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MICHIGAN
STATE HIGHWAY DEPARTMENT
Charles M. Ziegler
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A STUDY OF THE RIGIDITY OF VARIOUS DOWEL BAR JOINT ASSEMBLIES

By

L. T. Oehler, G. R. Cudney, R. D. Behr

Research Project 39 F-1 (3)

Research Laboratory
Testing and Research Division
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Since 1945 the Michigan State Highway Department has been permitting the use of dowel bar joint assemblies complying with minimum requirements as set forth in Plans E-4-130 and E-4-A-131 of the Road Design Division. In the summer of 1953, Mr. H. C. Coons, Deputy Commissioner-Chief Engineer, approved on a limited basis, a dowel bar joint assembly presented by the Bethlehem Steel Company. This assembly was wider and more sturdily constructed than that normally obtained under the Department's specifications and, in addition, it would accommodate 18-inch dowels.

After this unit had been used on several projects, it was so well liked that the Construction Division requested the Testing and Research Division to establish new specifications using the physical properties of the Bethlehem assemblies as a basis to obtain the factual stiffness of not only the Bethlehem assembly but that of several other assemblies submitted to the Research Laboratory for test.

In addition, an incidental study was made to determine the deflection and tipping due to load of the various assemblies while supported on a sand subbase both with and without sand plates and, in certain cases, with a wide range in the number of sand plates used.

This report presents the results of this study, including a description of the specimens tested, method of test, and summary of results. It is presented in two parts; part one covering the structural stiffness of the various assemblies and part two presenting the sand plate study.

Specimens Tested

The following dowel bar joint assemblies were tested:

Specimen	Source	
1. Type A - Expansion Joint	American	(See Figures 1 & 2)
2. Type A - Contraction Joint	American	(See Figures 3 & 4)
3. Type B - Expansion Joint	Universal	(See Figures 5 & 6)
4. Type B - Contraction Joint	Universal	(See Figures 7 & 8)
5. Type C - Expansion Joint	Bethlehem	(See Figures 9 & 10)
6. Type C - Contraction Joint	Bethlehem	(See Figures 11 & 12)
7. Type D - Expansion Joint[1]	Springfield	(See Figures 13 & 14)

PART 1

The Determination of the Structural Stiffness of the Various Dowel Bar Joint Assemblies

Testing Procedure

In the first phase of this study the dowel bar joint assemblies were tested for vertical stiffness by supporting the assemblies on an 8-foot span and loading with a concentrated load at the center of the span. (See Figure 15). The assemblies were supported from the test frame by four straps, two at each end, which hooked around the dowels (See Figure 16). The load applied at the center of the span was measured by means of dynamometers, (See Figure 17) which could be adjusted by threading to vary the magnitude of the load. Dials were used to measure deflection at each end of the support dowels and also for the dowel subjected to load. The slight settlement of the supports during loading was corrected in analyzing the deflection data. Deflections were observed as the load was applied in 25-pound increments to a maximum of 200 pounds.

To determine the structural stiffness of the assemblies subjected to horizontal loads, the testing arrangement shown in Figure 18 was used. The assemblies were supported from the test frame by straps while horizontal reactions were obtained by

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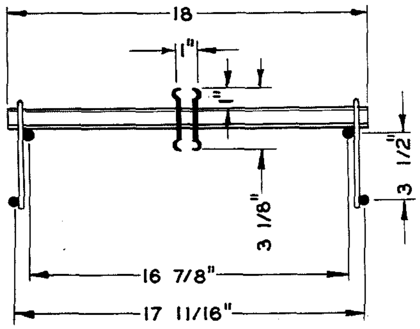
[1] This assembly was an expansion joint assembly but it was tested as a contraction joint assembly and will hereafter be referred to as such.

FIGURE 1. GENERAL VIEW.

DETAILED END VIEW.



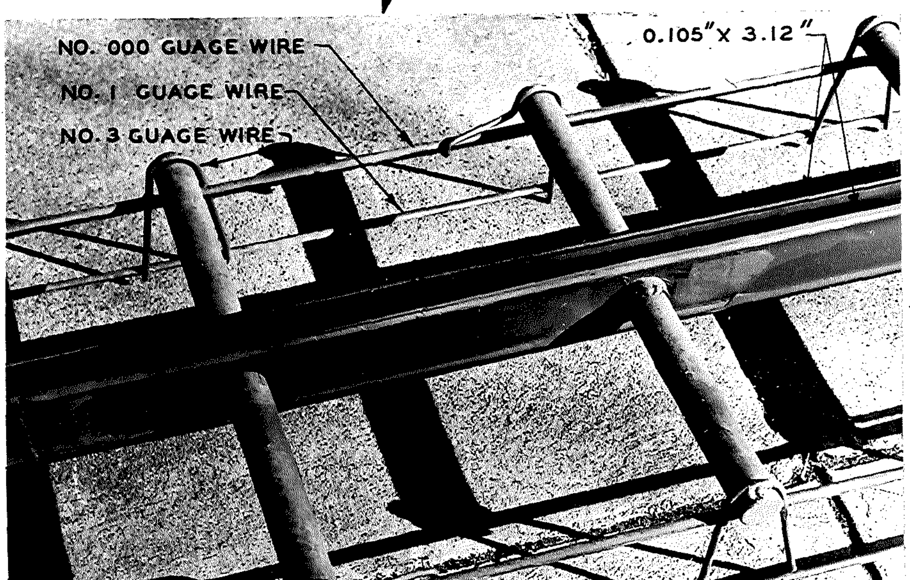


FIGURE 2. DETAILED PHOTOGRAPH.

TYPE A DOWEL BAR EXPANSION JOINT ASSEMBLY

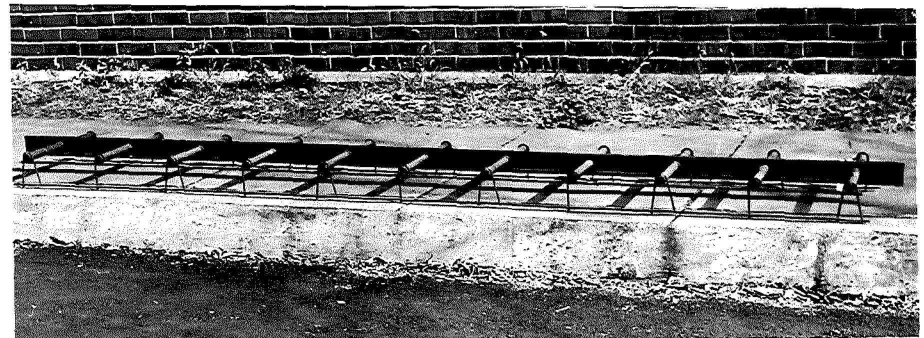
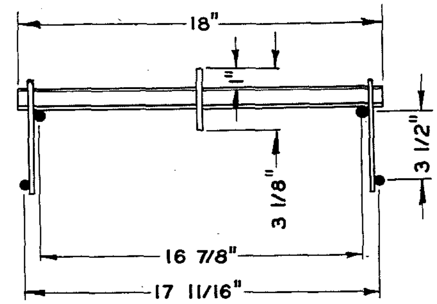


FIGURE 3. GENERAL VIEW.

DETAILED END VIEW.



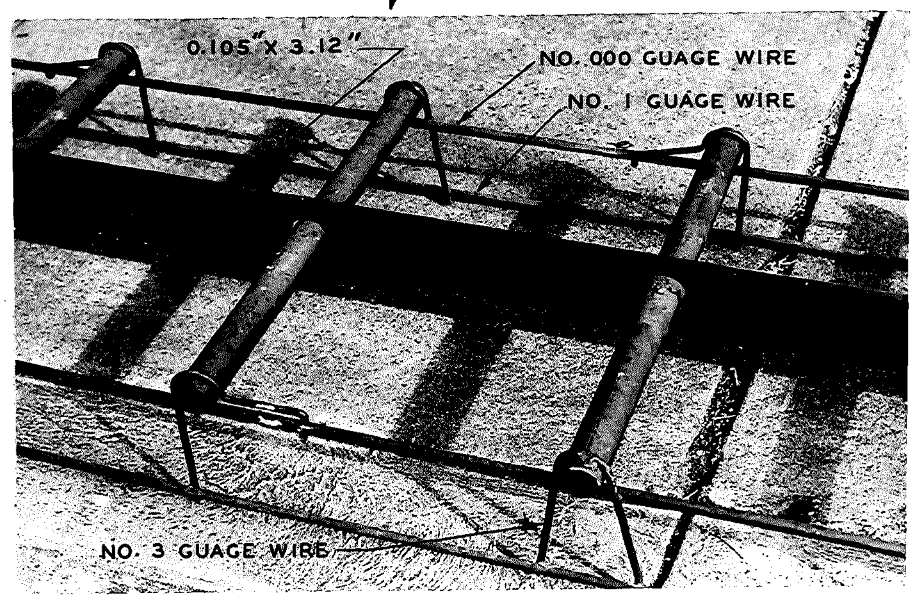
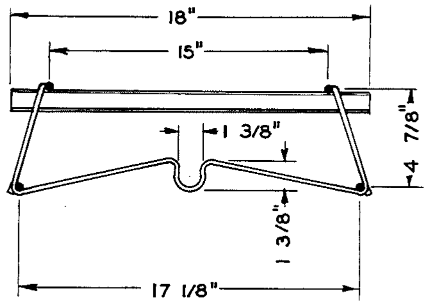


FIGURE 4. DETAILED PHOTOGRAPH.

TYPE A DOWEL BAR CONTRACTION JOINT ASSEMBLY

FIGURE 5. GENERAL VIEW.

DETAILED END VIEW.



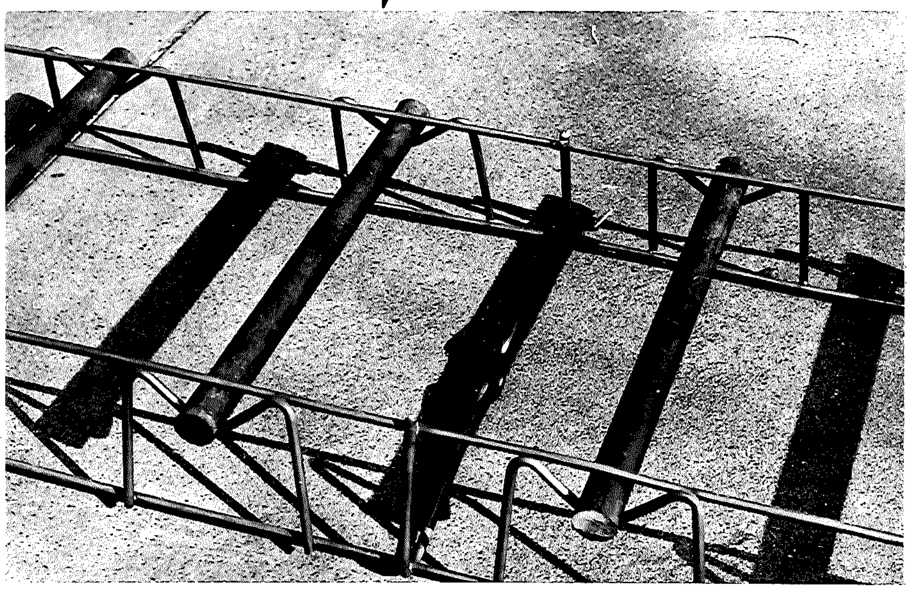
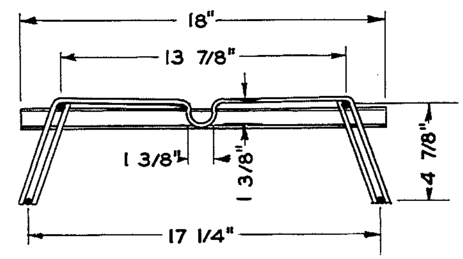


FIGURE 6. DETAIL PHOTOGRAPH.

FIGURE 7. GENERAL VIEW.

DETAILED END VIEW.



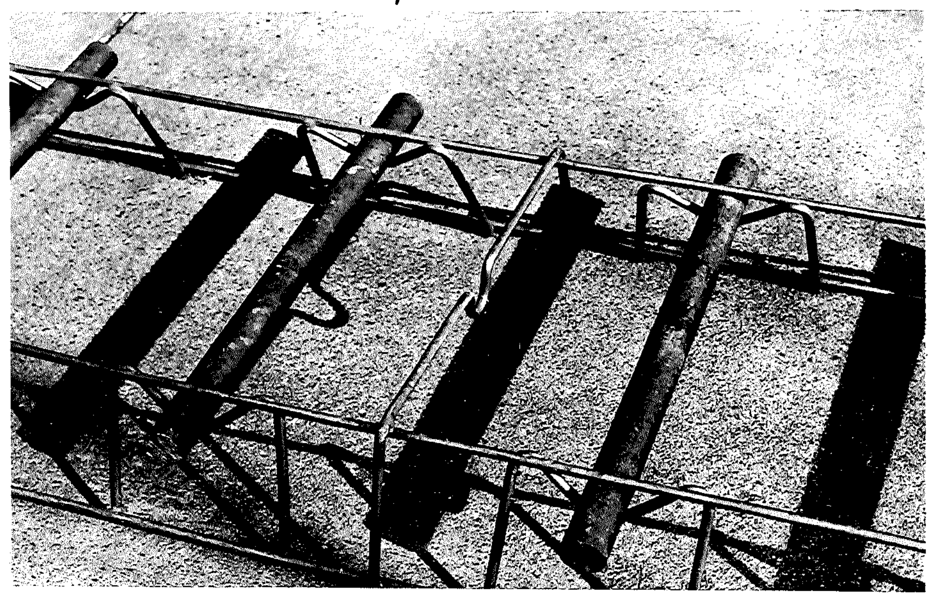


FIGURE 8. DETAIL PHOTOGRAPH.

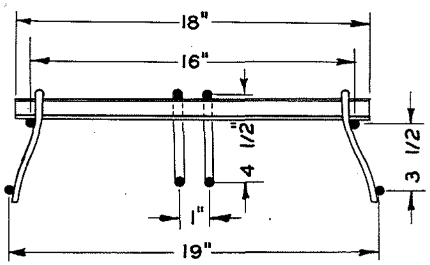
ALL FRAME WIRES OF No. 0 GUAGE

TYPE B DOWEL BAR EXPANSION JOINT ASSEMBLY

TYPE B DOWEL BAR CONTRACTION JOINT ASSEMBLY

FIGURE 9. GENERAL VIEW.

DETAILED END VIEW.



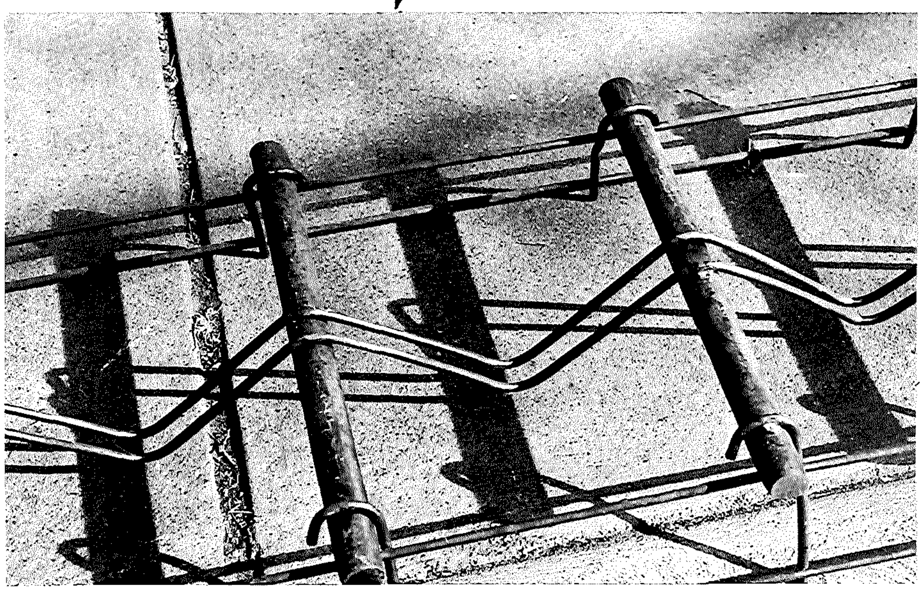


FIGURE 10. DETAIL PHOTOGRAPH.

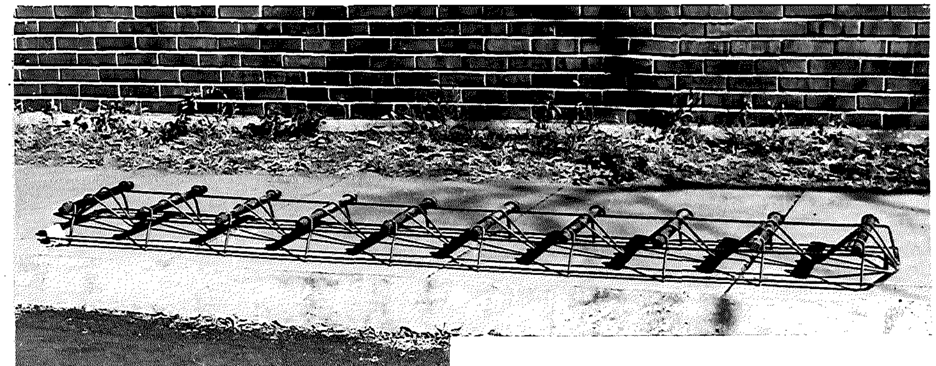
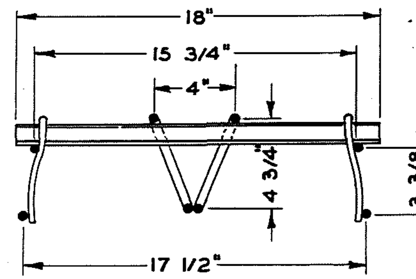


FIGURE 11. GENERAL VIEW.

DETAILED END VIEW.



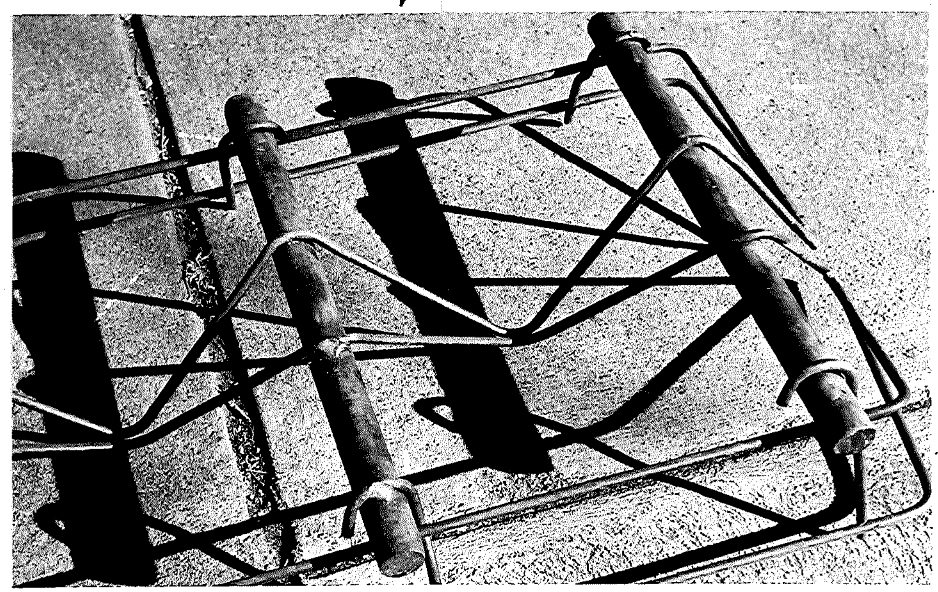


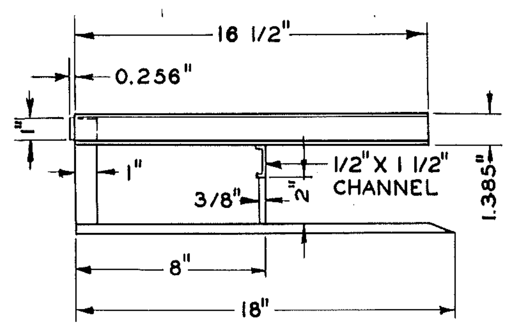
FIGURE 12. DETAIL PHOTOGRAPH.

ALL FRAME WIRES OF No. 0 GUAGE

TYPE C DOWEL BAR
EXPANSION JOINT ASSEMBLY

TYPE C DOWEL BAR
CONTRACTION JOINT ASSEMBLY

FIGURE 13. GENERAL VIEW.



DETAILED END VIEW.

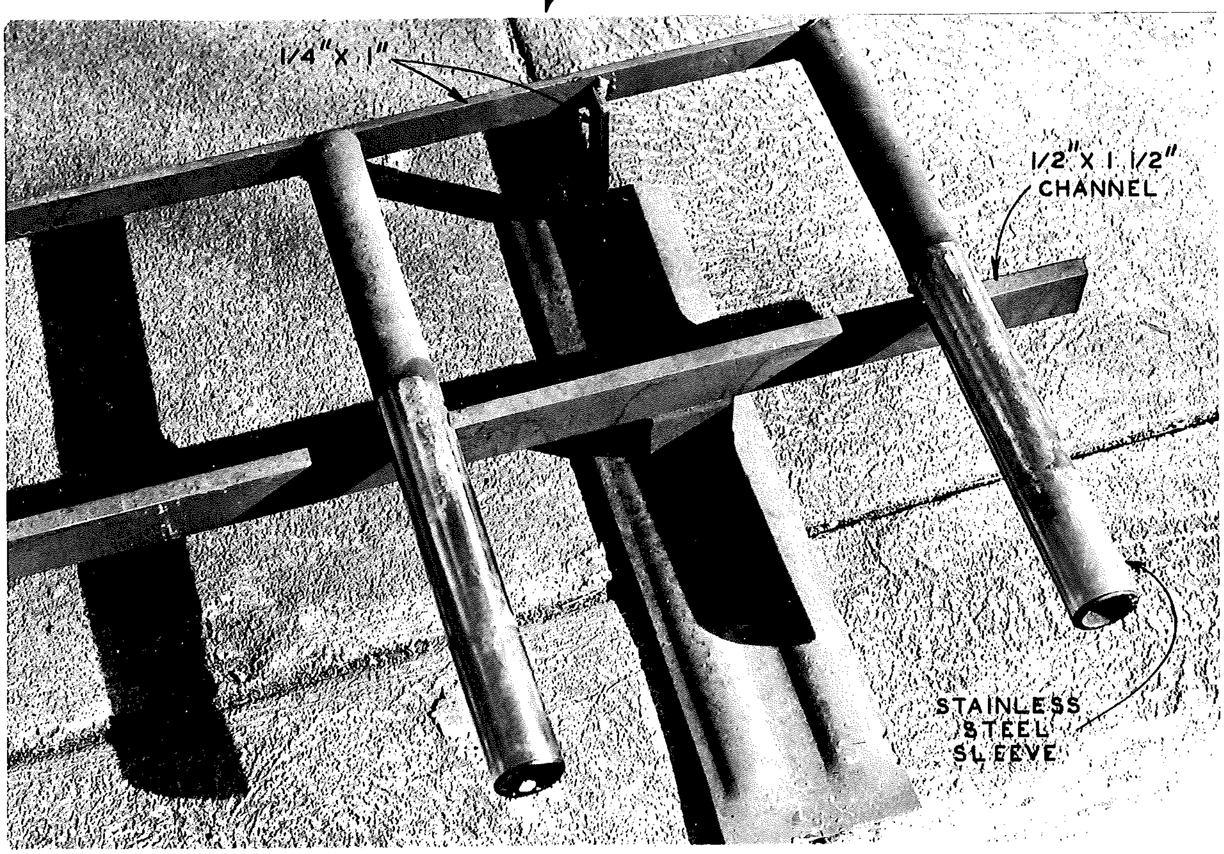


FIGURE 14. DETAILED PHOTOGRAPH.

TYPE D DOWEL BAR EXPANSION JOINT ASSEMBLY

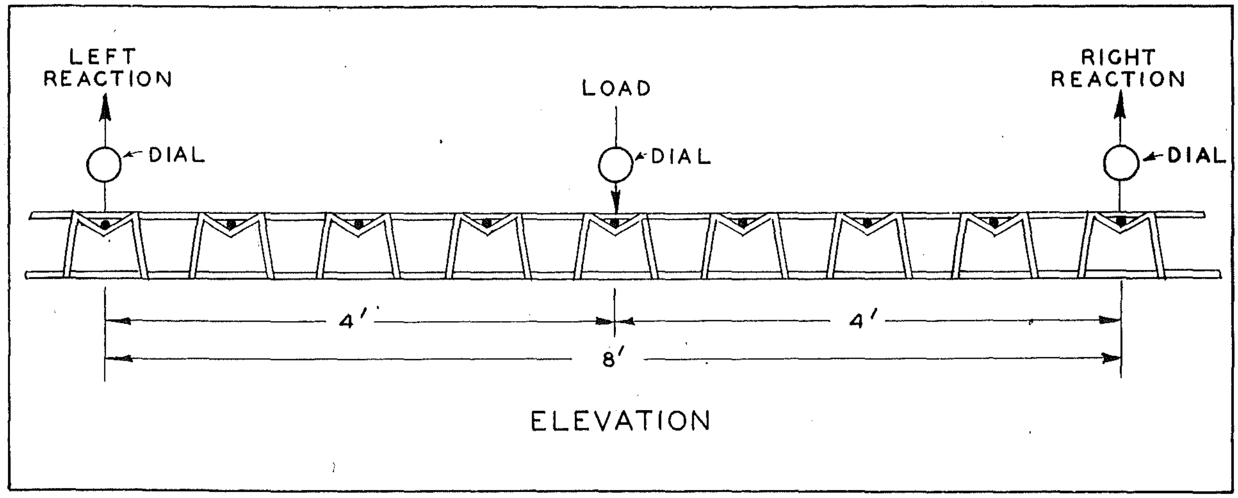


FIGURE 15. TESTING ARRANGEMENT FOR DETERMINING THE RIGIDITY OF VARIOUS DOWEL BAR ASSEMBLIES WHEN SUBJECTED TO VERTICAL LOAD.

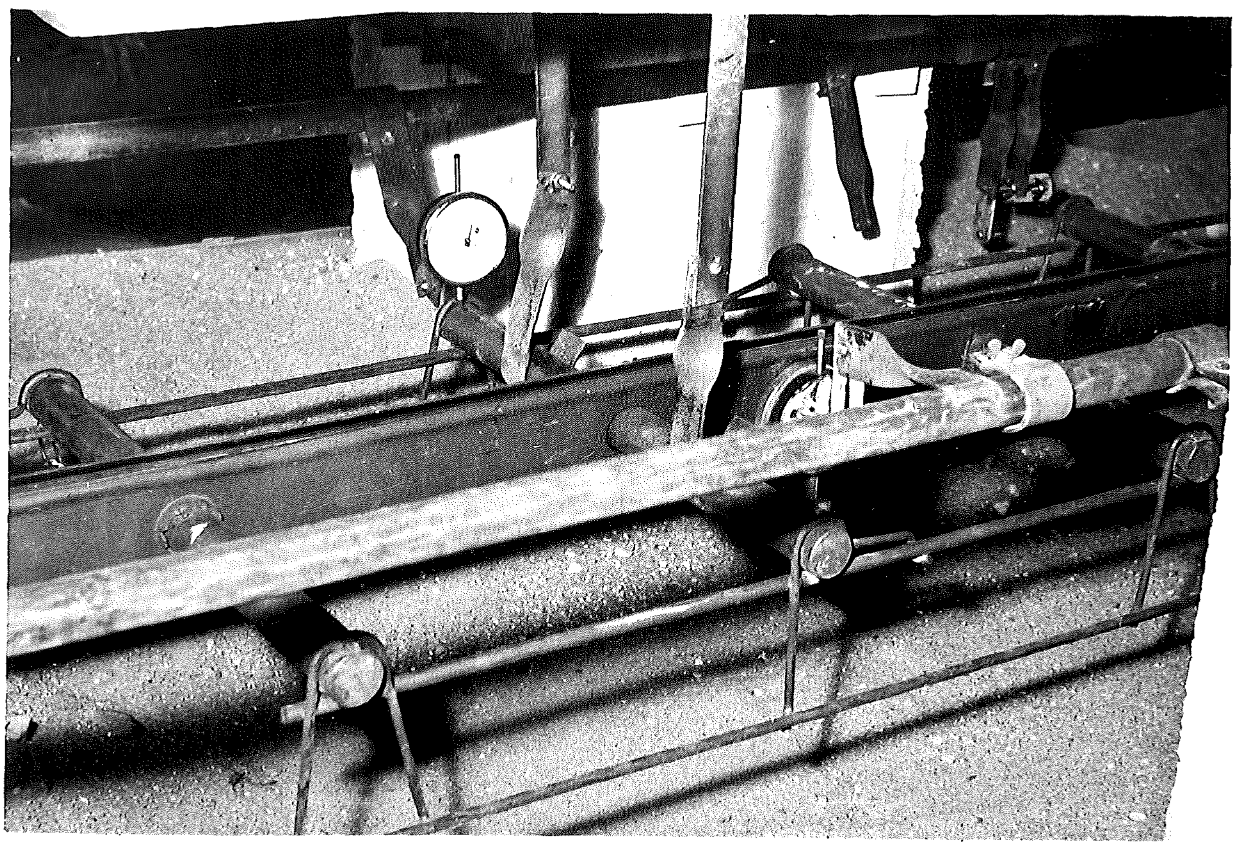


FIGURE 16. DETAIL OF METHOD OF SUSPENDING DOWEL BAR ASSEMBLIES WHEN SUBJECTED TO VERTICAL LOAD.

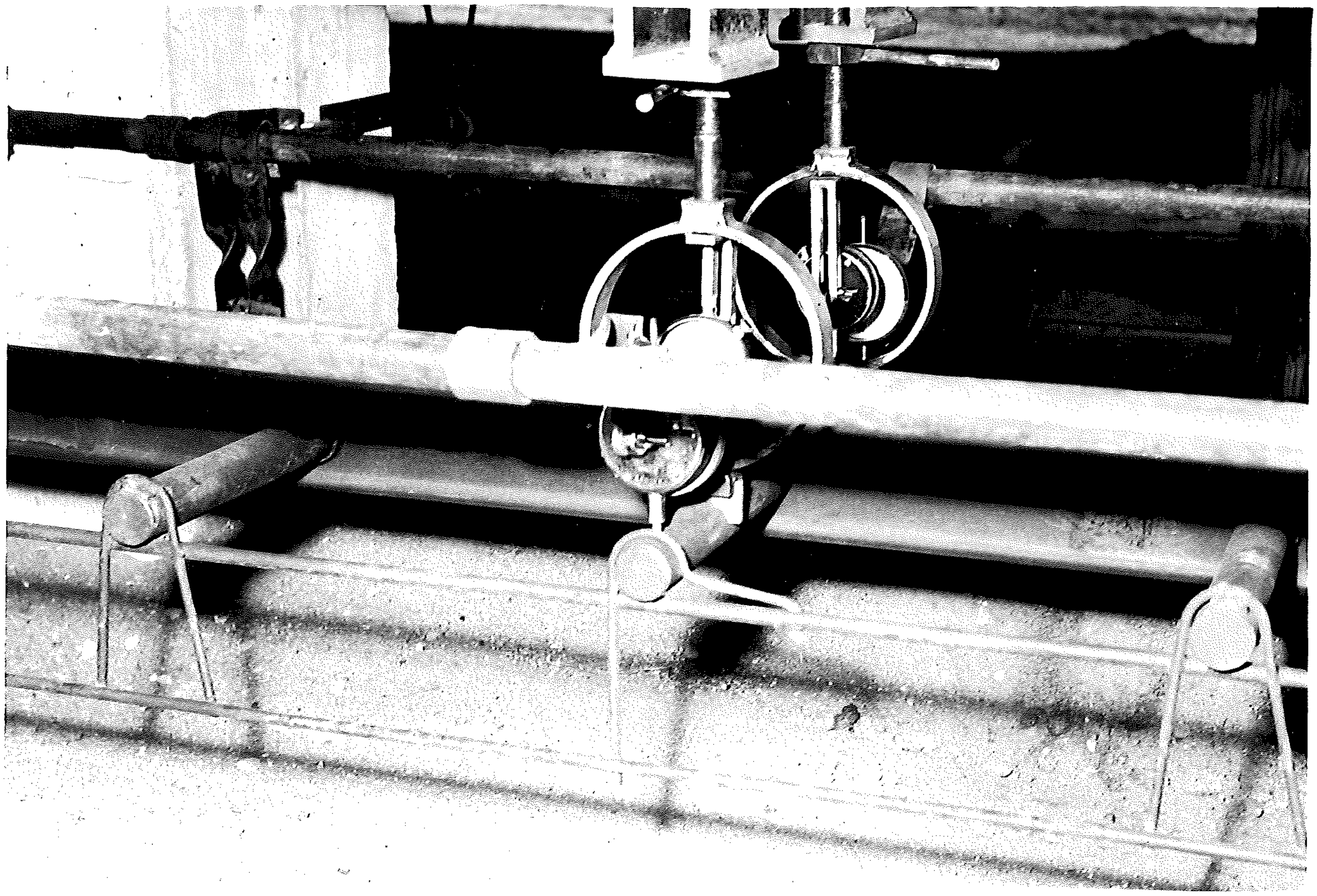


FIGURE 17. DETAIL OF METHOD OF LOADING DOWEL BAR JOINT ASSEMBLIES FOR VERTICAL LOAD.

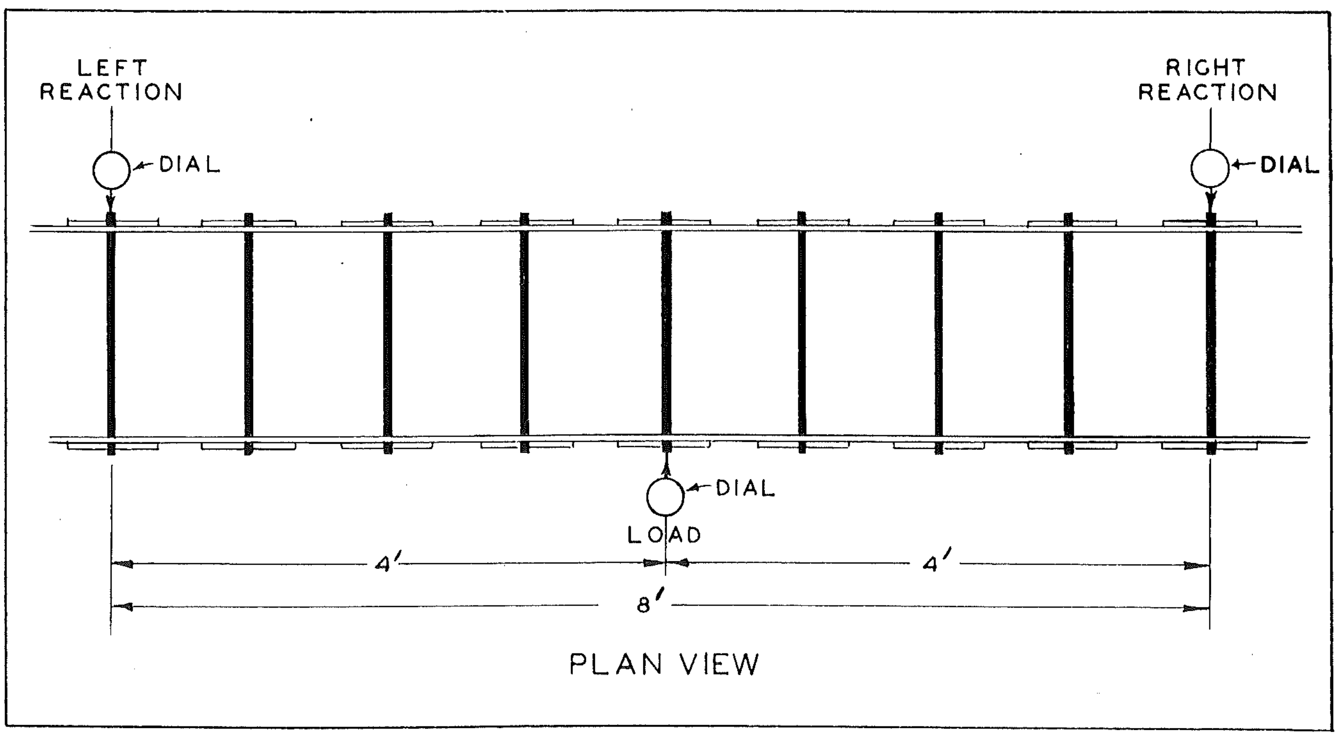


FIGURE 18. TESTING ARRANGEMENT FOR DETERMINING THE RIGIDITY OF VARIOUS DOWEL BAR ASSEMBLIES WHEN SUBJECTED TO HORIZONTAL LOAD.

means of concrete block anchors. The horizontal load was measured by means of a dynamometer. Reactions and loads were applied at the end of the dowels to obtain a uniform procedure for all assemblies. In the case of the Type B assemblies, which had loose dowels, it was necessary to spot weld one end of the two support dowels as well as the center loaded dowels to the holding assembly. The remaining dowels were left in the normal condition. Bending of the assembly in the horizontal plane was observed as the load was increased in 25-pound increments to a maximum of 150 pounds for the stiffest assembly.

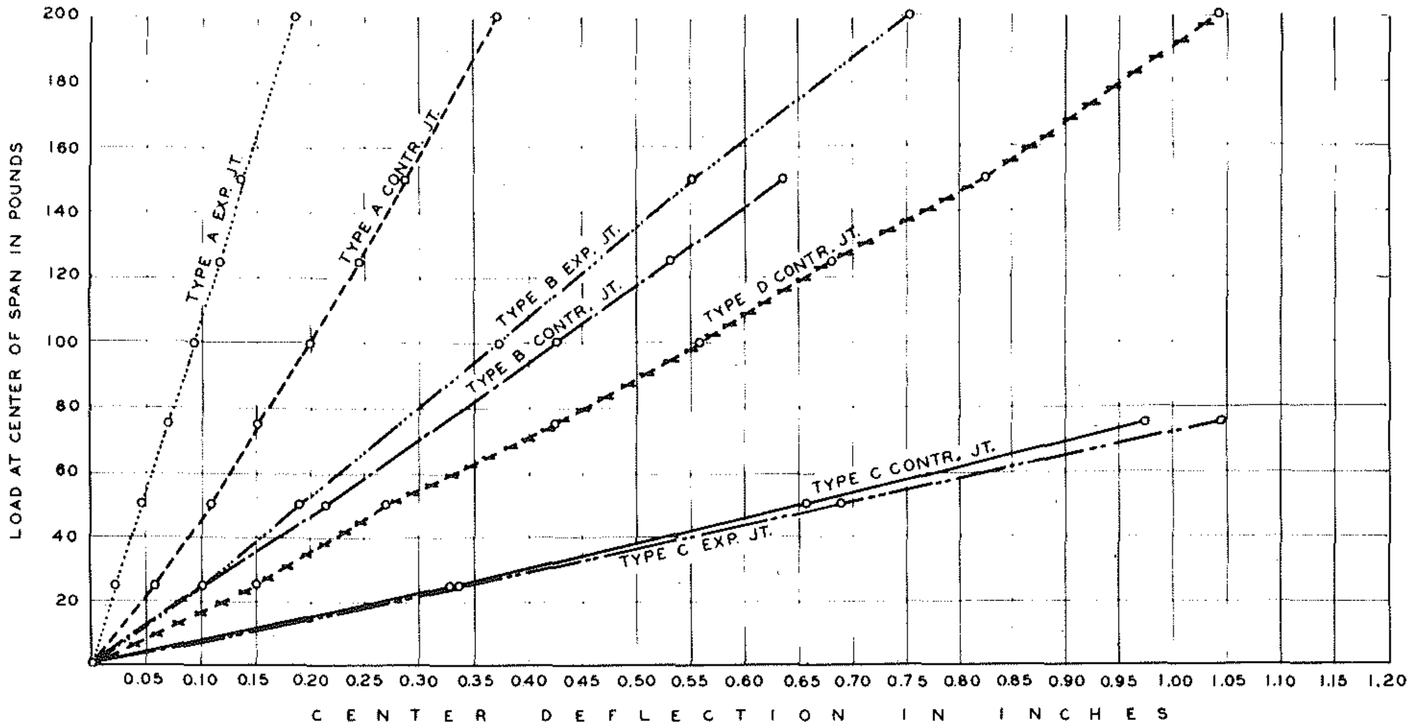
Results of Tests

In order to determine the relative rigidity of the dowel bar joint assemblies subject to vertical and horizontal loads, a comparison was made of the maximum deflections under a total superimposed load of 50 pounds.

According to the data represented in Figure 19, the Type A assemblies for expansion and contraction joints were those which were most rigid vertically. The deflection of the two assemblies was 0.06 and 0.10 inches, respectively. The Type C assemblies, for which deflections of approximately 0.7 inches were recorded, were the least rigid of the assemblies tested.

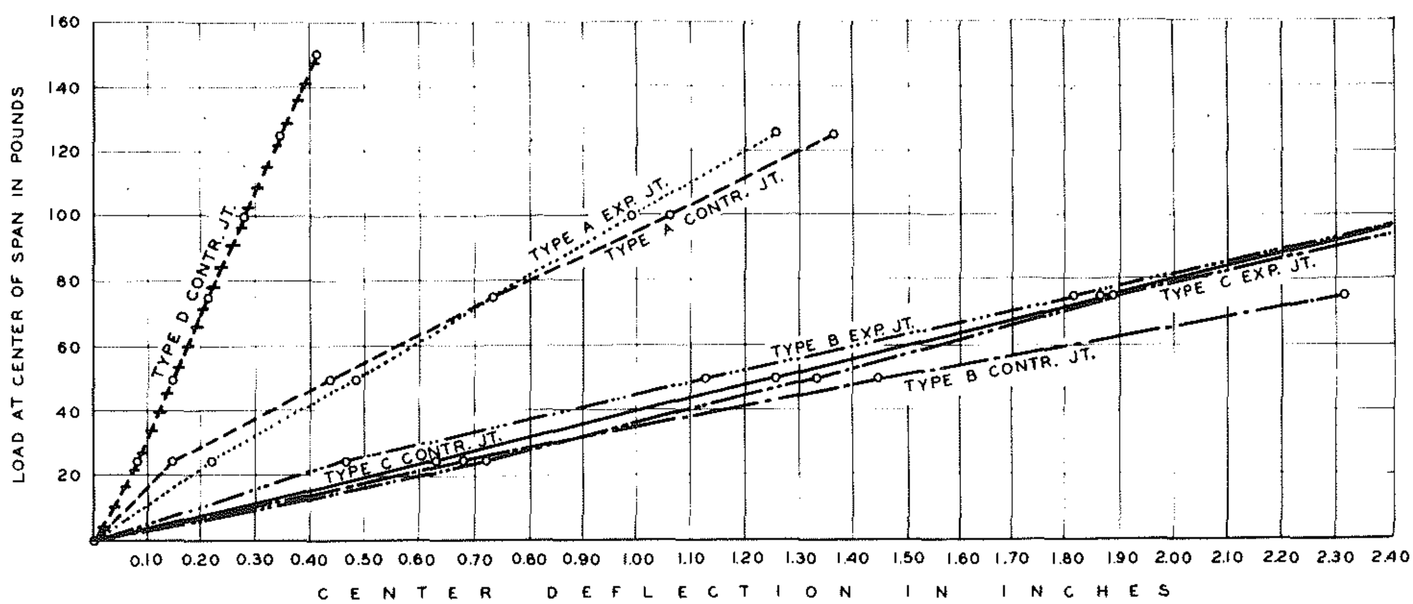
The Type D assembly was far superior to the other assemblies on the basis of horizontal rigidity. (See Figure 20) The deflection of the Type B contraction joint assembly, the assembly which was the least rigid, was 10.5 times the deflection of the Type D assembly (1.45 in. vs 0.138 in.).

Table I gives the moment of inertia of the various dowel bar joint assemblies for vertical and horizontal loads. This moment of inertia is the value calculated from the experimental tests of load and deflection. An attempt was made to calculate this value theoretically on the basis of the size and location of longitudinal wires in the



VERTICAL DEFLECTION OF DOWEL BAR ASSEMBLIES
TESTED WITH A CENTER VERTICAL LOAD ON AN EIGHT FOOT SPAN

FIGURE 19



HORIZONTAL DEFLECTION OF DOWEL BAR ASSEMBLIES
TESTED WITH A CENTER HORIZONTAL LOAD ON AN EIGHT FOOT SPAN

FIGURE 20

assembly frame. However, these assemblies are highly indeterminate structures which, it was found, are not readily susceptible to theoretical calculations.

TABLE I
Experimental Moment of Inertia of Various
Dowel Bar Joint Assemblies

	Moment of Inertia for Vertical Load[1]	Moment of Inertia for Horizontal Load[2]
Type A - Expansion Joint	0.677 in.^{4}	0.065 in.^{4}
Type A - Contraction Joint	0.317 in.^{4}	0.060 in.^{4}
Type B - Expansion Joint	0.170 in.^{4}	0.026 in.^{4}
Type B - Contraction Joint	0.148 in.^{4}	0.021 in.^{4}
Type C - Expansion Joint	0.046 in.^{4}	0.026 in.^{4}
Type C - Contraction Joint	0.048 in.^{4}	0.025 in.^{4}
Type D - Contraction Joint	0.115 in.^{4}	0.230 in.^{4}

1 Calculations based on vertical load of either 75 or 100 pounds.

2 Calculations based on horizontal load of either 75 or 100 pounds.

Conclusion

It appears from the data gathered that the rigidity of all dowel bar joint assemblies tested was equal to or better than that of the Type C assemblies. The Type C assemblies were authorized for use on a trial basis during the 1953 construction season and apparently proved satisfactory in field performance.

PART 2
The Determination of the Effect of Sand Plates on the Stability of Dowel Bar Joint Assemblies on a Sand Subbase

Testing Procedure

The testing frame shown in Figure 21 was constructed to supply the reaction for the vertical load on the dowels and to facilitate the positioning of the dials which were used to measure the vertical movement of the dowel bars. An 8-inch sand subbase of 2 MS mason sand with a fineness modulus of 2.21, was placed under the test frame. Before the beginning of each test, this subbase was leveled and then hand tamped. Rather than wetting the subbase surface, which is the procedure in actual practice, it was thought that a drier condition of the sand would have a more uniform moisture content during the test period. The average moisture content of the top 2.5 inches of the subbase varied from 1.5 to 2.8% during the testing period. The various joint assemblies were placed on the prepared sand subbase and loads were applied to the two central dowels at a point 3.5 inches from the end of the dowels on one side only. Each of the assemblies was tested under the following conditions: (1) no sand plates and (2) four sand plates. Also, in addition to this, several assemblies were tested with a greater number of sand plates to determine the minimum number of sand plates for a very small residual deflection of the assembly after the load was removed. When four sand plates were used they were placed in such a manner as to effect a seven-foot span. The load was applied in the center of this seven-foot span except for the Type D assembly which was loaded between supporting plates. All of the sand plates used were metal plates 6" x 6" x 0.075" (See Figure 22). Deflections were observed not only to determine the amount of vertical settlement of the assembly but also the amount of tipping caused by the loading of only one side of the assembly frame.

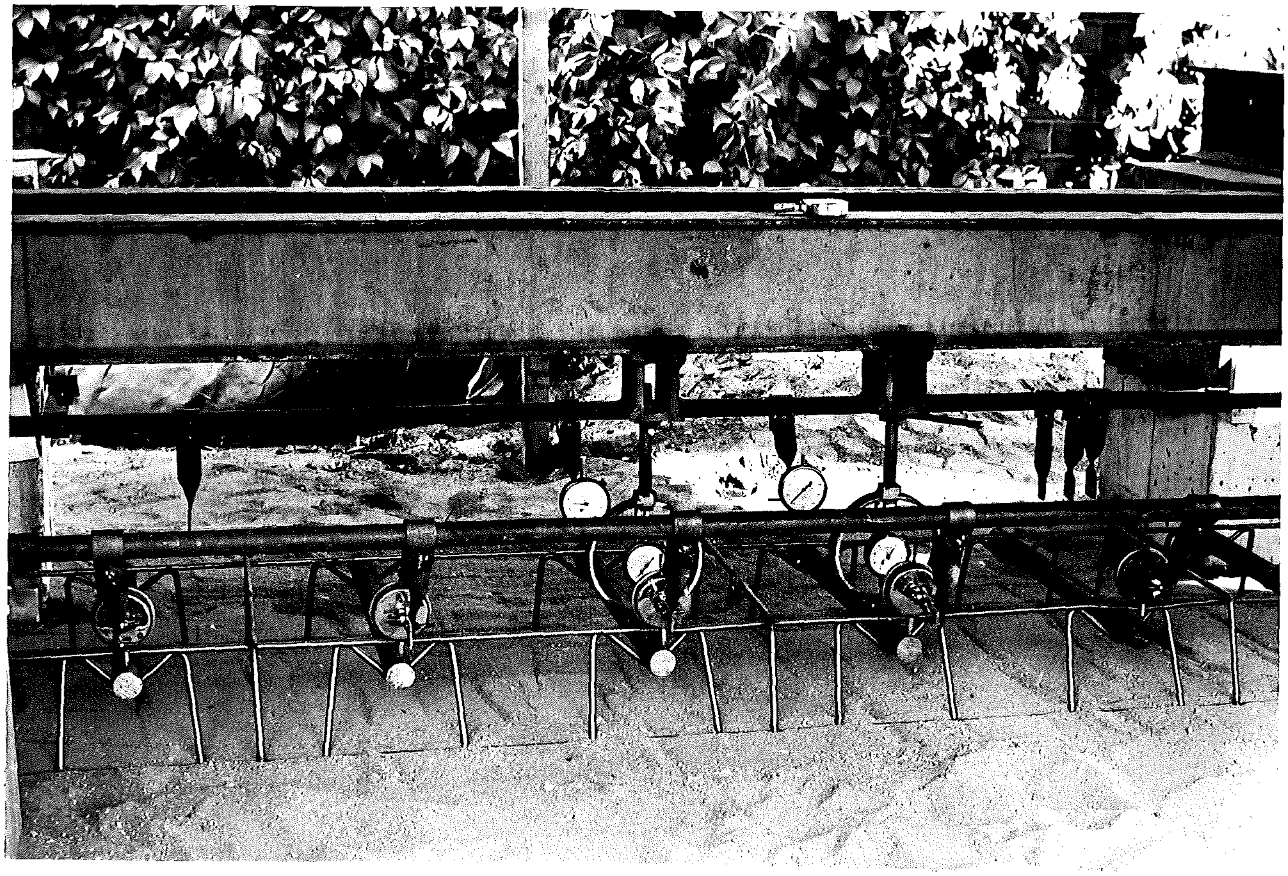


FIGURE 21. DETAIL OF TEST FRAME AND LOADING ARRANGEMENT.

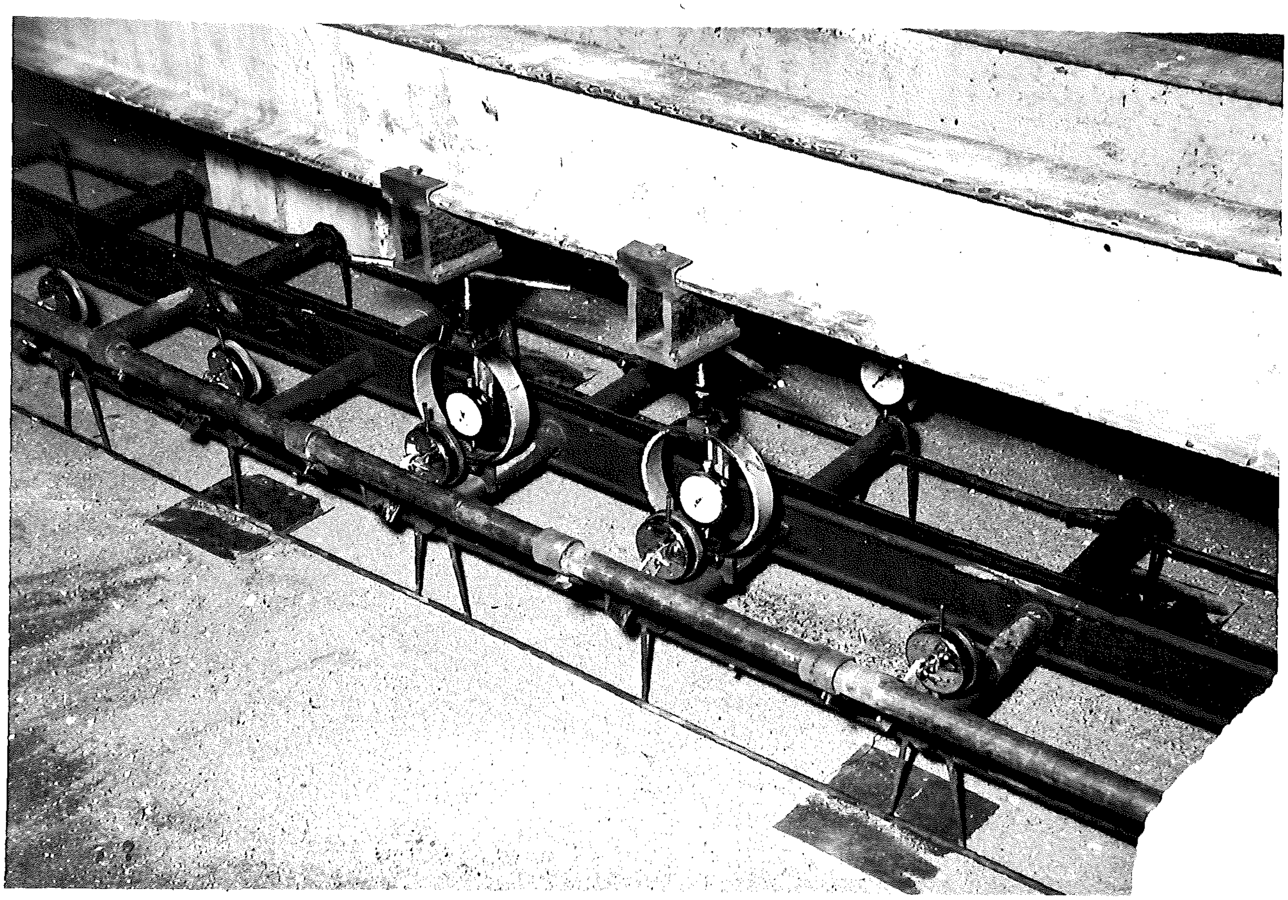


FIGURE 22. DETAIL OF THE METHOD OF SUPPORTING THE DOWEL BAR JOINT ASSEMBLIES USING SAND PLATES.

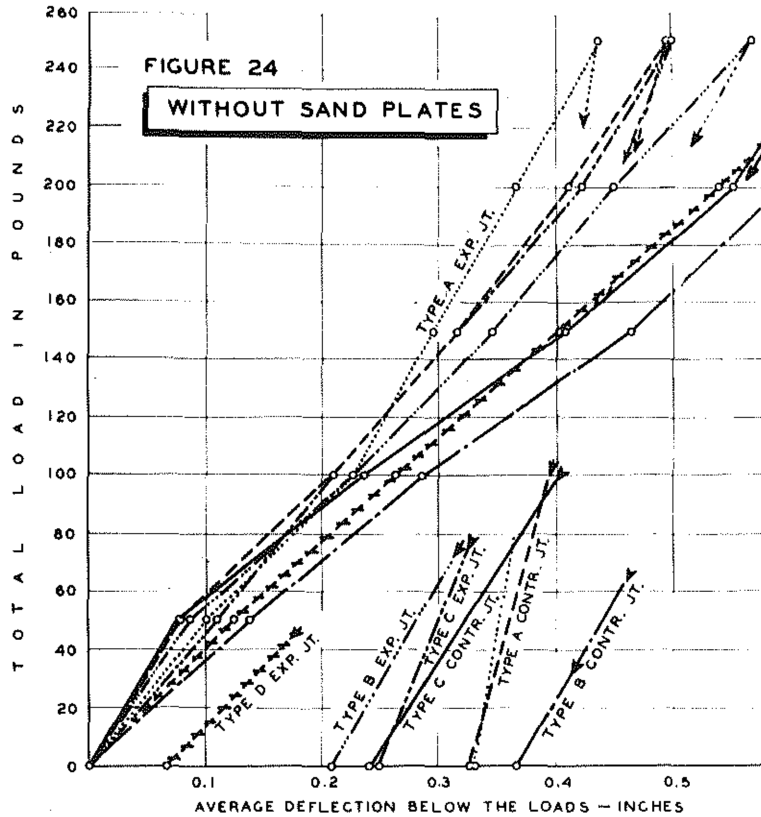
It is to be regretted that, in general, only one test under a given set of conditions was obtained. The testing program which, of necessity, was conducted outside, was not begun until October and inclement weather made it impossible to conduct a more extensive testing program. It would be desirable to obtain more data on this phase of the study and it is planned that the study will be continued in the spring.

<u>Results of Tests</u>

Table 2 contains the data pertaining to the tendency of the assemblies to sink into the supporting sand and to tip to one side when a load was applied eccentrically. The Type D assembly, having three bearing plates as an integral part of the assembly, was loaded midway between the center and one end on the unbraced side of the assembly. This was the most severe case of loading possible. All other assemblies were loaded eccentrically near the center of the span. Figure 23 illustrates the deflection due to load of one dowel bar joint assembly with no sand plates and with four sand plates.

With reference to Table 2, when the assemblies were supported solely by the sand, and loaded to 250 pounds, the Type A assembly for expansion joints deflected least (0.44 in.) and the Type B assembly for contraction joints deflected the most (0.73 in.). After the loads were removed, the residual deflection of the Type B assembly for contraction joints (0.37 in.) was greatest. The residual deflection of the Type D assembly (0.06 in.) was relatively small even though the deflection had been the second largest when it was loaded. (See Figure 24).

When the assemblies were supported on four sand plates, the Type A assembly for expansion joints deflected least (0.41 in.) and the Type B assembly for contraction joints deflected the most under the load. The residual deflections of these same two assemblies were 0.05 in. and 0.24 in., respectively, which represented the maximum and the minimum deflections recorded after the load was removed. (See Figure 25).



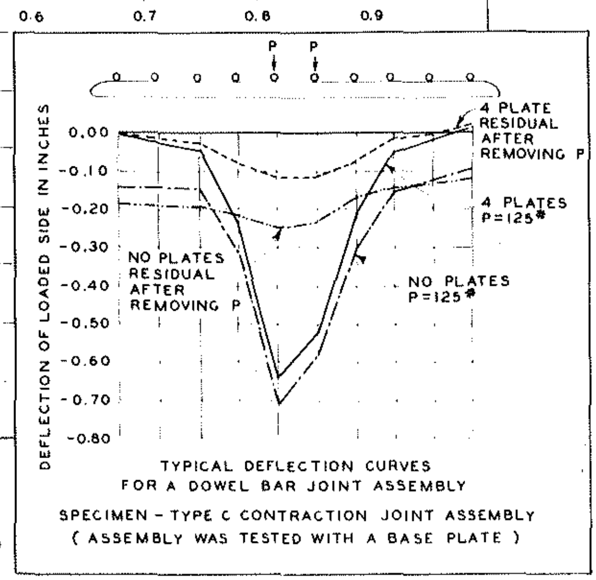
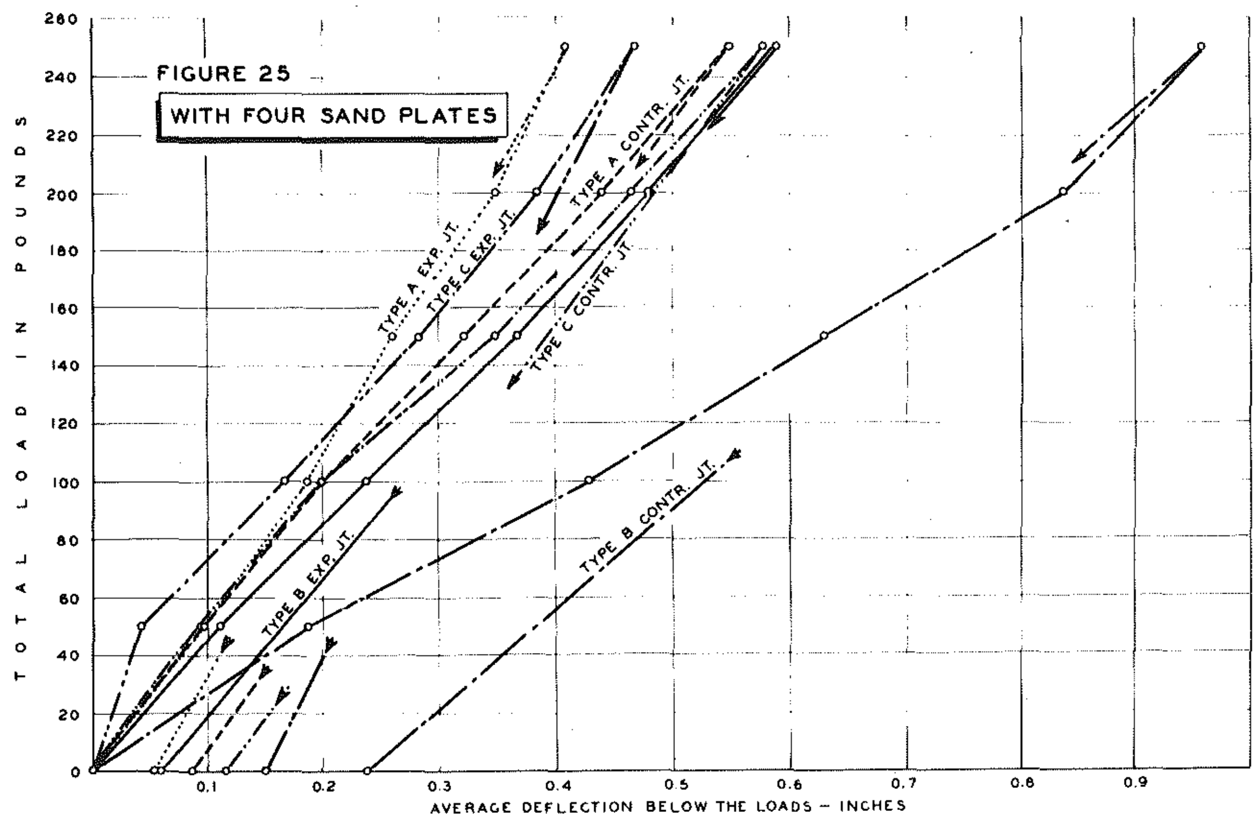


FIGURE 23



VERTICAL DEFLECTION OF DOWEL BAR ASSEMBLIES
SUPPORTED BY THE SAND AND SUBJECT TO TWO VERTICAL LOADS

TABLE 2
Tabulation of Results of a Load Deflection Study of Various Dowel Bar Joint Assemblies Supported on a Sand Subbase

			Type A Exp.		Type A Contr.		Type B Exp.		Type B Contr.		Type C Exp.		Type C Contr.		Type D Contr.	
		Load, lbs.	in.	Rank	in.	Rank	in.	Rank	in.	Rank	in.	Rank	in.	Rank	in.	Rank
Sinking in Sand[2]	No Plates	250	0.44	1	0.50	2.5	0.57	4	0.73	7	0.50	2.5	0.64	5	0.68	6
	No Plates	0*	0.33	5.5	0.33	5.5	0.21	2	0.37	7	0.25	4	0.24	3	0.06	1
	4 Plates	250	0.41	1	0.55	3	0.59	5	0.96	6	0.47	2	0.58	4		
	4 Plates	0*	0.05	1	0.09	3	0.06	2	0.24	6	0.15	5	0.11	4		
Tipping in Sand[1]	No Plates	250	0.38	1	0.43	2	0.47	3	0.59	4	0.73	5	0.91	7	0.81	6
	No Plates	0*	0.26	5	0.26	5	0.14	2	0.25	3	0.26	5	0.46	7	0.08	1
	4 Plates	250	0.57	2	0.66	3	0.50	1	0.91	6	0.74	4	0.77	5		
	4 Plates	0*	0.08	2	0.16	4	0.07	1	0.27	6	0.15	3	0.20	5		

1 Average Deflection of two loaded dowels

2 Difference between deflection of loaded side (ave. of 2 gages) and deflection of unloaded side (ave. of 2 gages opposite loads)

* The values recorded for 0 load were the residual deflections after the load was removed.

The use of four sand-base plates did not result in an appreciable decrease in the maximum deflection resulting from the application of an eccentric load at the center of the span; however, the residual deflection at the center of the span, after removal of the load, was considerably less when the assemblies were supported on the four sand plates. The reduction in residual deflection resulting from the support of the four sand plates varied from 36% for the Type B assembly for contraction joints to 85% in the case of the Type A assembly for expansion joints.

Two dowel bar joint assemblies were tested with a varying number and arrangement of sand plates. Figure 26 illustrates the arrangement of sand plates and gives the deflection of the assembly under a total load of 250 pounds and the residual deflection after the load was removed. It should be pointed out that the effect of sand plates not in the immediate vicinity of the load was negligible and thus in some cases a greater number of sand plates did not reduce the deflection of the assembly due to the applied load. However, a study of the arrangement of plates adjacent to the loads illustrates that the deflection under load and the residual deflection may be kept to a reasonably small value by using sand plates under each end of every third dowel. Eight sand base plates instead of four would be needed to support a twelve-foot assembly in thismanner.

A comparison of the deflection data for two assemblies supported on both dry and wet sand indicated that there was no marked or consistent difference resulting from the two conditions. The moisture content of the dry sand was approximately 2% and the average moisture content of the top 2.5 inches of the wet sand varied from 3.3 to 8.5%.

<u>Conclusion</u>

For dowel bar joint assemblies which are placed on a sand subbase it is recommended that the number of sand plates be increased from four to eight to obtain a more uniform support for the assemblies and to minimize the misalignment of the dowel bars.

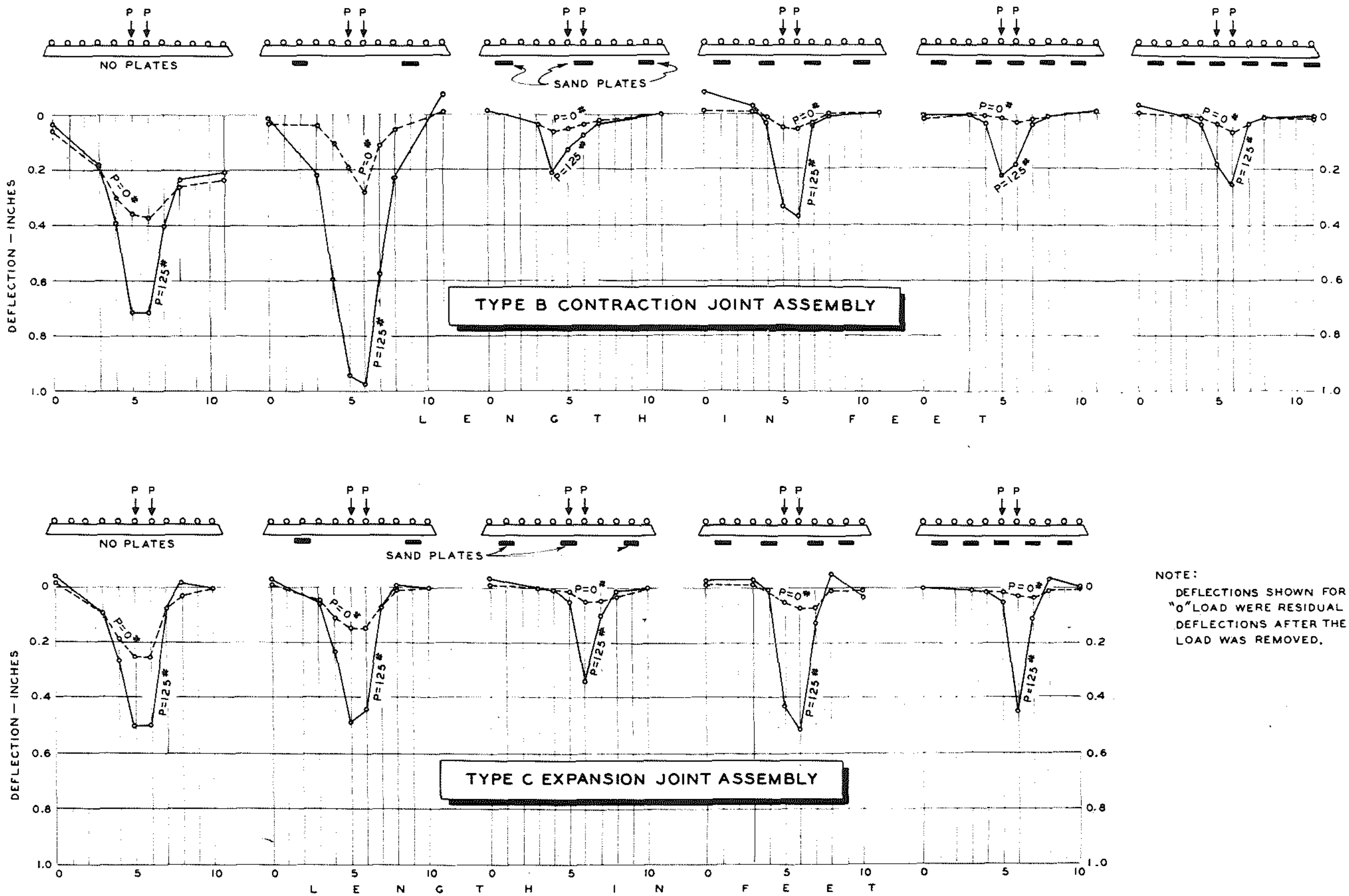


FIGURE 26

THE EFFECT ON DEFLECTION OF VARIOUS NUMBERS AND ARRANGEMENTS OF SAND PLATES

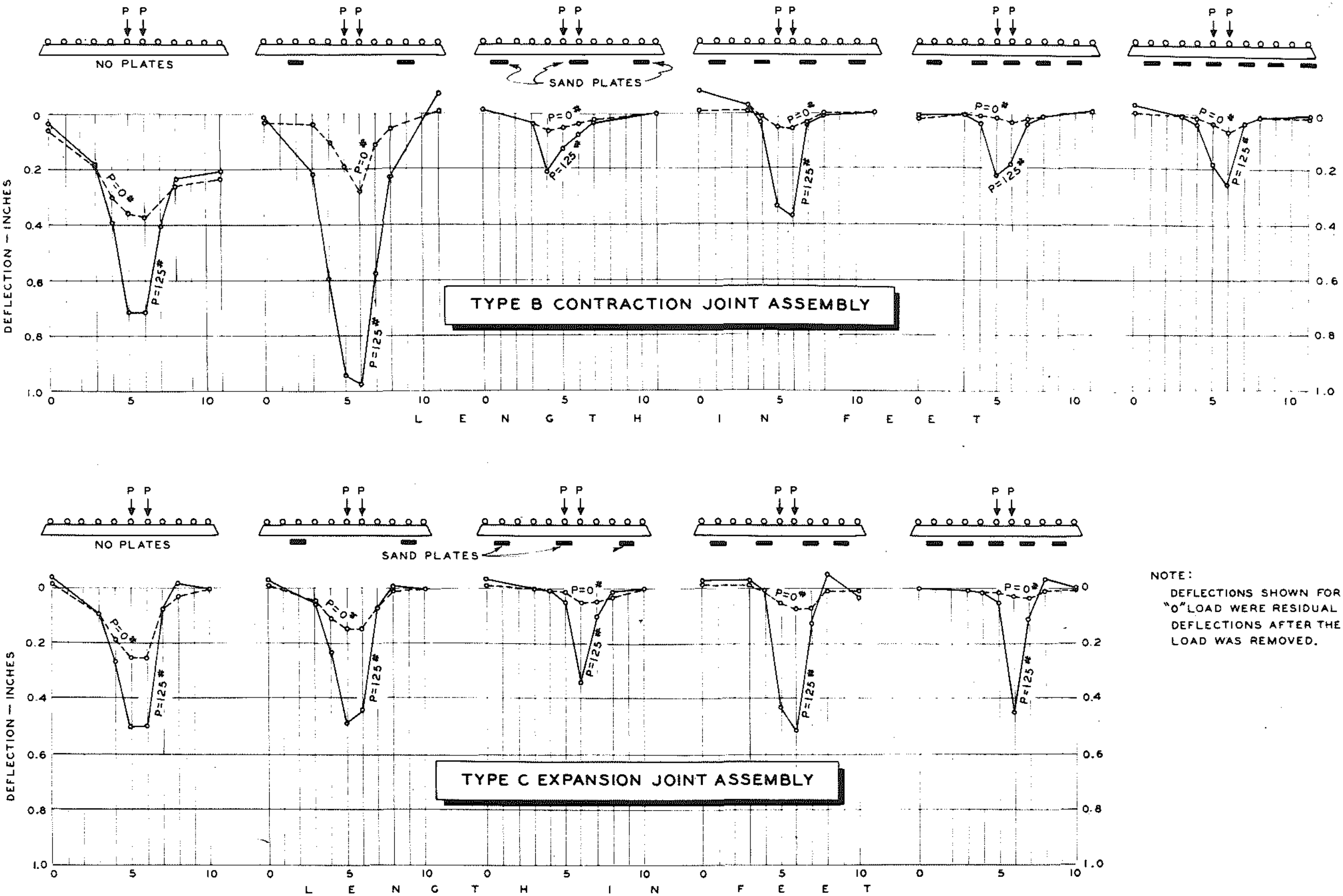


FIGURE 26

THE EFFECT ON DEFLECTION OF VARIOUS NUMBERS AND ARRANGEMENTS OF SAND PLATES