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A STUDY OF PAVEMENT DEFLECTIONS ON FAULTED AND CRACKED PAVEMENT SLABS ON US-24A, SOUTH OF ERIE

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A STUDY OF PAVEMENT DEFLECTIONS ON FAULTED AND CRACKED PAVEMENT SLABS ON U.S. 24A SOUTH OF ERIE

At the request of Mr. W. W. McLaughlin, Testing and Research Engineer, the Research Laboratory began an investigation of the behavior under heavy axle loads of a badly faulted and cracked section of pavement on U.S. 24A just north of the Ohio State boundary. This pavement of 9-inch uniform thickness was constructed in 1942 (Construction Project-58-30, C3) without load transfer devices or steel reinforcement, and with an expansion joint spacing of 120 feet. Five contraction joints were placed between expansion joints at approximately 20 feet intervals.

At the present time nearly every pavement joint has faulted to some extent, and the maximum faulting is approximately 3/4 inch. There is also faulting along the longitudinal joint between the passing and traffic lanes, which in some cases maybe as much as one inch. Separation to the extent of 1-1/4 inches also occurs in some places between lanes and the traffic lane is sometimes sloped or tilted down toward the edge of the pavement.

Due to the conditions mentioned above this pavement is extremely rough in riding quality. Roughometer measurements were made with the M.S.H.D. Roughometer which showed that the outside or traffic lanes had a roughness value of 279 accumulated inches per mile and the inside or passing lanes a value of 178 accumulated inches per mile. The average new pavement has a roughness value between 131 to 174 and a pavement is considered to have poor riding qualities if the value is over 175.

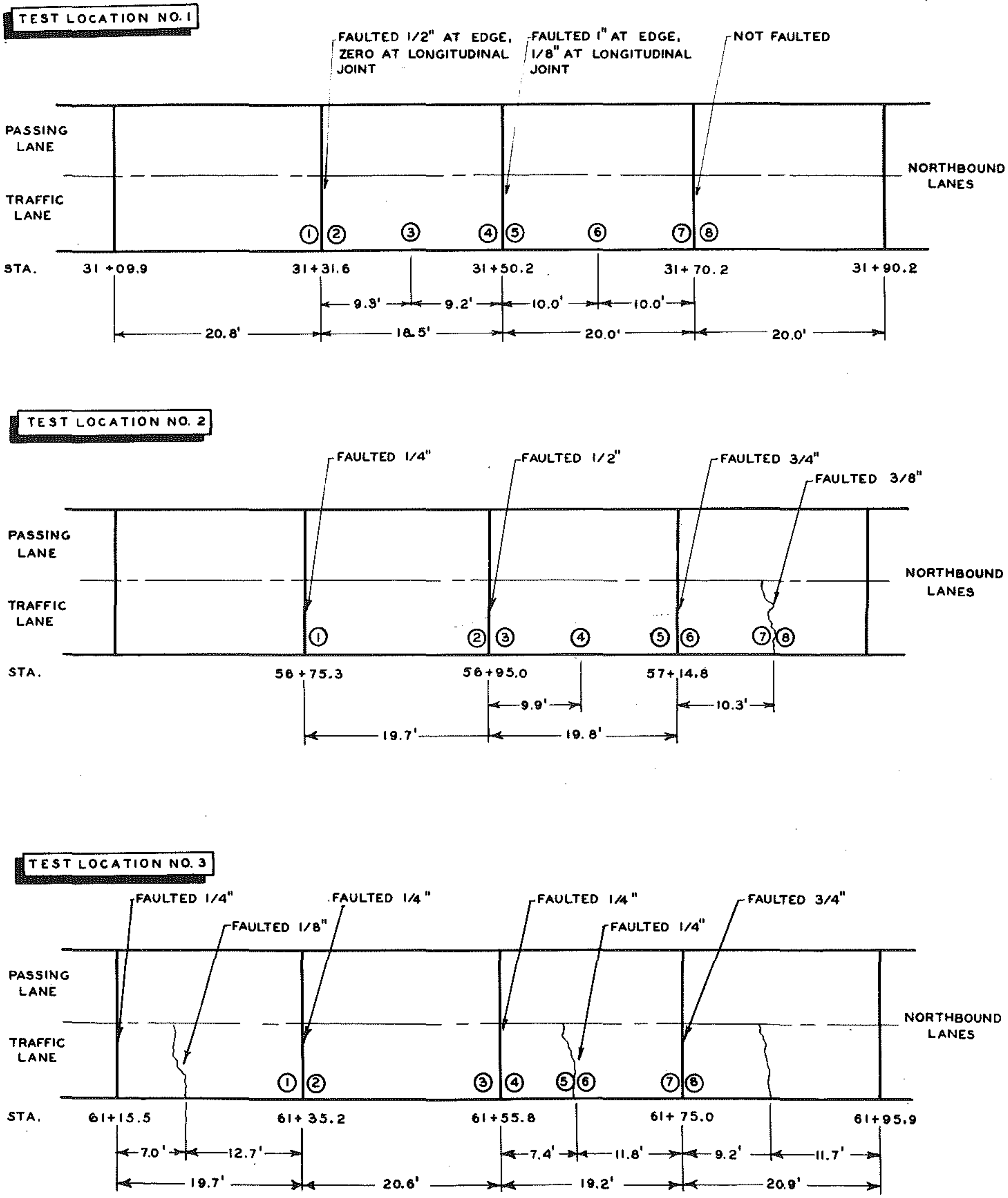
The objectives of this study were to determine: (1) the magnitude of the slab deflection under heavy trucks, (2) whether a residual deflection existed after the passage of a heavy truck, (3) the deflection charateristics between faulted and nonfaulted joints and cracks, and (4) whether these short slabs without load transfer devices had a tendency to rock due to passage of heavily loaded trucks. This report consists of a discussion of the method of obtaining the deflection data, the results of the test and a summary of findings.

Test Procedure

Three locations were selected along this project and slab deflections were taken at eight points at each location. A plan of each test location is given in Figure 1. Pavement deflection data was gathered at these locations by the use of the Walters test truck and a few selected trucks which happened to be passing the test location. The field study was conducted during August which is an ideal time for good subgrade support for the pavement slab.

Wire resistance strain gage deflectometers (see Figure 2) were used to obtain the movement of the pavement edge under the truck loads. These deflectometers were electrically connected to a twelve-channel Hathaway recording oscillograph which produced a photographic trace as a permanent record of the pavement deflection. The deflectometers were calibrated in the laboratory previous to field testing or mechanically in the field as shown in Figure 3. Thus the change in resistance of the strain gage could be related to the movement of the pavement which in turn led to a relation between the recorded trace deflection and the pavement deflection.

The Walters test truck was loaded in such a manner as to give as nearly as possible 18,000 pounds on the tractor drive axle and 22,000 pounds on the trailer axle. A photograph and a loading diagram for the truck are shown in Figure 4. The truck was driven along a painted guide stripe which positioned the outside edge of the tire contact area for the load axles at one foot from the pavement edge. Deflections were



NOTE: CIRCLED FIGURES INDICATE POINTS WHERE DEFLECTION DATA WAS OBTAINED

PLAN OF TEST LOCATIONS

FIGURE 1

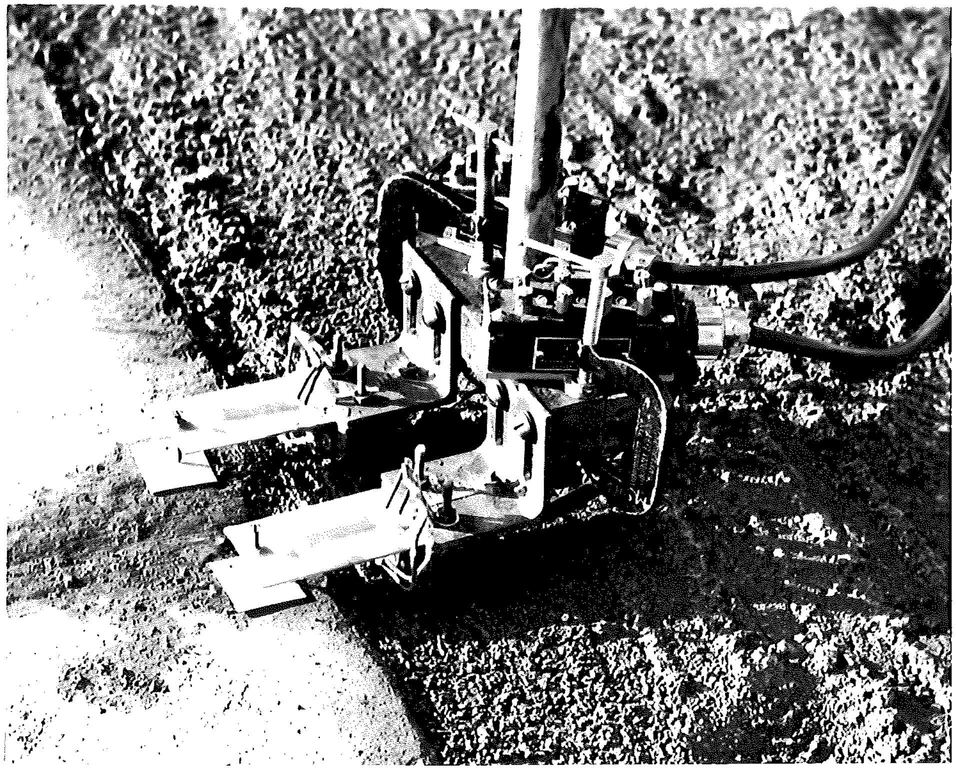


FIGURE 2. ELECTRICAL STRAIN GAGE DEFLECTOMETERS WHICH WERE USED FOR OBTAINING PAVEMENT DEFLECTIONS CAUSED BY TRUCK TRAFFIC.

FIGURE 3. CALIBRATION OF DEFLECTOMETERS IN THE FIELD BY A MECHANICAL CALIBRATOR CONSTRUCTED BY THE LABORATORY.

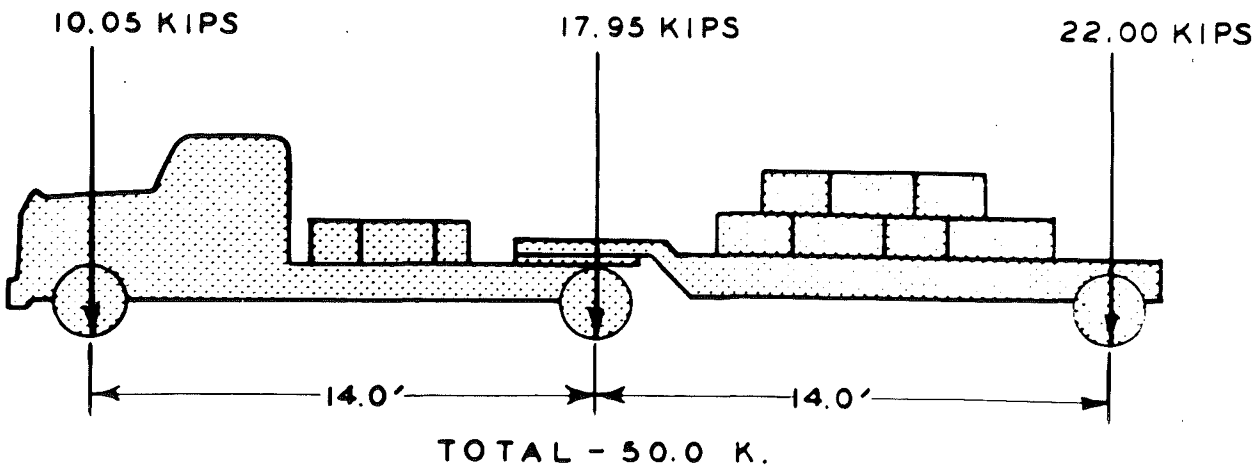


FIGURE 4. PHOTOGRAPH AND LOADING DIAGRAM OF WALTERS TEST TRUCK.

observed as the truck was operated five times at creep speed and five times at approximately fifteen miles per hour over the test location.

After completing the observations with the test truck additional data was gathered by directing certain passing trucks over the test site and recording the pavement deflection. The purpose of these observations was to obtain data with trucks operating at a higher speed, since the Walters test truck is very limited in this respect. This testing phase was only qualitative in nature since the axle loads of the miscellaneous trucks were not known and the truck alignment was not sufficiently accurate for quantitative purposes.

Test Results

The magnitude of the pavement edge deflections at various points in the test areas are shown in Figure 5 for the 18,000 pound axle of the Walters test truck operated at creep speed. It should be noted that each test point has its own individual charateristics and even among test points of a given type the magnitude of the deflection varies considerably. This tendency toward individuality has been apparent in previous load deflection studies and should not be miscontrued as due to experimental error or uncertainty.. However, the behavior of a given test point under numerous trials at a given truck operating speed was quite consistent. The greatest deflection (0.019 inch) occurred on the approach side of a joint which had faulted one inch. This joint had faulted to a greater extent than any of the other joints tested. Photographs of this joint are shown in Figure 6. It was not possible to consistently relate the magnitude of the pavement deflection at the various joints tested with the magnitude of the faulting at these joints.

Tables 1 and 2 give the average deflection at the pavement edge for various

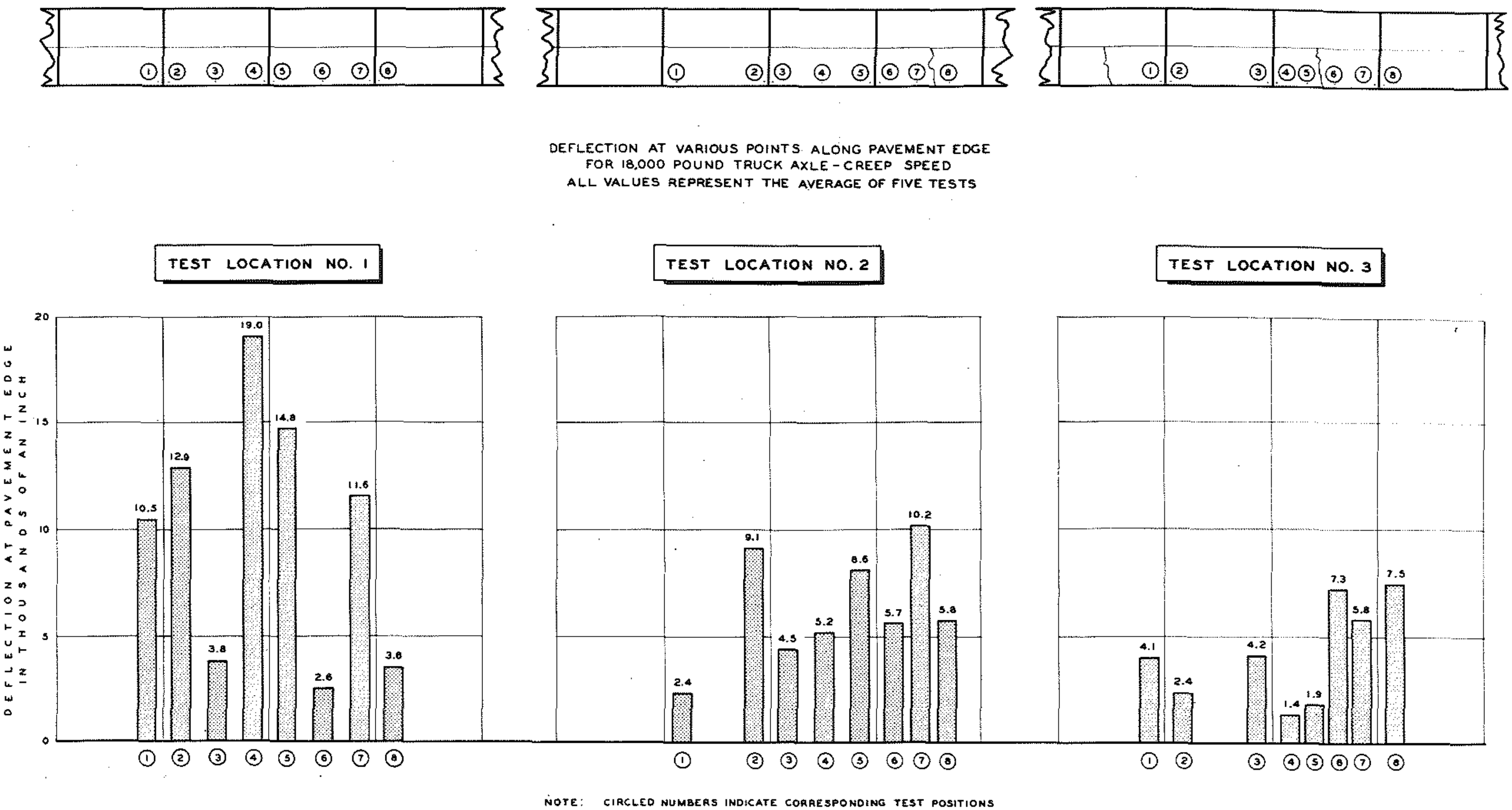
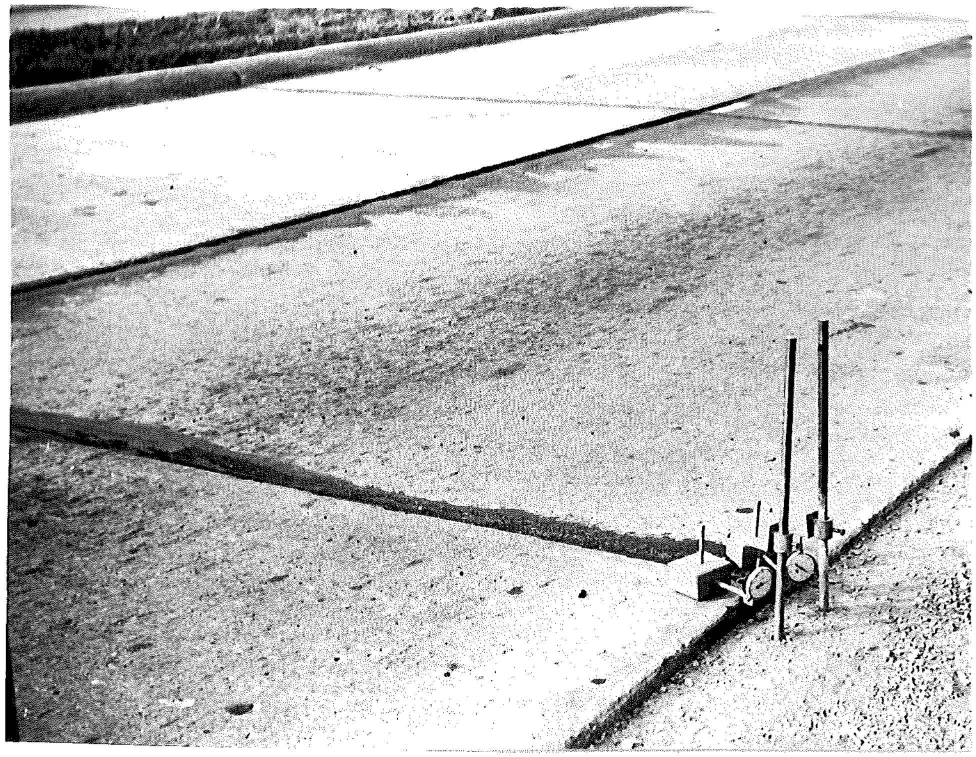
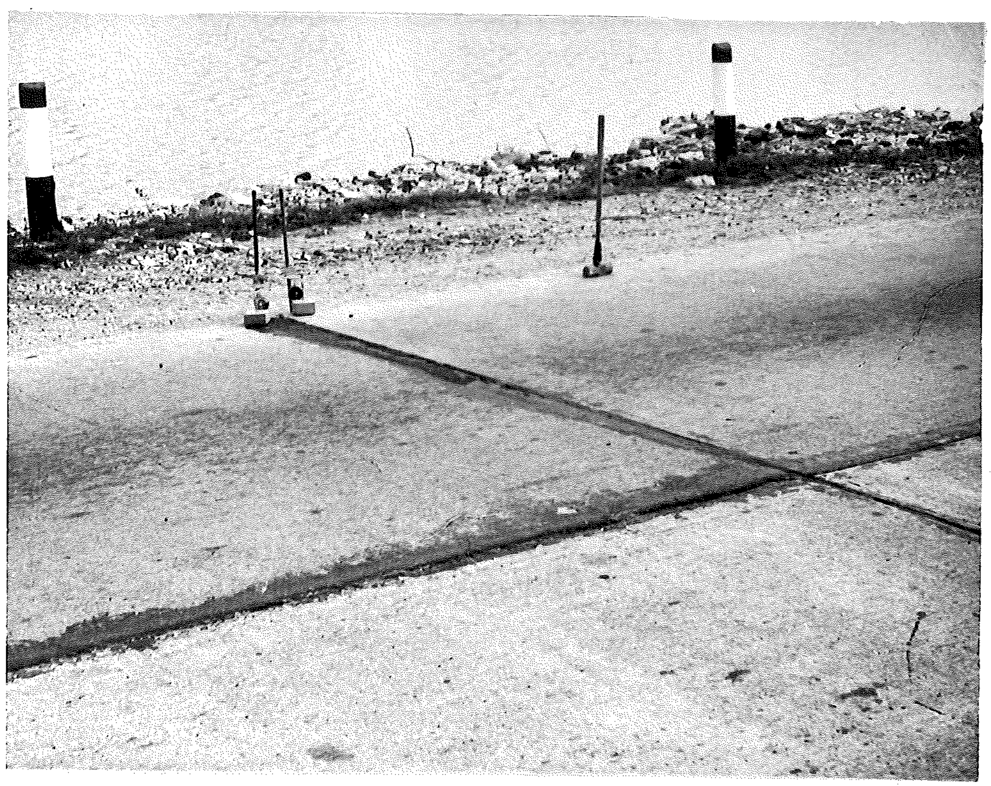


FIGURE 5

AVERAGE PAVEMENT DEFLECTION AT VARIOUS TEST POSITIONS.



LOOKING WEST



LOOKING EAST

FIGURE 6. PHOTOGRAPHS OF FAULTED JOINT AT STATION 31+50.2. THE MAXIMUM PAVEMENT DEFLECTION OCCURRED AT THIS POINT.

typical locations for both the 18,000 and 22,000 pound axles. The ratio of the deflection for the 22,000 pound axle compared to the 18,000 pound axle is also given. Previous daytime slab deflection studies on new pavement conducted in August indicate an average corner deflection at a joint of 0.006-inch and an average deflection at the longitudinal free edge of 0.004-inch for an 18,000 pound axle. The average deflection values for this pavement are approximately the same as for previous pavements tested, but at certain test points on this pavement the deflections are higher than would be expected on the basis of previous pavement studies. Table 1 shows the average deflection at creep speed (average speed 4.3 m.p.h.) while Table 2 gives the same data but for an average speed of 15.5 m.p.h. Of particular significance is the fact that at a joint the approach corner, or the higher corner where faulting occurs, has a greater average deflection than the leaving corner, or the lower corner of a faulted joint. Table 3 presents the comparison of the data in Tables 1 and 2 to show the effect of speed on pavement deflection. At a joint the average decrease in deflection at the joint corners was 9.2 percent for an average speed of 15.5 m.p.h. as compared to 4.3 m.p.h.; while for the same speed comparison the average decrease in pavement deflection at the longitudinal free edge away from the joint was 4.9 percent. An interesting comparison may be made between this data and that obtained from the Maryland Road Test which gave a percent reduction of 8 percent and 5 percent, respectively, for the same speeds as read from graphs for an 18,000 pound axle for a granular subbase. Such close agreement is quite remarkable.

In this study it was of interest to compare the magnitude of the deflection for slabs which had a tendency to rock with those slabs which had no tendency to rock. Table 4 indicates that the average pavement deflection for a given load for test points on slabs which rock was much greater than for test points on slabs which have no

TABLE I

PAVEMENT EDGE DEFLECTION AT VARIOUS LOCATIONS
For 18,000 and 22,000 Pound Axles - (Creep Speed)

Location	Deflection in Inches Due to 18,000 lb. Axle	Deflection in Inches Due to 22,000 lb. Axle	Ratio of Deflection for 22,000 lb. Axle / 18,000 lb. Axle
At Joints			
Approach corner - ave. of 8 locations - 40 tests	0.0091	0.0119	1.31
Leaving corner - ave. of 9 locations - 45 tests	0.0061	0.0076	1.25
At Mid-Point of Slab			
Longitudinal free edge - ave. of 3 locations - 15 tests	0.0039	0.0048	1.23
At Cracks			
Approach corner - ave. of 2 locations - 10 tests	0.0060	0.0082	1.37
Leaving corner - ave. of 2 locations - 10 tests	0.0066	0.0082	1.24
		Average	1.28

TABLE II

PAVEMENT EDGE DEFLECTION AT VARIOUS LOCATIONS

For 18,000 and 22,000 Pound Axles (Speed - approx. 15 mph.)

Location	Deflection in Inches Due to 18,000 lb. Axle	Deflection in Inches Due to 22,000 lb. Axle	Ratio of Deflection for 22,000 lb. Axle / 18,000 lb. Axle
At Joints			
Approach corner - ave. of 8 locations - 40 tests	0.0091	0.0105	1.15
Leaving corner - ave. of 9 locations - 45 tests	0.0060	0.0058	0.97
At Mid-Point of Slab			
Longitudinal free edge - ave. of 3 locations - 15 tests	0.0036	0.0047	1.31
At Cracks			
Approach corner - ave. of 2 locations - 10 tests	0.0049	0.0071	1.45
Leaving corner - ave. of 2 locations - 10 tests	0.0060	0.0068	1.13
		Average	1.20

TABLE III

EFFECT OF TRUCK SPEED ON PAVEMENT EDGE DEFLECTION
AT VARIOUS LOCATIONS

Location	Relative Deflection 15[1] mph. to 4[2] mph. 18,000 lb. Axle	22,000 lb. Axle	Average
At Joints			
Approach corner - ave. of 8 locations - 40 tests.	1.000	0.882	0.941
Leaving corner - ave. of 9 locations - 45 tests.	0.984	0.763	0.874
At Mid - Point of Slab			
Longitudinal free edge - ave. of 3 locations - 15 tests.	0.923	0.979	0.951
At Cracks			
Approach corner - ave. of 2 locations - 10 tests	0.817	0.866	0.842
Leaving corner - ave. of 2 locations - 10 tests	0.909	0.829	0.869
	Average		0.895

1 Range of speed was 14.5 to 16.9 mph. while average speed was 15.5 mph.

2 Range of speed was 3.2 to 5.4 mph. while average speed was 4.3 mph.

TABLE IV - COMPARISON OF PAVEMENT EDGE DEFLECTION AT VARIOUS LOCATIONS FOR POINTS ON ROCKING AND NON-ROCKING SLABS

18,000 Pound Axle Load - Creep Speed

	Test Points			Average Deflection in Inches At	
	Location	Position	Slab Length	Leading Corner	Leaving Corner
Rocking Slabs	1	2-4	18.5'	0.0129	0.0190
	1	5-7	20.0'	0.0148	0.0116
	2	6-7	10.3'	0.0057	0.0102
	3	6-7	11.8'	0.0073	0.0058
	Average			0.0102	0.0116
	Average - Leading and leaving corners			0.0109	
Non-Rocking Slabs	2	1-2	19.7'	0.0024	0.0091
	2	3-5	19.8'	0.0045	0.0086
	3	2-3	20.6'	0.0024	0.0042
	3	4-5	7.4'	0.0014	0.0019
	Average			0.0027	0.0060
	Average - Leading and leaving corners			0.0044	

tendency to rock. The average deflection for points on rocking slabs was 125 percent greater than for non-rocking slabs.

The data obtained did not indicate a residual deflection at any test points after the passage of the test truck. However, for each location five so-called "break-in" runs were made in the same manner as a test run except data was not recorded. The purpose of these runs was to make the recorded data more consistent since the deflections for the first few runs are likely to be more irradic, and likely to be larger than the later deflections.

Another phase of this study consisted of a study of the rocking tendency of these short slabs which contained no load transfer devices at joints or reinforcing steel to hold adjacent faces of transverse cracks in close contact. A rocking index was developed to quantitatively measure the amount of rocking. This index is defined below and is also explained and illustrated in Figure 7.

$$\text{Rocking Index} = \frac{\text{upward deflection for far corner of slab (unloaded corner)}}{\text{downward deflection for near corner of slab (loaded corner)}}$$

Of the 16 test points which were studied for rocking characteristics 7 of these points gave definite indications of rocking for some test runs while 9 test points gave no indications of rocking for any test runs. Of the 7 points where rocking was observed, the average rocking index varied from 0.04 to 0.34. The maximum rocking index value occurred at point 7 of location 2 which is at a crack and the slab length is 10.3 feet. The other end of this same slab had the second highest rocking index, 0.171. In case of point 7 this means that with the front axle load at point 6 the upward deflection of point 7 was approximately one-third as great as the downward deflection of point 6. Only the first and last axles and the corresponding deflections were used for this part of the study so that the effect of other axles would not influence the rocking index value

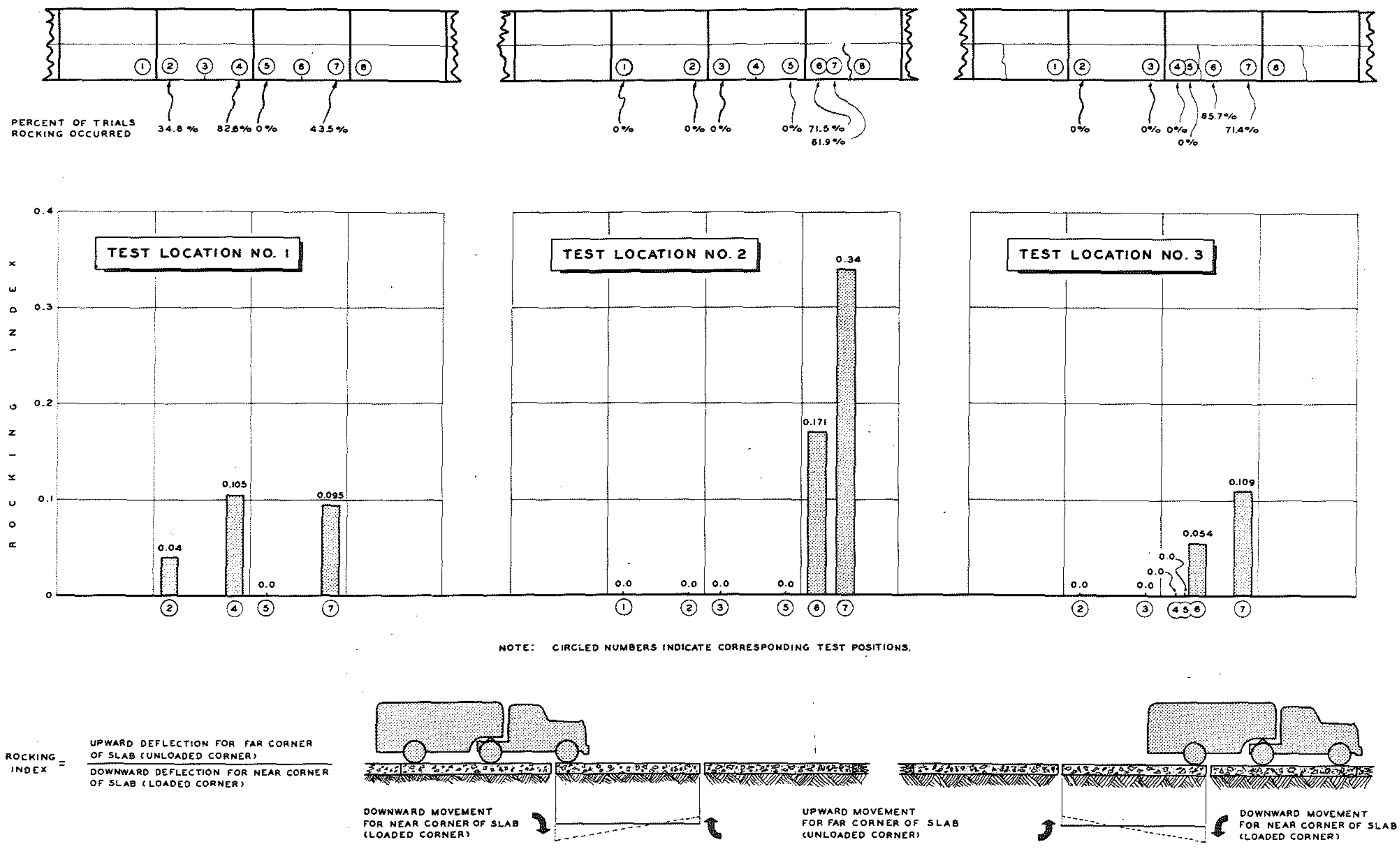


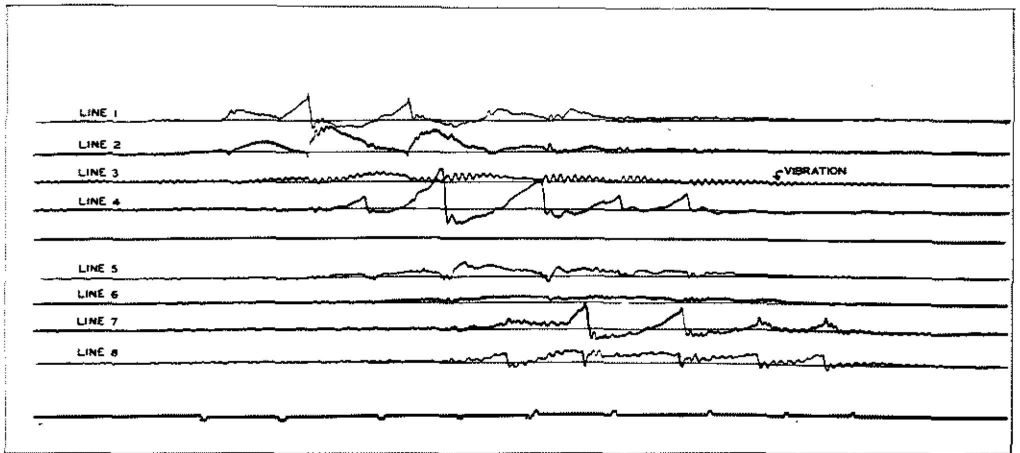
FIGURE 7

ROCKING INDEX VALUES AT VARIOUS TEST POSITIONS.

at the point under study.

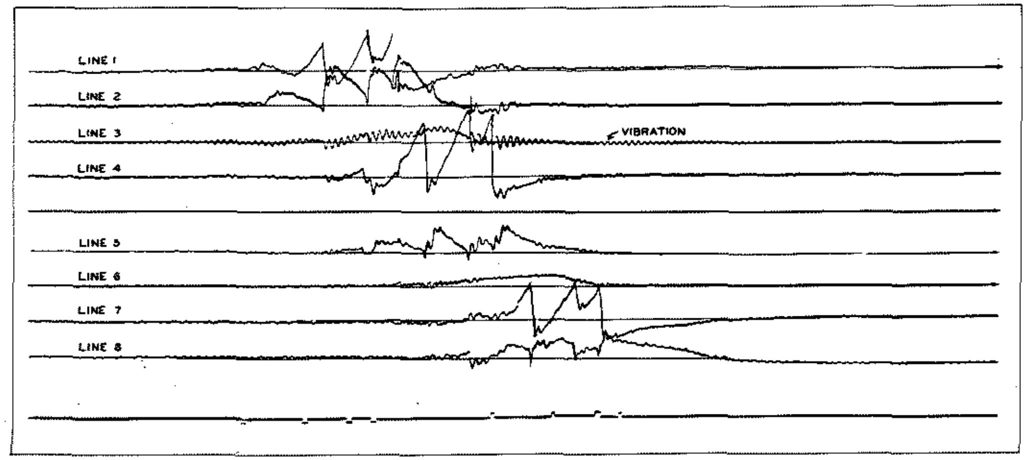
Although numerous load-deflection studies have been made on various pavements in the past, this pavement study uncovered a new type of phenomena. Prior to this, slab vibration had never been preceptible, but on this pavement, apparently due to an extensive loss of subgrade support, noticeable slab vibration did occur at 75 percent of the test points during one or more of the test runs. This vibration occurred after the axle load had passed the test point. Examples of this vibration are shown in Figure 8 and the tabulated date is given in Table 5. The pavement slabs generally vibrated at a frequency around 50 cycles per second, although the maximum range of vibration was from 30.5 to 73.3 cycles per second. The test joint which vibrated most readily (18 out of 23 trials) was test point 3 of location 1. This is the mid-point on an 18.5-foot slab which had the greatest pavement deflections at the end points of the slab for a given axle load. The deflection at this mid-point for an 18,000 pound axle load was relatively small,however, (0.0038 inch). The weighted average for the frequency of vibration of all test points was 56 cycles per second. An interesting comparison can be made between the vibration of the pavement slab and that of a cantilever beam with a similar cross-section and physical properties to that of the pavement. Assuming a modulus of elasticity for the pavement and for the cantilever beam of 5×10^6 pounds per square inch, a cantilever beam 62 inches long would have the same natural frequency of vibration as the average observed frequency of vibration of the pavement slab.

The normal truck traffic passing the test site was most useful for the slab vibration phase of this study for these vehicles could travel at a faster speed than the Walters test truck. The test data indicates that more of the test points on the pavement had a tendency to vibrate when the truck speed increased. Sixty percent of the



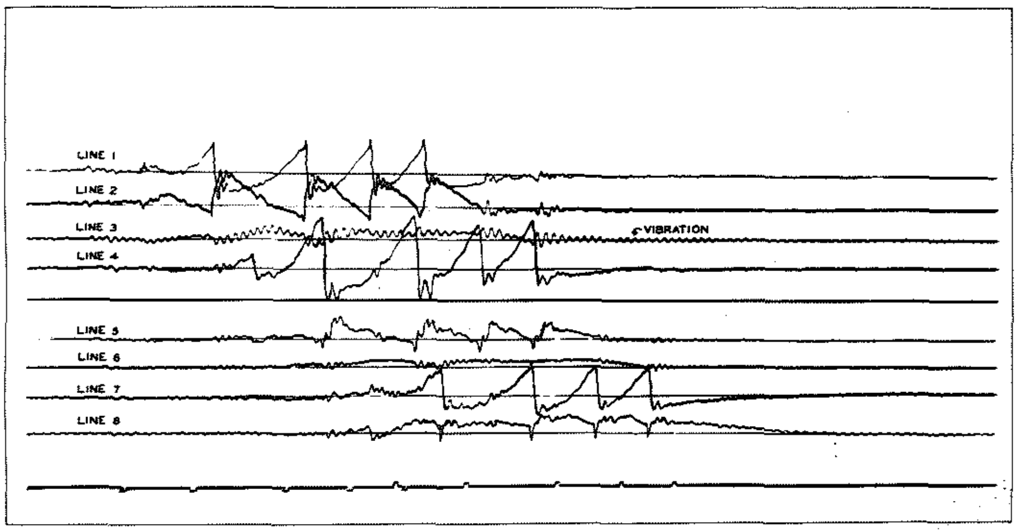
TRUCK TYPE 2S1-2 TRUCK SPEED: 25.95 M.P.H. DATE: AUGUST 5, 1953

TRACE 72 – TEST LOCATION ONE



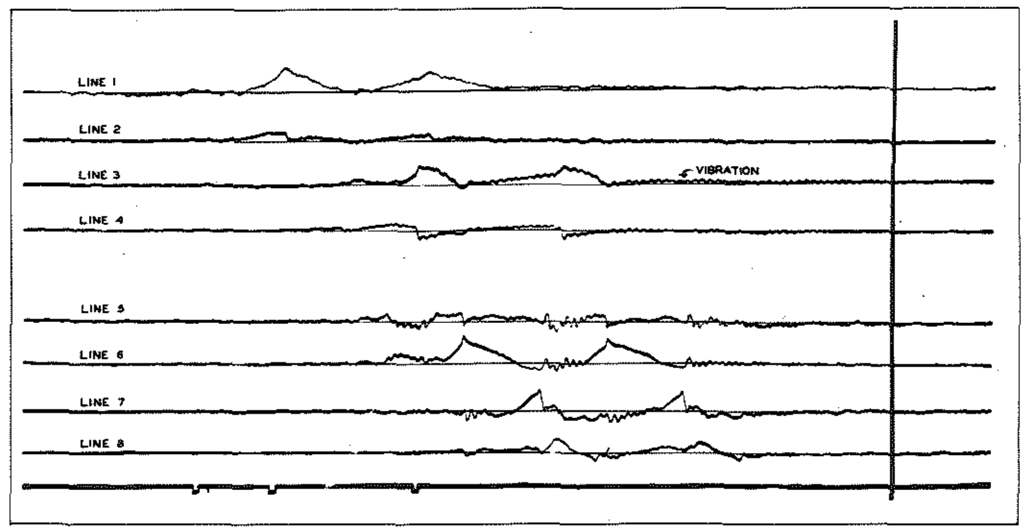
TRUCK TYPE 2S1-2 TRUCK SPEED: 30.15 M.P.H DATE: AUGUST 5, 1953

TRACE 66 – TEST LOCATION ONE



TRUCK TYPE 2S1-2 TRUCK SPEED: 33.7 M.P.H. DATE: AUGUST 5, 1953

TRACE 73 – TEST LOCATION ONE



TRUCK TYPE 2S1-2 DATE: AUGUST 12, 1953

TRACE 17 – TEST LOCATION THREE

NOTE: LINES 1 THRU 8 INDICATE THE PAVEMENT MOVEMENT AT CORRESPONDINGLY NUMBERED TEST POINTS.
TRACE DEFLECTION UPWARD INDICATES A DOWNWARD MOVEMENT OF THE PAVEMENT.

FIGURE 8. HATHAWAY OSCILLOGRAPH TRACES ILLUSTRATING SLAB VIBRATION AT CERTAIN TEST POINTS.

TABLE V TABULATED DATA ON PAVEMENT SLAB VIBRATIONS

Location	Test Point	Percentage of Test Runs where Slab Vibrations Occurred	Frequency Range of Slab Vibration cycles / sec.	Ave. Frequency of slab Vibration cycles / sec.
1	1	0	--	--
	2	0	--	--
	3	78	32.9 to 45.5	39.4
	4	0	--	--
	5	4	--	36.8
	6	13	43.5 to 51.3	48.8
	7	0	--	--
	8	26	30.5 to 63.8	41.7
2	1	5	--	53.4
	2	19	69.6 to 73.4	71.7
	3	14	68.4 to 73.3	71.7
	4	0	--	--
	5	24	60.2 to 65.9	63.3
	6	14	62.0 to 66.0	63.7
	7	0	--	--
	8	5	--	54.9
3	1	9	54.2 to 54.3	54.2
	2	30	52.8 to 55.1	54.2
	3	38	53.3 to 54.5	54.1
	4	15	53.0 to 53.6	53.3
	5	8	--	62.0
	6	15	61.5 to 63.8	62.6
	7	15	63.7 to 64.1	63.9
	8	8	--	58.4

test points had a tendency to vibrate due to trucks travelling at an average speed of thirty-seven miles an hour while only twelve percent of the test points had a tendency to vibrate due to trucks travelling at an average speed of fifteen miles per hour.

Summary

A complete study of the experimental data elicits the following major points:

1. Since this study was made in August while subgrade support was good, the deflection values are quite small. The magnitude of the pavement deflection for a given load was, in general, very similar to that for previous daytime deflection studies in August on newer pavements. While it might be expected that there would be some range in deflection values, the spread of the deflection values on this project was greater than would normally be expected.
2. No indication was obtained of a residual or permanent deflection of the slab after the passage of heavily loaded axles.
3. No consistent relationship between the magnitude of the deflection and the magnitude of the faulting at a joint could be found. However, the deflection was, in general, greater on the approach or high corner of a faulted joint than on the leaving or low corner.
4. Approximately 50 percent of the slabs tested had a tendency to rock. It was noted that the rocking slabs had a much greater total deflection, (tilting and load deflection), than did the non-rocking slabs. On an average, the total deflection was 125 percent greater.
5. In addition to rocking, this study revealed that 75 percent of the test points vibrated during one or more of the test runs, and in general, this vibration was not damped rapidly.

   The last two points, rocking and vibration, are of major importance and indicate that the subgrade support under the short pavement slabs at the time of test was not uniform.