STRAIN AND DEFLECTION MEASUREMENTS ON AN EXPERIMENTAL ORTHOTROPIC BRIDGE

MICHIGAN HIGHWAY RESEARCH LABORATORY SECTION

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

STRAIN AND DEFLECTION MEASUREMENTS ON AN EXPERIMENTAL ORTHOTROPIC BRIDGE

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This report covers results of an investigation concerning strain and deflection in an experimental orthotropic bridge (Crietz Rd over I 496 west of Lansing). The bridge is a two-span continuous structure with equal spans and a total length of 187-1/2 ft. All measurements reported herein were made in the north span.

This study represents one phase of the post-construction evaluation and performance characteristics of this structure as proposed by a Joint Departmental Committee following the experimental features of this particular bridge. The purpose of this experiment was to obtain strain and deflection data for evaluation and comparison with the theoretical design analysis.

The computed values of strain and deflection shown in this report were furnished by the Design Division. Main girders were designed for H20-44 loading, but computed strains and deflections were based upon a H15-44 vehicle which was approximated in the tests. Strains and relative deflections for floor beams, ribs, and deck plate were based on a pair of 12,000-lb dual wheel loads spaced 6 ft center-to-center. The design analysis was based on the AISC Design Manual for Orthotropic Steel Plate Deck Bridges, with minor variations.

Equipment

Two MDSH test vehicles were used for the experiment and are shown in Figures 1 and 2. The two-axle vehicle approximates the load distribution of a theoretical H15-44 design vehicle, while the semi-trailer provides a trailer axle load far removed from the influence of the weight of the tractor, simulating a pair of isolated dual wheel loads.

Strain gages were applied to the underside of the structure at the locations shown in Figure 3. Foil gages were used at all locations, with 90-degree rosettes applied on the deck plate. Static strain and deflection readings were made with the load vehicles at several different locations, and limited dynamic results were obtained. Dynamic deflections were measured by linearly variable differential transformers and results recorded on an oscillograph, along with dynamic strain information. Static deflections were measured by dial indicators, with 0.001-in. increments. Three separate tests were made for each location and load condition. Values reported are averages for the three trials.

Note: Static strain measurements, under the conditions involved, may be subject to considerable error when the magnitude of the measured strain is low. Reported values below 100 μ in./in. are only approximations and errors of 10 percent or more may be present at values of 150 μ in./in.

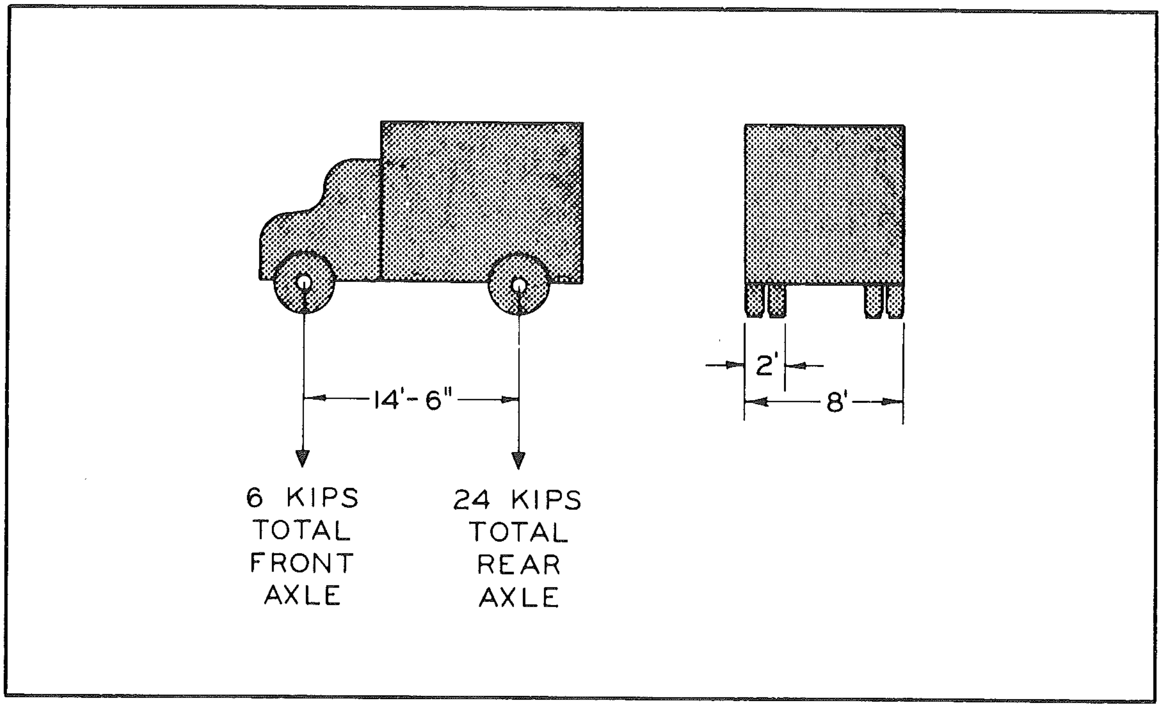
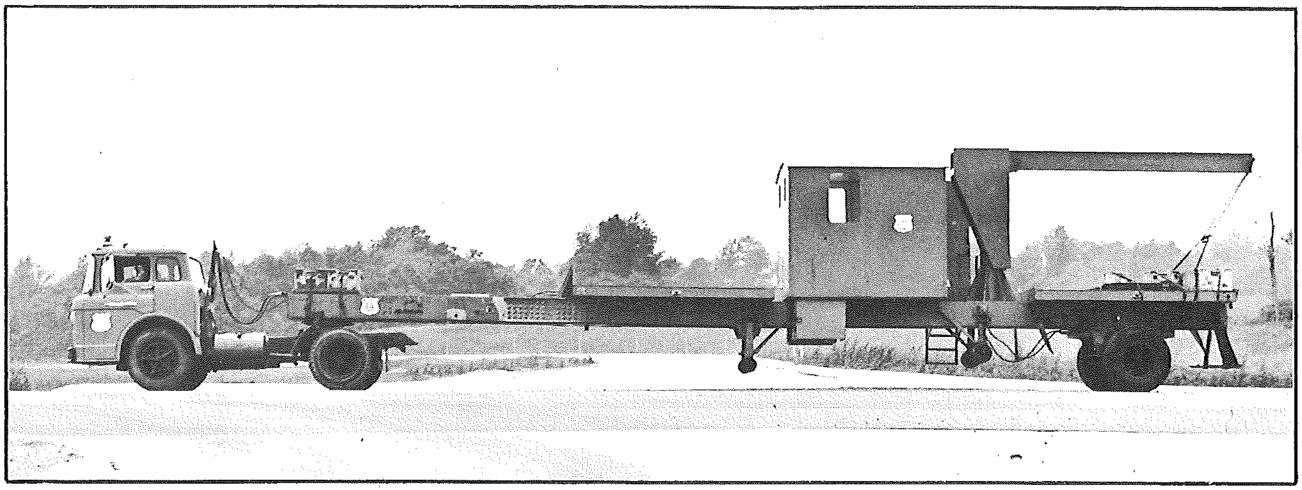
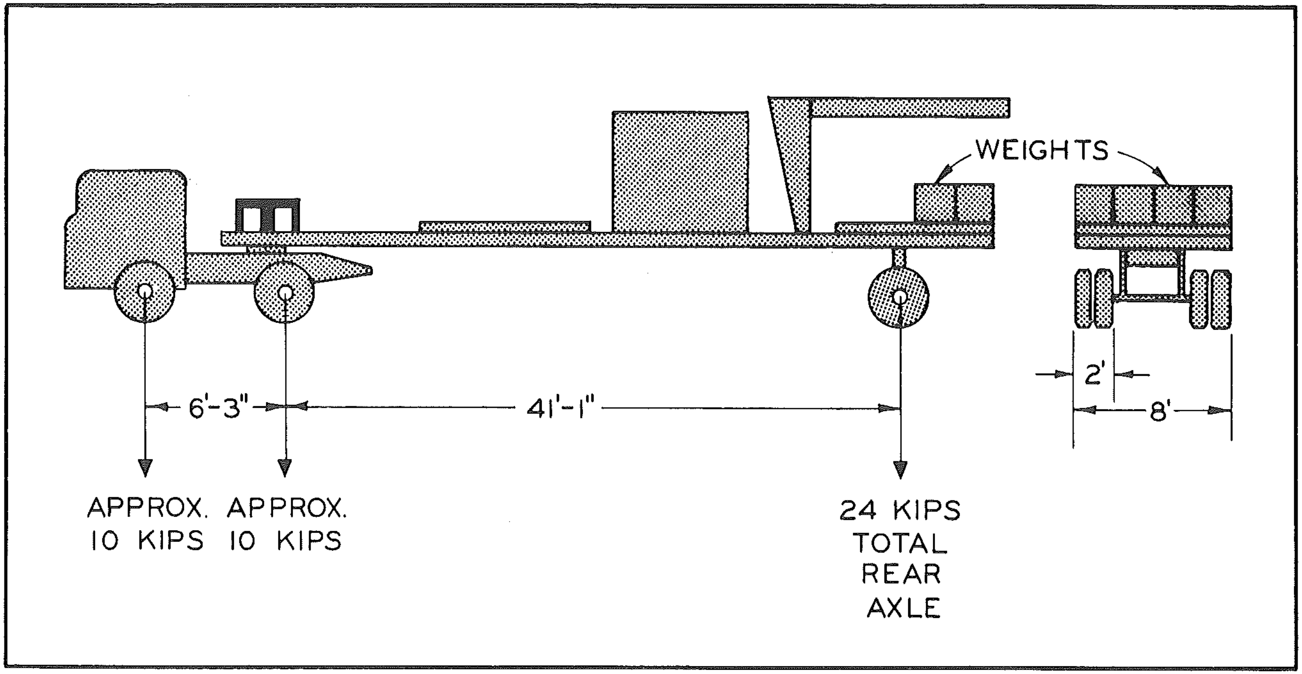


Figure 1. MDSH test vehicle -- Type 2D.





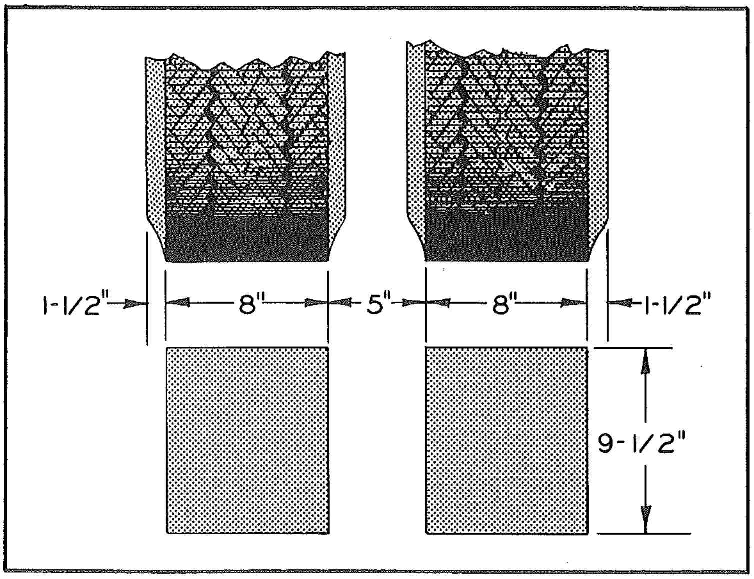


Figure 2. MDSH test vehicle -- Type 2S1 (top). Typical "foot-print" for 12,000-lb load on dual tires with 80 psi inflation (right).

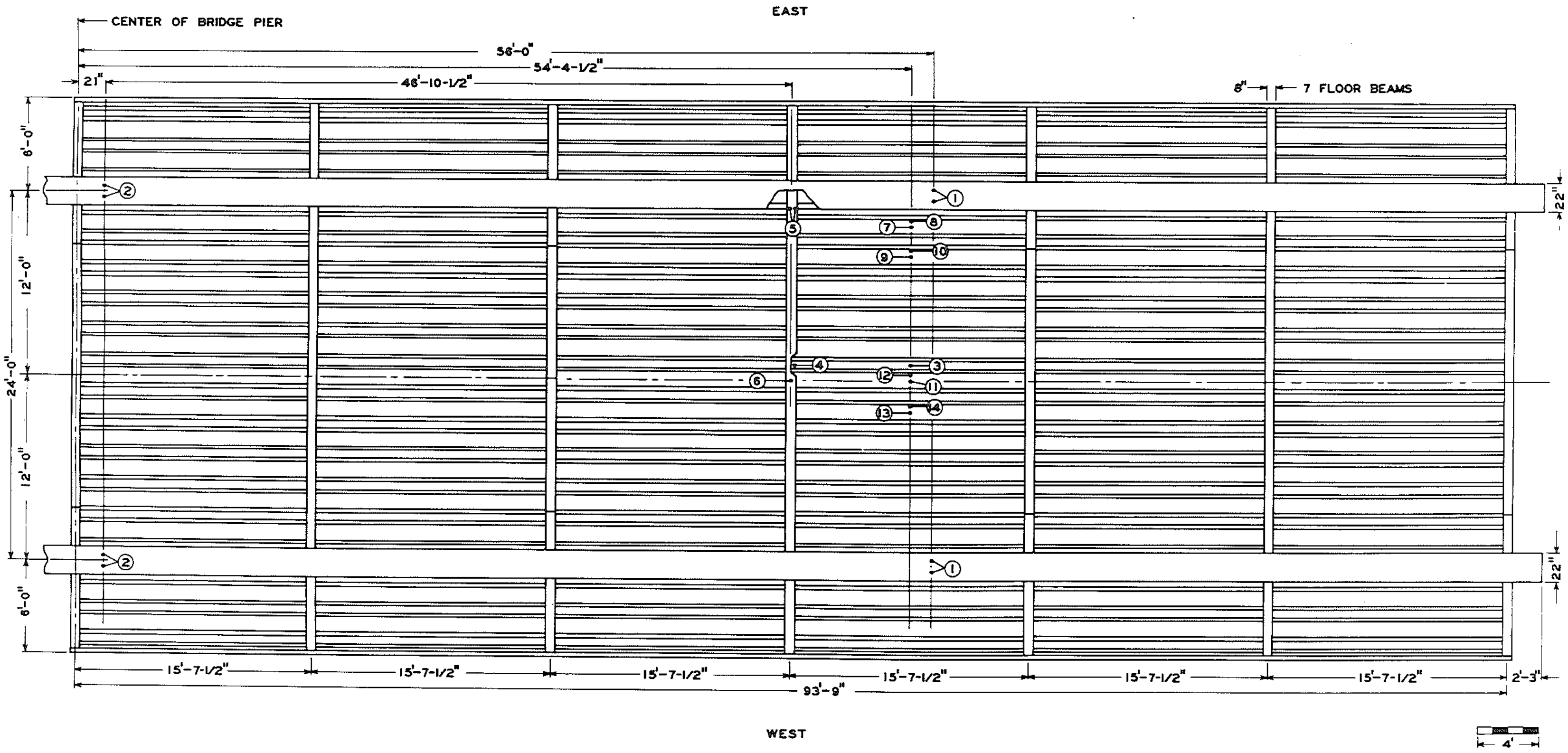


Figure 3. Bottom view of N span showing the location of strain gages.

Discussion of Test Results

1. Main Girders

Results of tests on the main girders are given in Table 1, with corresponding truck locations shown in Figure 4. Comparison of computed and measured values indicates that design assumptions are conservative, as is normally the case with other types of bridges. It was noted during testing that the bridge tends to rotate about the pier. Evidently there is sufficient friction in the system to maintain the elevation of the span slightly higher or lower, depending on which span was the last to be loaded.

Dynamic runs over the bridge at speeds of 15 and 30 mph gave peak strain and deflection values approximately 15 percent higher, due to vibration. Free vibration of the structure after the vehicle had passed was of extremely low amplitude. This is to be expected because of the high stiffness-to-mass ratio of the orthotropic design. Frequency of free vibration was roughly 4 cps.

2. Ribs

Table 2 shows the results of tests on a rib near the bridge centerline. Relative locations of the loading and gages are shown in Figure 5. Measured values are considerably lower than computed values, as was the case with the girders. Again, this indicates conservative assumptions.

The load vehicle was driven over the bridge at creep speed and at 20 mph, with the wheels passing over the instrumented rib. Indicated dynamic strains were slightly below the static values shown in the table. However, since lateral placement of the wheel load is critical in this case, and alignment is more difficult to obtain under dynamic conditions, little significance is attached to the slight difference in strain.

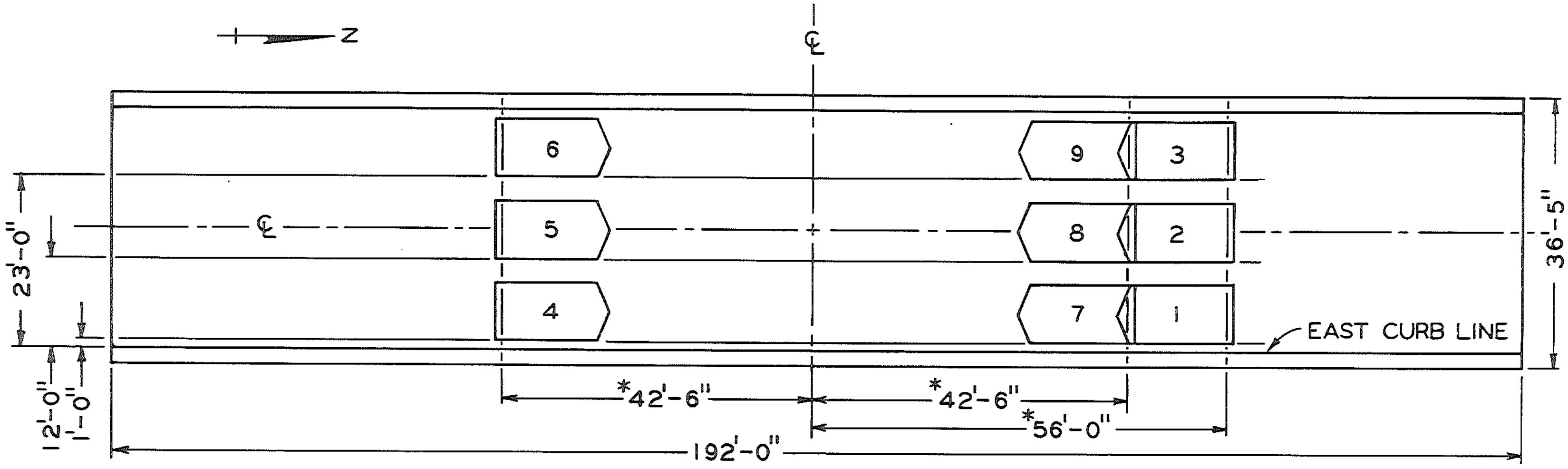
3. Floor Beams

Test results from floor beam tests are shown in Table 3, for loading conditions indicated in Figure 6. Here, again, measured values are considerably lower than predicted.

Dynamic runs at creep speed and at 20 mph indicated less than 10 percent increase in strain due to vibration.

TABLE 1
STATIC STRAIN AND DEFLECTION FOR MAIN GIRDERS (Load Vehicle Type 2-D)

Run No.	Truck Location	Gages Monitored	Strain (μ in./in.)				Deflection (in.)			
			E. Girder		W. Girder		E. Girder		W. Girder	
			Computed	Measured	Computed	Measured	Computed	Measured	Computed	Measured
1	1	1E & 1W	110	70	---	0	0.31	0.21	----	0.04
2	2	1E & 1W	---	30	---	30	----	0.12	----	0.12
3	3	1E & 1W	---	0	110	70	----	0.04	0.31	0.21
4	4	2E & 2W	-50	-40	---	0	----	----	----	----
5	5	2E & 2W	---	-20	---	-20	----	----	----	----
6	6	2E & 2W	---	0	-50	-40	----	----	----	----
7	7	2E & 2W	-50	-40	---	0	----	----	----	----
8	8	2E & 2W	---	-20	---	-20	----	----	----	----
9	9	2E & 2W	---	0	-50	-40	----	----	----	----



* MEASURED FROM CENTER OF BRIDGE TO CENTER OF EACH REAR AXLE

Figure 4. Positions of Type 2D load vehicle for testing main girders.

TABLE 2

STATIC STRAIN AND DEFLECTION FOR RIB (Load Vehicle Type 2S1)

(Tabulated deflection value is the deflection of the rib relative to the two adjacent floor beams)

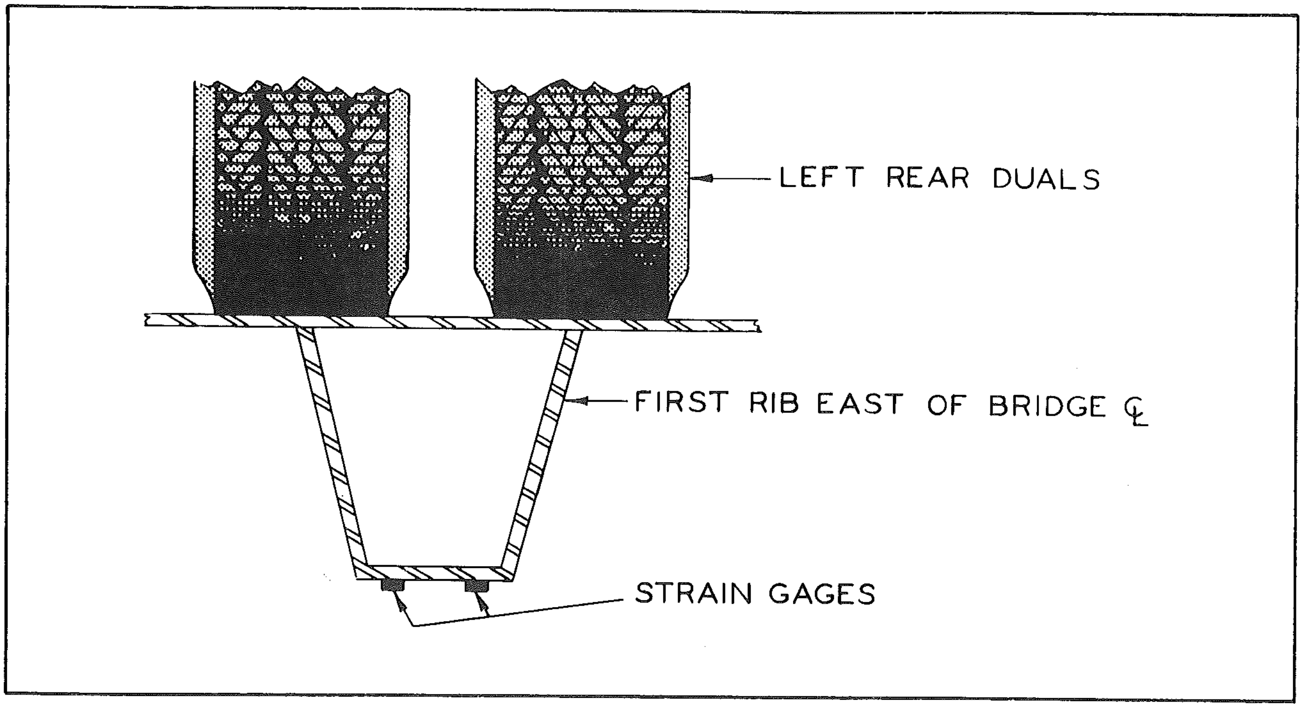
Run No.	Truck Location	Gage Monitored	Strain (μin./in.)		Relative Deflection (in.)	
			Computed	Measured	Computed	Measured
1	10	3	375	270	0.12	0.08
2	11	4	-160	-100	----	----
3	12	4	---	- 90	----	----

TABLE 3

STATIC STRAIN AND DEFLECTION FOR FLOOR BEAM (Load Vehicle Type 2S1)

(Deflection value given is the deflection of floor beam relative to the girders)

Run No.	Truck Location	Gages Monitored	Strain (μin./in.)			Deflection (in.)	
			Gage 5	Gage 6		Computed @ Gage 6	Measured @ Gage 6
				Computed	Measured		
1	13	5 & 6	0	255	140	0.09	0.06
2	14	5 & 6	0	255	140	0.09	0.06



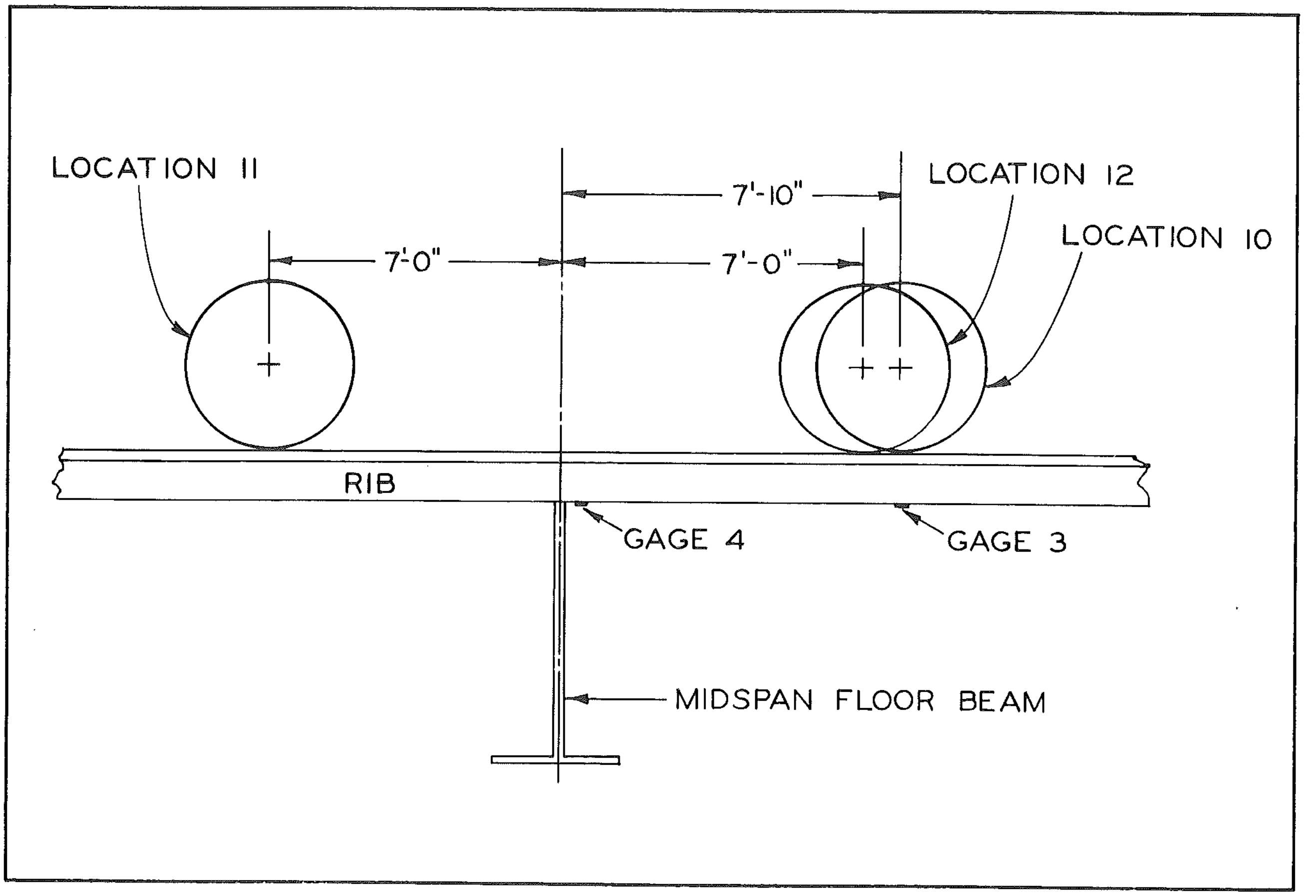
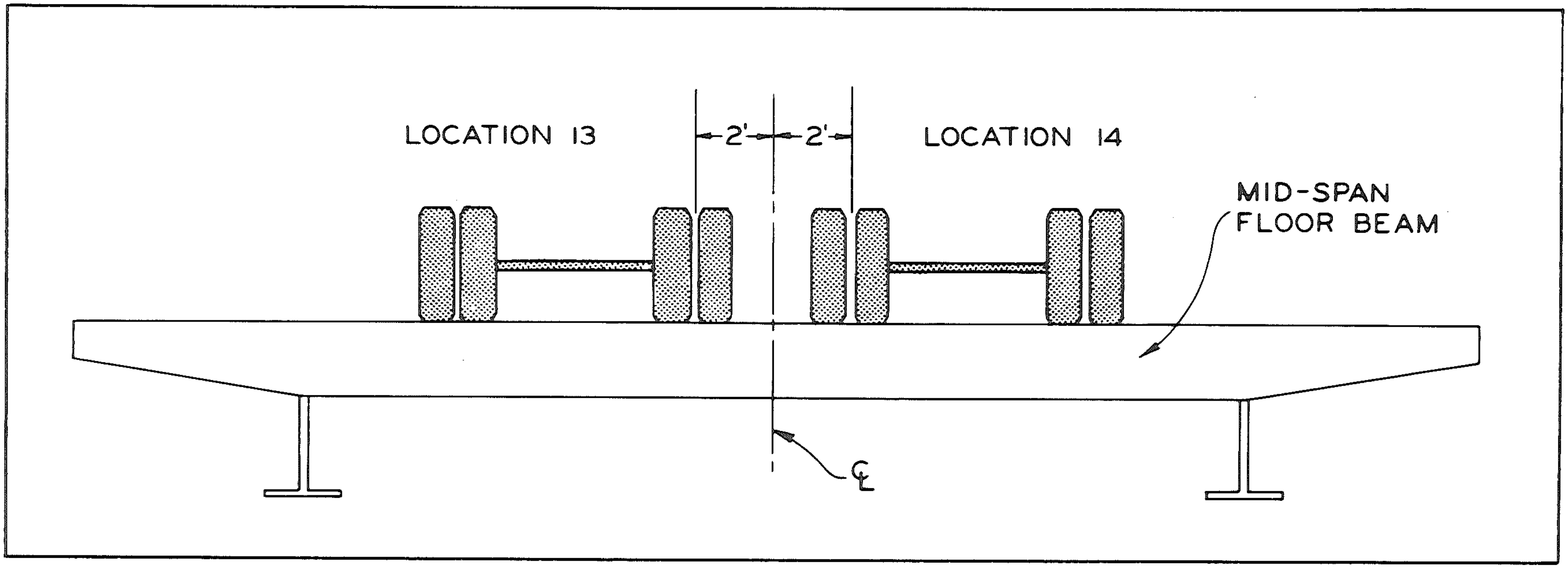


Figure 5. Loading positions for rib tests. Load vehicle Type 2S1 with 12,000-lb wheel load positioned as shown.



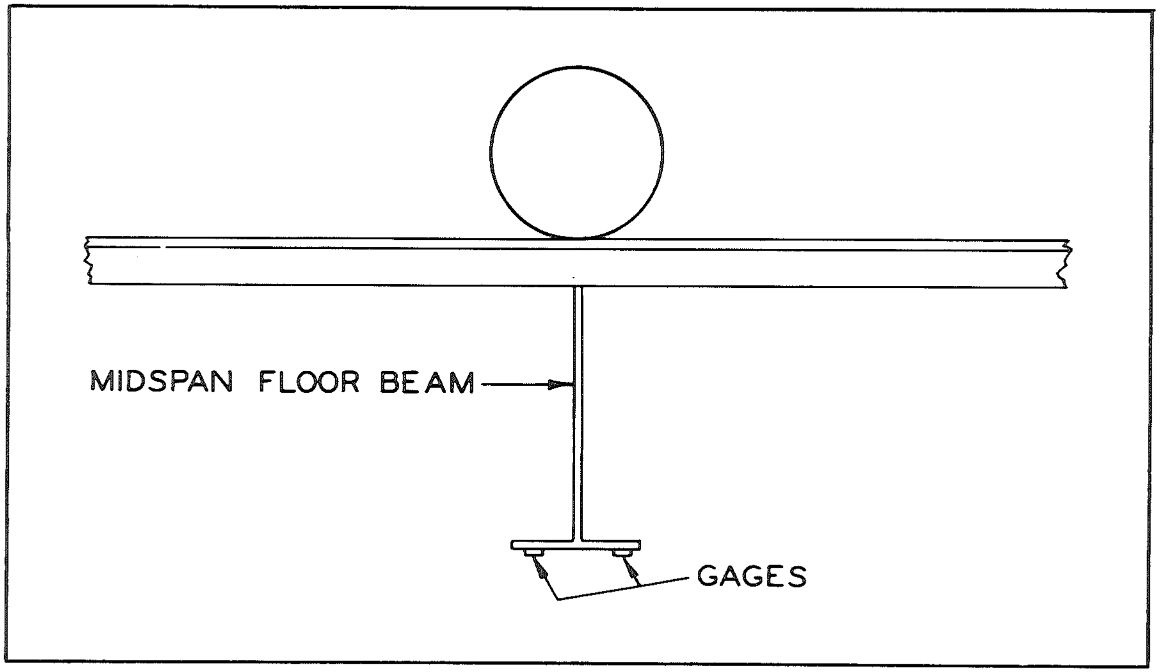


Figure 6. Loading positions for floor beam tests. Load vehicle Type 2S1 with 24,000-lb axle load positioned as shown.

4. Deck Plate

The deck plate proved to be very difficult to test because hot weather occurred during the time the tests were conducted. It was found that the floor beams provided effective restraint to lateral expansion of the deck plate when the plate was heated by the sun. The result was a slight wrinkling or buckling of the plate between the ribs. When the sun was shining brightly, lateral pressures in the plate sometimes were sufficient to hold the plate in a slightly deflected position after removal of the load. It was also noted that the shadow of the load vehicle caused changes in strain and deflection of the plate in the area, evidently due to localized cooling of the heated plate. Temperature changes in the deck occurred quite rapidly because of high thermal conductivity and low mass. Therefore, the plate tests had to be rerun several times, and still were not considered to be entirely satisfactory.

Strain and deflection data presented in this section are believed to be reasonable approximations but should not be taken as absolute, because of the problems noted above.

Gages mounted on the plate were rosettes, with arm No. 1 measuring plate strain in the transverse direction, arm No. 2 longitudinal, and No. 3 at 45° to the other two (bisecting the angle).

Results of the deck plate tests are shown in Table 4 for load positions indicated in Figure 7. The design assumption for plate loading considers the load to be uniformly distributed over a rectangular area approximating the imprint area of the dual tires. Calculations based on this assumption indicated maximum transverse strains of nearly 700 micro-inches per inch, and relative deflections of more than 0.060 in. Test results indicate maximum transverse strains of about 100 micro-inches per inch, with deflections less than 0.010 in. The sketches in Figure 7 show approximately how the load is applied by the tires and it can be seen that the actual load distribution differs from the assumed distribution. Therefore, strains could be expected to be lower than predicted. However, it was noted during testing that the single tire of the steering axle of the truck caused as much or slightly more deflection of the plate than the 12,000-lb dual wheel, even though the steering axle weight was only 10,000 lb. It can be seen from the sketches that the single tire load distribution fits readily within the unsupported span of the plate between the rib side plates, yielding a more critical loading case. Also, since there is no other load nearby to hold down the adjacent plate, the plate can rotate more readily about the ribs when the single-tired load is applied. The end result is more deflection at lower applied load.

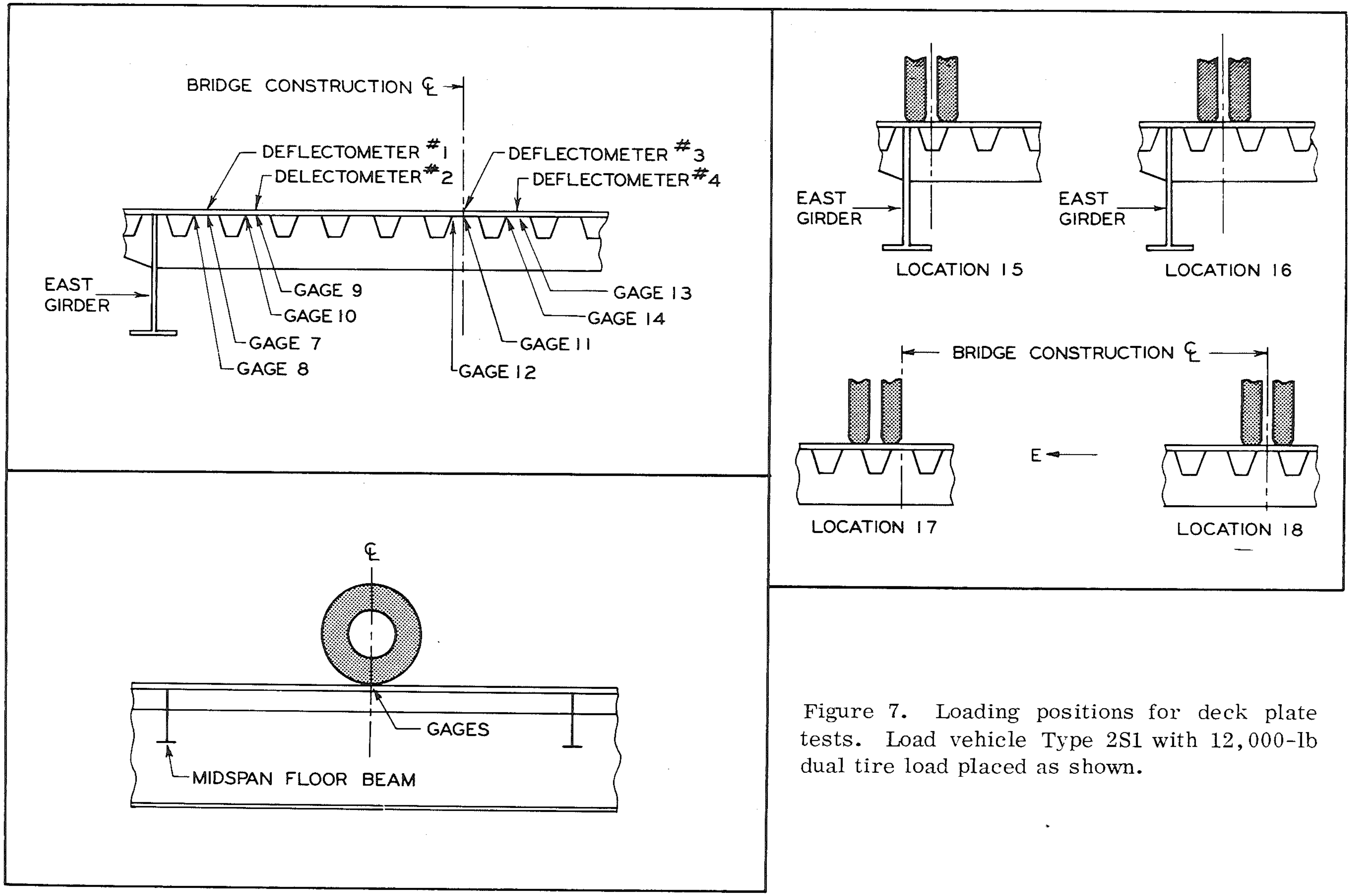


Figure 7. Loading positions for deck plate tests. Load vehicle Type 2S1 with 12,000-lb dual tire load placed as shown.

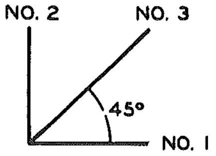
TABLE 4
STATIC STRAIN AND DEFLECTION FOR DECK PLATE

(Positive deflection is downward)

Truck Location	Deflection, in.		Gage Location											
			7			8			9			10		
			Arm			Arm			Arm			Arm		
	D_1	D_2	1	2	3	1	2	3	1	2	3	1	2	3
15	0.001	-0.002	20	-60	-40	-40	-60	-80	20	-40	-20	-20	-40	-40
16	0.009	-0.001	120	20	80	0	-40	-80	0	-40	-20	0	-40	-20

Truck Location	Deflection, in.		Gage Location											
			11			12			13			14		
			Arm			Arm			Arm			Arm		
	D_3	D_4	1	2	3	1	2	3	1	2	3	1	2	3
17	0.002	-0.002	0	-60	-40	40	-60	-20	0	-40	-20	0	-40	-20
18	0.008	-0.001	100	0	60	-40	-40	-40	0	-40	-20	40	-40	0

NOTE: Locations 7 through 14 each have 3-gage rosettes. Arm No. 1 is transverse to bridge ℄ , No. 2 parallel to the ℄ , and No. 3 at 45° .



Gages 7 through 10 were intended for comparing deck plate strains near the girder where the rib support conditions are quite stiff; with gages 11 through 14 indicating deck strains near the bridge centerline where the rib support is more flexible. However, the results do not seem to be sufficiently accurate to make a valid conclusion, since the differences to be detected are quite small.

Conclusions

Results of the tests indicate that design assumptions are conservative. All measured strains and deflections were well below calculated values.

Measurements of strain and deflection on the orthotropic bridge bear similar comparisons to design values as do comparable measurements in slab-on-beam bridges of approximately the same size.