Session Three

SELECTED SPECIAL STUDIES

Presiding: E. H. HOLMES, Chairman,
Report Review Committee, AASHO Road Test

Special Deflection Studies on Flexible Pavement

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The flexible pavement performance study at the AASHO Road Test indicated that the life of a pavement was related to the level of pavement deflection as measured with the Benkelman beam. It is probable, therefore, that planners of satellite or pavement evaluation programs will include measurements of pavement deflection in their experimental programs. In order to interpret the measurements of pavement deflection taken in any experimental program, some knowledge of the factors that affect the measurement is required.

At the AASHO Road Test special pavement deflection experiments were conducted to determine the effect of varying the Benkelman beam procedure and to consider an alternative method of measurement using an electronic device. Numerous other special experiments were carried out to determine the relationships of pavement deflection to wheel load, vehicle speed, tire pressure and pavement temperature. In addition, a program of plate load testing made possible a correlation between plate load test data and Benkelman beam data.

Test data are summarized by means of tables, graphs and mathematical equations. The equations express the pavement deflection as functions of wheel load, vehicle speed and pavement temperature.

• Studies of pavement deflection measured with the Benkelman beam were carried out at the AASHO Road Test, Ottawa, Ill. These studies were made in connection with research involving flexible and rigid type pavements of known design and traffic treatment.

The principal objectives of the pavement deflection studies were as follows:

1. To provide information that could be used in the fulfillment of Road Test Objective 5 which called for in part ". . . test procedures, data, charts, graphs, and formulas which will reflect the capabilities of the various test sections."
2. To determine what beam deflection measurement error, if any, could be attributed to testing procedures.
3. To develop relationships showing how deflection is influenced by vehicle load, vehicle speed, tire pressure, and pavement temperature.
4. To investigate the correlation between Benkelman beam deflection data and plate load test data.

This report is concerned with Objectives 2, 3, and 4. Data fulfilling Objectives 3 are described in AASHO Road Test Reports 5 and 6 (HRB Special Reports 61E and 61F). These data are summarized in this report to present a comprehensive review.

The main part of this report is a discussion of the experiments and the results of the analyses. Details of the mathematical analysis to determine the pavement deflection-temperature relationships are given in Appendix A. Appendix B is a bibliography concerning Benkelman beam deflection testing.

COMPARISON OF TESTING METHODS

The Benkelman beam was developed at the WASHO Road Test for the purpose of measuring the deflection of a flexible pavement under a loaded pneumatic tire. The beam fulfilled a need for a simple instrument that could quickly and conveniently measure the pavement surface deflection at any point. It consisted essentially of a lever rotating about a fulcrum that was fixed to a datum beam. The datum beam was supported on the pavement at three points. Figure 1 shows the beam, which was designed at the WASHO Road Test (*1, 2*), built by the Bureau of Public Roads, and used extensively at the AASHO Road Test. The lever (probe arm) was 12 ft long with 8 ft forward and 4 ft to the rear of the fulcrum. The distance from the front supports of the datum to the measuring point was 8 ft 10 in. A buzzer attached to the datum beam provided vibration to overcome friction of the parts during the test. An Ames dial was fixed to measure the relative motion of the rear of the probe arm with respect to the datum beam.

The testing procedure developed at the WASHO Road Test (hereafter referred to as the normal procedure) was adopted at the AASHO Road Test. The probe arm of the beam was inserted from the rear between the dual tires of a loaded test vehicle to a distance of about 4½ ft, lining up the probe arm by eye in such a position that rubbing of the probe arm and the tire wheels did not occur when the vehicle was moved forward. While the truck was standing, the probe arm was release from its locked position and the buzzer was turned on. The initial reading of the dial was taken. The vehicle was then moved slowly forward (creep speed) until the rear tires were at least 10 ft past the probe point. While the vehicle was being moved forward the maximum dial reading was noted and recorded. This reading occurred when the dual tires were opposite the probe point. The final dial reading was recorded when the truck had moved the minimum 10 ft past the probe point and the dial had come to rest. The normal-procedure pavement deflection is defined as the maximum dial reading less the initial dial reading multiplied by the lever-arm ratio of the probe arm (2 for the Road Test beam). The normal-procedure rebound pavement deflection is the maximum dial reading less the final dial reading multiplied by 2.

The normal-procedure pavement deflection was considered to give an accurate measure-

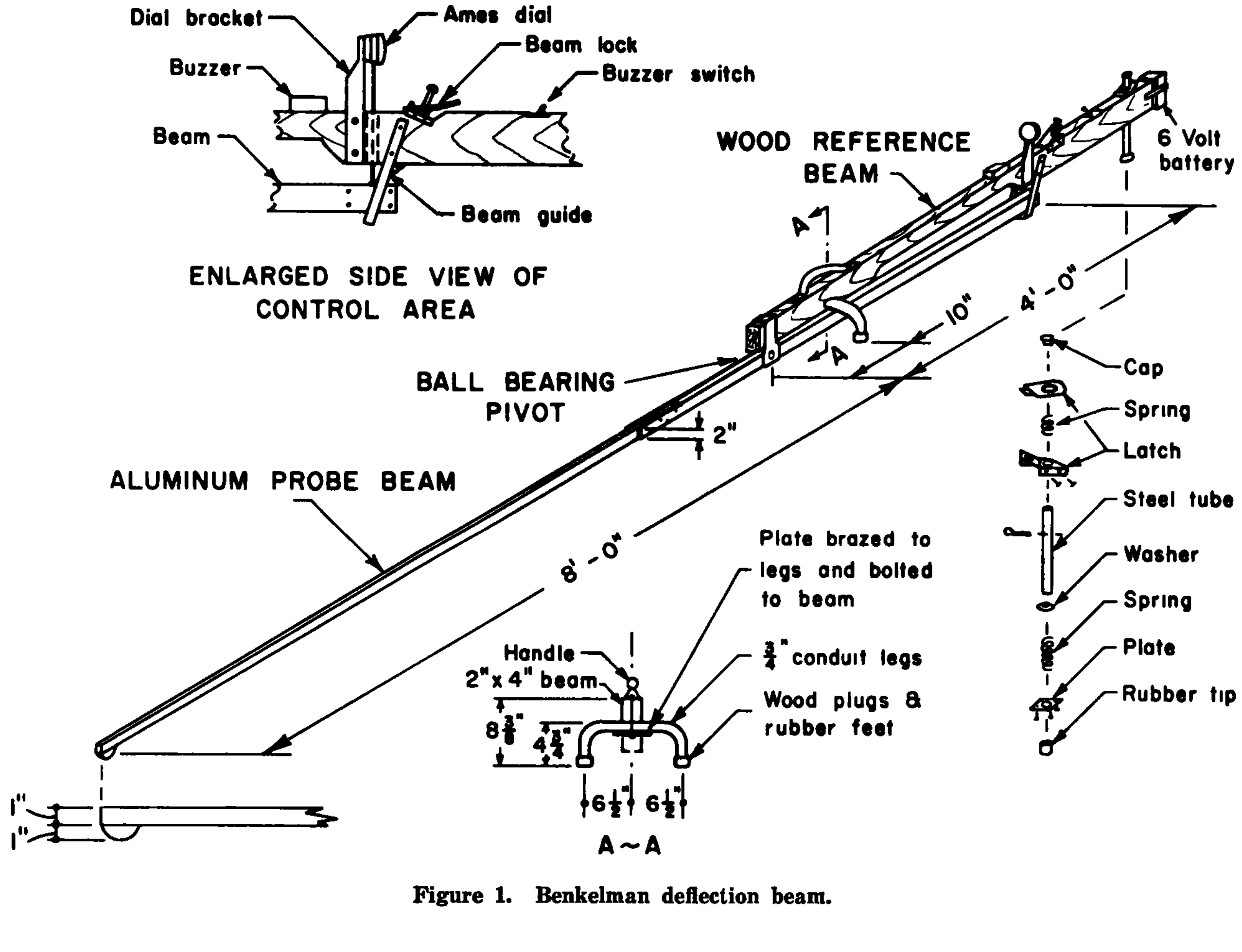

Figure 1. Benkelman deflection beam.

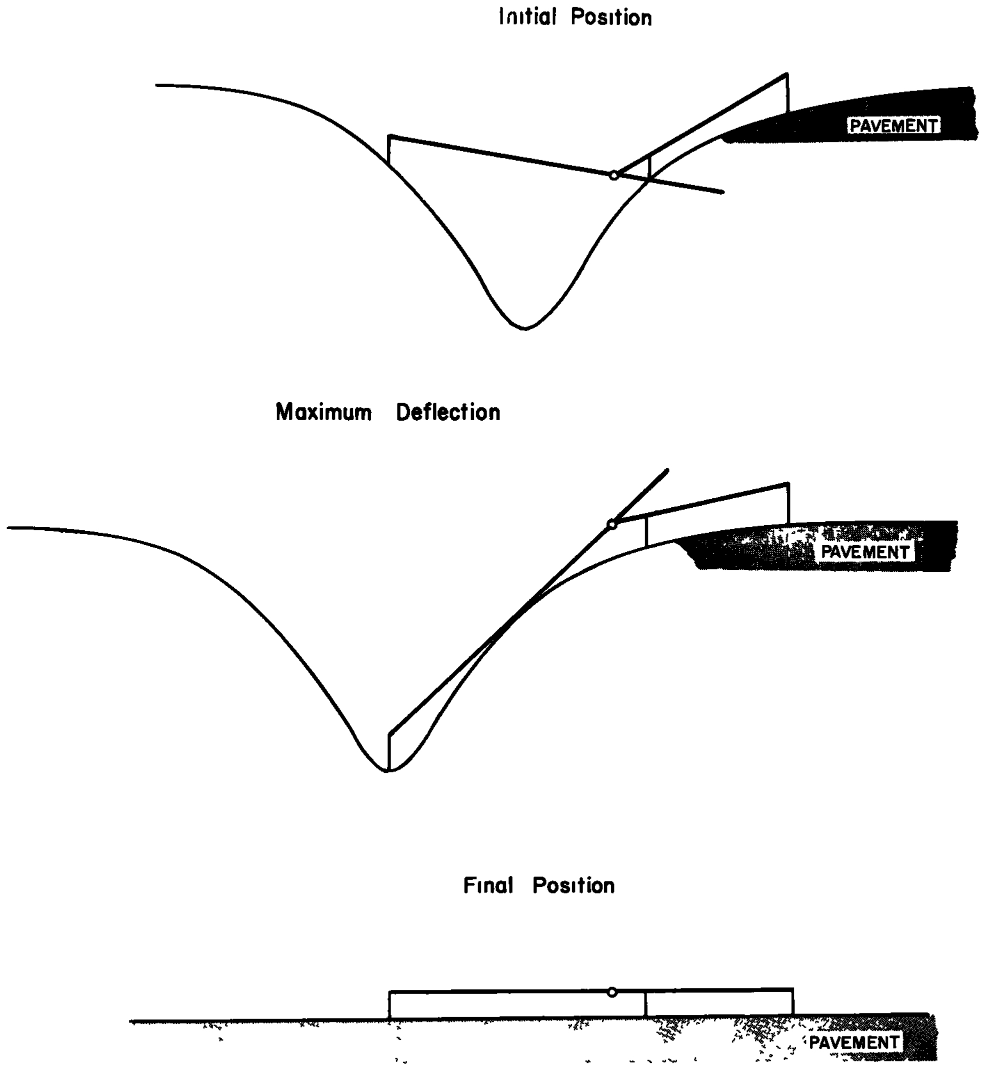

Figure 2. Derivation of positive residual deflection employing the Benkelman beam normal procedure (courtesy of Canadian Good Roads Association).

ment of the movement of the pavement surface between a set of dual tires as long as the reference beam supports were out of the "deflection basin" during the test. Should the front support legs and the probe point be in the deflection basin the resulting error will cause the normal deflection to be an overestimate of the true deflection (Fig. 2). In other words, the normal deflection would be larger than the rebound deflection.

During the progress of testing at the AASHO Road Test the staff became aware of large measurement errors being recorded by other investigators using the normal procedure (*12*, *18*). Special tests were undertaken to evaluate the measurement error, if any, that was being experienced at the Road Test. For this purpose the rebound procedure was developed, a procedure similar to the normal procedure except that the probe point was inserted between the dual tires of the test vehicle to a distance of 1 or 1½ ft instead of 4½ ft. Initial, maximum, and final dial readings were recorded as in the normal procedure. The pavement rebound computed from the maximum and final dial readings was termed the rebound-procedure pavement deflection. With the rebound procedure the test vehicle in its initial position is 7 ft 10 in. or 7 ft 4 in. from the supporting legs of the reference beam depending upon whether the probe point is inserted 1 ft or 1½ ft. Experimental data from the non-traffic loop deflection traces using a Benkelman beam equipped with an electronic recording device indicated that the distance from the wheel to the end of the deflection basin was less than 7 ft 4 in. in almost all tests.

During the period from May 4, 1959, to June 3, 1959, three series of tests were made using the rebound procedure. Information concern-

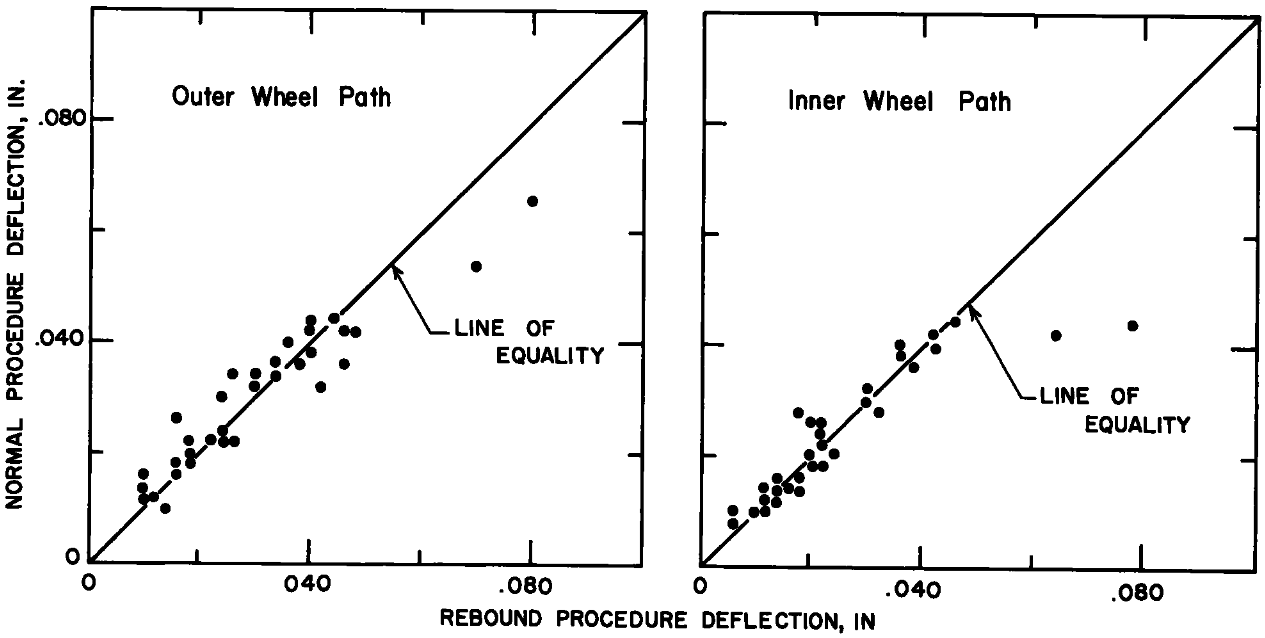

Figure 3. Comparison of Benkelman beam test procedures for 3-kip wheel load.

ing the test loops tested, the test loads, and the distance the probe arm was inserted between the dual wheels is given in Table 1.

TABLE 1

Series No.	Loop	Wheel Load (kips)	Distance[1] (ft)
1	1	3	1½
2	1	3	1
3	6	15	1½

[1] Distance between the probe arm contact point and the initial position of the rear dual wheels of the test vehicle.

Deflection testing using the normal procedure was not programed to coincide with the rebound-procedure deflection testing. To compare normal-procedure pavement deflections with rebound-procedure pavement deflections it is necessary to interpolate the routine normal-procedure data for the week prior and the week after the rebound-procedure test. Such comparisons are made in Figures 3 and 4 for series 2 and 3, respectively. Data from series 1 are not given because they are very similar to series 2 data. Each point represents two tests made at the same location. For series 1 and 2 carried out on the non-traffic loop with a light 3-kip wheel load the two test procedures appeared to give identical results. However, series 3 tests made on Loop 6 test sections with a heavier 15-kip wheel load indicated the normal procedure deflections to be higher in the outer wheelpath suggesting that the front supporting legs of the datum beam were in the deflection basin at the start of the test. If such was the case, the overestimation of deflection while using the normal procedure was a source of measurement error. In the inner wheelpath no such error was observed. No satisfactory explanation of the differences between wheelpaths was found. For the range of pavement deflections measured in the outer wheelpath (0.018 to 0.126 in.) the magnitude of the differences between procedures did not increase with the total deflection value. In fact, for very large pavement deflections the data from the two procedures are more nearly identical. These large pavement deflections were obtained from pavements considered thin for the 15-kip wheel load. The thin pavements were more flexible than the thicker pavements and in some cases, the continuity of the pavement was broken by considerable cracking. One would expect shorter deflection basins under these conditions and hence more nearly identical results for the two procedures.

Series 3, Loop 6 data, suggesting possible measurement error due to movement of the datum beam, led to a more extensive investigation in the traffic loops. In September 1959, a fourth series of tests was made on Loops 4 and 6 using both the normal and rebound procedures. Two loop test vehicles were used to measure deflections at four stops in each 100-ft test section. Test procedure was alternated from one stop to the next. The second truck's order of procedure was the reverse of that for the first. Thus, for stop 1 of any test section, the pavement deflection using the rebound procedure with vehicle No. 1 is compared to the normal procedure deflection with vehicle No. 2

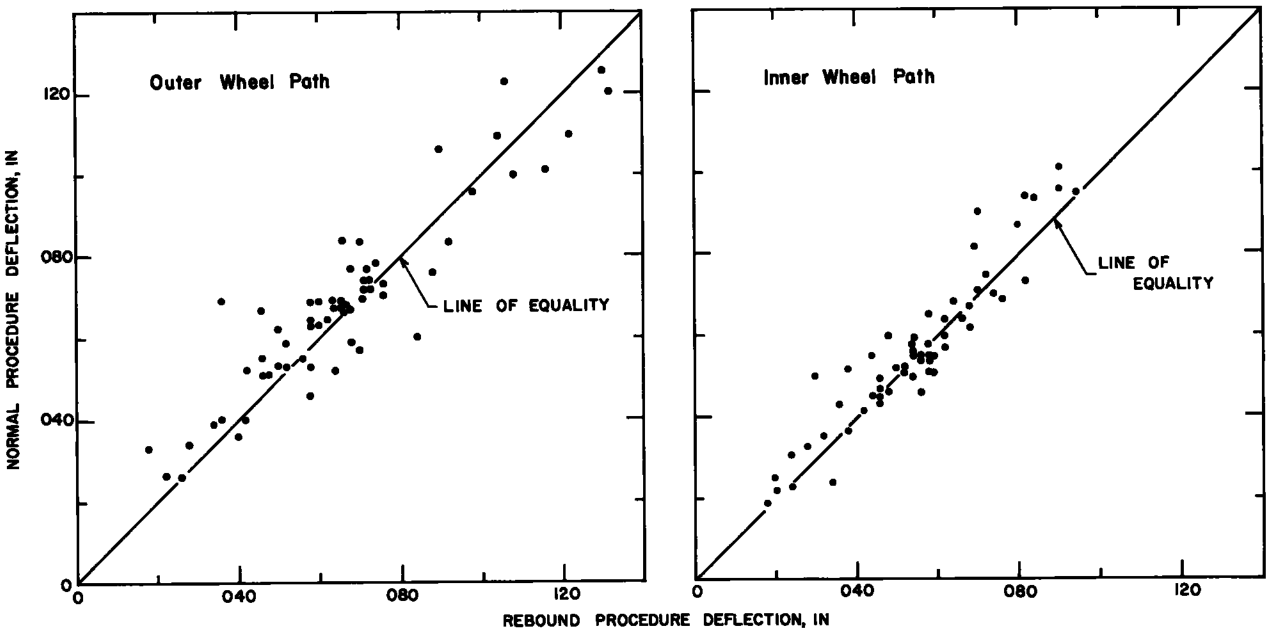

Figure 4. Comparison of Benkelman beam test procedures for 15-kip wheel load (series 3).

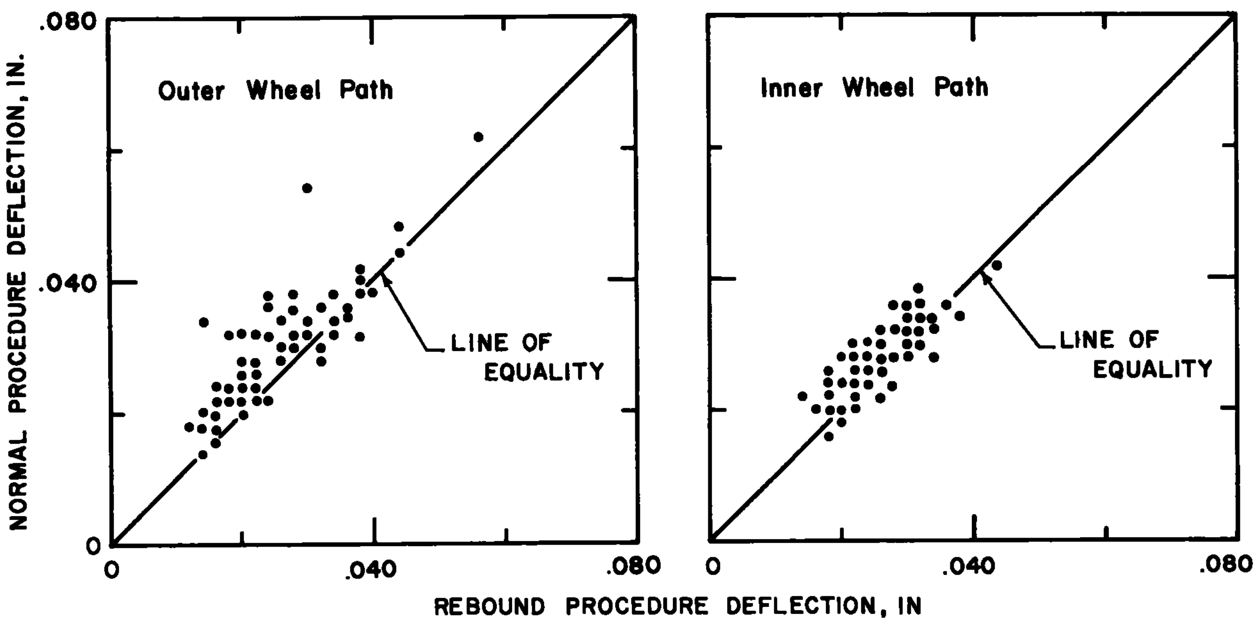

Figure 5. Comparison of Benkelman beam test procedures for 9-kip wheel load (series 4).

or vice versa. Such comparisons are shown in Figures 5 and 6 for data from Loops 4 and 6, respectively. Slight differences of the order of 0.003 in. are indicated by the larger normal procedure deflections in Loop 4 and differences of the order of 0.006 in. are indicated in Loop 6. The increasing differences for increasing axle load is in agreement with the trend indicated in the previous test series.

Frequency distributions of various sizes of this measurement error are shown in Figures 7 and 8 for the September series of special measurements. The residuals are computed by subtracting the final dial reading using the normal procedure from the initial dial reading and multiplying by 2 (lever-arm ratio). In only one test was a negative residual recorded. In both wheelpaths of both loops a positive residual of 0.004 to 0.005 in. occurred more frequently than any other.

In addition to measuring pavement deflections with the beam, extensive testing was done with a fixed installation deflectometer using a linear variable differential transformer

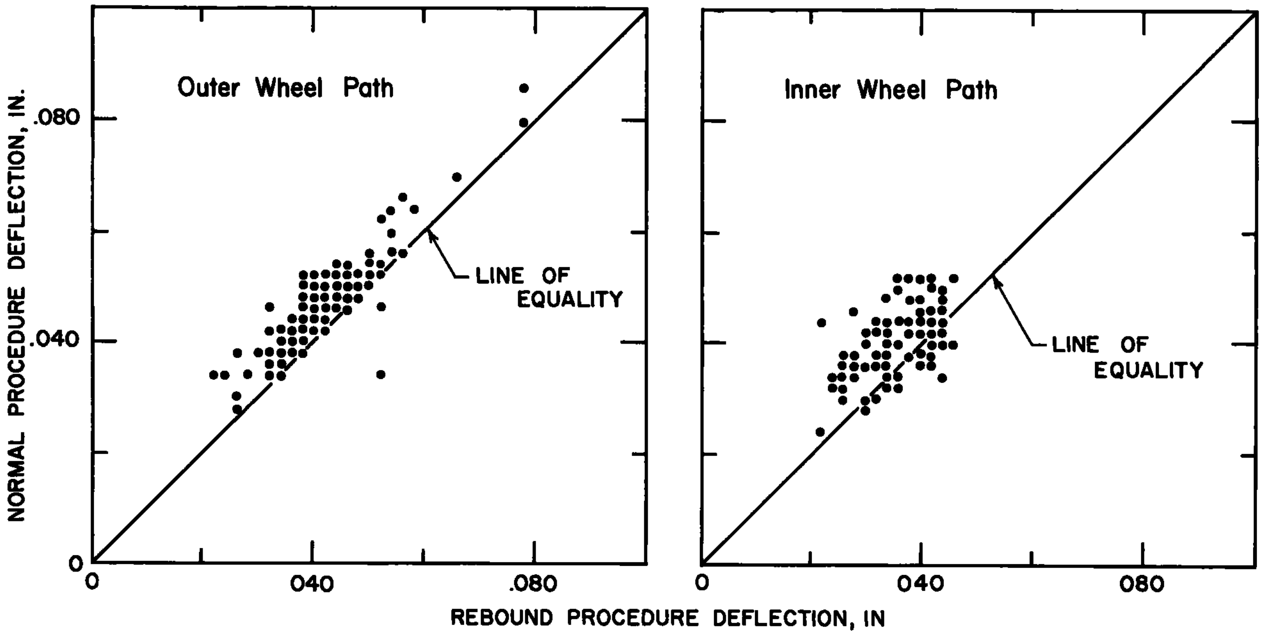

Figure 6. Comparison of Benkelman beam test procedures for 15-kip wheel load (series 4).

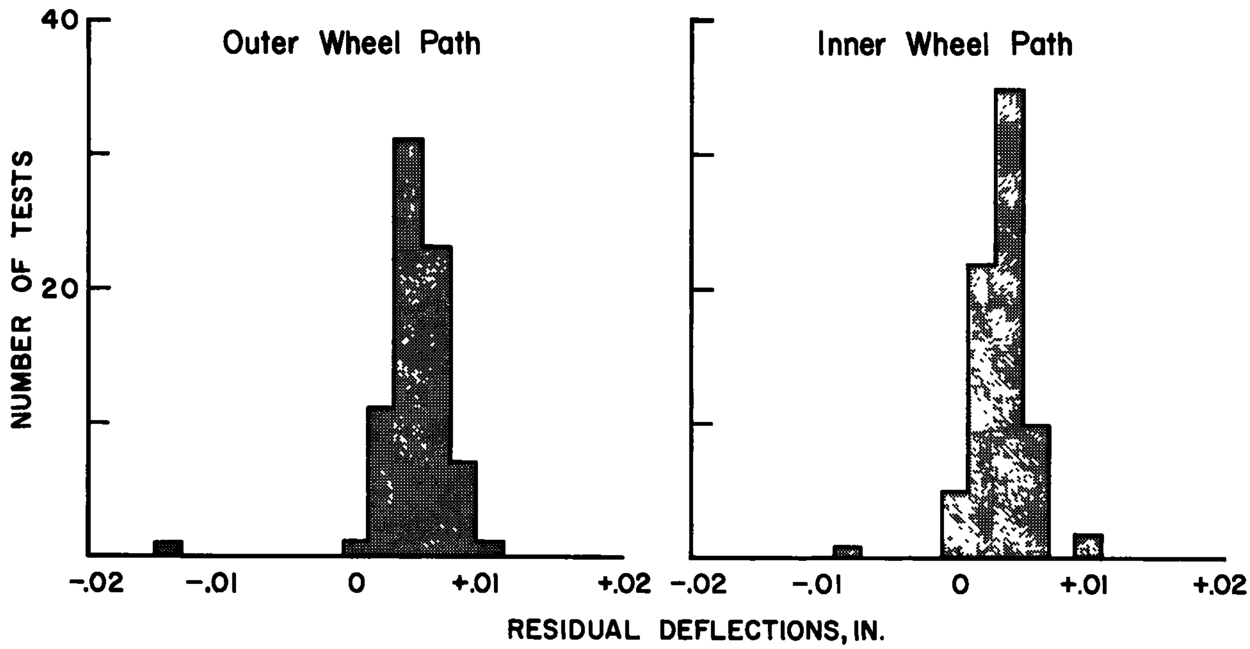

Figure 7. Residual deflections obtained by normal procedure, 9-kip wheel load.

(LVDT) as its transducer. The LVDT is a small linear transformer. It is mounted in a ¾-in. diameter shell and installed at the pavement surface with its movable core foot resting on the top of a reference rod. This rod is anchored securely to a perforated plate located 6 to 8 ft below the pavement surface. A continuous deflection trace may be recorded using conventional oscillographic equipment or the maximum deflection may be detected and recorded on punched tape in the field. The advantages of this type of measurement over the beam are (a) it can measure movement directly under a tire, and (b) the vehicle can move at any speed. Disadvantages of such an instrument are (a) comparatively few points in a given test section can be tested and consequently the data may not be representative, and (b) there is no assurance that the existence of the installation does not affect the quantity being measured.

From a special study it is possible to com-

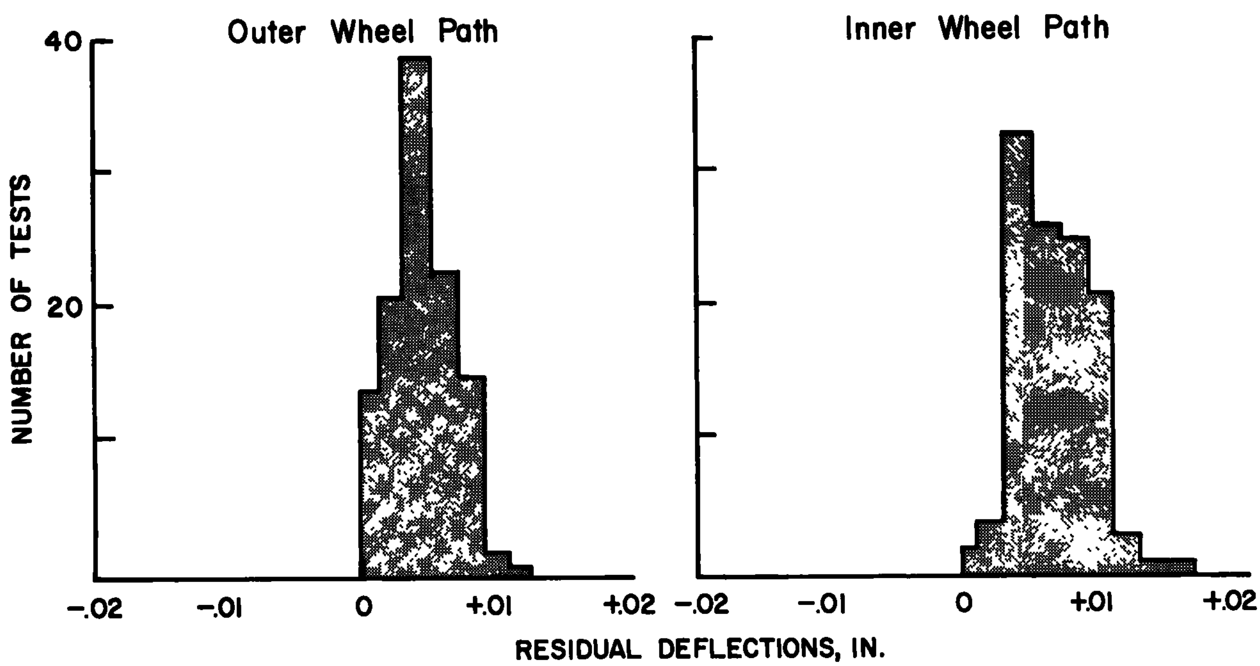

Figure 8. Residual deflections by normal procedure, 15-kip wheel load.

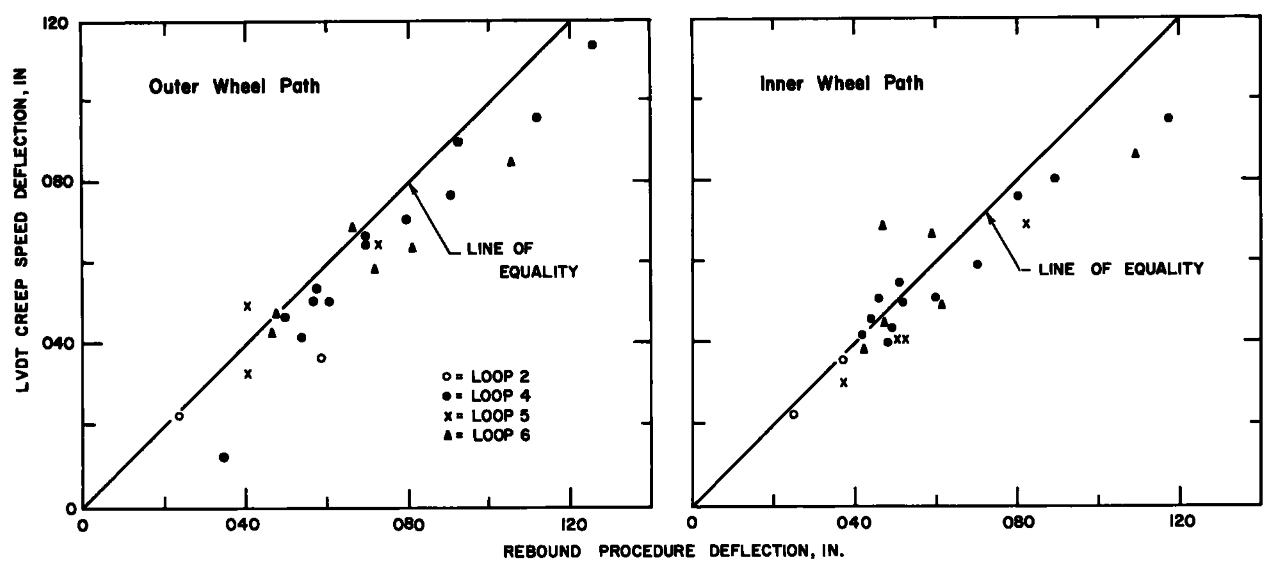

Figure 9. Comparison of LVDT deflection with Benkelman beam rebound-procedure deflection.

pare creep-speed (2 to 3 mph) LVDT dynamic deflections measured with the center of the dual wheels over the LVDT with beam rebound-procedure deflections (Fig. 9). Unfortunately, no data are available to compare static LVDT rebound deflections with beam rebound-procedure deflections where the effect of vehicle speed would be eliminated. The data (Fig. 9) were obtained from tests on all loops made on May 6, 7, and 8, 1959. The trend and magnitude of the differences between creep-speed dynamic deflections and the rebound-procedure deflections appeared to be the same for all loops. For all but a very few tests the beam rebound-procedure deflection was larger than the LVDT dynamic deflection and the difference increased as the pavement deflection increased. For a rebound-procedure deflection of 0.060 the dynamic deflection was 0.006 to 0.008 smaller. This difference could be the result of two factors: (a) movement of the reference plate and (b) a reduction in deflection from 0 mph to creep speed. From a previous investigation of reference rod movements in March 1959, for 18 single-axle loads an average movement of 0.004 to 0.005 in. was indicated

for reference rods anchored to plates 6 to 8 ft below the pavement surface (AASHO Road Test Data System 5142). No effect of pavement design could be found on the reference rod movement nor was any method available to determine if reference rod movement took place at higher vehicle speeds. The study of the reduction of pavement deflection with vehicle speed indicated for an 18-kip single-axle load a reduction of 0.001 to 0.002 in. for an increase in vehicle speed from 0 to 3 mph. Thus, the vehicle speed and plate movement effects appear to account for the differences between creep-speed LVDT deflections and rebound-procedure deflections (Fig. 8).

The LVDT type of deflectometer is able to record the pavement deflection directly under the tire as mentioned previously. In addition to the data collected in May 1959 with the center of the dual tire assembly directly over the LVDT, data were recorded with the center of the tire over the LVDT. It is possible then to evaluate the differences in pavement deflection between the dual tires and under the tires. For each test location the creep-speed deflection at different transverse placements of the center of the duals was plotted. A typical example is shown in Figure 10. Curves were fitted by eye to a number of such graphs and the differences in pavement deflection between the dual wheels and under one wheel (noted as the "pushup") are given in Table 2. The differences in the pavement deflection ranged from 0 to 0.014 in. for a range in pavement deflection between duals from 0.040 in. to 0.098 in. There was an indication of the pushup increasing with increasing total deflection for Loop 4 data (Fig. 11). This trend was not evident for the data plotted from the other loops although consider-

TABLE 2

PUSHUP BETWEEN THE DUAL WHEELS MEASURED WITH LVDT EQUIPMENT, MAY 1959

Loop	Design	Outer Wheelpath (0 001 in.)		Inner Wheelpath (0 001 in.)	
		Deflection at ℄ of Duals	Pushup	Deflection at ℄ of Duals	Pushup
2	3-0-4	—	—	95	—
	3-6-0	37	11	35	7
	3-6-4	23	5	—	—
3	3-6-4	54	—	—	—
	4-6-4	42	4	43	5
	3-3-8	57	6	66	4
4	5-6-4	56	—	44	—
	4-0-12	72	12	58	6
	4-6-4	90	11	—	—
	3-6-12	46	6	42	—
	4-0-12	66	7	50	—
	5-6-4	78	10	80	8
	5-0-12	66	14	50	7
	4-6-12	—	—	40	5
	5-6-12	41	5	41	4
	3-6-12	50	6	55	4
	5-0-12	—	—	76	2
	4-6-12	51	7	50	4
	5-6-4	98	—	98	0
	5-6-4	—	—	—	—
5	5-6-8	51	2	—	—
	4-9-12	46	4	47	3
	4-9-8	—	—	60	5
	4-6-12	65	4	69	4
	4-9-12	32	—	28	3
	5-6-12	50	2	41	—
	5-9-8	—	—	42	4
6	6-9-16	47	3	38	3
	6-3-16	70	—	67	—
	5-3-16	58	—	61	5
	6-9-8	58	—	50	—
	5-9-16	42	—	44	12
	6-9-8	64	—	68	5
	6-3-8	85	4	85	7

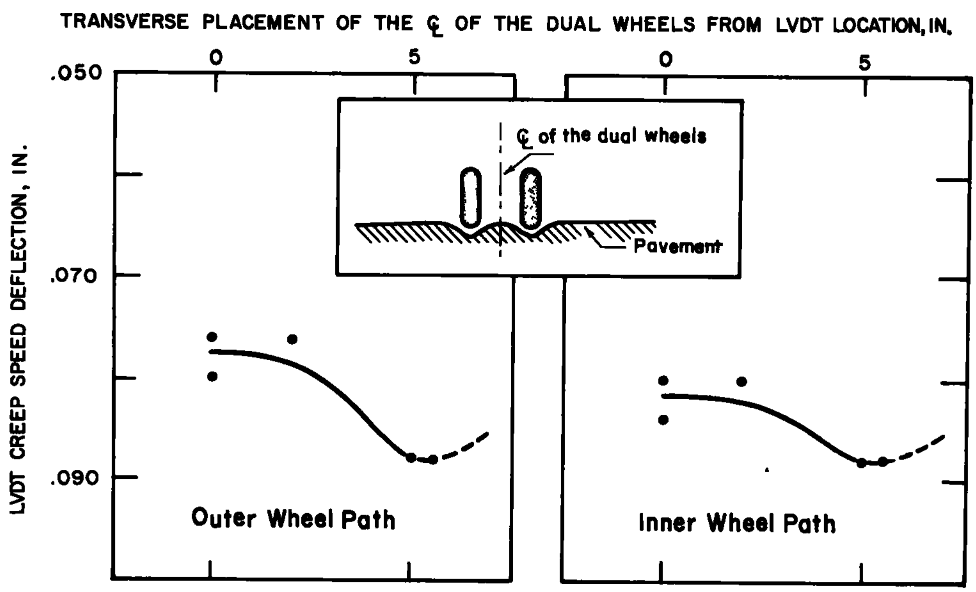

Figure 10. Typical sections of transverse pavement deflection profiles.

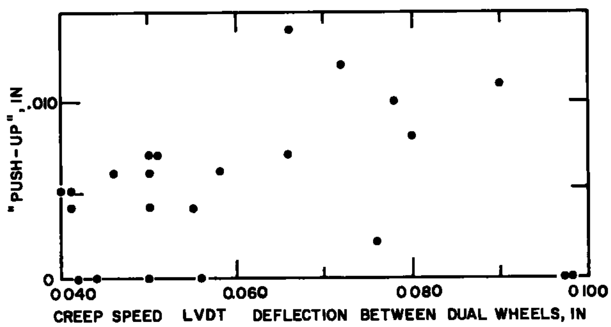

Figure 11. Correlation of "push-up" between dual wheels and magnitude of deflection.

ably fewer measurements were made in the other loops.

SPECIAL STUDIES OF PAVEMENT DEFLECTION

The wide range of axle loads used in the experimental program at the AASHO Road Test provided an opportunity to examine the effects of wheel load, speed, tire pressure, and pavement temperature on pavement deflection. Measurements were made using the Benkelman beam and the normal procedure. All of these variables except pavement temperature were controlled. These studies are described in detail in AASHO Reports 5 and 6 (HRB Special Reports 61E and 61F). In the following, the findings from each report are summarized.

Wheel Load Relationships

To study the effect of wheel load on pavement deflection the experimental program included four series of special tests. The time of each series, the loops tested, and the testing vehicles used are given in Table 3.

There were 6 test sections included in series 1, 2, and 3; and 4 sections in series 4. The pavement designs and wheel loads included in each series are given in Table 4.

Pavement deflections at four locations in each wheelpath were measured with the beam using the 1-ft rebound procedure for each section included in the first three series. In addition (series 2 tests), creep-speed dynamic

TABLE 3

Series No.	Time	Loop	Testing Vehicle
1	Spring 1959	6	Conventional single, tandem axles
2	Fall 1959	6	Conventional single, tandem axles
3	Fall 1959	4	Conventional single, tandem axles
4	Spring 1961	6	Conventional single, tandem axles, and small and medium scraper units.

pavement deflection for the section with a 6-9-16 pavement design (inches of surface, base, and subbase, respectively) were measured using the LVDT equipment. All deflections in test series 4 were measured with the LVDT equipment.

TABLE 4

Series	Design [1]	Wheel Load	
		Single	Tandem
1 and 2	5–9–12	3	6
	5–9–16	6	8
	6–6–12	9	10
	6–9–12	11 2	12
	6–6–16	15	—
	6–9–16	—	—
3	4–6–8	3	6
	4–6–12	6	8
	5–3–8	9	—
	5–3–12	—	—
	5–6–12	—	—
4	5–9–16	6[2]	4[2]
	6–9–8	9[2]	5[2]
	6–6–16	—	—
	6–9–16	—	—

[1] Designs are indicated by inches of surfacing, base and subbase thicknesses, respectively. Each pavement design listed was tested with all the loads in the wheel load columns

[2] Wheel load for conventional single, tandem axle equipment. For the small scraper unit the wheel loads ranged from 7 7 to 23 5 kips and for the medium scraper unit the range was from 10 7 to 33 8 kips. The pressures and tire sizes varied with the wheel load. This information is contained in HRB Special Report 61F.

The results of series 1, 2, and 3 are presented in AASHO Road Test Report 5 (SR 61E) in the form of graphs and regression equations for each section tested in each series. Regression equations were based on the following mathematical model:

$$d = A_0 L_1^{A_1} L_2^{A_2} \quad (1)$$

in which

d = the deflection, in.;
L_1 = the axle load, kips;
L_2 = the number of axles (*i.e.*, 1 for single-axle configuration and 2 for tandem-axle configuration); and
A_0, A_1, and A_2 = constants determined from the regression analysis.

This model may be linearized as:

$$\log d = \log A_0 + A_1 \log L_1 + A_2 \log L_2 \quad (1a)$$

Typical results of series 1 and 2 are shown in Figure 12 for the 5-9-16 pavement design in Loop 6. Each point is the mean of 8 measurements, 4 in each wheelpath. The constants and correlation coefficient (r^2) from the anal-

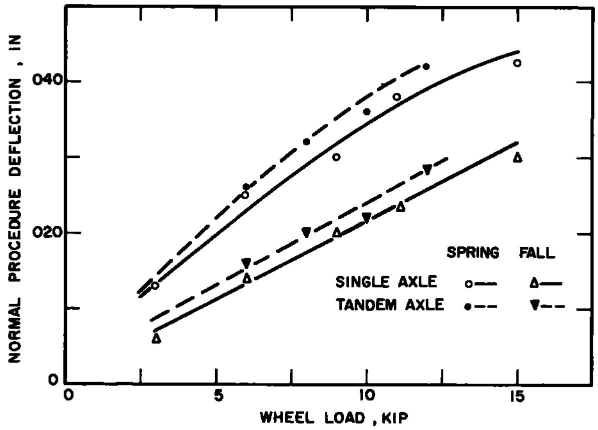

Figure 12. Effect of wheel load on pavement deflection measured with the Benkelman beam—typical section, Loop 6, 5-9-16 Design.

yses for the 5-9-16 pavement design are as follows:

	A_0	A_1	A_2	r^2
Series 1	0.552	0.751	−0.616	0.99
Series 2	0.075	0.958	−0.759	0.98

Similar results were obtained for series 3.

The downward curvature indicated in Figure 12 was typical for all but two of the sections tested in three series. In other words, the rate of increase of pavement deflection with wheel load appeared to be decreasing with increasing load.

Further evidence of this downward curvature trend was indicated by series 4 with the construction equipment. Wheel loads for this equipment could be increased beyond the maximum limit for the conventional equipment, thus allowing a greater range of load. Typical results of this study are shown in Figure 13 for the section with the same pavement design as in Figure 12. Each point is the average of

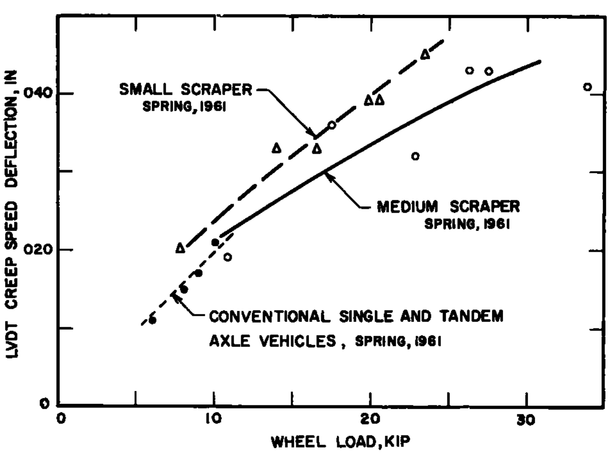

Figure 13. Effect of wheel load on pavement deflection —typical section, Loop 6, 5-9-16 Design.

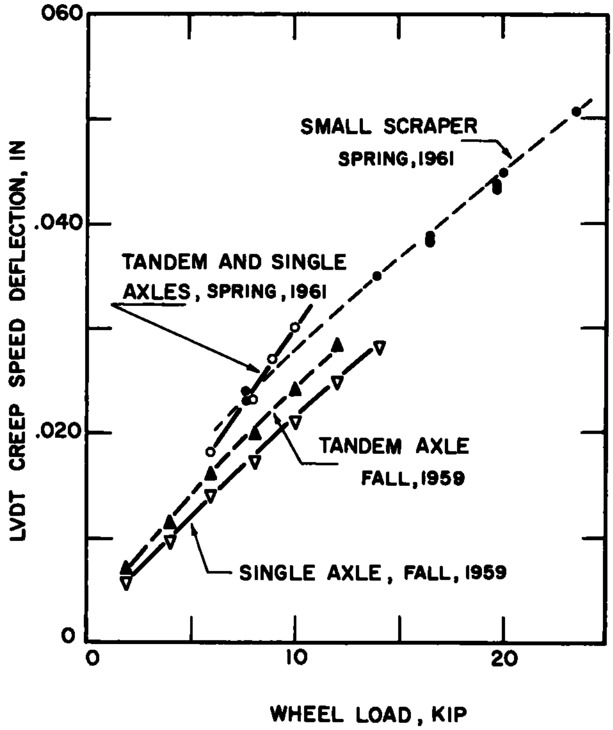

Figure 14. Comparison of load-deflection studies for fall and spring—typical section, Loop 6, 5-9-16 Design.

the 5 highest deflection measurements recorded. Presumably these values occur when the tires pass directly over the instrument. The test-load range for the conventional vehicle was too small to establish any curvature but when these data are combined with the data for the scraper units a slight downward curvature is evident. The magnitude of pavement deflection and the amount of curvature would appear to vary with vehicle type as evidenced by the differences between the small and medium scraper units.

It was difficult to compare the deflection values for spring 1961 (series 4) with the data from spring 1959 (series 1) because different methods of measurement were used. All deflections measured in spring 1959 were measured with the Benkelman beam whereas the LVDT was used during spring 1961. A comparison of creep-speed LVDT deflections could be made, however, for the special section tested during fall 1959 (series 2) and the same section tested during spring 1961. This comparison is shown for the section with the 6-9-16 pavement design in Figure 14. Tandem-axle and single-axle data are shown separately for the fall 1959 series, but are combined for the spring series. As expected, the level of deflection was higher for the spring series but the general trend of pavement deflection with wheel load remained much the same. It is to be recognized that tire pressures and tire sizes increased with increasing wheel load. The effects of these variables on the wheel load-deflection relationships cannot

be determined from the data. However, as it is common practice to increase tire sizes and pressures with increasing loads, the relationships derived are believed to be representative of normal highway behavior for the pavement designs tested.

Speed Relationships

Because vehicle speed was not a variable in the Road Test there were no routine data to examine in order to determine the effect of vehicle speed on pavement deflection. For this purpose three special series of tests were conducted in 1959: the first in August, the second in September, and the third in December. The sections included in the tests were as follows: Loop 4—3-6-12, 5-6-4, 5-6-4, 5-6-12; and Loop 6—4-9-16, 6-9-8, 6-9-8, 6-9-16.

The pavement deflections were measured using the electronic LVDT equipment. The measurements in this study were taken at speeds ranging from creep to 47 mph under two single-axle wheel loads, 6 and 9 kips on Loop 4, and 6 and 15 kips on Loop 6.

Equations were developed for each section included in the tests, for each load used, and for each date tested. The model selected to fit the observed data was

$$d = 10A_0 - A_1 v \qquad (2)$$

in which

d = the pavement deflection;
v = the vehicle speed;
A_0 = a test section constant; and
A_1 = the speed coefficient.

All analyses indicate a marked reduction in deflection with increase in vehicle speed. Reductions for increases in vehicle speed from creep to 35 mph were of the order of 40 to 50 percent. Typical examples of speed-deflection data are shown in Figure 15 together with computed curves. Good agreement was found between the observed values of deflection and those computed from the equations.

Examination of the equations for each section indicated that there was no consistent trend of the coefficients with pavement design that would indicate the need of including a design term or a design-speed interaction term. However, the range of pavement designs included in the study was small. In order to simplify the presentation of the data, equations were developed for each lane by averaging the values of A_0 and A_1 appearing in the individual equations. These values are given in Table 5 for each date of testing and for each of the loads used in the two loops; the percentage reduction in deflection with speed from 2 to 35 mph and the average pavement temperature are also given. These data indicate no consistent variation of percentage reduction with surface temperature between 87 and 40 F. Also, no effect of pavement design on the percent reduction is indicated when the Loop 4 data are compared to the Loop 6 data for the same axle load (12 kip). However, Table 5 indicates clearly that the speed coefficient is reduced as load is increased indicating that load and speed do not act independently.

Tire Pressure Relationships

During the regular test traffic phase of the Road Test, several small studies were conducted to investigate the effect of varying tire pressure on pavement deflection. In the first study the tire pressures were varied from 40 to 70 psi using the conventional test vehicles. In the second study the conventional and low pressure-low silhouette (LPLS) tires were

TABLE 5

CORRELATION DATA FOR SPEED-DEFLECTION STUDY

Date	Loop	Single-Axle Load (kips)	A_0	A_1	Corr. Coeff., r^2	Percent Reduction [1]
Aug. 26, 1959[2]	4	12	1 386	0 0072	0 86	43
	4	18	1 559	0 0058	0 79	36
	6	12	1 278	0 0070	0 84	41
	6	30	1 638	0 0055	0 86	34
Sept. 30, 1959[3]	4	12	1 287	0 0070	0 94	41
	4	18	1 440	0 0062	0 93	38
	6	12	1 183	0 0075	0 93	43
	6	30	1 534	0 0058	0 91	36
Dec. 2, 1959[4]	4	12	1 277	0 0062	0 89	38
	4	18	1 420	0 0058	0 93	36
	6	12	1 128	0 0060	0 86	37
	6	30	1 491	0 0058	0 86	36

[1] Reduction of pavement deflection from 2 to 35 mph.
[2] Surfacing temperature, 87 F.
[3] Surfacing temperature, 62 F.
[4] Surfacing temperature, 40 F.

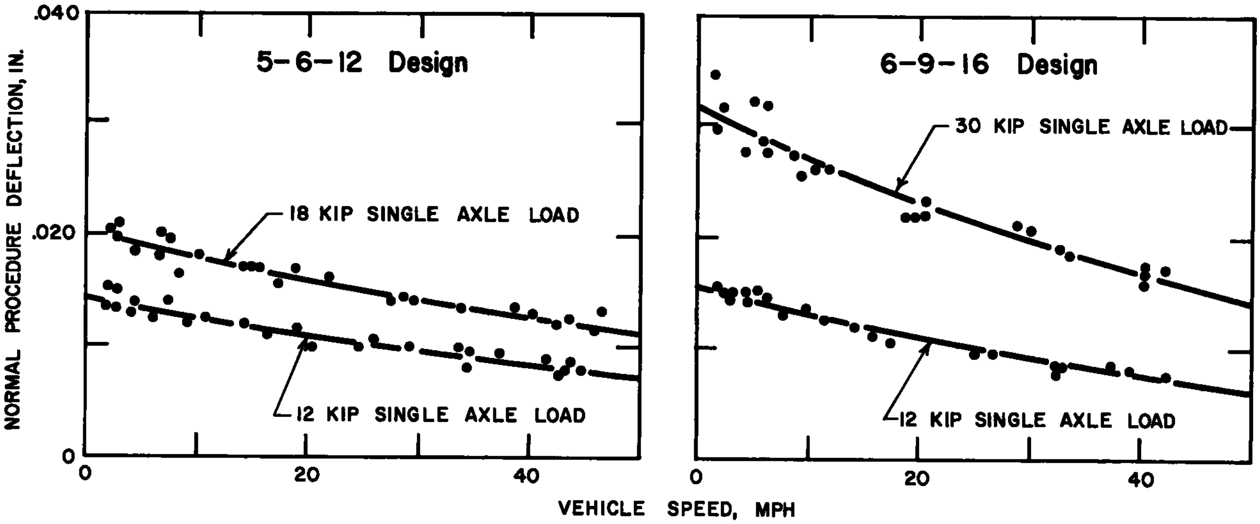

Figure 15. Correlation of Benkelman beam deflection to vehicle speed.

used and pressures were varied from 23 to 70 psi.

Results of the first study indicated that no relationship existed between tire pressure and pavement deflection. The second study showed higher pavement deflections for lower tire pressures although the results of these studies were complicated by a change in tire type.

Findings during the regular traffic phase were used to plan a more extensive series of tests during the 1961 special post-traffic studies. For these studies, conventional tires and a special wire-cord tire were used. For each of 4 wheel loads and 3 vehicle speeds, levels of 60, 80, and 100 psi were selected for the conventional tires. Tire pressures for the wire-cord tire, depending on the wheel load, ranged from 100 to 130 psi. Pavement deflections were measured with the LVDT equipment at creep-speed (Table 6). Examination of the data revealed no indication of an effect of tire pressure on pavement deflection. Similar conclusions were evident from the data for the other two vehicle speeds.

Further information was obtained from the studies using small and medium scraper units during spring 1961. A small study of tire pressure effects on the pavement deflection was undertaken for each selected wheel load and vehicle speed. Two levels of tire pressure were selected, 30 psi and 45 psi. Results of this study are given in Table 7 for the medium and small scraper units. No effect of changing the tire pressure from 30 psi to 45 psi was found.

All studies of the effect of changing tire pressure on pavement deflection at the AASHO Road Test indicated no relationship between the two factors. It must be remembered, however, that only the maximum deflection was measured. No attempts were made to establish the size of the deflection basin or the radius of curvature which might have been affected by tire pressure. A very limited range of pavement design was included in the experiments. It is possible that the geometry of the pavement and the materials used would have an effect on any tire pressure-pavement deflection relationships.

Temperature Relationships

Information concerning the effect of surfacing temperature on pavement deflection measured with the Benkelman beam employing the normal procedure was obtained from a number of special 24-hr studies conducted at times when it was anticipated that there would be

TABLE 6

PAVEMENT DEFLECTION DATA (LVDT) FOR TIRE PRESSURE STUDY USING CONVENTIONAL EQUIPMENT

Wheel Load (kips)	Tire Size	Tire Pressure (psi)	Creep-Speed LVDT Deflection (0 001 in.)			
			Design 5–9–6	Design 6–9–8	Design 6–6–16	Design 6–9–16
9S	9 00x20N[1]	100	17	28	16	20
	10 00x20N	80	16	29	15	22
	10 00x20N	80	17	31	18	22
	12 00x20N	60	16	29	15	20
	8 25x20W[2]	115	17	30	17	22
11 2S	10 00x20N	100	20	37	22	25
	11 00x20N	80	21	35	31	27
	12 00x20N	60	21	36	22	24
	9 00x20W	125	20	36	19	24
16T	8 25x20N	100	15	25	16	17
	9 00x20N	80	15	27	15	18
	11 00x20N	60	16	27	14	17
	8 25x20W	100	14	25	14	17
20T	9 00x20N	100	18	32	19	21
	11 00x20N	80	17	31	17	21
	11 00x20N	80	20	36	23	24
	12 00x20N	60	19	32	22	23
	8 25x20N	130	19	32	19	22

[1] N = Nylon cord.
[2] W = Wire cord.

TABLE 7

INNER WHEELPATH LVDT DEFLECTION DATA FOR TIRE PRESSURE STUDY USING CONVENTIONAL SCRAPER UNITS

Vehicle Type	Axle Load (kips)	Tire Pressure (psi)	LVDT Deflection (0.001 in.) Design 5-9-16 Creep	Design 5-9-16 15 mph	Design 6-9-16 Creep	Design 6-9-16 15 mph	Design 6-9-8 Creep	Design 6-9-8 15 mph	Design 6-6-16 Creep	Design 6-6-16 15 mph
Small scraper	15.4	30	18	16	23	16				
		45	20	19	24	20				
	28.0	30	31	28	41	30				
		45	33	25	35	30				
	32.9	30	34	29	39	31				
		45	33	31	39	31				
	39.6	30	36	34	44	35				
		45	39	34	44	33				
	40.9	45	39	33	45	35	73	57	43	40
	47.0	45	45	36	51	38	78	62	48	45
Medium scraper	21.4	30	22	15						
		45	19	18						
	35.0	30	36	39						
		45	36	23						
	45.6	30	35	26						
		45	32	27						
	52.5	30	36	29						
		45	43	26						
	55.0	45	43	33	39	41	77	65	44	40
	67.5	45	41	33	34	41	78	63	42	35

TABLE 8

Series No.	Date	Loop [1]	Single-Axle Load (kips)	Temp. Range (°F)
1	Oct. 1958	3, 5, 6	12, 22.4, 30	45–85
2	Oct. 1960	6	30	55–75
3	May 1959	1	6	59–78
4	June 1959	1	6	88–124
5	Aug. 1959	1	6	83–120
6	Oct. 1959	1	6	62–77
7	Dec. 1959	1	6	31–50
8	May 1960	1	6	50–67
9	Aug. 1960	1	6	70–94

[1] Single-axle lanes only.

TABLE 9

Loop 3 Surf. (in.)	Loop 3 Base (in.)	Loop 3 Sub. (in.)	Loop 5 Surf. (in.)	Loop 5 Base (in.)	Loop 5 Sub. (in.)	Loop 6 Surf. (in.)	Loop 6 Base (in.)	Loop 6 Sub. (in.)
2	0	8	3	3	8	4	3	12
2	0	8[1]	3	6	4	4	6	8
2	3	4	3	9	12	4	9	16
2	6	0	4	3	12	5	6	12
3	0	0	4	6	8	5	6	12
3	3	8	4	6	8[1]	5	9	8
3	6	4	4	9	4	5	3	16
4	0	4	5	3	4	6	3	8
4	3	0	5	6	12	6	6	16
4	6	8	5	9	8	6	9	12

[1] Replicate section.

appreciable changes in the level of the surfacing temperature. The series numbers, dates, loops tested, and temperature ranges are given in Table 8. The first two series were run on the traffic loops. The remaining seven series were run on the no-traffic loop.

Series No. 1 was conducted prior to the start of regular test traffic. A 12-kip single-axle load was used on all loops. The pavement designs included are given in Table 9. The average base and subbase thicknesses were the same for each surfacing thickness. For example, in Loop 5 sections with 3-in. surfacing averaged 14-in. total thickness of base and subbase as do the sections having 4-in. surfacing and 5-in. surfacing.

Series 2 was made on the special base wedge test sections of Loop 6. The surfacing thickness over all base types was 4 in., the subbase thickness beneath the bituminous and cement base, 4 in., and beneath the stone base, 8 in. Base thicknesses are as follows:

Base Type	*Base Thickness* (in.)
Bituminous	8.6, 12.4, 16.1
Cement	9.3, 11.8
Crushed stone	13.0, 17.0

The remaining seven no-traffic loop series covered all seasons of the year. All test sections in Loop 1, lane 2, were tested with a 6-kip axle load except the section with a 1-0-0 pavement design.

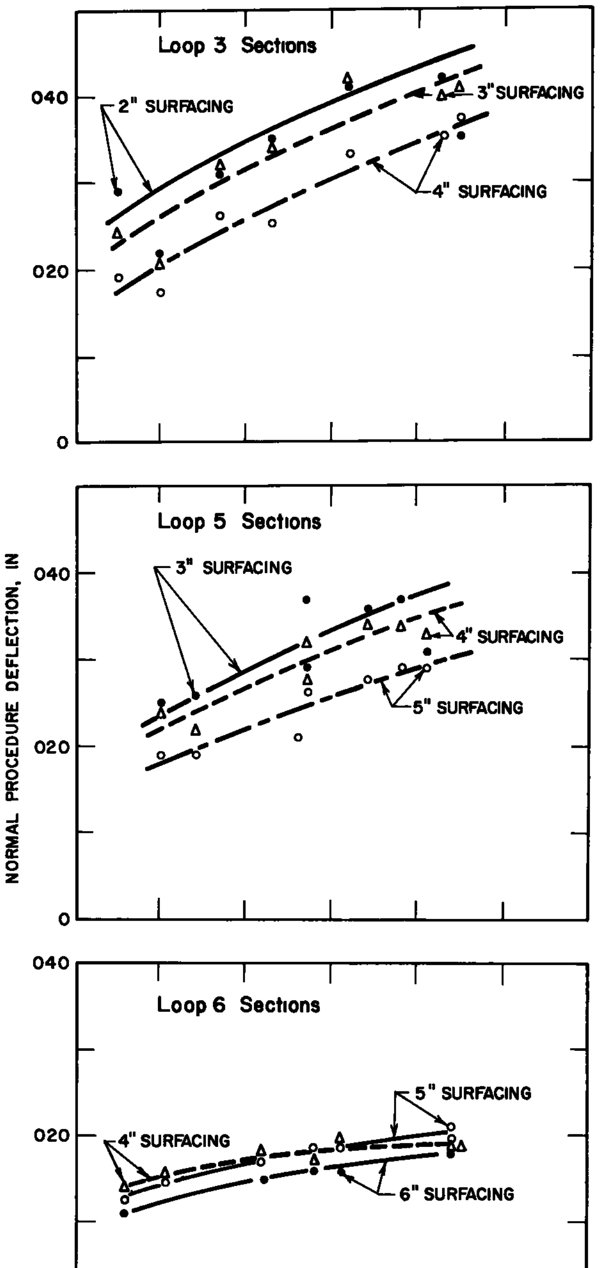

Figure 16. Deflection-temperature data—12-kip single-axle load (series 1).

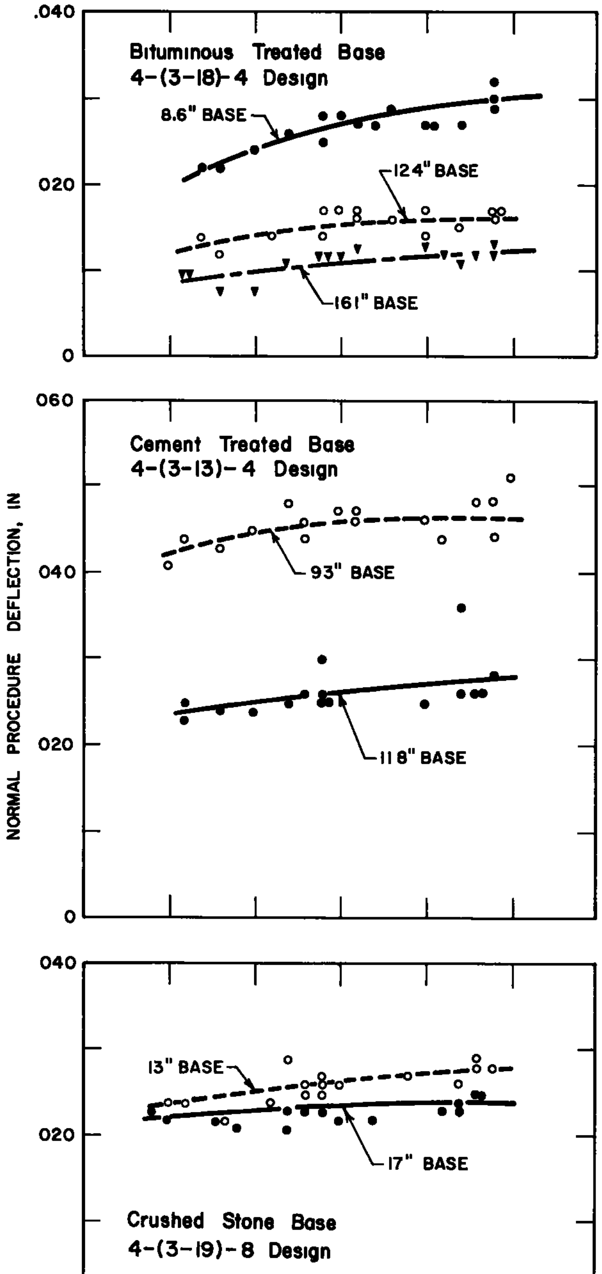

Figure 17. Deflection-temperature data—30-kip single-axle load (series 2).

The results of series 1 are shown in Figure 16, in which each point is the average of all measurements within each loop for test sections with the same surfacing thickness. Measurements were made at four locations in each test section, two in the inner wheelpath and two in the outer wheelpath.

Figure 17 shows the results of the second series. Each point is the average of two measurements, one in the inner wheelpath and one in the outer wheelpath. All curves were fitted to the plotted points by eye.

The results of the tests on traffic loop sections at creep-speed using the beam indicate that considerable reduction in pavement deflection may result from a decrease in pavement temperature. The trend appeared to be curvilinear downward. Direct comparisons of base type cannot be made from the series 2 data due to different pavement thicknesses tested for each base type.

Results of the seven series of testing on the no-traffic loop with the 6-kip axle load are shown in Figure 18, in which each point is the average for all pavement designs tested for each surfacing thickness. An equal number of test sections were tested in each series. When all series were plotted together for each surfacing thickness the same trend was evident that was found for the traffic loop tests. Unfortunately, however, a wide range in pavement temperature was not obtained for any single series to establish any curvature. The curves in Figure 18 were derived from a mathematical analysis which is described in Appendix A. These curves were computed assuming that the trend indicated by the plots of all the data together was valid for each series.

From season-to-season the level of pavement deflection changed; however, for each surfacing thickness the change in deflection per degree change in temperature appeared to be independent of the level of deflection. Above about 80 F the pavement deflection was practically constant. This trend is in general agreement with the data from the traffic loops with the exception of series 1 which was conducted immediately after construction and before test traffic. Data from this series indicated that the pavement deflection was decreasing at 85 F, whereas the data from the other series indicated little or no change at 80 F. No explanation could be found except perhaps differences in surfacing characteristics which might arise from oxidation of the asphaltic concrete. From 50 F down to about 30 F the change in the no-traffic loop series, with one exception, was most pronounced. The lone exception was in the group of sections having 5 in. of surfacing, tested December 3, 1959 (series 7). Before this date, air temperatures as low as 15 F had been recorded with several minor cycles of freezing and thawing. The lack of temperature influence on the deflections for the thickest surfaced sections may have been due to the presence of frost, if frost remained in these sections for longer periods of time. A comparison of the data for each surface thickness indicated that the decreases in pavement deflection with decrease in temperature below 50 F were the greatest for the 1-in. surfacing and the least for the 5-in. surfacing. Although the surfacing thickness affected the pavement deflection-temperature relationship in this study the differences between the 3-in. surfacing designs and 5-in. surfacing designs were small and may not be of practical significance.

CORRELATION WITH SURFACE PLATE LOAD TEST DATA

The data used in these studies were obtained as part of the no-traffic loop subsurface investigations on flexible pavement. Trenches were excavated at periodic intervals (except in winter) in test sections ranging in design from 3 in. of surfacing, no base and no subbase to 3 in. of surfacing, 6 in. of base, and 16 in. of subbase. Prior to cutting a trench, nine Benkelman beam deflection measurements using a 6-kip axle load were made on the surface at 3, 6, and 9 ft from the pavement edge on the centerline of the proposed trench and on lines both 5 ft ahead and behind the centerline. Plate load tests using a 12-in. diameter plate and occasionally 18- and 24-in. diameter plates were also made on the surface before opening the trench. The locations of these tests were between the wheelpaths on the centerline of the trench.

The plate load test procedure, used on the AASHO Road Test, provided for the application of three repetitions of three different increments of load, and the measurement of gross and elastic rebound movements. The loads were applied for approximately 15 sec, without provision for the deformation to come to equilibrium. The applied loads for various plate sizes were selected to approximate what might be expected under loaded trucks, and to prevent excessive strain in the layer. The following plate sizes and their corresponding unit loads were used in the study:

Plate Size (diameter, in.)	*Unit Load* (psi)
12	16, 48, 70
18	16, 32, 48
24	10, 20, 28

Because the Benkelman beam measures presumably an elastic deflection, it was felt that better correlations would exist using elastic plate deflections rather than gross plate deflections. Thus, the plate load data in this report are expressed in terms of elastic rebound deflections or an elastic modulus, k_E. The k_E is computed by dividing each unit load by the elastic rebound deflection and averaging the three values for the test. The modulus values are in pounds per cubic inch. Details of test equipment and procedures are described in Appendix D, AASHO Road Test Report 5 (HRB Special Report 61E).

Before gathering the test data was complete the authors became aware of similar research being conducted by the Pavement Design and Evaluation Committee of the Canadian Good Roads Association. Sebastyan (*19*) showed a correlation between the load on a 30-in. plate for 0.5-in. deflection at 10 repetitions of load to beam deflections measured with an 18-kip single-axle load. Thus, it was not surprising to find a good correlation existing between beam deflections and elastic plate load deflections.

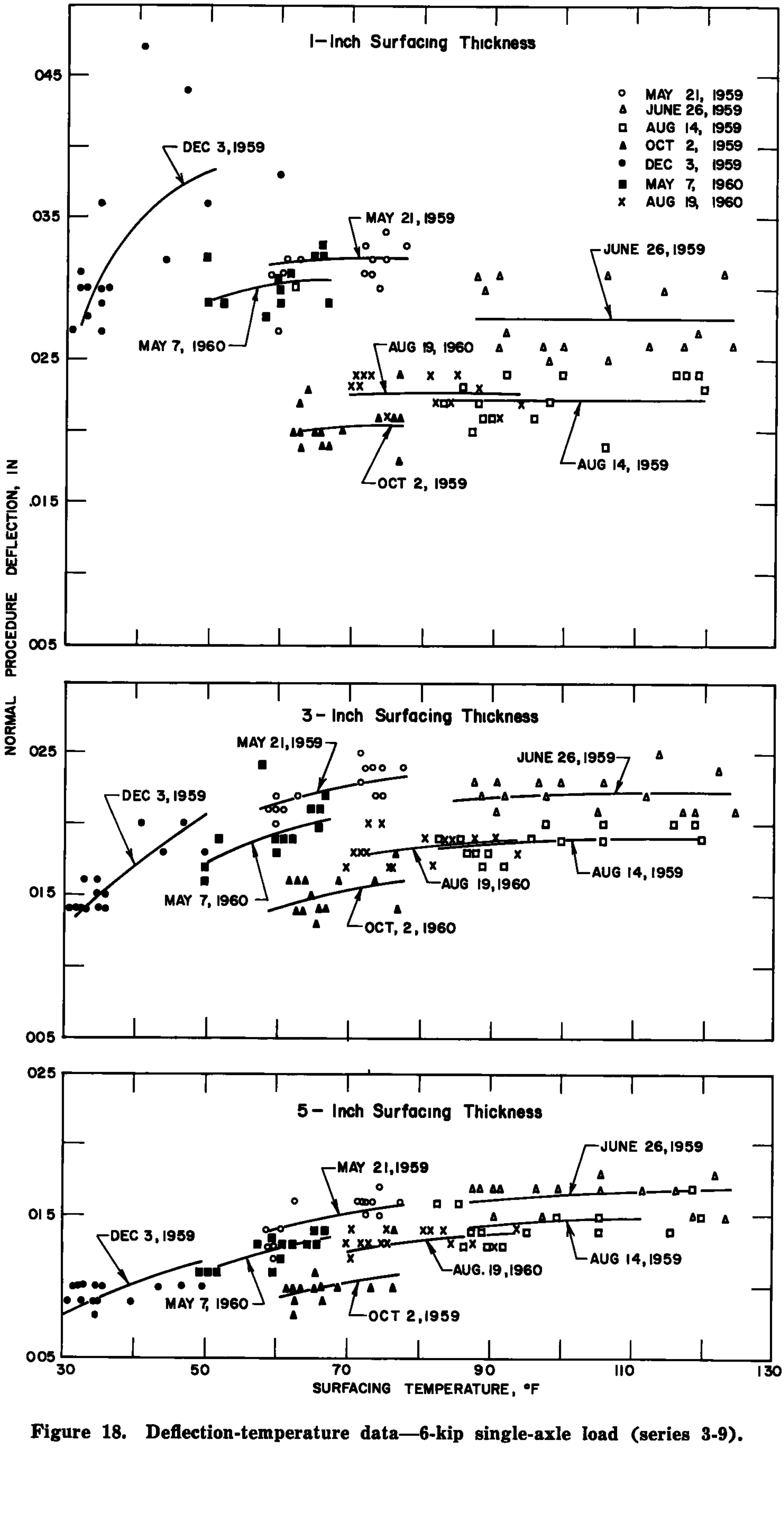

Figure 18. Deflection-temperature data—6-kip single-axle load (series 3-9).

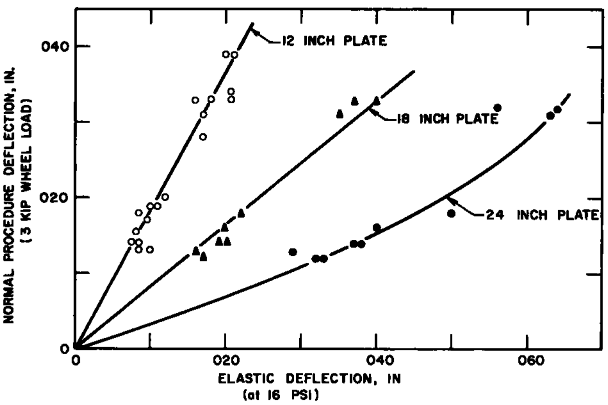

Figure 19. Relationship between Benkelman beam and plate load deflections.

Figure 19 shows the relationship for various plate sizes and a unit load of 16 psi on the plates (the elastic deflection values for the 24-in. plate at 16 psi were interpolated). The beam deflection data are the mean deflection values for the measurements taken in the outer and inner wheelpaths and between the wheelpaths. It is evident that within the range of test data the relationships are practically linear for 12- and 18-in. diameter plates and slightly curvilinear for the 24-in. plate. No satisfactory explanation was found for the curvilinearity existing for the 24-in. plate.

Figure 20 shows the same beam deflection and elastic plate deflection data for various unit loads on a 12-in. diameter plate. If the assumption is made that the stresses in the pavement and subgrade can be similar for the 12-in. plate and pneumatic tire, a linear relationship between beam and elastic plate deflections would indicate that the beam measures primarily an elastic deflection. The relationships in Figure 20 suggest the beam deflections were elastic for this study.

Elastic plate deflections may be summarized by the elastic modulus k_E described previously. These data were correlated with the Benkelman beam deflection data using linear regression techniques and the following mathematical model:

$$k_E = \frac{A_0}{d^{A_1}} \tag{3}$$

in which

k_E = elastic modulus, in pci;
d = Benkelman beam deflection using the normal procedure, in in.;
$A_0 A_1$ = empirical constants computed from the analysis.

This model may be linearized as

$$\log k_E = \log A_0 + A_1 \log d \tag{3a}$$

Constants A_0, A_1 and correlation coefficient (r^2) were determined by a regression analysis. The resulting equations are as follows:

For the 12-in. plate:

$$k_E = \frac{32.7}{d^{0.957}} \qquad r^2 = 0.99 \tag{4}$$

For the 18-in. plate:

$$k_E = \frac{22.1}{d^{0.886}} \qquad r^2 = 0.94 \tag{5}$$

For the 24-in. plate:

$$k_E = \frac{25.2}{d^{0.688}} \qquad r^2 = 0.95 \tag{6}$$

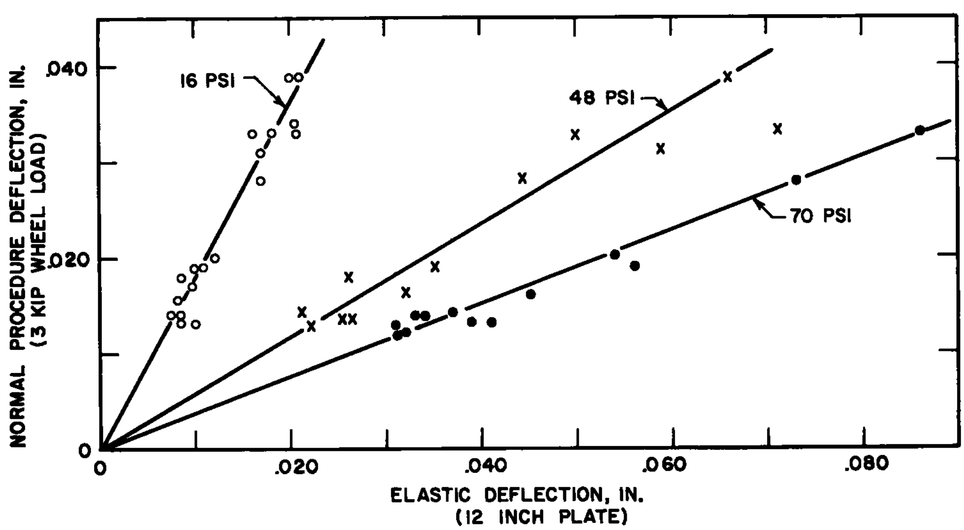

Figure 20. Relationship between Benkelman beam and plate load deflections.

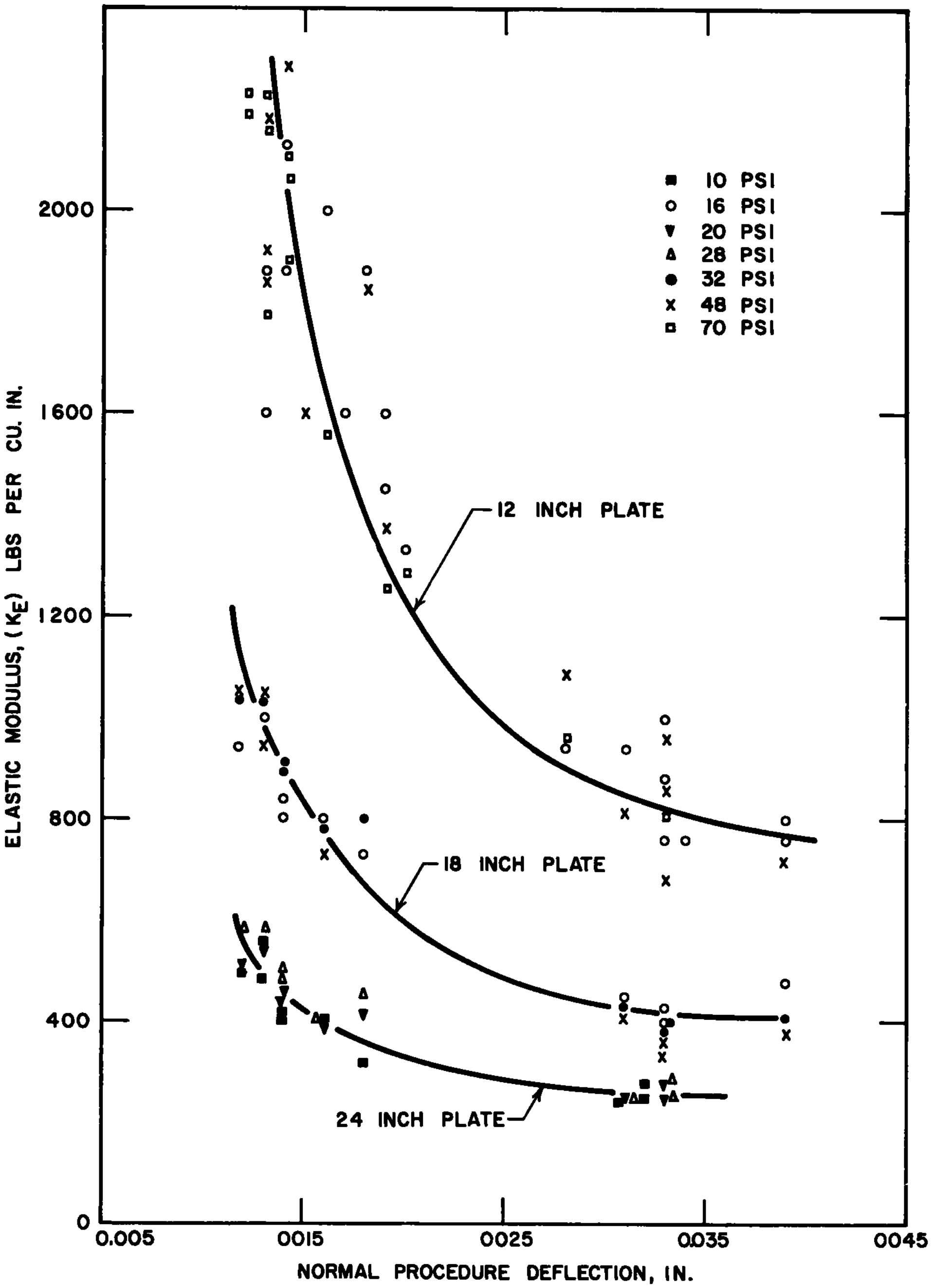

Figure 21. Relationship between elastic modulus and Benkelman beam deflection for pavement surface tests.

These relationships are plotted in Figure 21 together with the data to show how well the equations fit the data. Good agreements are evident.

The correlations between plate load test data and beam deflections clearly show the beam test to be the equivalent of a plate bearing test for the strength testing of highway pavements. The beam's ease of operation and quick provision of test data make it the preferred test for most occasions.

SUMMARY

1. Four series of special tests were conducted at the AASHO Road Test to determine if any measurement error in the Benkelman beam pavement deflection data was due to the procedures employed. Pavement deflections between the dual tires of a loaded test vehicle were measured using two different testing procedures. The first procedure, termed the normal procedure, was developed at the WASHO Road Test. The probe arm of the

beam was inserted a distance of about 4½ ft so that the distance from the probe point to the legs of the reference beam was halved. For the second procedure, termed the rebound procedure, the probe arm was inserted between the dual wheels to a distance of only 1 ft or 1½ ft. Comparisons of the measurement data from the two procedures indicate for the fall of 1959 that the normal procedure values were consistently higher than the rebound-procedure values. Differences of the order of 0.003 to 0.006 inches were being recorded depending upon the axle load. These differences suggest that some measurement error resulted from the front support legs of the datum beam being in the deflection basin at the start of the test when the normal procedure was employed.

2. During spring 1959, a comprehensive study was carried out to determine what correlation existed between pavement deflection measurements made with the Benkelman beam using the rebound procedure and those made with the electronic LVDT equipment at creep speed (center line of the dual wheels directly over the LVDT). Sections in Loops 2, 4, 5, and 6 were tested with 6-, 18-, 22.4- and 30-kip axle loads, respectively. A comparison of the two methods of measurement indicated that the LVDT measurements underestimated the beam deflection measurements. Data from other studies indicated that the differences may be accounted for by slight movements of the reference plates and a reduction in pavement deflection from 0 to 2 mph.

3. By varying the transverse placement of the dual wheels in spring 1959 creep-speed LVDT deflection study, data were obtained concerning the magnitude of the difference between the deflection directly under the tire and the deflection between the dual tires. The differences were in the order of 0.006 in. for the 18-kip single-axle load.

4. Four series of special tests were carried out on Loops 4 and 6 to investigate the relationship of pavement deflection to wheel load. The results of the analysis indicated that the rate of increase of deflection with load decreased as the load was increased.

5. Three series of special tests were carried out to determine the influence of vehicle speed on pavement deflection. The results of tests conducted on Loops 4 and 6 are represented by equations for each wheel load considered. Appreciable reduction in the order of 40 to 50 percent in the pavement deflection was evident with an increase in speed from 2 to 35 mph. No effect of pavement design was noted for the small range in pavement designs considered.

6. Pavement deflections were measured for tire pressures ranging from 23 psi to 130 psi with various sizes and types of tires. No consistent change in pavement deflection was evident.

7. Extensive testing over 24-hr periods was conducted on the traffic and no-traffic loops to determine the influence of pavement temperature on deflection. The results of this study indicated a most pronounced change in pavement deflection with changes in pavement temperature from 30 F through 50 F. Above 80 F the pavement deflection was practically constant. In addition, for each surfacing thickness the change in deflection per degree change in temperature appeared to be independent of the level of deflection.

8. From the subsurface study in the no-traffic loop it was possible to compare normal procedure Benkelman beam deflection data with elastic plate load test data. A strong relationship was found when data from the two tests were compared, indicating that the Benkelman beam deflection test may be considered a strength test equivalent to the plate bearing test for highway pavements. The results of the analysis are summarized by an equation having different empirical constants for each plate size.

ACKNOWLEDGMENTS

These studies were carried out as part of the research at the AASHO Road Test. The authors wish to acknowledge the contributions of all those who were connected with various phases of the investigations, particularly guidance given by Fred Finn, work in the field by Lloyd Dixon, the helpful assistance in the analysis by Harold Schmitt and the preparation of the preprints by the staff of W. E. Chastain.

Appendix A

MATHEMATICAL ANALYSIS OF PAVEMENT DEFLECTION-PAVEMENT TEMPERATURE DATA

Preliminary analyses fitted linear curves by regression techniques to the pavement deflection-temperature data for each surfacing thickness and series. The slopes for each surfacing thickness data and series are given in Table 10. The slopes decrease as temperature increases. The sequence of the dates or the magnitude of the deflection does not appear to affect the relationship as evidenced by the May 1959 series and the December 1959 series. These slope data were analyzed for each surfacing thickness datum using the following mathematical model:

TABLE 10

Series No.	Date	Mean Temp.	1-In Surf Slope	3-In. Surf. Slope	5-In. Surf. Slope
8	May 1960	37	+0.678	+0.311	+0.030
5	Aug. 1959	60	+0.088	+0.214	+0.160
7	Dec 1959	67	+0 039	+0.081	+0 149
3	May 1959	68	+0.024	+0.164	+0 180
6	Oct. 1959	79	−0.045	+0 029	+0.024
9	Aug. 1960	100	+0.060	+0 059	+0.043
4	July 1959	104	−0.026	−0.004	0.000

$$\log S = \log A_0 + A_1 (t - 32) \qquad (7)$$

in which

S = the slope of the pavement deflection-temperature relationship for each series;

t = the mean temperature for each series;

A_0 and A_1 = constants determined from the analysis.

The resulting computed relationships are shown in Figure 22. In addition, the observed data are plotted to show how well the data fit the relationships. The constants for A_0 and A_1 determined from the analyses are as follows:

Surface Thickness	A_0	A_1
1 in.	1.32	−0.045
3 in.	0.583	−0.020
5 in.	0.190	−0.007

It is apparent from the reduction in constants A_0 and A_1 with increase in surfacing thickness that pavement design played a part in determining the reduction in pavement deflection with decreases in pavement temperature.

The resulting equations were integrated to obtain equations for pavement deflection in terms of pavement temperature. The resulting equations, in which C is the constant of integration, are as follows:

For 1-in. surfacing:

$$C - d = \frac{1.32\ (10)^{-0.015\ (t - 32)}}{0.045\ (\log_e 10)} \qquad (8)$$

For 3-in. surfacing:

$$C - d = \frac{0.583\ (10)^{-0.020\ (t - 32)}}{0.020\ (\log_e 10)} \qquad (9)$$

For 5-in. surfacing:

$$C - d = \frac{0.190\ (10)^{-0.007\ (t - 32)}}{0.190\ (\log_e 10)} \qquad (10)$$

Thus, for any temperature range the curvature of the deflection- temperature relationship may be found. The curves plotted in Figure 18 are fitted through the mean pavement deflection for each series

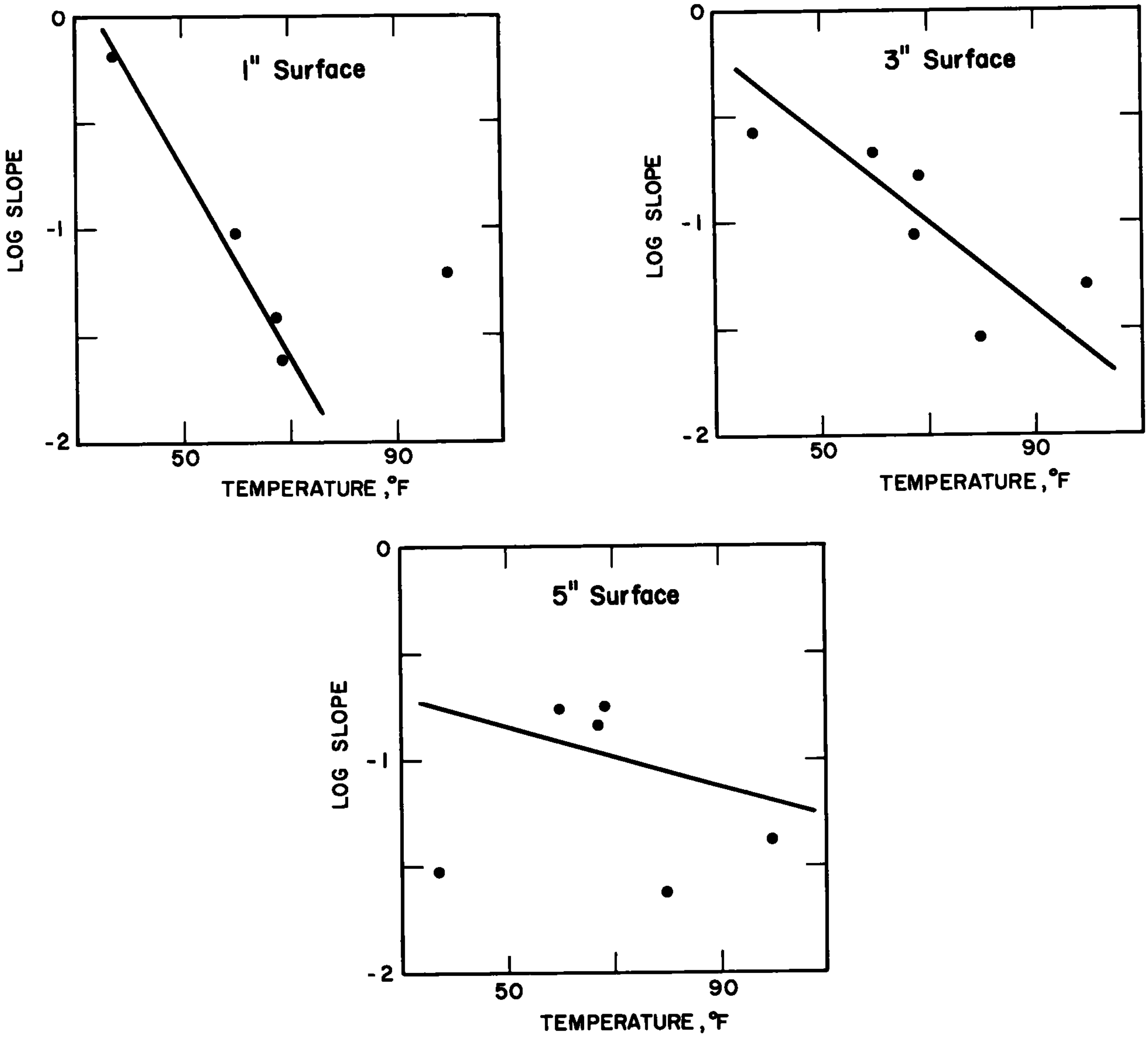

Figure 22. Computed relationships for Loop 1, deflection-temperature data.

Appendix B

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DISCUSSION

C. R. Keshava Rao, Banaras Hindu University, India.—I suppose that probably the normal expectation would be that higher tire pressures would produce higher bridge deflections. You carried from 35 to 130 psi. Would you say there is conclusive evidence regarding higher bridge deflections when tire pressures of 200 or 300 psi are used?

Kingham.—Our experiments considered a maximum tire pressure of 130 psi using a nonconventional wire-cord tire. For the studies discussed in this paper, deflection measurements were made on flexible pavements only and not on bridges. These experiments produced no data concerning the effect of increasing tire pressures to 200 or 300 psi on pavement deflections or on bridge deflections.

As tire pressure is increased one would expect the contact area between tire and pavement to decrease. D. M. Burmister (*HRB Proc.* 23:126-149, 1943) showed that the pavement deflection of a two-layer system using a flexible bearing area is a function of the contact pressure p, the radius of the plate r, the modulus of elasticity of the bottom layer or subgrade E_2, and a settlement coefficient F according to the following relationship:

$$d = \frac{1.5\,p\,r}{E_2}F = \frac{1.5\,P}{\pi\,r\,E_2}F$$

where P = the total load. As the contact area is decreased the r term will tend to increase the pavement deflection. However, a decrease in r will increase the ratio of top layer thickness to the plate radius, resulting in a decrease of the settlement coefficient F. These opposing actions tend to compensate for one another and may explain why a change in tire pressure had little effect on the pavement deflection in the experiments.

Keshava Rao.—So your conclusions regarding tire pressure and deflection are based only on the observations made so far.

Kingham.—For the tire pressures and tire sizes used no relationship was found between pavement deflection and tire pressure. Certainly one cannot conclude from these data that this trend will continue for the very much higher tire pressures of 200 to 300 psi.

R. A. Crawford, South Dakota Department of Highways.—Our South Dakota data for wheel load and deflection show a curve, but it is concave upward and yours is concave downward. Can we assume, as Francis Hveem says, that this is a linear relationship?

Kingham.—The data in Figure 12, where wheel loads as heavy as 34 kips were used, show the relationship between wheel load and pavement deflection to be slightly curvilinear (concave downwards). Curves fitted by regression analyses indicated the same curvilinearity. However, if a linear assumption is made very little difference in the values obtained by interpolation would result. Therefore, if one lacks load deflection information for a particular truck and pavement, a linear assumption would appear to be reasonable within the range of loads and pavement designs used at the Road Test.

R. G. Mitchell, Connecticut State Highway Department.—I noticed that you had higher deflections with the small scraper than you did with the medium scraper. I wonder if the names have been interchanged?

Kingham.—For equivalent wheel loads the small sized scraper did produce higher pavement deflections than the medium sized scraper. Perhaps tire sizes could account for the differences in deflection.

J. B. Bidwell, General Motors Research.—From the viewpoint of tire pressure, and also plate loading deflection, if a road is considered a semi-infinite surface and the plate (loaded) area is fairly large with respect to the total area affected, the deflections can be considered as being due essentially to a concentrated load. If the effects of this bearing plate example are analyzed—that is, the deflection is simply correlated with the total load on the plate—the three curves shown will be essentially one. If a very large area is affected by these loads, the load can be considered as essentially a concentrated one. This is why tire pressure has little effect on deflection. This does not mean that

the maximum stresses are the same, but simply that the deflection measured in this large area probably is not changed.

Louis Marick, United States Rubber Company.—Did you make the direct comparison of a single replacing the dual, using equivalent loads?

Kingham.—For the conventional equipment used on the various loops during the traffic phase of the Road Test we did not replace a dual combination with a single tire.

Marick.—Would you expect any differences there with the total load on the single being the same as the total load on the dual?

Kingham.—During the planning stage of the 1961 special studies, a pilot deflection study was conducted using the low-pressure, low-silhouette tires on a military M52 truck and trailer combination in addition to conventional equipment with dual-tire combinations. Tire pressures for the study ranged from 23 to 70 psi which, of course, was accompanied by a tire design change. The low-pressure tires caused slightly greater deflections than did the higher-pressure tires. This small study was the only study where the deflection under a single tire was compared to that for a dual-tire combination. No studies were conducted using one test vehicle where a dual combination was replaced by a single tire.

H. M. Bixby, Agency for International Development.—I wonder if the curvilinear relationship which was downward, but in South Dakota upward, might not have been the result of your performing the tests on the thicker or surviving sections. Could curvilinear relationship be the result of consolidation of the base course or the subbase layer?

Kingham.—Does your question refer to the relationship developed in South Dakota or our relationship? For our relationship, I do not believe the curvilinearity was due to any consolidation in the base or subbase courses. All the test sections used had experienced a substantial amount of test traffic prior to these special tests. A number of the special tests were conducted during the late summer and at that time, in particular, we are reasonably certain that consolidation in the granular layers was negligible.

F. N. Hveen, California Division of Highways.—This comment is on whether or not the shape of the deflection curve is linear or curvilinear. I think one point that has not been mentioned is that it is most probable that the shape is due to the nature of the underlying material. In California deflection studies, we have found one project several miles in length in which every single load-deflection curve was markedly curvilinear downward as was similarly shown here, only to a greater degree. But in the majority of all the measurements we made, even to 30,000-lb wheel loads, the relation was generally linear. So I think in concluding whether or not this pattern is curvilinear downward or straight you have to keep in mind what type of material is underlying the pavement that is supporting the deflection.

Crawford.—In South Dakota we have to write a final report on our research this year, and what I would like to do is report beam-deflection data on a basis of 7,500-lb wheel load. We have done quite a bit of testing at 12,000-lb wheel loads. In the report should we try to convert our 12,000-lb wheel load deflections to 7,500 lb using the linear relationship? Perhaps, we should put in both sets of data.

Kingham.—The state of our knowledge now really is such that we could not very well assume curvilinearity in either direction, if we are forced to interpolate.