Load-Deflection Study of Selected High-Type Flexible Pavement in Maryland

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A cooperative program of load-deflection tests of several high-type flexible pavements in Maryland was inaugurated in the spring of 1955. A single test consisted of the application of a slowly moving 11,200-lb wheel load of a single-axle truck to an arbitrarily selected point on the pavement and the measurement of the resulting pavement deflection and rebound. Measurements were made at a point between the dual tires by means of the pavement-deflection indicator known as the Benkelman Beam. Tests were made in the spring and in the fall at approximately 1,000 marked locations over a distance of about 85 lane miles. The pavements tested range in age from two to eleven years and are in excellent condition.

This report contains a description of the pavements studied, the test procedure used, and the results of the tests conducted to date.

● A LIMITED PROGRAM of structural tests of several high-type flexible pavements in service was initiated in early 1955. The program is a cooperative effort of the Maryland State Roads Commission and the U. S. Bureau of Public Roads. Basically the purpose of this study is to gain further knowledge of the structural behavior of nonrigid pavements and to ascertain whether maximum deflection might be considered as a measure of their adequacy.

The study consists essentially of a series of load-deflection tests in the spring and fall of each year and an attempt to correlate the data obtained with some of the variables known to affect pavement behavior. A single load-deflection test generally consists of the application of a slowly moving 11,200-lb wheel load to the pavement and measurement of the resulting maximum deflection and rebound or recovery.

A brief account of this study and the highlights of the findings after the first year of observations are included as a part of a previous paper (1). In view of the fact that the investigation is a continuing one, this paper is simply a progress report of the work done to date. However, since there is little previously published information regarding tests of the type described herein, an account of the more important factors that were considered and a fairly detailed description of the manner in which the tests are being conducted will be included.

Three of the four pavements under study are located in Carroll, Frederick, Washington, and Montgomery Counties in the central part of the state; the fourth is in Queen Annes County on the Eastern Shore. All are high-type flexible pavements of modern design with 12-ft lanes. They were constructed on new location on important routes and all are in excellent condition.

To obtain an indication of the effect on pavement deflection of changes in the condition of the pavement structure and subgrade caused by seasonal changes, tests were conducted at two periods during the year. It was planned to select a period in the spring when conditions were at their worst, and in the fall when conditions were good. Selection of the most desirable test periods was based on visual observation of pavements in the area and on personal judgment. Thus far, four series of tests have been completed. These were made during the following periods:

1. Late March and early April 1955.
2. Mid-November 1955.
3. Early April 1956.
4. Mid-November 1956.

It has been found difficult to estimate in advance the period during which the most adverse conditions will exist and to recognize this period when it comes. As a result, it is believed that the spring test series of both years were made several weeks late.

The device used to measure the vertical movement of the pavement is the lever-type pavement deflection indicator known as the Benkelman Beam. Descriptions of this device and the details of the procedure for using it have been previously published (2). A general view of the test truck with the instruments in position just prior to the beginning of a test is shown in Figure 1. It is sufficient to say here that this is a simple and inexpensive device that measures the deflection at the pavement surface of a point between the rear dual tires of a truck moving at creep speed as well as the rebound or recovery of the pavement after the wheel has passed.

The final or recovery measurement was made after the load had passed well beyond the point where it might affect the instrument and after observation of the micrometer dial indicator showed no further movement of the pavement. The difference between the deflection and recovery measurements is referred to as the residual.

The organization of the field party for conducting tests of this nature is quite simple. Assuming that the test sites and points have been selected and marked in advance and that one truck and two deflection indicators will be used, the party might consist of a recorder, two instru-

Figure 1. Deflection indicators in position at beginning of test.

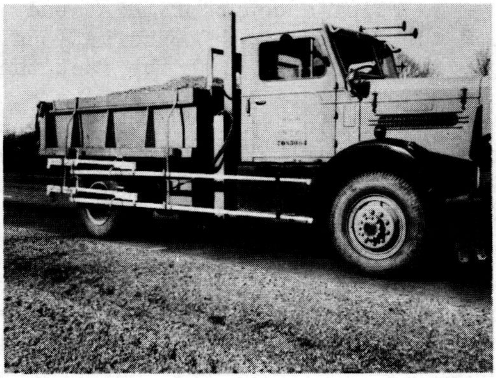


Figure 2. Deflection indicators in carrying position.

ment operators, two flagmen, and a truck driver. The recorder may act as party chief. All personnel can be trained within a day to perform their jobs and to work as a team. The most important characteristic required of the party chief and instrument operators is their sense of responsibility. They must realize that they are working with a precise instrument and that care must be exercised in order to obtain accurate results.

The vehicle used to apply the test load for the tests in the central part of the state was a two-axle, dual-tired dump truck. For the first series of tests (spring 1955) two such trucks were used, one having a 7,000-lb wheel load, the other having an 11,200-lb wheel load, the latter being the legal load limit in Maryland. The remaining three test series were made with the 11,200-lb load only. The desired wheel load was obtained by loading the truck with crusher-run stone and weighing on either platform or loadometer scales. Tire equipment consisted of 10.00 x 20 tires inflated to 80 psi. The truck used for the tests on the Eastern Shore was of the same general type as the others and was equipped with 11.00 x 20 tires.

It has been found that the best way to transport the deflection indicators is on the right side of the test truck. Specially designed, removable metal brackets fastened to the truck body were used for this purpose (Fig. 2).

Because for each test the probe arm of the deflection indicator was routinely placed between the two tires of a dual-tired wheel, the space available between the tires is of importance. The device must be placed in position so that as the vehicle moves forward the lever arm is not touched by either tire. The device is aligned by eye. The minimum space

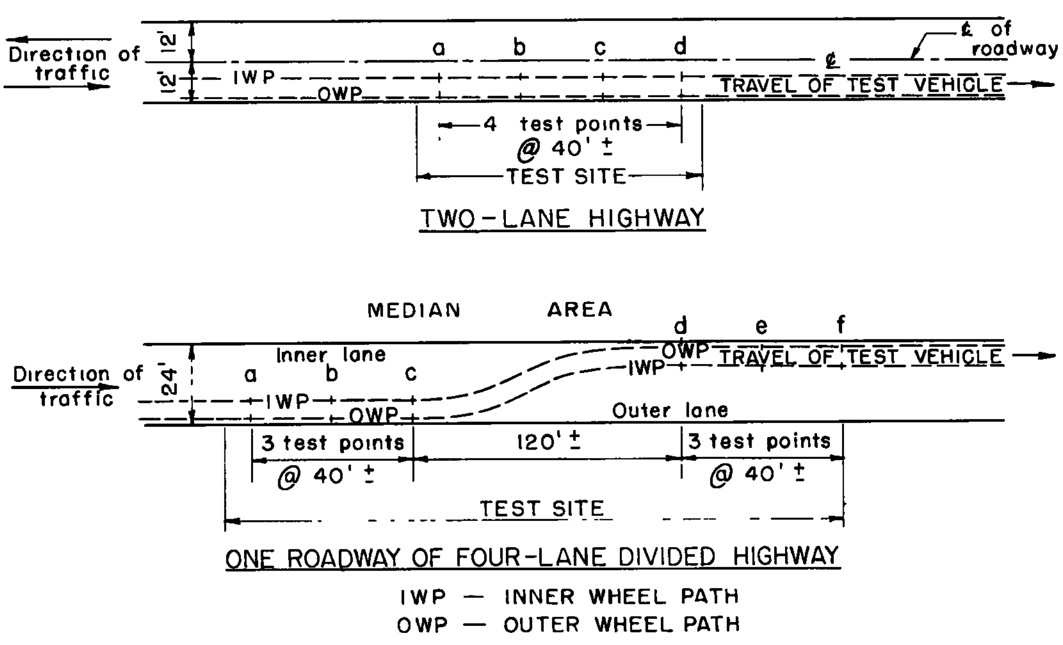


Figure 3. General layout of test site, showing testing procedure on the two highway types.

between tires on the trucks used for these tests was $1\frac{1}{2}$ in., whereas the minimum distance between contact areas was 4 1/8 in.

It has been found by experience that this is about the minimum space desirable, although studies to determine the effect of increasing the space between dual tires on deflection of the pavement have not been made. It has been noticed, however, that for certain pavements and under certain conditions there can be a tendency for the surface material to squeeze upward between the contact areas of the tires. For this reason, the distance between contact areas may have some significance and therefore should be kept to a reasonable maximum of about 5 in.

The scope and extent of the study was determined by the anticipated availability of the personnel and equipment required to make the field tests. Initially, portions of the three pavements in the central part of the state totaling 45 mi in length were selected. It was decided to allow a period of two weeks for completion of a test series. Previous experience with similar tests elsewhere made it possible to estimate the time required to complete a given number of tests over a known length of pavement.

Test sites were selected at random intervals averaging about $\frac{1}{4}$ mi along each of the pavements tested. The intervals range from a minimum of 0.1 mi to almost 1 mi, the chief consideration in the selection of the individual test sites being that of safety. It is essential that drivers of vehicles approaching the halted test truck have adequate sight distance and ample warning from the flagman. For this reason sites on or near horizontal or vertical curves were usually avoided. Other factors that should be taken into consideration are pavement condition, pavement design, type of subgrade soil, construction methods, grade line location, culverts and bridges, and drainage.

On the three pavements in the central part of the state, 171 test sites were selected. The layout of individual test points for the two highway types studied is shown in Figure 3. On two-lane highways four tests at approximately 40-ft intervals were made in one lane only; on four-lane divided highways, three tests at this interval were made in each of the two lanes of one roadway. All test points were marked with paint so that tests of all test series could be repeated at exactly the same spots. Two deflection indicators were used so that tests could be made in both the inner wheel path (IWP) and outer wheel path (OWP) simultaneously.

In the fall of 1955 initial tests were made on the fourth pavement included in the study. This added 10 mi of pavement and 38 test sites to the 45 mi and 171 sites previously mentioned, making a total of 55 mi and 209 sites. Because tests were made in both lanes of one roadway of the divided highways, it is apparent that approximately 85 lane-miles of pavement were studied. The average rate of progress for the entire study has been the measurement of 48 deflections at 24 points representing six test sites per hour.

Previous studies have shown that the location of the wheel load with respect to the pavement edge has a significant effect on the magnitude of the deflection. Also it was considered desirable to repeat each series of tests at the same points on the pavement, within practical limits. For these reasons it was decided to attempt to make all tests with the outside of the outside rear tire 3 to 6 in. from the pavement edge. This placed the centerline of the outer and inner rear wheels about 1.5 and 7.5 ft, respectively, from the edge of the pavement. This distance was selected because it places the outside wheel at or near the most critical location on the pavement.

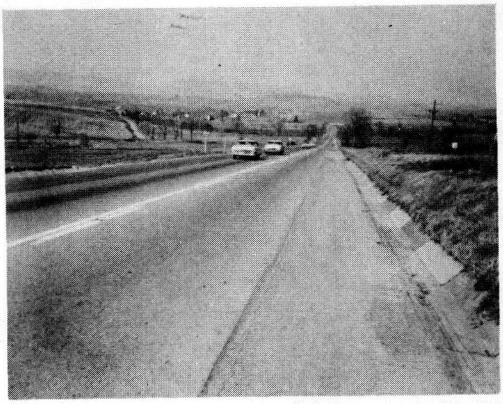
The sections of pavement selected for this study are as follows:

1. Westbound lane of the 16.5-mi long section of US 40 west of Frederick between its intersection with US 40 (Alternate) and Hagerstown.

2. Eastbound lanes of US 40 east of Frederick, from the Monocacy River to the vicinity of Ridgeville, a distance of 12 mi.

3. Southbound lanes of the 16-mi long section of US 240 south of Frederick between the US 15 and State Route 118 interchanges.

4. Northbound lane of the portion of the Blue Star Memorial Highway, 10 mi in length, between State Routes 305 and 300 northeast of Centreville. For the sake of simplicity these four pavement sections are referred to as US 40W, US40E, US 240S, and Blue Star, respectively.



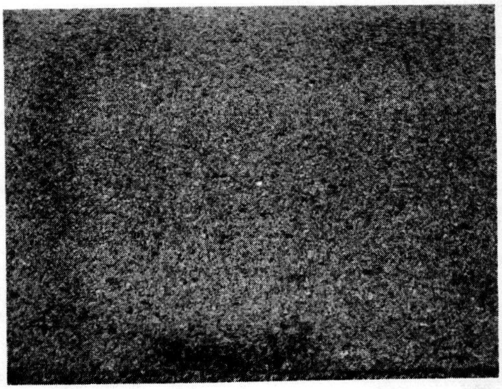


Figure 4. General view of roadway (upper), and detail of typical pavement surface (lower) - US 40W.

US 40W is a two-lane highway located in mountainous terrain with maximum grades of 8 percent. A general view and a close-up of the pavement surface are shown in Figure 4. It was constructed on a relocation of the old route, the grading for which had been completed a number of years earlier, and was opened to traffic about eleven years ago. A soil survey of the new grade was made just prior to construction of the flexible pavement structure. It was found that about 80 percent of the material at the subgrade level is A-5 soil consisting of silt, hard or soft shale, and decomposed rock, with solid rock at or near the surface at some locations. The remainder is composed, in general, of A-4 and A-7 soils. A cross-section of the pavement structure is shown in the upper part of Figure 5. This design, which is uniform throughout the 16.5-mi length, consists of a 2-in. stone screenings blanket or insulation course, an 8-in. waterbound macadam base course topped by a 4-in. penetration macadam course, and a 3-in. asphaltic concrete surface course, making a total thickness of 17 in.

US 40E is a four-lane divided highway in rolling terrain with a maximum grade of 6 percent, but with much of the pavement on grades of less than 4 percent. A general view of the eastbound roadway and close-up of the present pavement surface are shown in Figure 6. It was planned and built as a stage construction project, the asphaltic concrete surface course having been initially omitted. In its place a temporary surface course consisting of a double-surface treatment about 1 in. in thickness

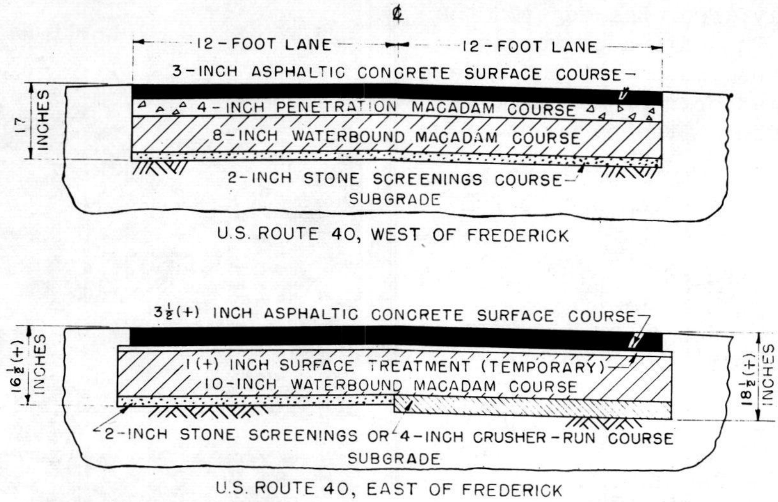


Figure 5. Transverse sections showing components of pavement structure.

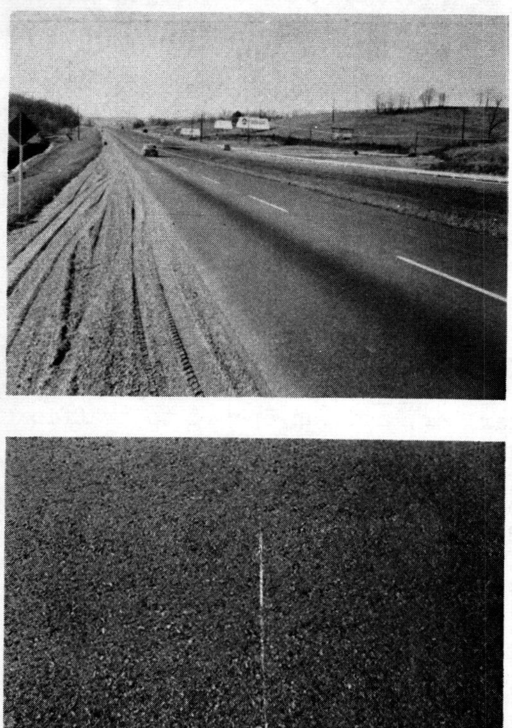


Figure 6. General view of eastbound roadway (upper), and detail of typical pavement surface (lower) - US 40E.

was laid. Early in the life of this uncompleted pavement structure extensive cracking of the surface began to develop and at the time of the first deflection test series (spring 1955) the road was undergoing considerable maintenance. Later in the year, but prior to the fall test series, the asphaltic concrete surface was placed. This surface was about one year old, in January 1957, whereas the remainder of the structure was about two years old. Since placement of the final surface, the performance of this pavement has been excellent. The predominating soils found on this route are an A-5 micaceous silt, decomposed shale and rock, and an A-4 silt. A cross-section of the pavement structure is shown in the lower half of Figure 5. On four of the five sections of this project the 4-in. crusher-run subbase shown to the right of the section centerline was constructed. On the fifth section a 2-in. stone screenings course was placed in lieu of this. The base course on four sections consists of 10 in. of waterbound macadam compacted in one layer by a vibratory method, whereas on the fifth section two 5-in. layers were compacted by rolling. This was first surfaced with a double surface treatment approximately 1 in. thick, and finally with a minimum of $3\frac{1}{2}$ in. of asphaltic concrete.

US 240S is a part of the Washington National Pike between Frederick and Rockville and is a four-lane divided highway. A view of the southbound roadway and a close-up of the pavement surface are shown in Figure 7. It was constructed on new location paralleling the old route and is in undulating topography with maximum grades of 4 percent. The first section was completed in 1952 and the last in 1954. The predominating soil is A-5 micaceous silt and decomposed rock, although a considerable amount of A-4 silt is also found on this route. A section showing the components of the pavement structure is given in the upper half of Figure 8. The part of the pavement located in Montgomery County has a 2-in. stone screenings course between the base course and subgrade, as indicated in the right half of the section. On the remainder of the project this course was omitted. The base course consists of an 8-in. thick-

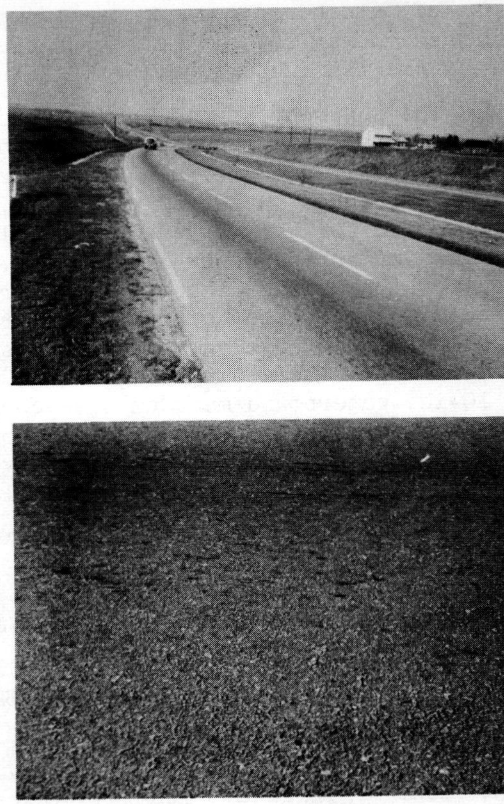


Figure 7. General view of southbound roadway (upper), and detail of typical pavement surface (lower) - US 240S.

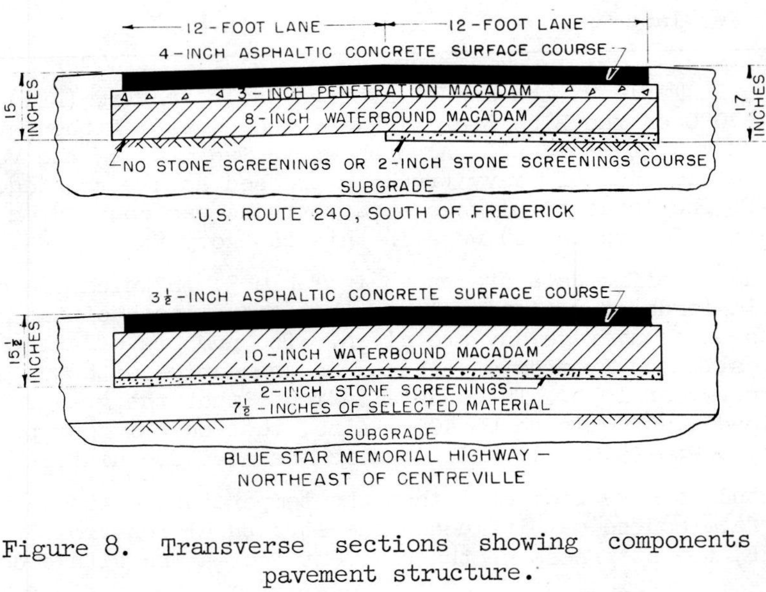


Figure 8. Transverse sections showing components of pavement structure.

ness of waterbound macadam topped with 3 in. of penetration macadam. The surface course is 4 in. of asphaltic concrete, making a total thickness of pavement structure of 15 to 17 in.

The pavement section designated Blue Star is a portion of a new north-south route that connects the Chesapeake Bay Bridge to major routes in Delaware. It was designed as a four-lane divided highway, but only two lanes were constructed at this time. The section under study has been open to traffic for only a year. It is located on comparatively flat terrain, the maximum grade being 1.5 percent. The predominant soil type is an A-4 silt, which exists at about two-thirds of the test sites. At most of the remaining sites the soils are A-2 or A-3 sands and gravel. A typical cross-section of the pavement structure is shown in the lower part of Figure 8. A 2-in. stone screenings course was placed on a 7½-in. layer of select soil. A 10-in. waterbound macadam base course was then constructed and finally surfaced with 3½ in. of asphaltic concrete. The base course material on one-half the project is crushed slag; on the remainder, crushed stone. The structure thickness, excluding the layer of select material, is 15½ in.

For convenience and for the sake of clarity the foregoing general information is summarized in Table 1.

TABLE 1

SUMMARY OF DESCRIPTIVE INFORMATION REGARDING THE FOUR PAVEMENT SECTIONS STUDIED

Pavement Designation	Highway Type	Length, mi	Pavement Thickness, in	Predominant Soil Type	Age, yr	Maximum Grade, %
US 40W	Two-lane	16.5	17	A-5	11	8
US 40E	Four-lane divided	12	16½+ or 18½+	A-5	2	6
US 240S	Four-lane divided	16	15 or 17	A-5	2 to 4	4
Blue Star	Two-lane	10	15½	A-4	1	1.5

As shown in Table 2, the annual average daily traffic (ADT) in 1955 ranged from 3,000 on the Blue Star Highway, the newest of the pavements, to 7,700 on US 40W, the oldest. Also shown in Table 2 are the volumes of commercial vehicles and of heavy trucks expressed as a percentage of the total volume. The largest volume of heavy trucks was counted on US 40E, where 9 percent (585 vehicles) were in this category.

Additional traffic data are shown in Table 3, in which the estimated number of axle loads of various weights that travel each of the four pavement sections on an average day are given. The numbers of axle loads tabulated were estimated from data obtained in connection with the statewide loadometer survey of 1956. These data indicate that the greatest frequency of heavily loaded axles is on US 40E. Also, that on all four pavement sections the 14,000-to-15,999-lb axle load is the most frequent.

Other studies have indicated that the temperature of the asphaltic concrete surface course may influence the structural behavior of a flexible pavement, the stiffness of the pavement increasing with a decrease

TABLE 2

SUMMARY OF TRAFFIC DATA, 1955

Pavement Designation	Annual Average Daily Traffic[a]	Percentage of Total Traffic	
		Commercial Vehicles	Heavy Trucks[b]
US 40W	7,700	15	5
US 40E	6,500	19	9
US 240S	4,900	12	4
Blue Star	3,000	20	3

a All lanes, both directions.
b 5 tons or more.

TABLE 3

ESTIMATED NUMBER OF AXLE LOADS OF VARIOUS RANGES IN MAGNITUDE FOR AN AVERAGE DAY IN 1956

Range in Axle Load, lb	Axle Loads			
	US 40W	US 40E	US 240S	Blue Star
12,000 - 13,999	136	240	81	47
14,000 - 15,999	176	300	103	63
16,000 - 17,999	167	293	99	58
18,000 - 19,999	128	227	77	44
20,000 - 21,999	64	116	45	28
22,000 and over	41	74	30	18

in temperature. However, the relation between the deflection of a pavement of this type and the temperature of its surface course for a given condition of loading has not been established. In the present studies, as a matter of general interest, air and pavement temperature were measured in the morning, at noon, and in the evening of each test day. Pavement temperatures were measured with a mercury thermometer inserted in an oil-filled hole in the pavement surface. The hole, approximately $\frac{1}{4}$ in. in diameter and $1\frac{1}{2}$ in. deep, was located about $1\frac{1}{2}$ ft from the pavement edge.

A summary of the pavement temperature measurements obtained during the four test periods is given in Table 4. These data indicate that:

TABLE 4

SUMMARY OF PAVEMENT TEMPERATURE RANGES FOR EACH TEST SERIES

Pavement Designation	Pavement Temperature Range, F			
	1955		1956	
	Spring	Fall	Spring	Fall
US 40W	58-90	38-67	58-96	38-71
US 40E	33-67	44-62	61-89	39-59
US 240S	40-92	45-76	55-91	45-78
Blue Star	-	36-54	48-78	40-59

1. For any one pavement section and test series there was a temperature variation from about 20 to as much as 50 F.

2. Temperatures were generally about 10 to 20 F less in the spring of 1955 than in the spring of 1956, whereas those of the two fall test series were about the same.

3. Temperatures during the fall tests were generally 10 to 20 F less than those of the spring tests.

Plots of typical deflection data obtained on the four pavement sections are shown in Figures 9 through 14, the maximum deflection values in the upper and the residual values in the lower part of each figure. Each plotted value is the average of the three or four individual measurements at each test site. The test sites are plotted at equal intervals along the abscissa, although actually they are located at irregular intervals along the pavements as explained earlier. The lines connecting the plotted points have no particular significance, but were drawn merely to emphasize the relative values of the points and the trends that might be indicated. All figures show deflections for an 11,200-lb wheel load and for all test series completed to date, with the exception of Figure 11, which is for the 7,000-lb wheel load used in the first test series only.

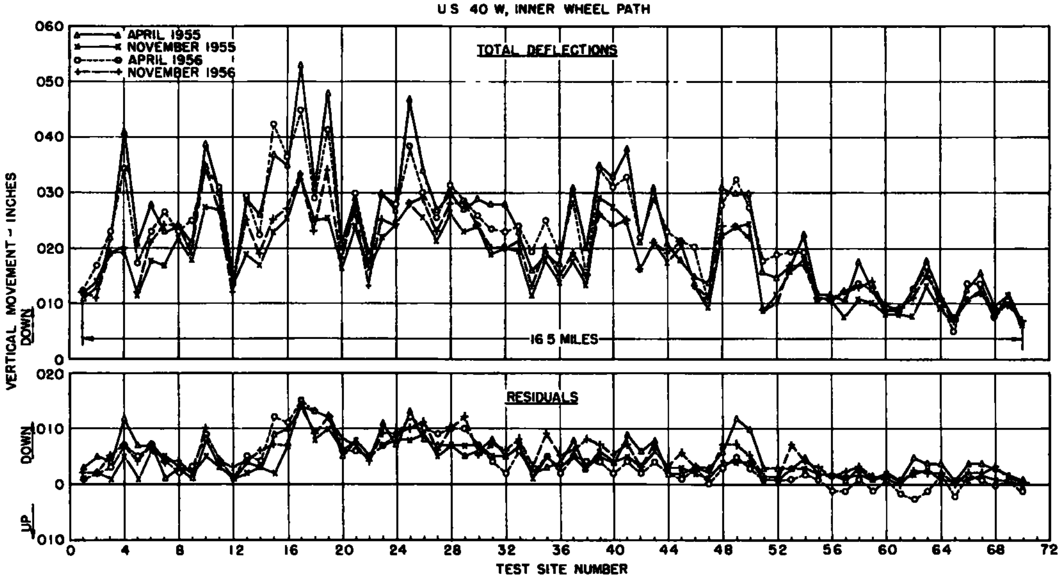


Figure 9. Average deflection and residual values at each test site for the various test periods - 11,200-lb wheel load.

Figures 9, 10 and 11 show all of the data obtained on US 40W in both wheel paths. Figures 9 and 10 are for an 11,200-lb and Figure 11 for a 7,000-lb wheel load. However, because the trends discussed are the same for either lane and either wheel path, the detailed data of the remaining three pavements are presented in Figures 12, 13 and 14 for the outer wheel path of the outer lane only. This is done for the sake of brevity and to avoid repetition.

Several general observations of the data contained in Figures 9 through 14 that are characteristic of the results obtained on all four pavement sections may be made, as follows:

1. For any one test series the deflection and residual values vary markedly from site to site.

2. Where the deflection value is relatively large or relatively small with respect to those of other sites for one test series, it generally remains so for the other test series. This is true also of the residual values, although the data for these are more erratic.

3. Values of deflection obtained in November are appreciably less than those measured in spring.

4. The residual values tend to vary directly as the deflection values.

5. Residual values are larger than might be expected.

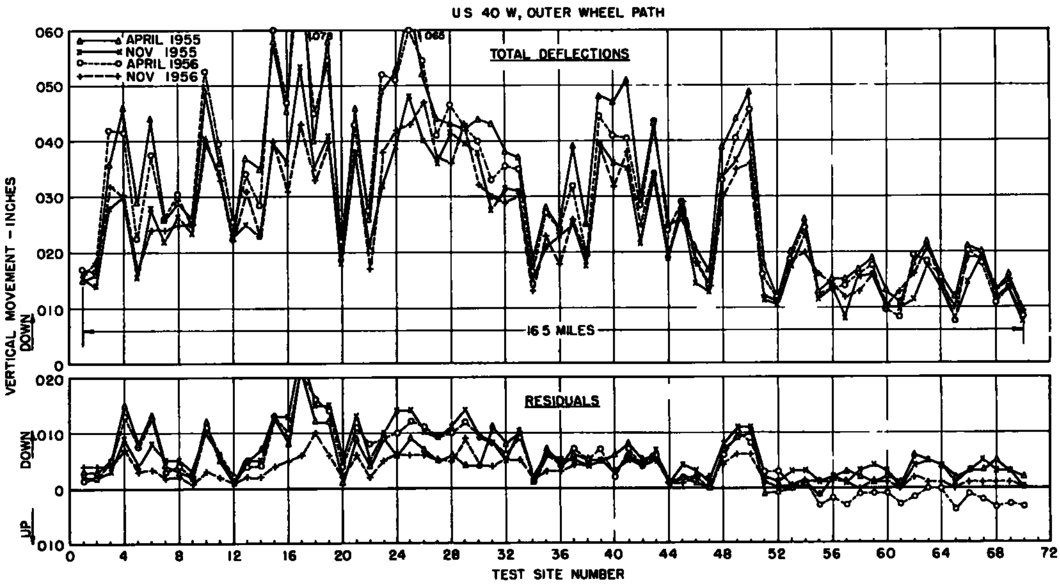


Figure 10. Average deflection and residual values at each test site for the various test periods - 11,200-lb wheel load.

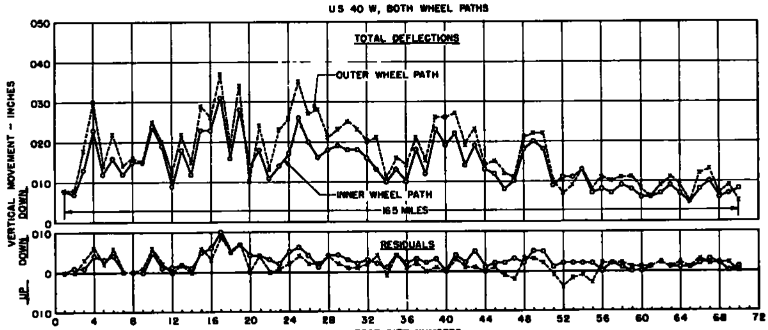


Figure 11. Average deflection and residual values at each test site in the spring of 1955 - 7,000-lb wheel load.

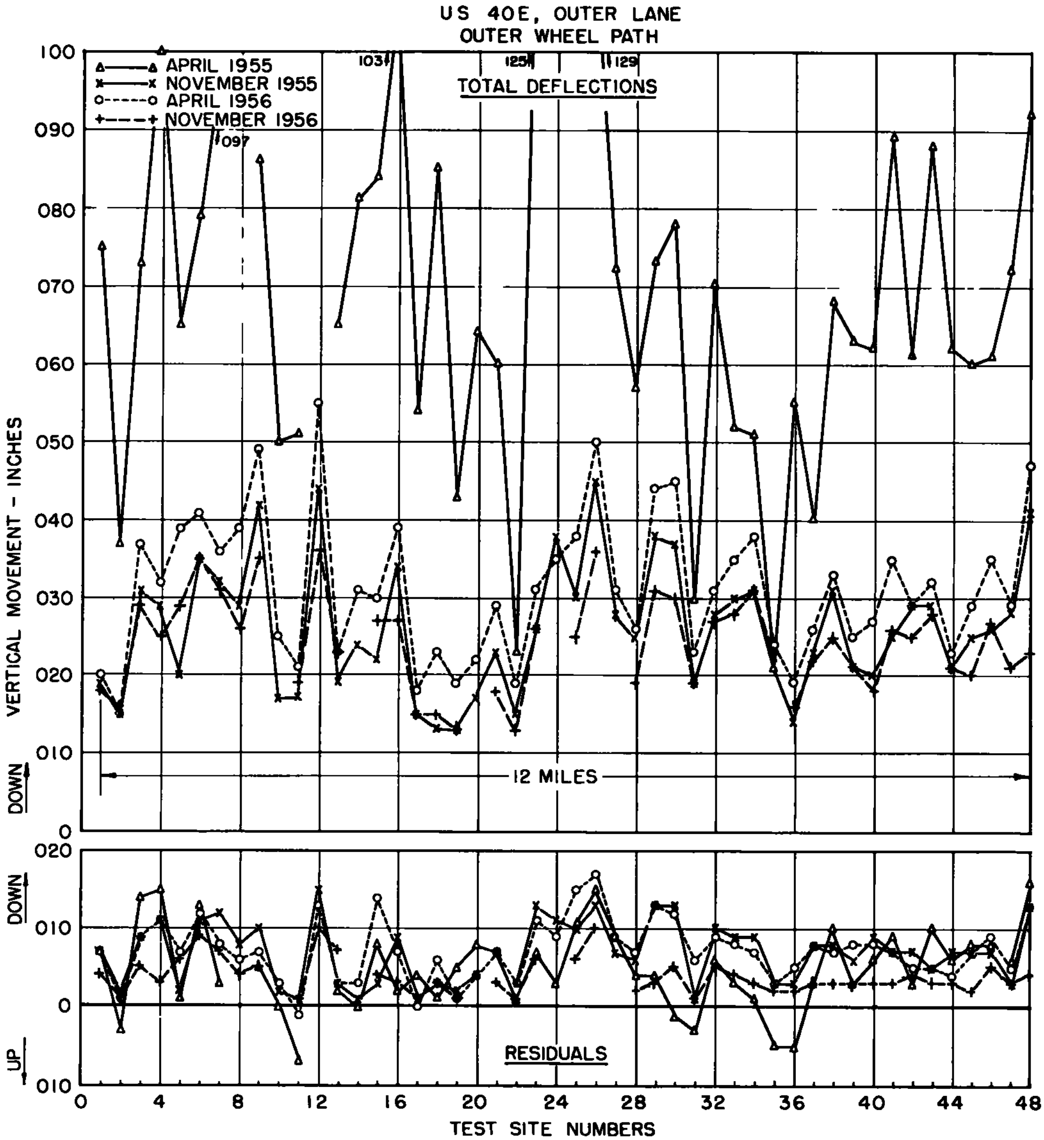


Figure 12. Average deflection and residual values at each test site for the various test periods - 11,200-lb wheel load.

The reason for the large variations in deflection and residual values from one location to another has not been determined thus far in the study. Attempts to correlate pavement deflection with the type and nature of the subgrade soil, as determined by surveys conducted prior to construction, have not been successful. Also, careful visual inspection of the pavement surface at locations where deflection values are comparatively large has resulted in no explanation for this behavior, except in the case of the spring tests on US 40E, where surface cracking was evident. However, it is known that large variations of this sort are typical of data previously obtained on other flexible pavement by the same methods (3). This has also been found on similar tests conducted in several other states, the results of which have not been published.

Except for the first test series on US 40E, the average residual values in the various wheel paths for all test series on the four projects range from 7 to 29 percent of the corresponding average deflection values. However, in most cases these percentage values lie between 15 and 25.

A comparison of the data in Figures 9 and 10 shows that although the deflection and residual values are appreciably larger in the outer wheel path, the variations from site to site are generally the same. Also, a comparison of the values of either wheel path for the four test series discloses that those of the two fall test series are of about equal magnitude. This is not as true of the two spring series, where those of 1955 are, in general, somewhat the larger. In the inner wheel path the relations between the residuals for the various test series are quite erratic. However, in the outer wheel path those of the first test series (April 1955) are the largest and those of the fourth series are the smallest.

The data for both wheel paths of US 40W obtained with the 7,000-lb wheel loading are shown in Figure 11. Comparison of Figure 11 with Figure

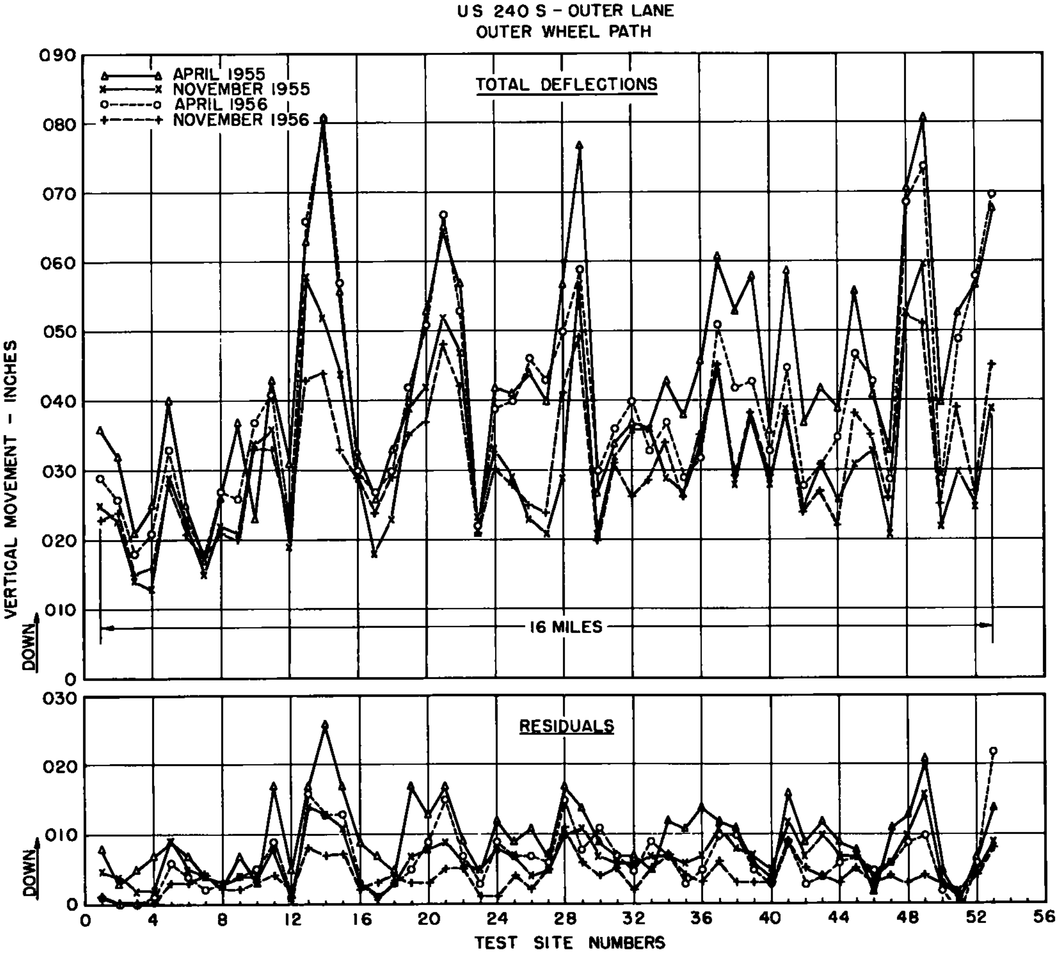


Figure 13. Average deflection and residual values at each test site for the various test periods - 11,200-lb wheel load.

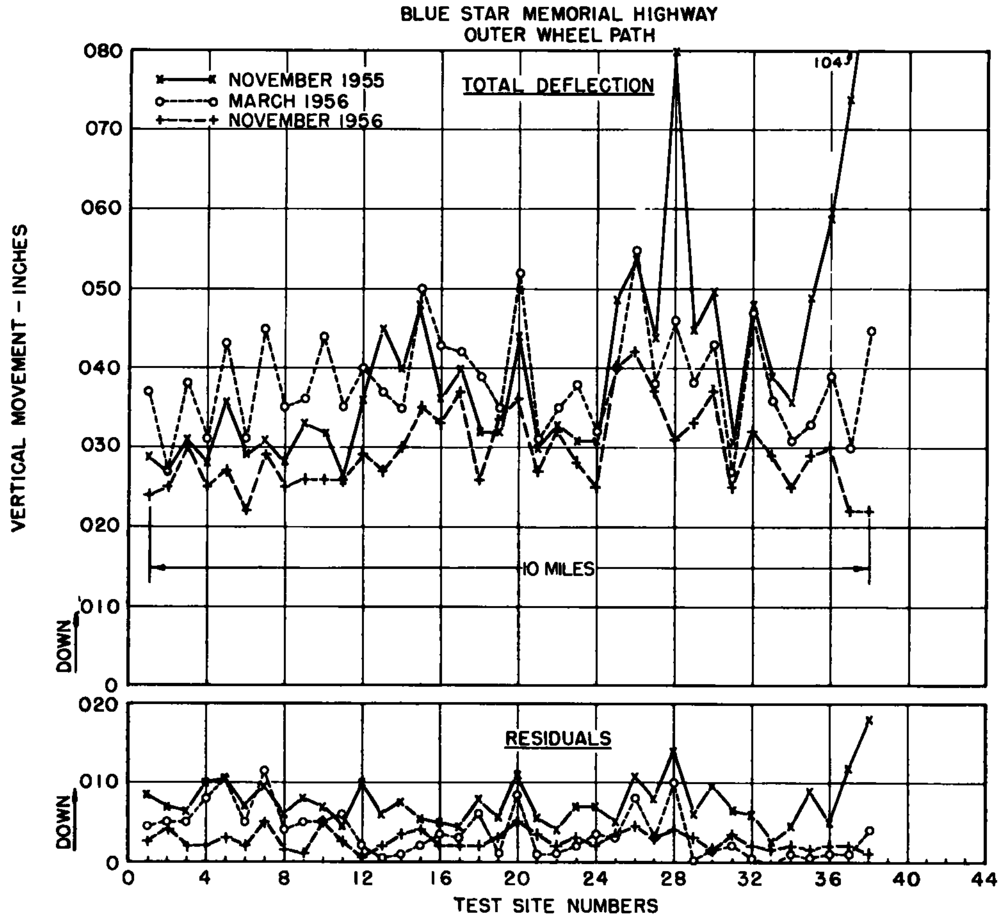


Figure 14. Average deflection and residual values at each test site for the various test periods - 11,200-lb wheel load.

9 or Figure 10 shows that although the magnitude of the deflection and residual values is proportionately less, the variations from site to site are about the same. A direct comparison of the deflection and residual values for the two wheel paths is afforded in Figure 11. At nearly all sites the deflection in the outer wheel path is larger than that of the inner. However, the residual values show no definite trend in this regard.

The detailed data for the outer wheel path of the outer lane of US 40E are given in Figure 12. It should be recalled before studying this figure that at the time of the initial series of tests (April 1955) the final surface had not been placed on the structure and signs of surface distress were prevalent. The deflection values of the April 1955 test series are extremely large compared to those of the later test series. During the late summer and fall of 1955 the final asphaltic concrete surface course was constructed. Following this, the second series of tests was made. As stated previously, the values of this and subsequent series were considerably smaller. Residual values of the first test series are the most erratic, some indicating permanent upward movement. Those of the most recent test series are the least erratic and also the least in magnitude.

The average deflection and residual values at each site for US 240S are shown in Figure 13. The relations between the deflections of the four test series are about the same as those of US 40W; that is, those of the first and fourth test series are the largest and smallest, respectively.

The deflection and residual data for the Blue Star pavement are given in Figure 14. This project was completed in November 1955, and the initial test series was made late that month. This series corresponds to the second test series of the other three pavements. The deflection data obtained at the first 24 test sites generally indicate that the March and November 1956 values are the largest and smallest, respectively, and the others are in between. However, for the remaining test sites the November 1955 val-

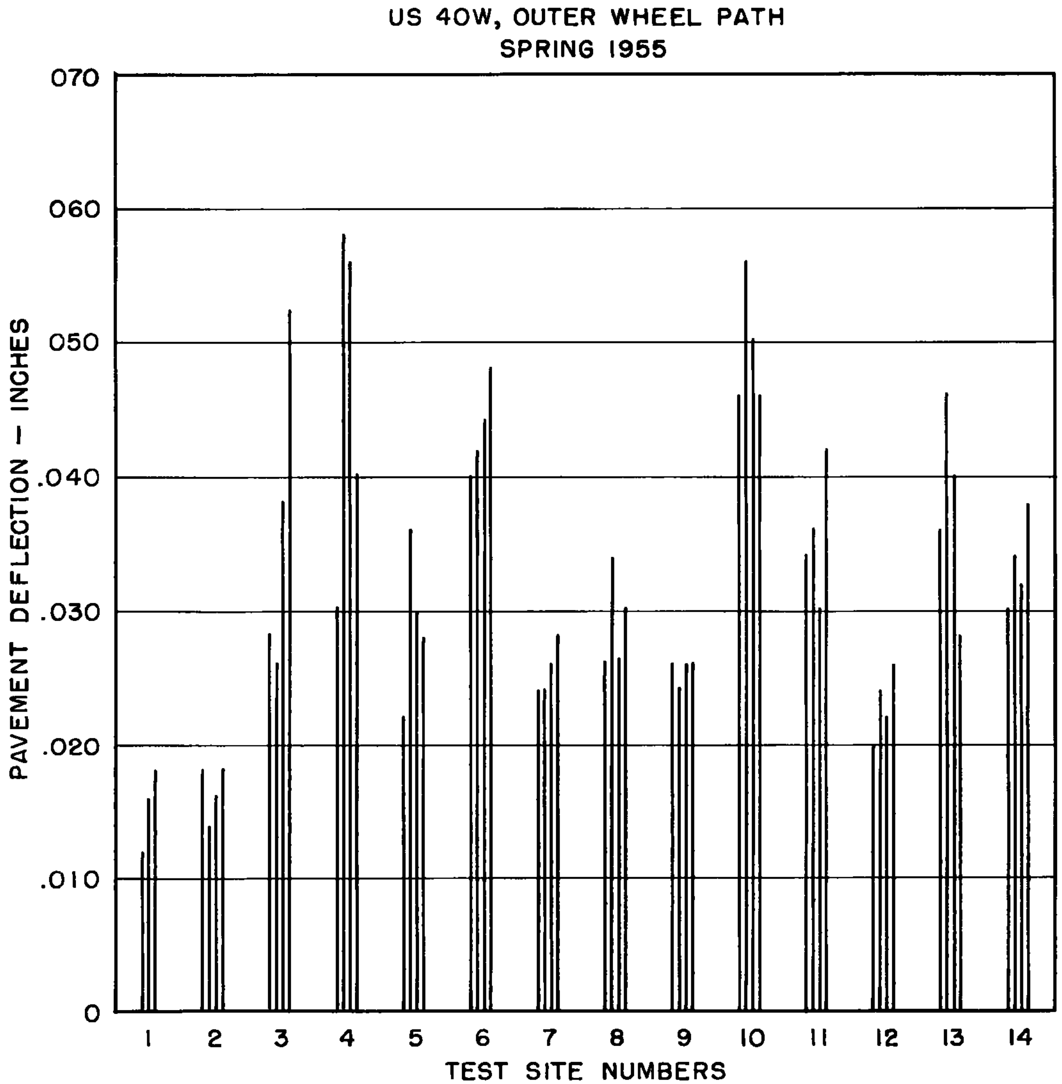


Figure 15. Typical deflection measurements at a number of test sites showing the variations in the individual values obtained - 11,200-lb wheel load.

ues are the largest. In fact, at sites 28, 37, and 38 the deflection values of this test series are exceptionally large as compared to those at the other sites.

When these measurements were obtained, it was noted that there was a tendency for the pavement to "roll" ahead of the truck tire. However, in spite of this unusual type of movement observed immediately after construction, subsequent measurements have indicated only normal movements at these locations. The residual values for the first test series were appreciably larger than those of the other test series. The values at sites 28, 37, and 38 were particularly large at that time.

The data previously presented show the rather large variations in deflection values which may be found from site to site of a given pavement. In addition, it was found that the three or four individual deflection measurements obtained under constant test conditions at a single site may vary considerably. This is illustrated by the data shown in Figure 15, obtained at a series of typical although arbitrarily selected test

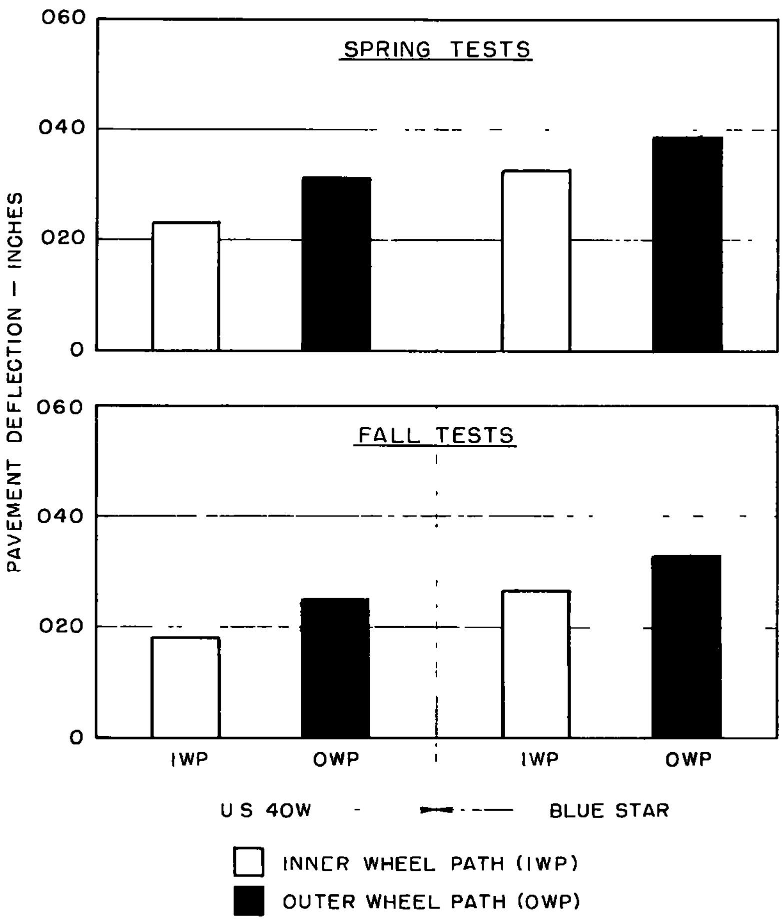


Figure 16. Comparison of average deflections in the inner and outer wheel paths of the two-lane highways - 11,200-lb wheel load.

sites. The variations in values range from a minimum of 0.002 in. at site 9 to a maximum of 0.028 in. at site 4.

A comparison of the average deflection values of the inner and outer wheel paths of the two-lane highways (US 40W and Blue Star) is made in Figure 16. Each value shown for US 40W is the average of about 550 measurements. The spring test values for Blue Star are the average of about 150 and the fall test values of about 300 measurements. Figure 16 indicates that for both pavements and both seasons the values in the outer wheel path are considerably larger than in the inner wheel path.

Similar graphs of the average deflection in the four wheel paths of the four-lane divided highways (US 40E and US 240S) are shown in Figures 17 and 18, respectively. Each value for the spring tests of US 40E is the average of about 140 measurements, the first series of readings being excluded, whereas the values for the fall tests include 280 measurements. The values for US 240S are the average of 300 measurements.

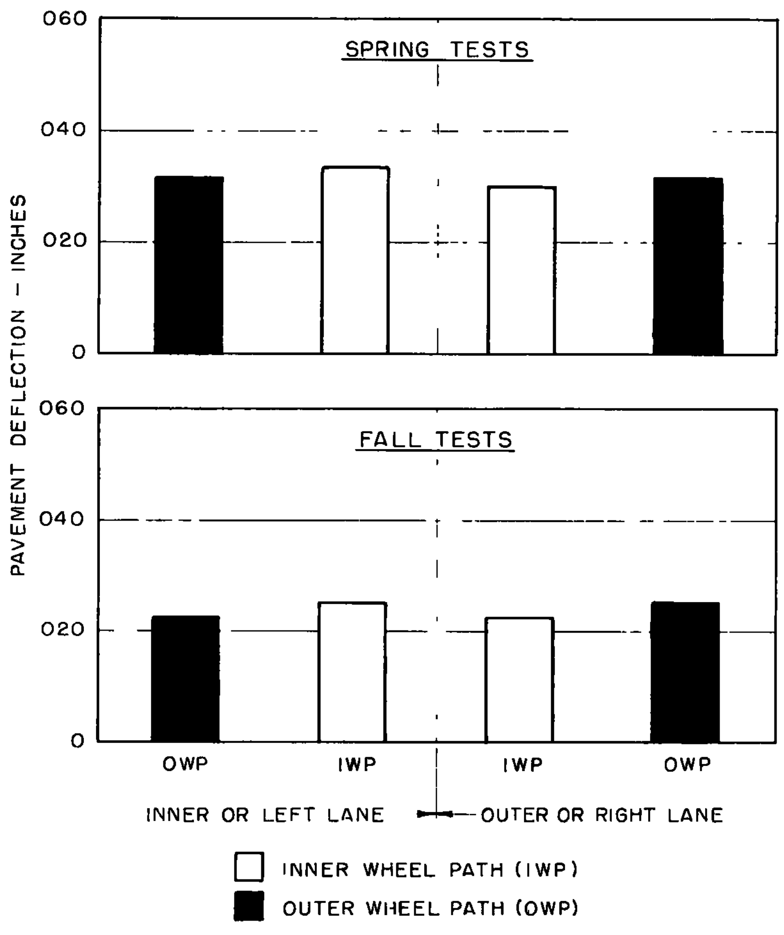


Figure 17. Comparison of average deflections in the four wheel paths of the eastbound lanes - US 40E, 11,200-lb wheel load.

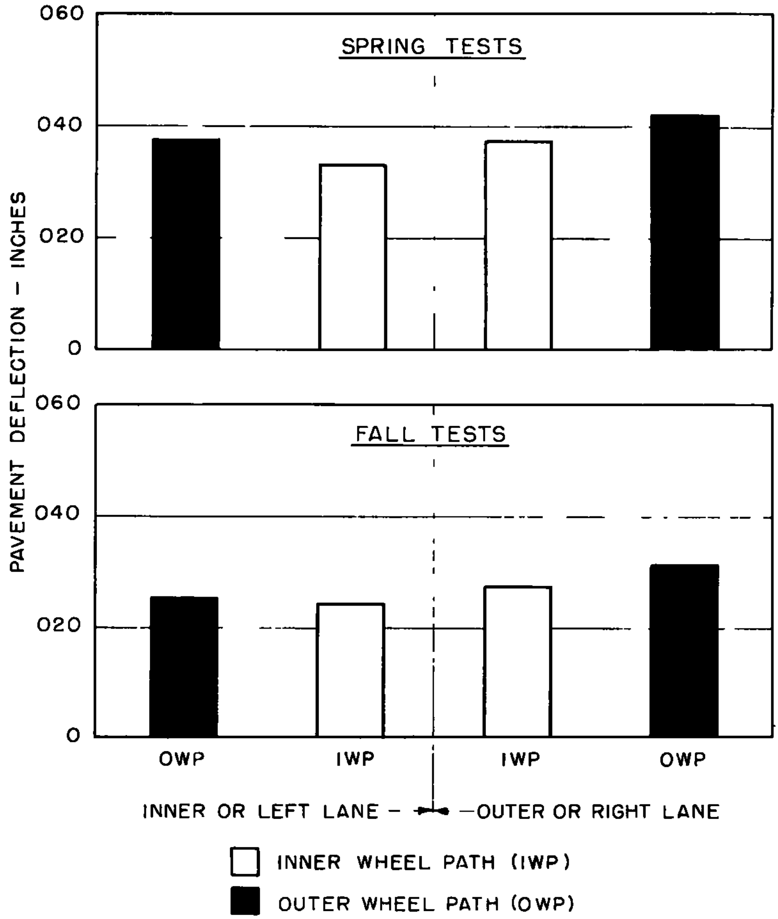


Figure 18. Comparison of average deflections in the four wheel paths of the southbound lanes - US 240S, 11,200-lb wheel load.

The relations for US 40E indicate that in the outer lane the deflection in the outer wheel path is slightly the larger, whereas in the inner lane, the reverse is true. The relations for US 240S show a somewhat more marked difference between the values in the two wheel paths of both lanes. However, the differences are much less pronounced than are those of the two-lane highways. Also, the inner or left lane deflection values are somewhat less in magnitude than those of the outer or right lane.

A comparison of the grand average deflection values for all four test series on the four pavements studied is shown in Figure 19. The values plotted are the averages of measurements made in all lanes and wheel paths. The following comments may be made concerning these data:

1. With the exception of the spring 1955 value for US 40E, all deflection values are between 0.022 and 0.038 in.
2. The deflections of US 40W are generally the smallest and, with the exception of the first test series of US 40E, those of US 240S the largest.
3. The values obtained in the spring are in all cases the largest,

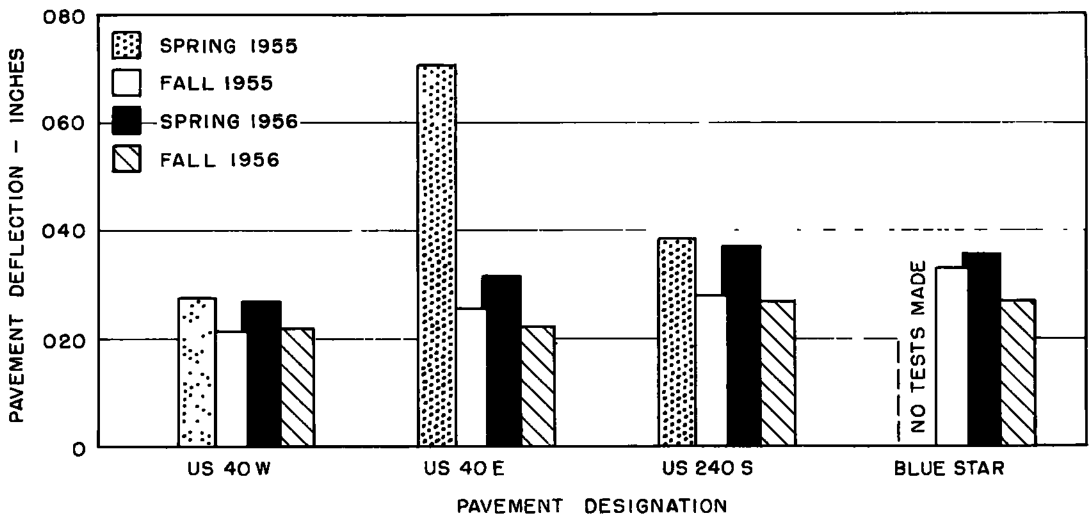


Figure 19. Comparison of average deflections of the four pavement sections for each test series - 11,200-lb wheel load.

that of the initial test series of US 40E being exceptionally large (about 0.070 in.).

4. For the two older pavements (US 40W, 11 years, and US 240S, 2 to 4 years) the seasonal changes in deflection have been of appreciable magnitude, but quite constant. On the other hand, the seasonal variation between the spring and fall of 1956 on the two newer pavements is somewhat greater than that between the fall of 1955 and spring of 1956.

SUMMARY

As mentioned earlier, this is a progress report on a study of the structural performance of certain high-type flexible pavements in service by means of load-deflection tests. Fairly detailed descriptions of the test procedure used, the pavements studied, and the more interesting findings obtained, are included.

Studies of this type were made possible by the development in 1953 of the Benkelman Beam pavement deflection indicator. The test procedure was developed to make maximum use of this instrument in the time available. The four pavement sections studied are of modern design, range in age from 1 to 11 years, are on moderately traveled routes, and are in excellent condition.

The average deflection in April 1955 for the stage-constructed pavement (US 40E) that showed signs of distress before receiving the final surface course, was about 0.070 in. However, many individual measurements exceeded this value and a few exceeded 0.100 in. Because of the excellent performance of this pavement since the addition of the final surface course, and the similar performance of the other three pavements to date, no other correlation could be made between their structural adequacy and total deflection. With the exception of the value previously mentioned, the grand average deflections for all seasons on all pavements ranged from 0.022 to 0.038 in.

It was found that the magnitude of the deflections of a certain pave-

ment of constant design may vary to a great degree from site to site, and even at different points at the same site. Also, that in spite of the comparatively large deflections at some test sites for the spring test series there is no evidence of structural distress at these sites. An attempt to correlate the magnitude of the pavement deflection with the results of the subgrade soil surveys made prior to construction has not shown any definite trends.

The residual values generally range from 0 to 0.015 in., but comparatively few values are larger than 0.010 in. They tend to vary directly as the deflection and, in general, range from about 15 to about 25 percent of the deflection values. Although the residual values seem quite large, only one of the four pavements studied has a measurable amount of permanent settlement or consolidation in the wheel paths. It is believed that most or all of the residual movement is eventually recovered by slow elastic action and the "ironing out effect" of traffic.

The magnitude of the deflection of the outer wheel path of the two-lane highways is considerably larger than that of the inner wheel path—about 40 and 25 percent for the US 40W and Blue Star pavements, respectively. On the other hand, the differences are not as marked in the case of the four-lane highways. In fact, for the US 40E pavement the deflection of the inner wheel path of the inner lane is larger than that of the outer wheel path.

The effect of changes in climatic conditions on pavement deflection is quite marked, the spring values being the greater. The seasonal variations between spring and fall have been generally quite constant. It was found difficult to schedule the tests for the most adverse period in the spring, there being indications that both spring test series followed the spring breakup period by several weeks.

It is expected that periodic observations of these pavements will be continued in the future in an effort to establish a correlation between pavement performance and deflection under a single-wheel load.

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Discussion

W. H. CAMPEN, Manager, Omaha Testing Laboratories, Omaha, Nebraska—Can it be concluded from this study that flexible pavements can tolerate about 0.05 in. total deflection without cracking and, consequently, failing the bituminous mats? This question is prompted by the fact that Hveem in 1955 (HRB Bulletin 114) indicated that a much lower deflection would cause failure.

STUART WILLIAMS and ALLAN LEE, Closure—A conclusion such as suggested cannot be drawn from the results of this study. Because the pavements observed are now generally in excellent condition, the data are not of sufficient scope to justify broad conclusions. Perhaps as data accumulate it may become possible to correlate structural adequacy and total deflection.