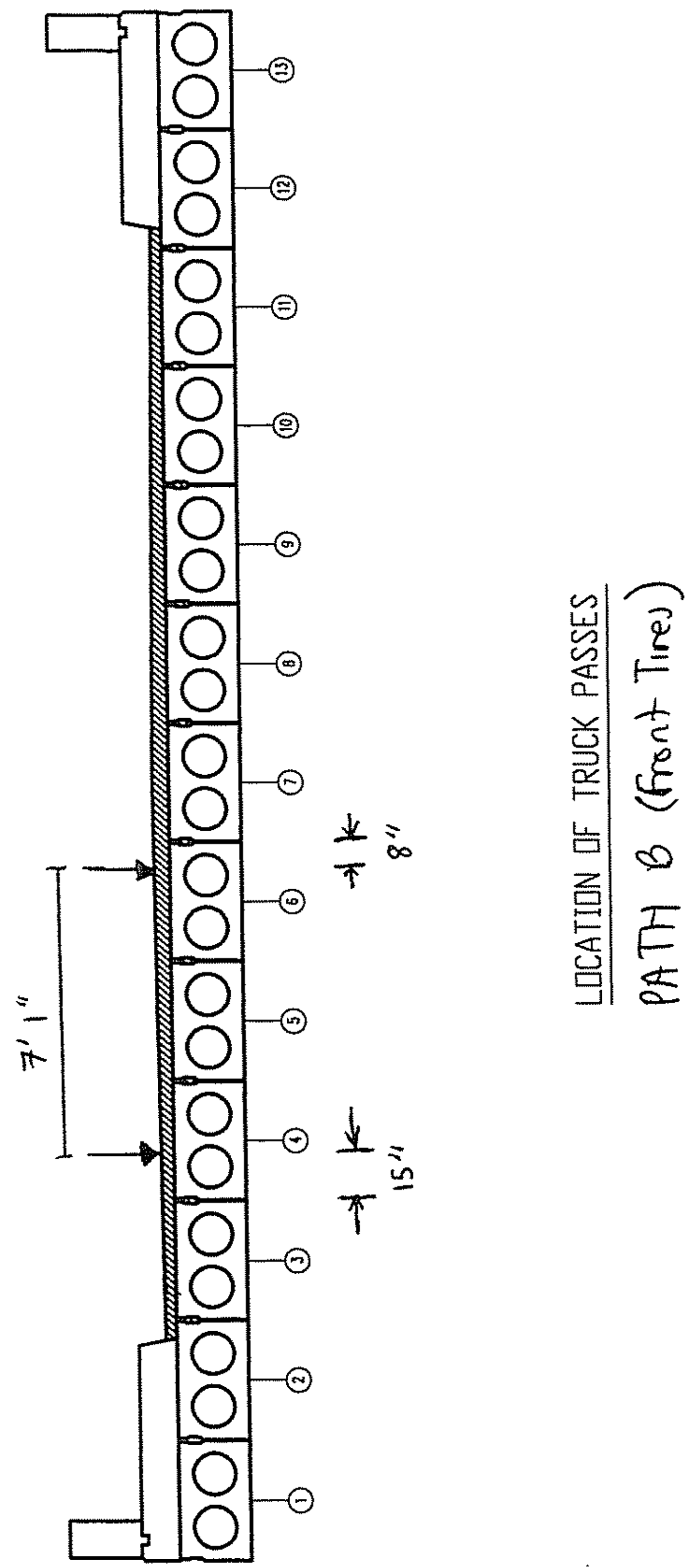
DRAWN BY: B.W.D.

APPROVED BY: W. W. FINCH, JR.

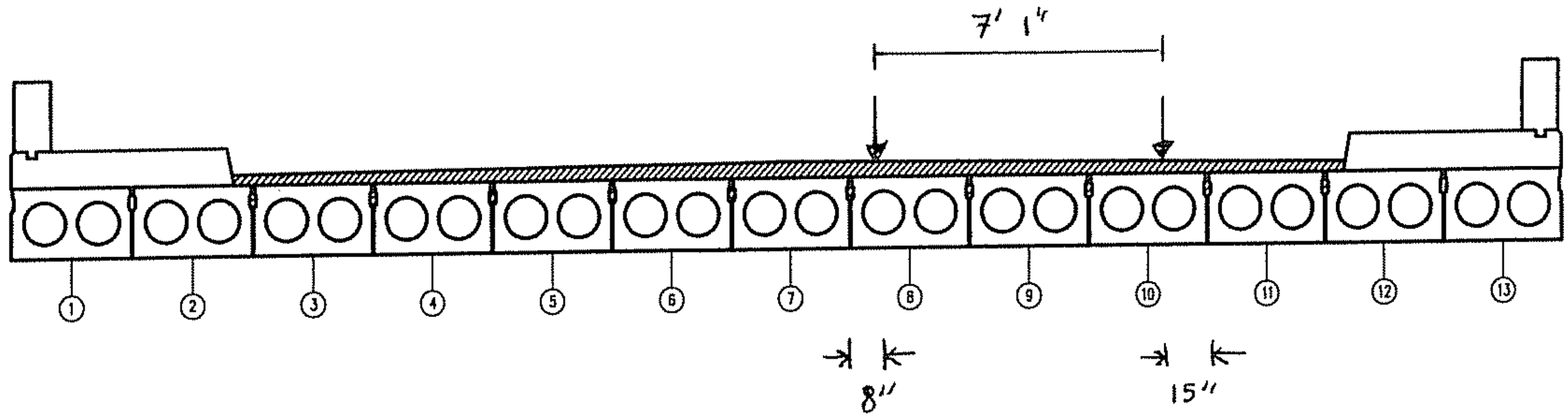
SCALE: N.T.S.

DATE: 06-01-99

DWG NO. SK7



UNIVERSITY OF DELAWARE DEPT. OF CIVIL ENGINEERING NEWARK, DELAWARE 19716	PROJECT: BRIDGE 3-437 STATE ROUTE 54 OVER ASSAWOMAN BAY	TITLE: DRAWN BY: B.W.D. APPROVED BY: W. W. FINCH, JR. SCALE: N.T.S. DATE: 06-01-99	DWG NO. SK8



LOCATION OF TRUCK PASSES

PATH C (Front Tires)

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DEPT. OF CIVIL ENGINEERING

NEWARK, DELAWARE 19716

PROJECT:
BRIDGE 3-437
STATE ROUTE 54 OVER
ASSAWOMAN BAY

TITLE:

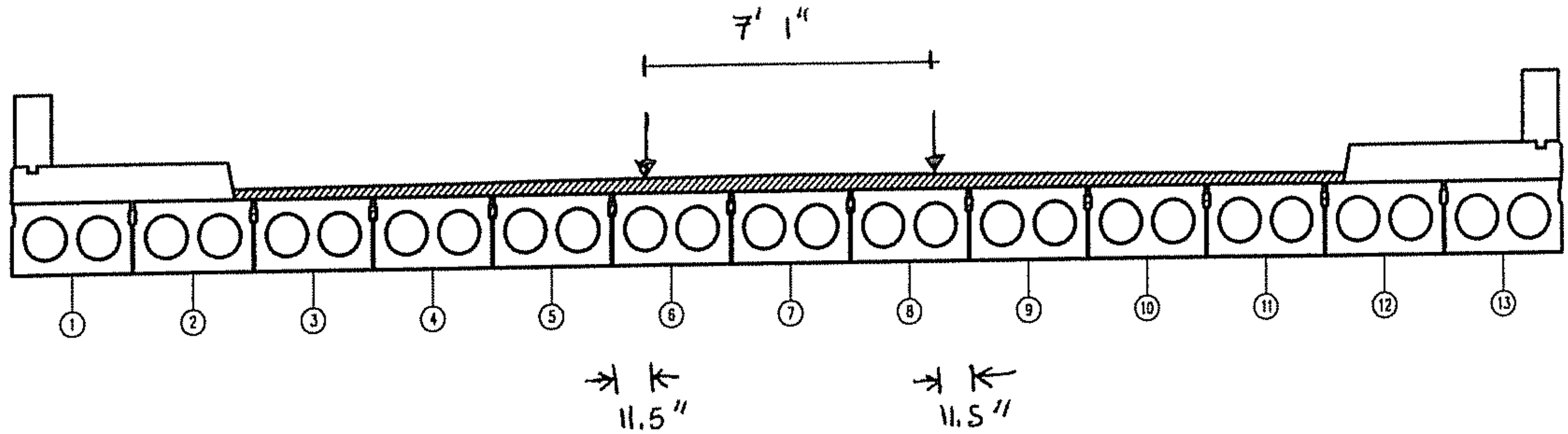
DRAWN BY: B.W.D.

APPROVED BY: W. W. FINCH, JR.

SCALE: N.T.S.

DATE: 06-01-99

DWG NO. SK9



LOCATION OF TRUCK PASSES

PATH 0 (Front Tires)

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DEPT. OF CIVIL ENGINEERING

NEWARK, DELAWARE 19716

PROJECT: BRIDGE 3-437
STATE ROUTE 54 OVER ASSAWOMAN BAY

TITLE:

DRAWN BY: B.W.D.

APPROVED BY: W. W. FINCH, JR.

SCALE: N.T.S.

DATE: 06-01-99

DWG NO. SK10

A.2 APPENDIX - TABLES

TABLE 1

Fenwick Island - Route 54 Bridge

Suumary of Peak Strains for all Passes (all values are micro-strain)

	Span #1												Span #4											
Beam	12	11	10	9	8	7	6	5	4	3	2	1	10	9	8	7	7 MS	6	5	5 MS	4	3	2	1
Transducer	344	305	342	356	295	349	317	292	336	348	294	350	291	337	299	533W	312	302	306	315	318	339	296	298
Pass 1	Passenger Tire on white line																							
Max1	3	3	6	8	13	15	23	23	27	11	16	17	5	9	12	0	15	18	26	23	13	23	16	19
Max2	4	3	7	9	14	17	27	23	29	9	14	15	5	9	11	0	14	18	24	21	13	20	15	18
Pass 2	Eastbound lane																							
Max1	5	3	8	10	16	20	31	24	30	9	13	14	7	11	15	0	19	22	26	24	16	13	12	14
Max2	5	3	8	10	16	20	29	23	29	10	12	13	7	11	15	0	19	22	24	23	15	13	11	13
Pass 3	Westbound lane																							
Max1	14	10	33	25	28	22	13	8	7	4	4	4	24	30	27	0	18	13	11	11	4	5	4	5
Max2	14	10	30	23	25	19	12	7	7	4	3	3	22	28	24	0	16	12	10	10	4	4	4	4
Pass 4	Dual - east and westbound lanes																							
Max1	21	15	39	23	40	38	43	31	37	13.	17	18	29	40	41	0	35	0	35	33	19	18	15	18
Pass 5	Straddle yellow line																							
Max1	8	5	15	12	28	27	27	14	14	5	6	7	12	21	28	0	24	0	19	18	7	8	7	8
Max2	9	6	16	13	31	28	29	14	14	6	7	7	12	22	29	1	24	0	20	19	7	8	7	8
Pass 6	High speed - eastbound lane																							
Max1	6	4	10	7	19	23	36	27	33	11	15	16	7	12	15	0	18	0	25	24	17	14	12	15
Max2	5	3	8	5	16	19	30	24	29	10	13	14	6	11	14	1	18	0	23	23	15	13	11	14

Note - truck 2921 was first on all passes except pass 5 in which truck 2739 was first.

Max 1 corresponds to maximum for first truck

Max 2 corresponds to maximum for second truck

A.3 APPENDIX - FIGURES

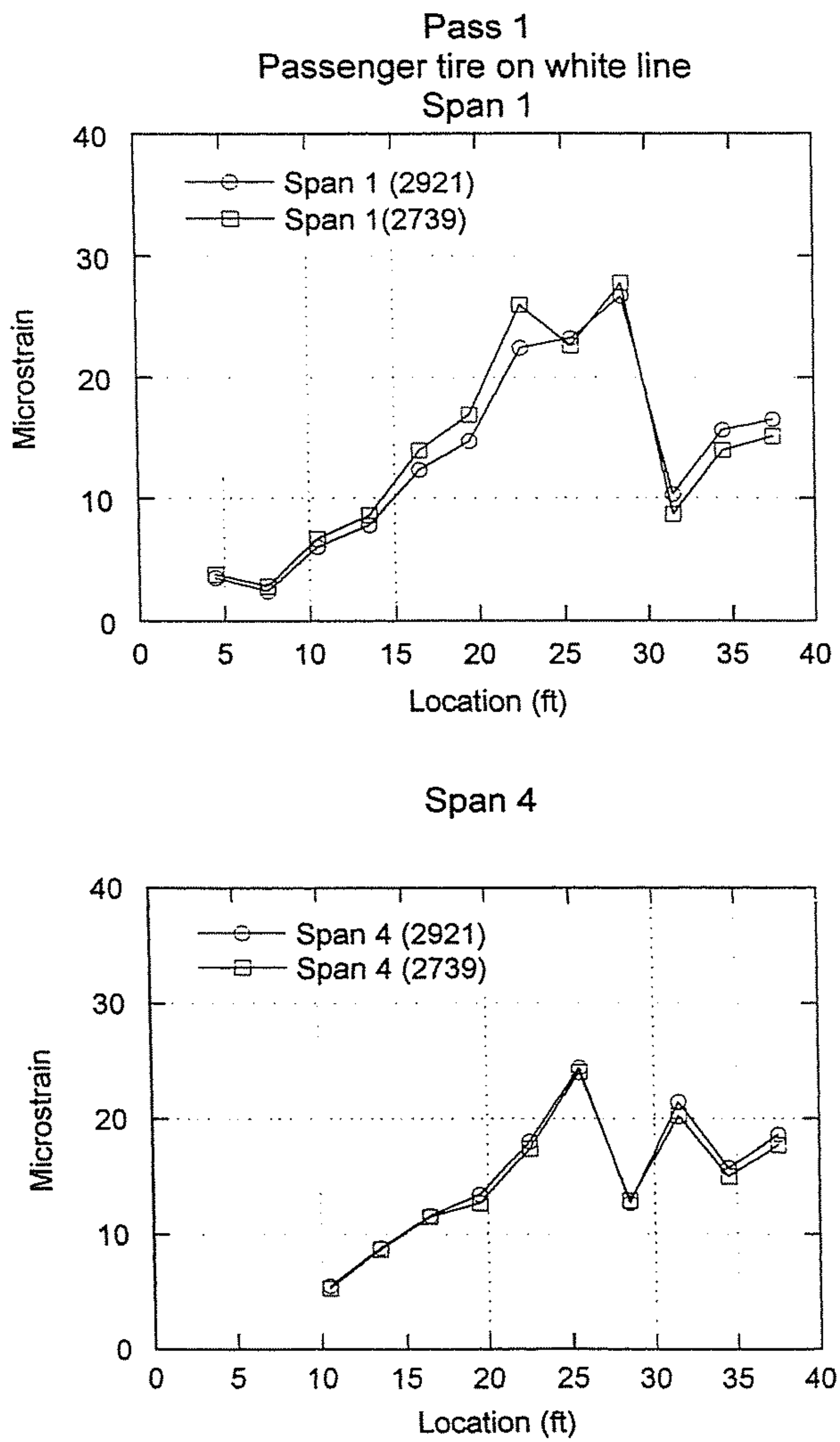
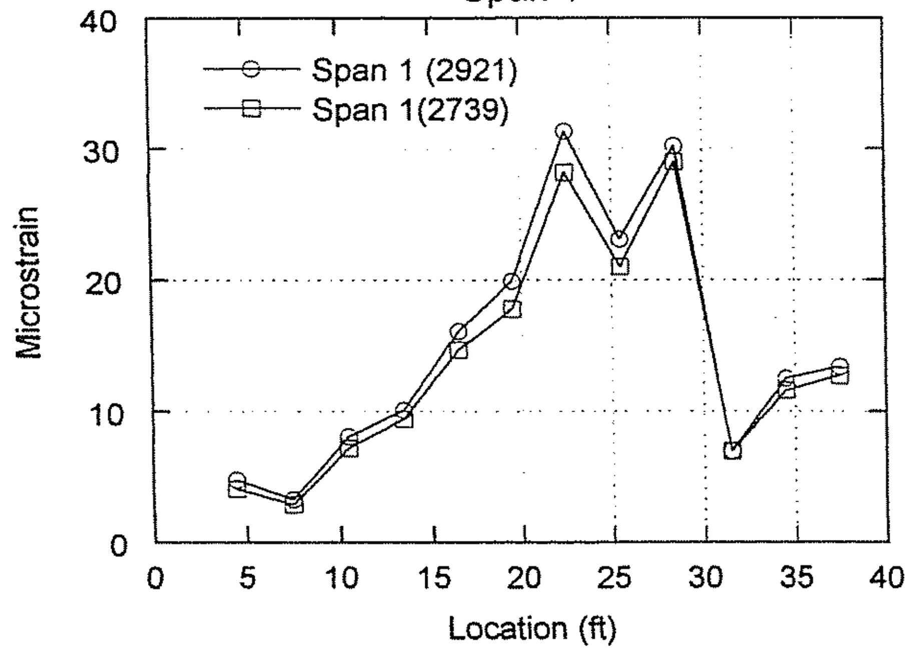

Pass 1
Passenger tire on white line
Span 1
Span 1 (2921)
Span 1(2739)
Microstrain
Location (ft)
Span 4
Span 4 (2921)
Span 4 (2739)
Microstrain
Location (ft)

Figure 1

Pass 2
Eastbound lane
Span 1



Span 4

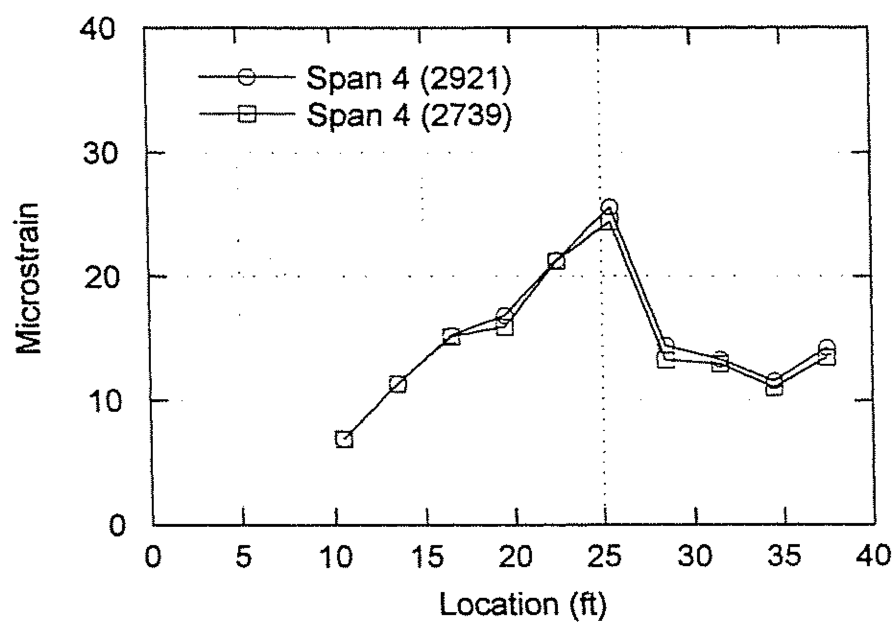
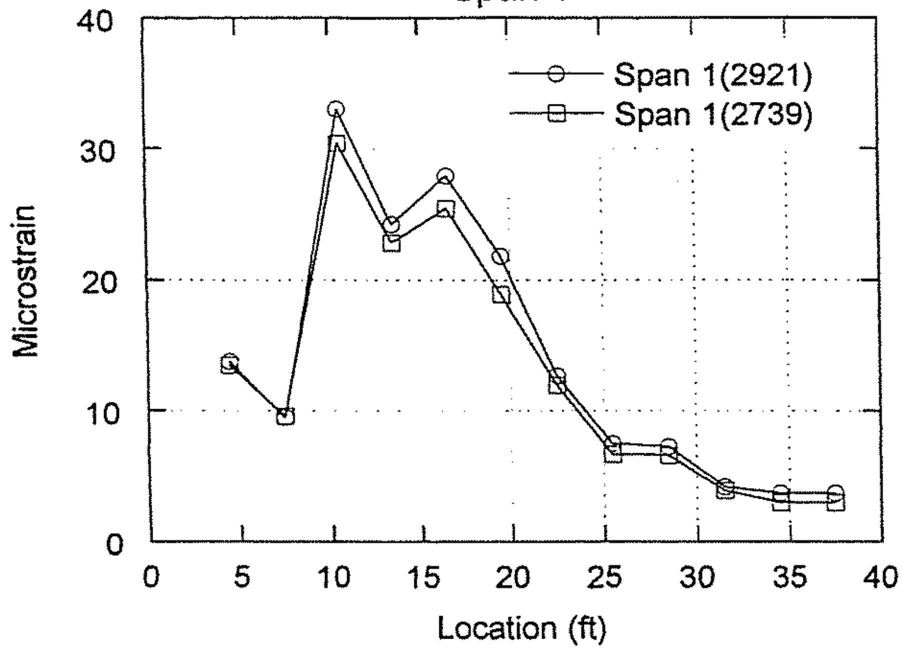


Figure 2

Pass 3
Westbound lane
Span 1



Span 4

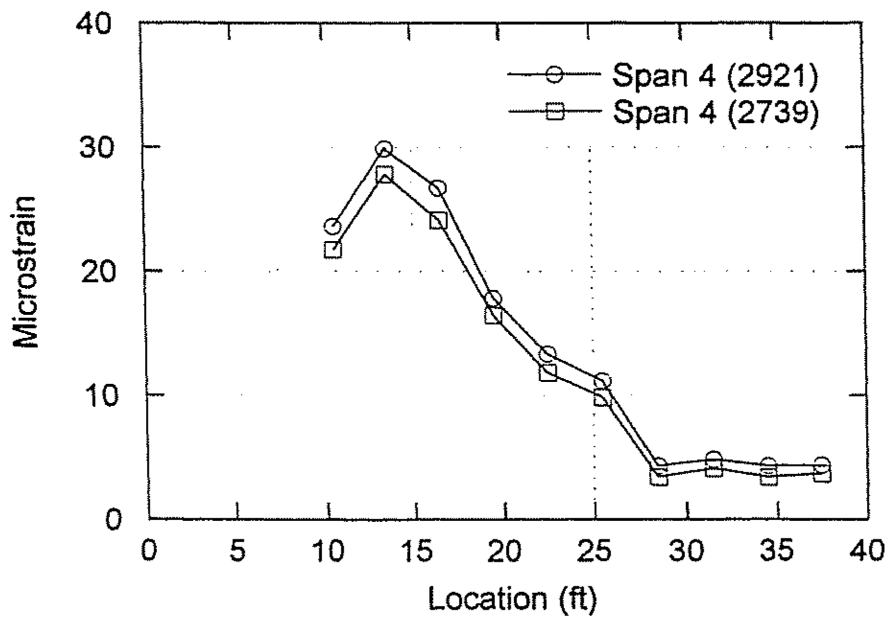


Figure 3

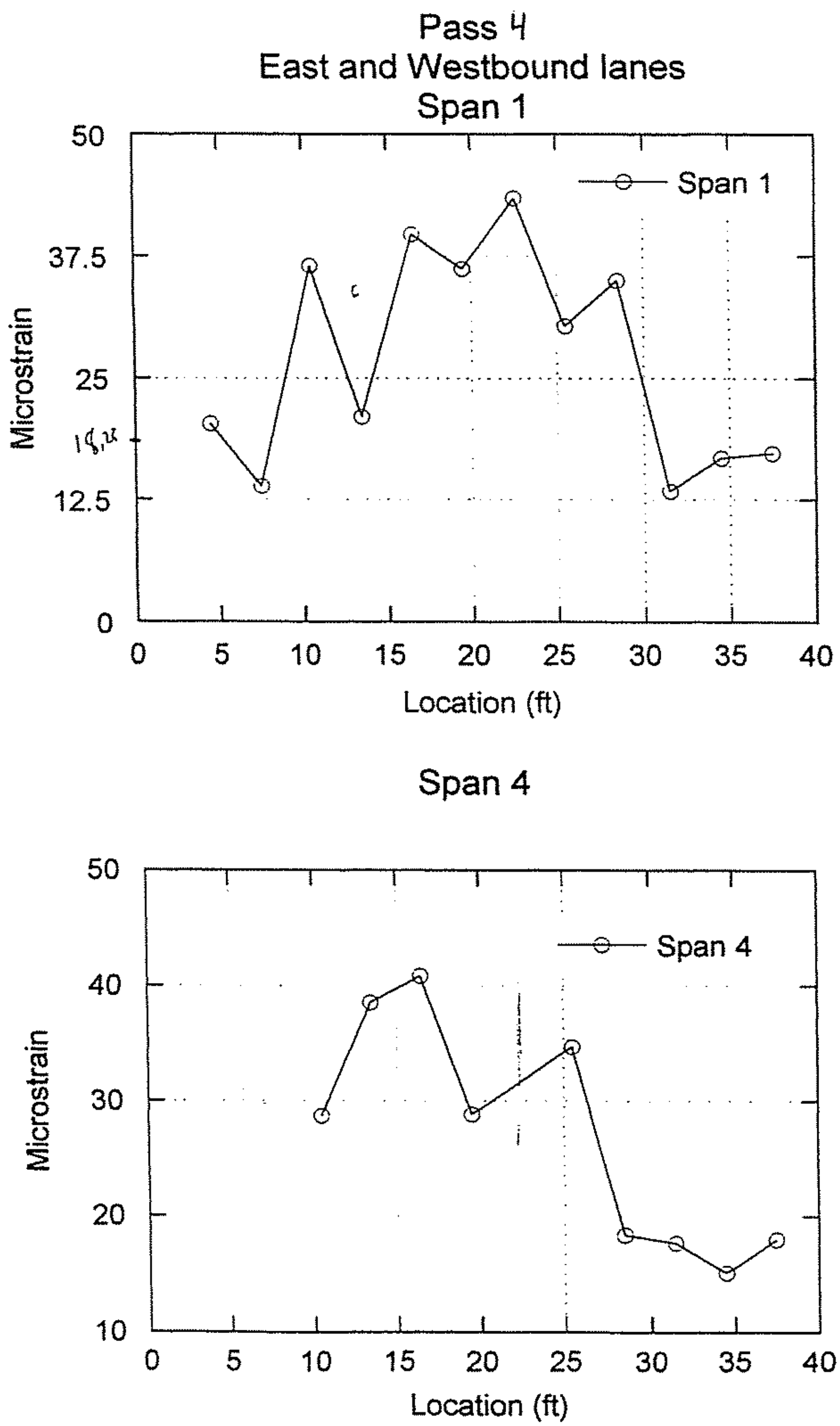

Pass 4
East and Westbound lanes
Span 1
Span 1
Microstrain
50
37.5
25
12.5
0
0 5 10 15 20 25 30 35 40
Location (ft)
Span 4
Span 4
Microstrain
50
40
30
20
10
0 5 10 15 20 25 30 35 40
Location (ft)

Figure 4

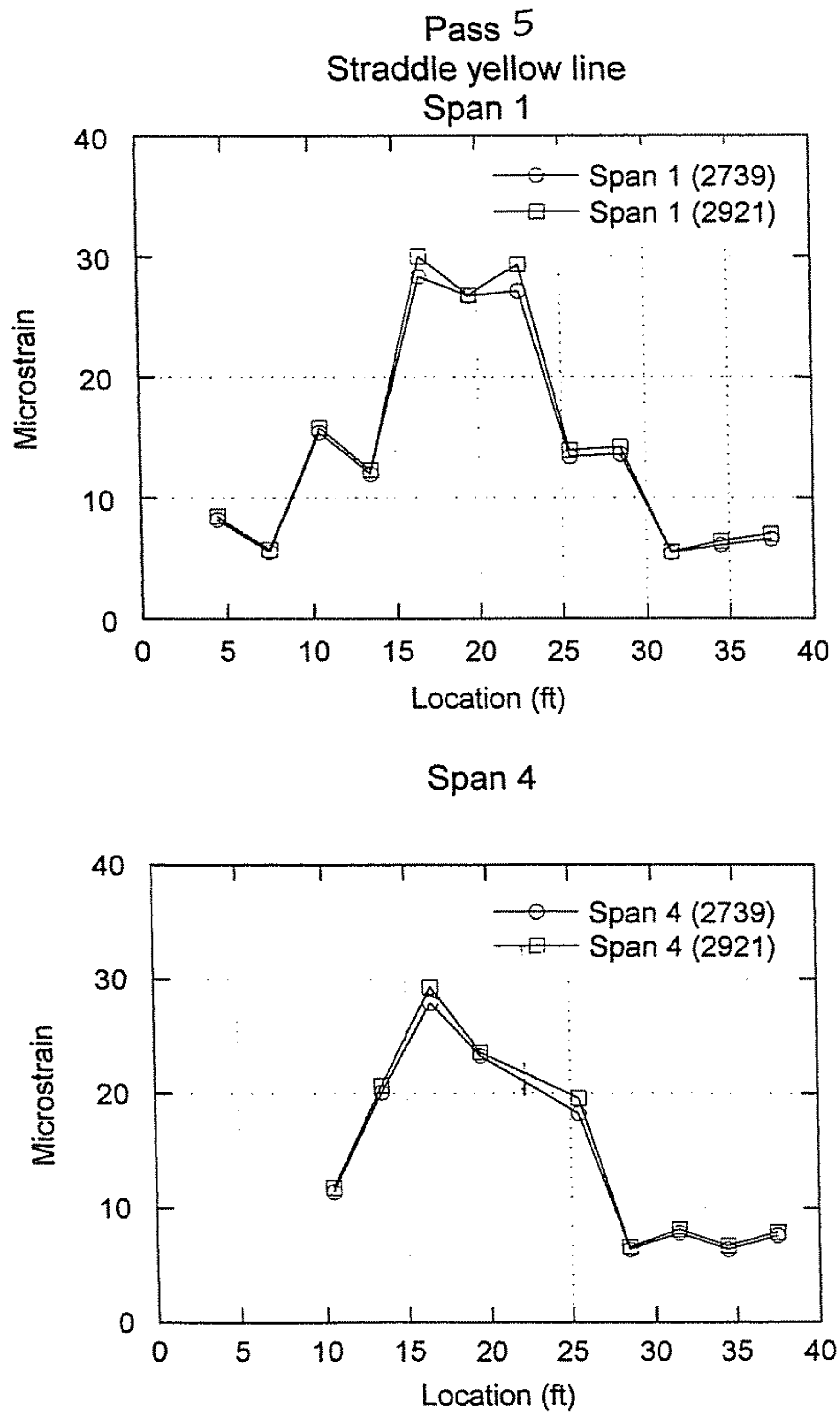

Pass 5
Straddle yellow line
Span 1
Span 1 (2739)
Span 1 (2921)
Microstrain
Location (ft)
Span 4
Span 4 (2739)
Span 4 (2921)
Microstrain
Location (ft)

Figure 5

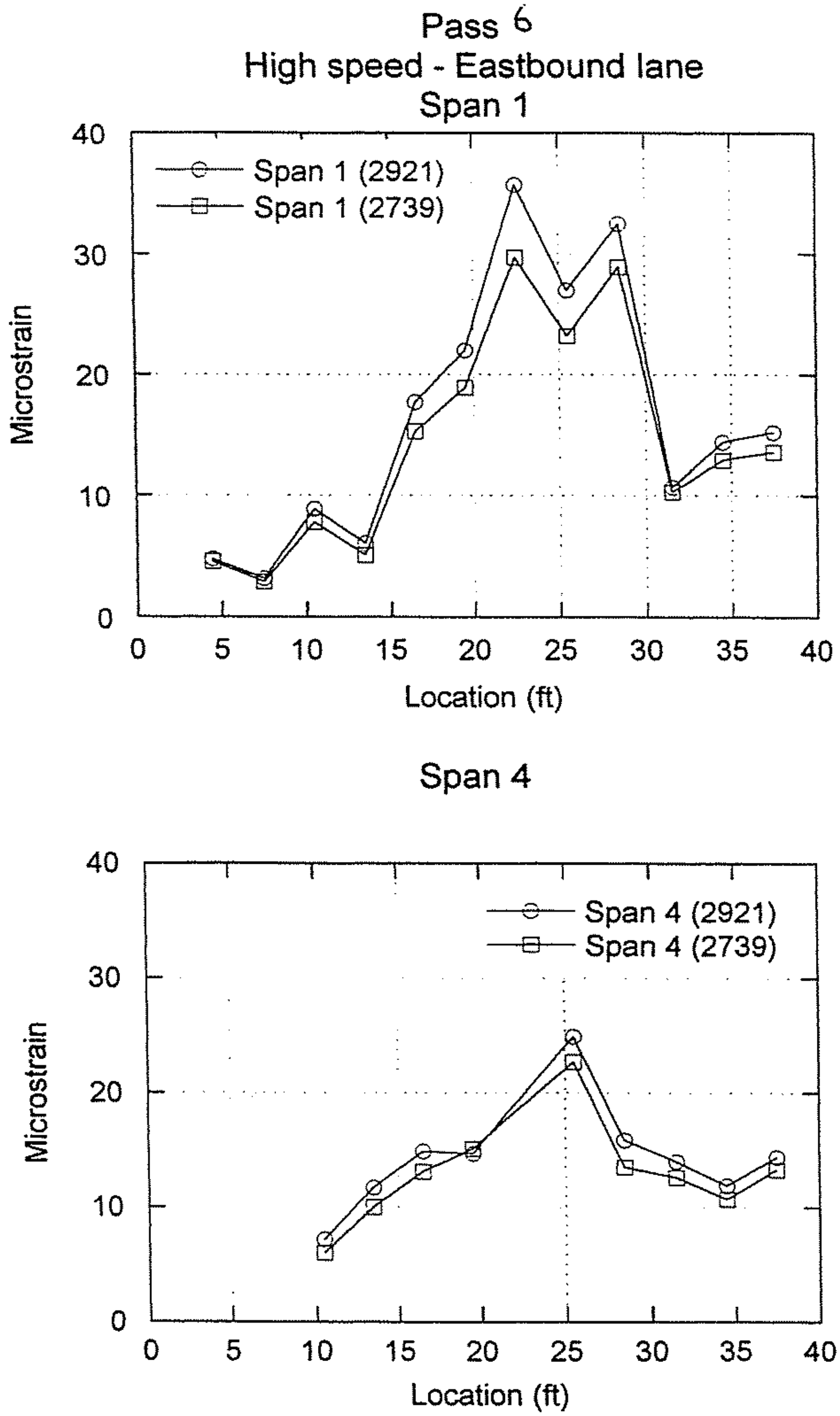
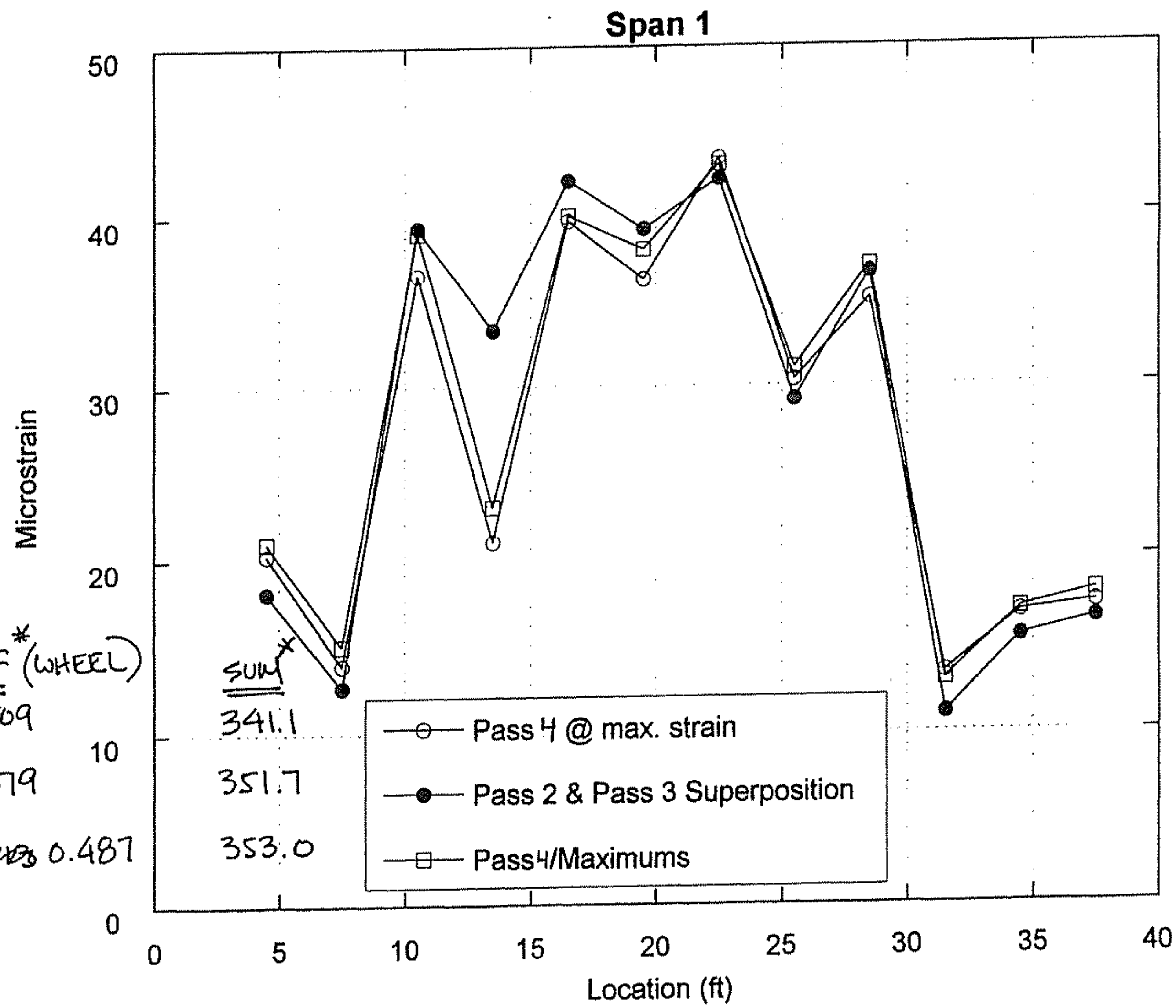

Pass 6
High speed - Eastbound lane
Span 1
Span 1 (2921)
Span 1 (2739)
Microstrain
Location (ft)
Span 4
Span 4 (2921)
Span 4 (2739)
Microstrain
Location (ft)

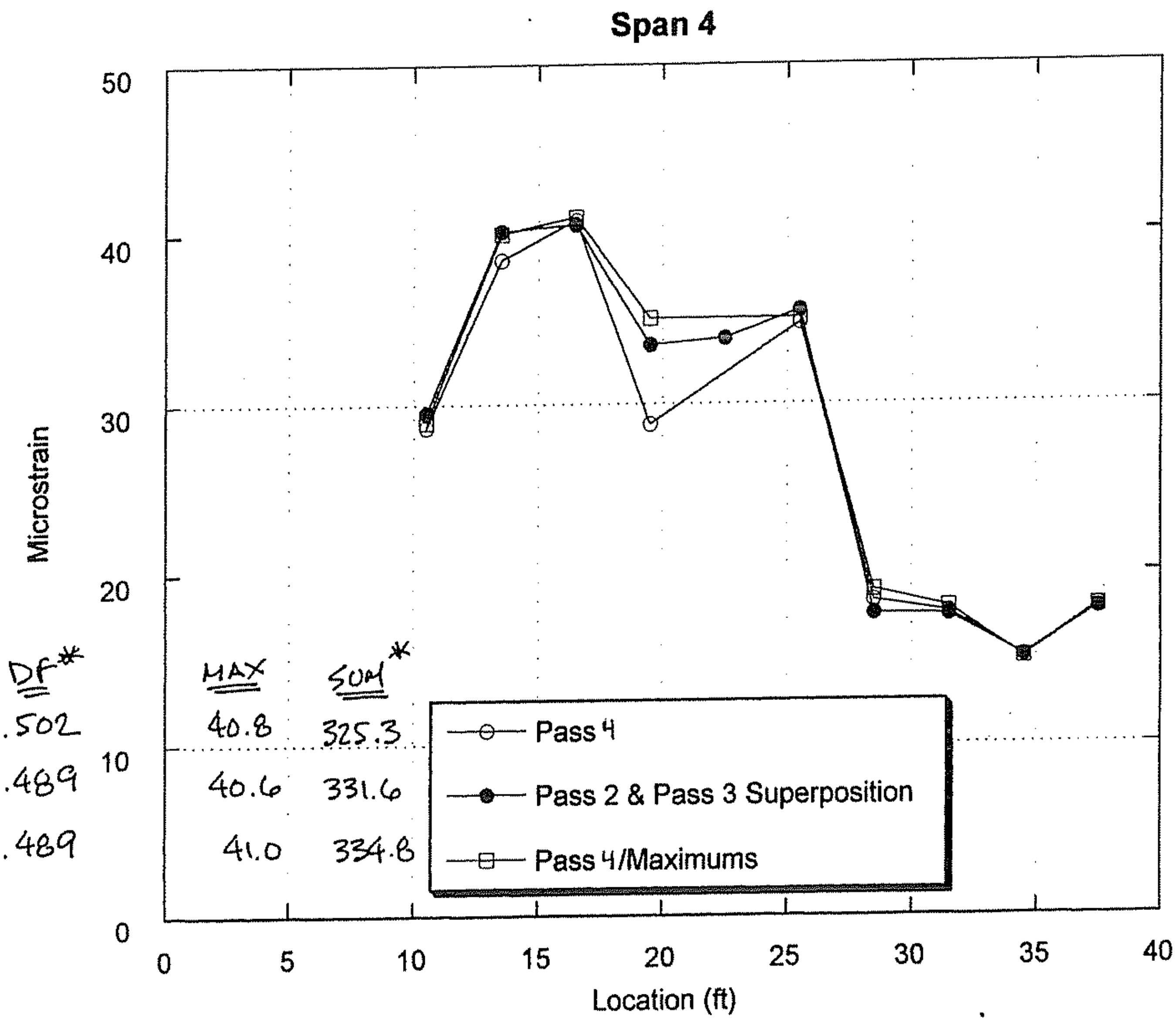
Figure 6



MAX	DF* (WHEEL)	SUM*
43.4	0.509	341.1
42.1	0.479	351.7
43.0	0.487	353.0

* GAGE 350 REFLECTED TO BEAM 13 FOR CALCULATIONS

Figure 7



DF*	MAX	SUM*
0.502	40.8	325.3
0.489	40.6	331.6
0.489	41.0	334.8

* GAUGES 339, 296 & 298 REFLECTED TO BEAMS 11, 12 & 13 FOR CALCULATION

* SUPERPOSITION VALUE USED FOR BEAM #6 IN PASS 5 & PASS 5/MAX CALCULATIONS

Figure 8

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