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MICHIGAN
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INVESTIGATION
OF
CONCRETE PAVING FORMS

by

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TABLE OF CONTENTS

INVESTIGATION OF CONCRETE PAVING FORMS

At the suggestion of the Construction Division the Research Laboratory of the Testing and Research Division undertook an investigation of concrete paving forms with the view of determining whether or not the forms now in use by the various contractors possess sufficient rigidity and strength to meet the requirements of present and future concrete pavement construction. Obviously the riding qualities of the pavement may be affected to an appreciable extent by the behavior of the paving forms under loads imposed by the various units of construction machinery and these loads have been steadily increasing with the growth in size and capacity of modern paving equipment.

The simplest and most practical way of evaluating the strength and rigidity of paving forms is to test them as simple beams by measuring vertical deflections produced by a concentrated load at the center. Although testing the forms as simple beams may be open to some criticism from the standpoint of measuring actual performance in service, it does provide means of selecting the most desirable forms.

DESCRIPTION OF TESTS

The method of test adopted in this investigation consisted essentially in applying a concentrated load of 3500 pounds at the center of a 9 foot 6 inch span and measuring the deflections produced. The test load of 3500 pounds was arrived at by dividing by four the total weight (14,000 pounds) of the heaviest finishing machine in use at the present time and represents the vertical force exerted by a single wheel. Several other States specify a test load of 1750 pounds, which corresponds to the wheel load of a considerably lighter machine, but it is evident that the test load must be increased in proportion to the increase in equipment weight without allowing a corresponding increase in vertical deflections if former standards are to be maintained. This means that sturdier forms must be provided in order to properly support the greater loads.

A tentative limit of .150 inch for the maximum allowable deflection under the conditions of the test has been chosen for the purpose of discussion for several reasons: first, the present Department specifications limit the deviation from a true plane of the finished pavement to 1/8 (.125) inch in 10 feet; second, the same limit of 1/8 inch applies to vertical variations in the top surface of the form; and third, it became evident as the tests progressed that a vertical deflection of .150 inch indicated a fairly definite line of demarcation between forms of desirable and undesirable characteristics. (This figure may make a slight allowance for the effect of subgrade support.) It should be kept in mind that the deflection requirement tentatively chosen in the simple beam test is more or less arbitrary and has little relation to actual deflections encountered in practice except under extreme conditions of subgrade support. It is conceivable, however, that these extreme subgrade conditions could occur in some cases to cause the form to react essentially as a simple beam.

__Forms Used in the Tests__

Standard forms commonly used in concrete highway construction are divided into two general classes according to their cross sections, namely L shaped and trapezoidal forms. There were three makes of the L type forms and one of the trapezoidal type represented in this study. The three makers of the L type forms are referred to in the report as A, C and D; B refers to the manufacturer of the trapezoidal form. In order to evaluate the performance of the forms in actual use by various contractors a number of used sections representative of the different makes and sizes were borrowed from their owners. These forms varied in degree of preservation from almost unserviceable to almost new. However, after preliminary tests of these used forms it was deemed advisable to procure unused forms and these were also tested as simple beams.

Simple Beam Tests

All forms were tested as simple beams of 9 foot 6 inch span with a concentrated load of 3500 pounds applied vertically at the center of the span. It was discovered early in the investigation that the forms warped laterally when tested as simple beams. To eliminate this warping, and thus obtain the true vertical deflection, some forms were tested in pairs, clamped face-to-face.

Single Forms as Simple Beams: The forms were supported on one inch half-round steel bars which in turn rested on unyielding supports. The load was applied in three increments of 1000 pounds and one of 500 pounds in order to obtain data for load-deflection curves. The applied force was measured by a proving ring with a ten-thousandth dial and the deflections of the form were measured by one-thousandth dials.

Simple Beam Tests of Two Forms Clamped Face-to-Face: As previously stated, in order to obtain a more reliable measure of vertical deflections, some forms were tested in pairs to eliminate the warping tendency under a vertical load. The setup was similar to that for the single form test except that two forms and a total load of 7000 pounds were used.

Tests on Sand Subgrade

In order to secure information on joint performance and the extent to which vertical deflections are influenced by the supporting subgrade, some of the forms were tested on a sand subgrade which had been prepared in the laboratory in connection with another experiment. These tests were not complete because of the fact that two forms of the same type and dimensions were required for each test, and duplicate samples of all sizes were not available at the time.

Two forms were set up level, in a straight line and securely connected. The dial holders were hinged on the box containing the subgrade soil, with their ends resting on 4 inch x 4 inch posts extending to the concrete floor below the subgrade. Prior to every test the forms were tamped with a mechanical tamper. Loads were applied singly and in pairs 6 feet 6 inches apart by hydraulic jacks using the same increments of loading employed in the simple beam tests.

DISCUSSION OF RESULTS

Simple Beam Tests

All forms displayed elastic characteristics in the load range employed and the load-deflection curves obtained were all practically straight lines with the exception of small variations at the initial increments. The results of the loading tests are given in Table I and the graphs of Figure 1 through 10.

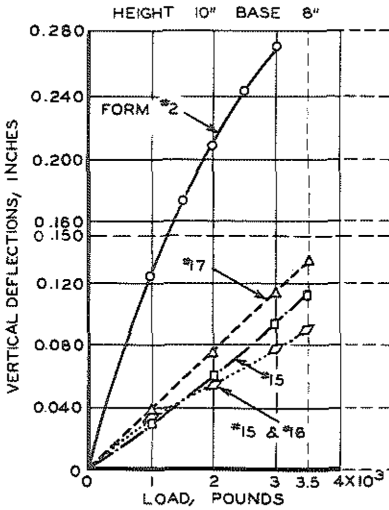
The graphs in the figures have been grouped according to dimensions of height and base of the form. Table I should be consulted for additional pertinent data on the individual forms, such as thickness of metal and

TABLE 1

VERTICAL DEFLECTIONS OF CONCRETE PAVING FORMS UNDER LOAD
Single Form, Concentrated Load of 3500 Pounds at Center
Two Forms Clamped Face-to-Face, 7000 Pounds at Center

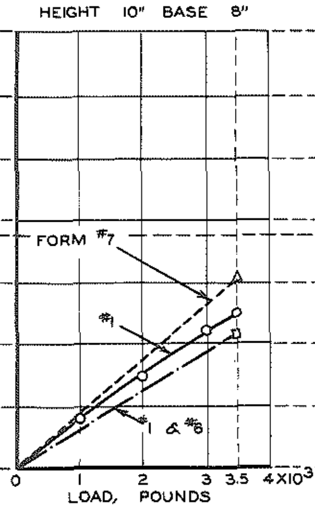
								Maximum Vertical Deflections				
								Single Beam, 9'-6" Span			Uniformly Supported on Sand Subgrade*	
Form No.	Mfr.	Type of Section	Thickness of Metal - Inches Nominal	Thickness of Metal - Inches Actual	Height Inches	Base Inches	Wt. lbs. per 10 ft. Length	Single Form Inches	2 Forms Clamped Face-to-Face Inches	Reduction of Deflection Percent	Single Form Inches	2 Forms Face-to-Face Inches
7	B	Trap.	5/32	.142	10	8	169	.123				
1	B	Trap.	3/16	.183	10	8	207	.101	.085	16	.038	.029
2	A	L	3/16	.177	10	8	157	.301				
17	A	L	3/16	-	10	8	186	.134				
3	C	L	3/16	.200	10	8	161	.245				
4	C	L	3/16	.189	10	8	163	.211				
11	D	L	3/16	.183	10	8	173	.242	.189	22		
5	C	L	3/16	.201	9	8	155	.258				
13	C	L	3/16	.187	9	8	152	.256	.169	34		
9	D	L	7/32	.227	10	8	205	.152	.133	13	.048	
15	A	L	1/4	.260	10	8	215	.115	.090	19	.038	.018
22	C	L	1/4	.243	10	8	207	.148	.119	20		
25	C	L	1/4	.244	9	8	193	.182				
24	C	L	1/4	.248	9	9	203	.158				
18	A	L	1/4	.249	9	9	207	.134				
20	A	L	1/4	.255	8	9	204	.134				
19	A	L	1/4	.250	8	8	188	.163				
23	C	L	1/4	.250	8	8	187	.200				

* Deflections of center relative to ends.



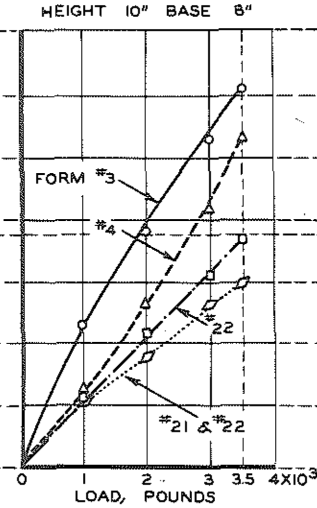
L SECTION-MFR. A

FIG. 1



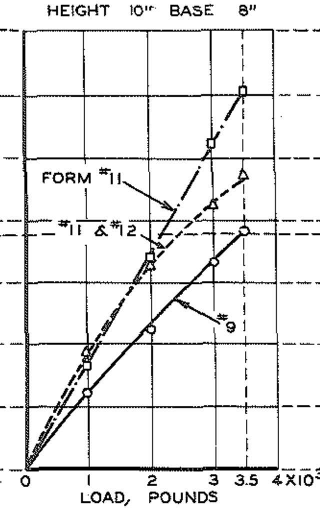
TRAPEZOIDAL SECTION
MFR. B

FIG. 2



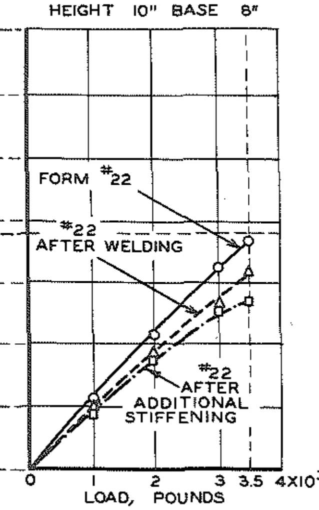
L SECTION-MFR. C

FIG. 3



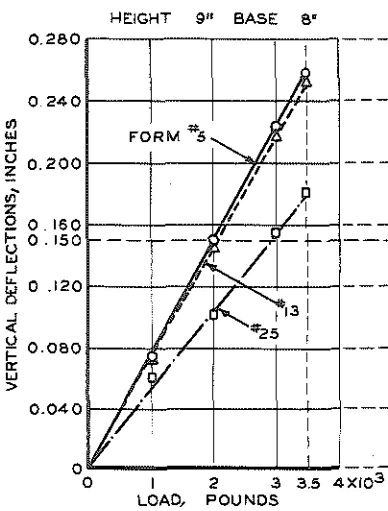
L SECTION-MFR. D

FIG. 4



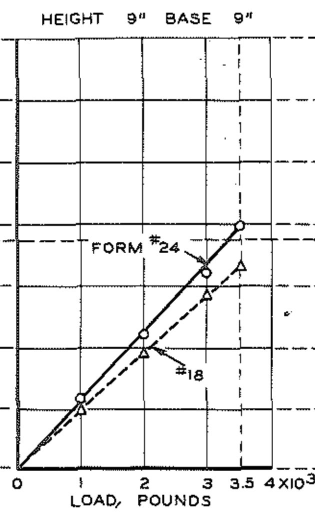
L SECTION-MFR. C
(MODIFIED)

FIG. 5



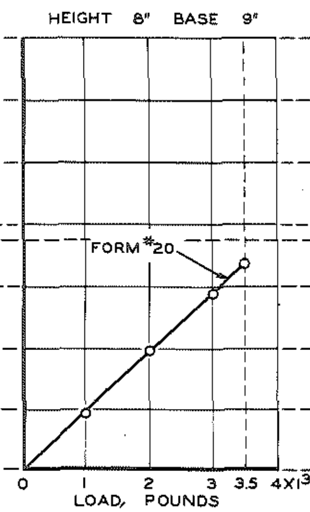
L SECTION-MFR. C

FIG. 6



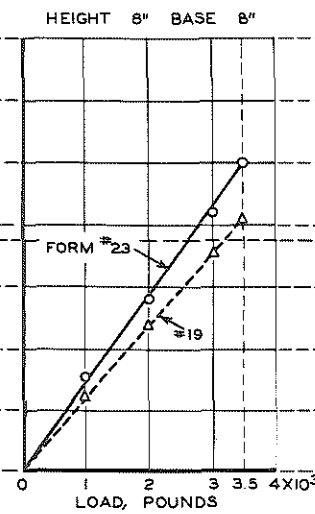
L SECTION
FORM 24 MFR C
FORM 18 MFR. A

FIG. 7



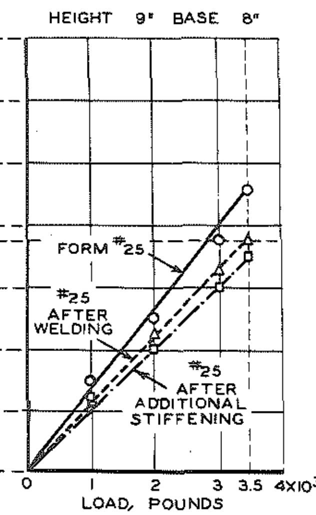
L SECTION-MFR. A

FIG. 8



L SECTION
FORM 19 MFR. A
FORM 23 MFR. C

FIG. 9



L SECTION-MFR. C
(MODIFIED)

FIG. 10

VERTICAL DEFLECTIONS of PAVING FORMS TESTED as SIMPLE BEAMS

weight per 10 foot section. Forms numbered 1 through 14 had been in service for varying periods of time; those numbered 15 through 21 were obtained directly from the manufacturer and had never been used.

All forms deflected horizontally as well as vertically when subjected to a vertical center load. This warping tendency is more pronounced in the L-section than in the trapezoidal forms, and in the L section it decreases with an increase in the thickness of the plate. By clamping the forms together face-to-face vertical deflections were reduced. This is shown graphically in Figures 1 through 4 and clearly indicates that if the warping tendency is restrained the vertical deflection characteristics are improved.

Vertical deflections of the L-section forms were, with a single exception, greater for forms of 3/16 inch plate thickness than for those of 1/4 inch thickness. As noted previously, the warping tendency also increases as the plate thickness decreases. It is evident that a minimum thickness of 1/4 inch is a necessary condition in order to produce the desired stability in the L-section forms but not a sufficient one, since not all forms of this type and thickness were able to meet the tentative deflection requirement. Owing to the different distribution of metal in the trapezoidal section, a somewhat thinner plate is sufficient to bring about the required rigidity. From the practical standpoint of durability in handling and use, however, trapezoidal forms should be constructed of metal not less than 3/16 inches in thickness.

In the simple beam tests of single forms there was revealed an interesting result. It was noted that some of the new L type forms shipped to the laboratory directly from Manufacturer C failed to meet the .150 inch maximum deflection tests. The forms appeared to be well constructed of 1/4 inch plate and it was noted that the stake pockets were riveted to the base and to the face of the form but had no rigid connection to the back lip of the top rail nor were they attached to the upturned edge of the base. It was also noted that stake pockets of the same size were used on forms of both eight and nine inch base, probably for economy in construction. In doing this the greater stabilizing effect which would be secured by a wider stake pocket on the nine inch base is lost. An attempt was made to improve their rigidity by welding the stake pockets to the top rail and, later, by adding angle iron stiffeners midway between the stake pockets.

Tests were made on two of the original forms, repeated after welding the stake pockets, and again after adding the stiffeners. The rigidity of both forms was sufficiently improved by these changes to result finally in vertical deflections well below the tentative limit of .150 inch. The improvement in performance of the two forms after each operation may be seen in the load-deflection curves of Figures 9 and 10. This experiment emphasizes the fact that forms of L section, even when constructed of 1/4 inch metal, must be designed and fabricated for maximum possible rigidity in order to properly support the given load.

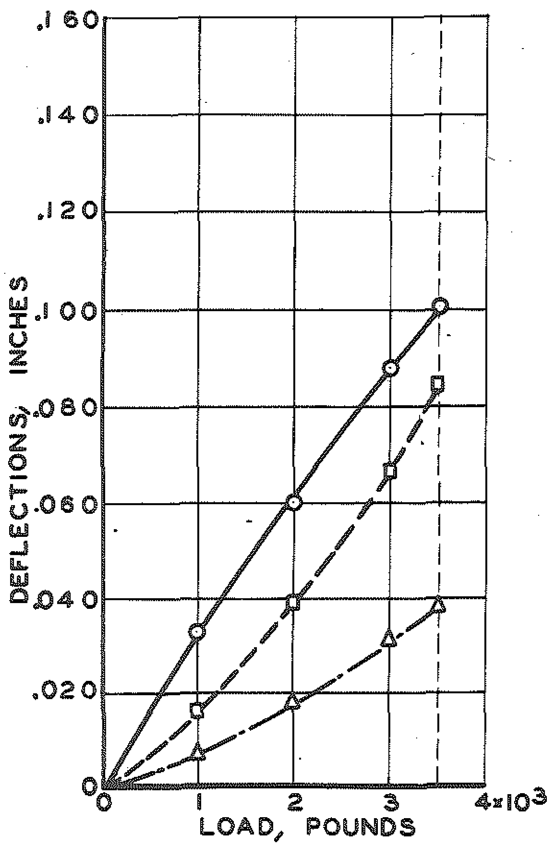
Tests on Sand Subgrade

Vertical deflections at the center obtained by loading forms on the sand subgrade were in all cases lower than those obtained by testing the forms as simple beams. Table 1 and the graphs of Figures 11 to 15 show that the deflections of the center relative to the ends are small when the

EFFECT of TYPE of SUPPORT on VERTICAL DEFLECTIONS

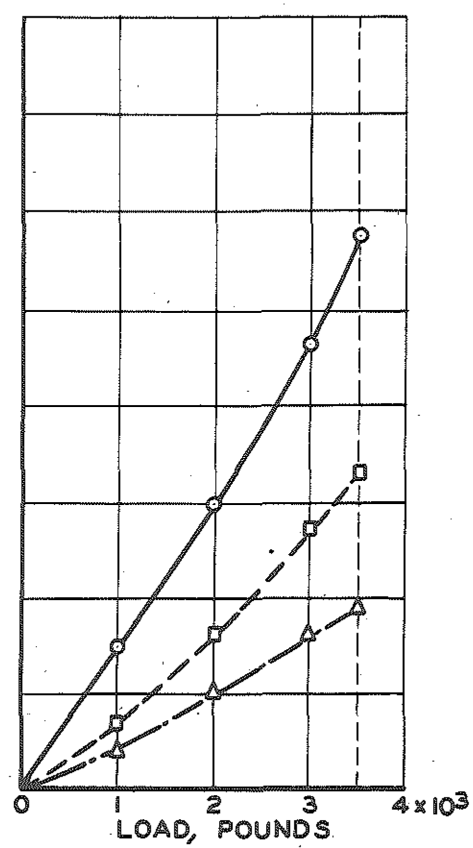
LOAD AT CENTER 3500 LBS. SUBGRADE MODULUS K= 100 P.C.I.

LEGEND:
- o———o SIMPLE BEAM, HEIGHT 10 IN, BASE 8 IN.
- □– – –□ ABSOLUTE DEFLECTIONS ON SUBGRADE
- Δ—·—Δ DEFLECTIONS OF CENTER RELATIVE TO ENDS, ON SUBGRADE



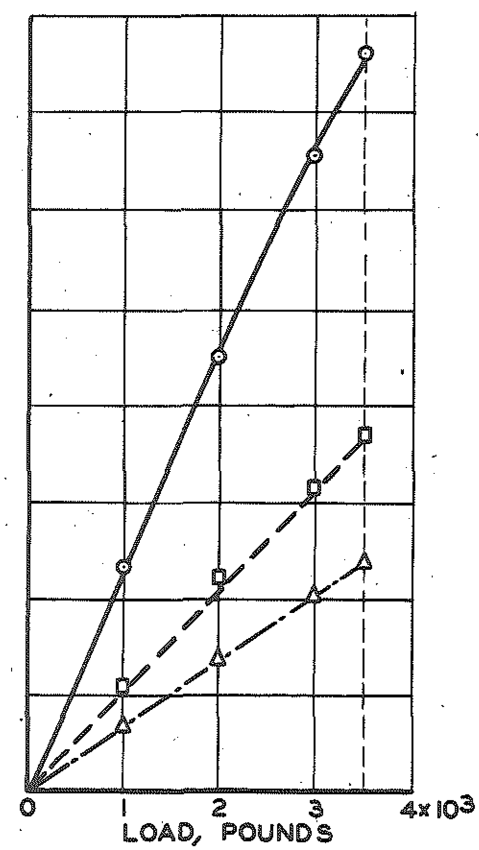
TRAPEZOIDAL SECTION
MFR B

FIG. 11



L SECTION
MFR. A

FIG. 12



L SECTION
MFR. D

FIG. 13

forms are uniformly supported, but that a depression of the whole form occurs when loaded. The amount of this depression was found to vary according to the condition of the subgrade at the time of test.

At load positions near the joint, faulting is apt to occur between abutting ends of the forms, the extent of which depends largely on the design and condition of the connector and the amount of gap. There is a distinct difference between the characteristics of the connectors used on trapezoidal and L-section forms. Whereas the connector plate in all of the L-section forms is generally symmetrical and the movement at the joint is essentially the same whether the load is applied on one side of the joint or the other, the trapezoidal form joint has distinctly male and female ends and the amount of faulting depends on whether the load is applied on the male or female end. The rounded lower end of the trapezoidal form connector, while a desirable feature from the standpoint of ease of installation and removal of the forms, does not provide full load transfer when the load is applied to the male end of the form, especially when the ends are not butted tightly.

A simple comparison of the joint connection of different forms was made by splicing duplicate forms of each make and supporting them at the outside ends and at the connector. Then the center support was removed and the deflection at the joint relative to the ends was measured. The deflections were as follows:

Form Make	A	C	D
Deflection, Inches	1-3/16	1-1/4	2-1/2

The trapezoidal forms collapsed when the support at the joint was removed. This comparison was made to show that the tolerance in the splicing plate varies with different forms. The trapezoidal form joint should perform satisfactorily in service if the form ends are butted tight and the joint is firmly supported by the subgrade, but a loose joint on a soft spot of the subgrade could cause an excessive vertical deflection.

It is reasonable and logical to require that vertical deflections at the joint should be no greater than vertical deviations elsewhere. Because of the existing requirement of 1/8 inch maximum vertical deviation in the pavement and top surface of the forms, the vertical movement at the joint should also be limited to 1/8 inch under the load of the heaviest machine carried on the forms.

ACKNOWLEDGMENT

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