Session Four

PAVEMENT PERFORMANCE

Presiding: K. B. Woods, Chairman
National Advisory Committee, AASHO Road Test

Structural Deterioration of Test Pavements: Flexible

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• An extremely important phase of the research at the AASHO Road Test was the observance of the trend of serviceability of the flexible pavements with time or load application. It was considered necessary to determine with as much precision as possible how the pavements deteriorated structurally in order that corrective measures appropriate to the prevention of such deterioration might be taken in the design and construction of new pavements.

The three elements of serviceability observed at the AASHO Road Test were slope variance (a measure of longitudinal roughness), rutting in the wheelpaths, and cracking and patching. The extent to which each of these elements affected the serviceability was determined from the equation:

$$p = 5.03 - 1.91 \log (1 + \overline{SV}) - 0.01\sqrt{C + P} - 1.38\overline{RD}^2 \qquad (1)$$

in which

p = the present serviceability index;
$\overline{SV}$ = the mean of the slope variance in the two wheelpaths × 10^6;
$C + P$ = a measure of cracking and patching in the pavement surface; and
$\overline{RD}$ = a measure of rutting in the wheelpaths.

Nearly all the flexible pavement sections rutted to some degree in the wheelpaths during the course of the traffic test. Since there was no indication of loss of surfacing material in the traveled wheelpaths, the observed rutting was considered to be due to one or both of two phenomena. These were additional consolidation and/or lateral displacement of one or more of the pavement layers and the embankment soil.

Information for use in the study of rutting was obtained from a number of different observations including surface elevation changes, transverse profiles, layer thickness changes from in-place measurements, and from trenches cut into the pavement sections.

Transverse profiles of the pavement surface measured at different times during the traffic test are shown in Figures 1 and 2. Comparison of the profiles taken in the three periods shows the magnitude of the change in elevation of the surface of the pavement with seasons. For example, the 3-6-4 pavement under the 2- and 6-kip axle loads of Loop 2 heaved about 0.04 ft between October 1959 and March 1960. By October 1960, the pavement had gone down about 0.01 ft below the October 1959 level. Although the magnitude of this rise and fall varied somewhat from section to section, the same general trend was observed in most of the pavements.

The changes in elevation at the edge, outer wheelpath, between wheelpaths, inner wheelpath and at the pavement centerline between fall 1959 and spring 1960 are shown graphically in Figure 3. Apparently there was almost twice as much heaving at the extreme edge of the pavements as in the interior portions. This situation was much the same for all loops even though the actual amount of heaving varied appreciably from loop to loop. The greater heaving at the pavement edge was attributed to the presence of more moisture in the base, subbase and embankment soil beneath the shoulders, and also to a faster downward rate of frost penetration in the shoulder material than through the pavement. Whereas heaving decreased from Loop 1 through Loop 4, the reverse trend occurred from Loop 4 through Loop 6. To this extent the data are inconsistent insofar as the effect of pavement thickness on frost

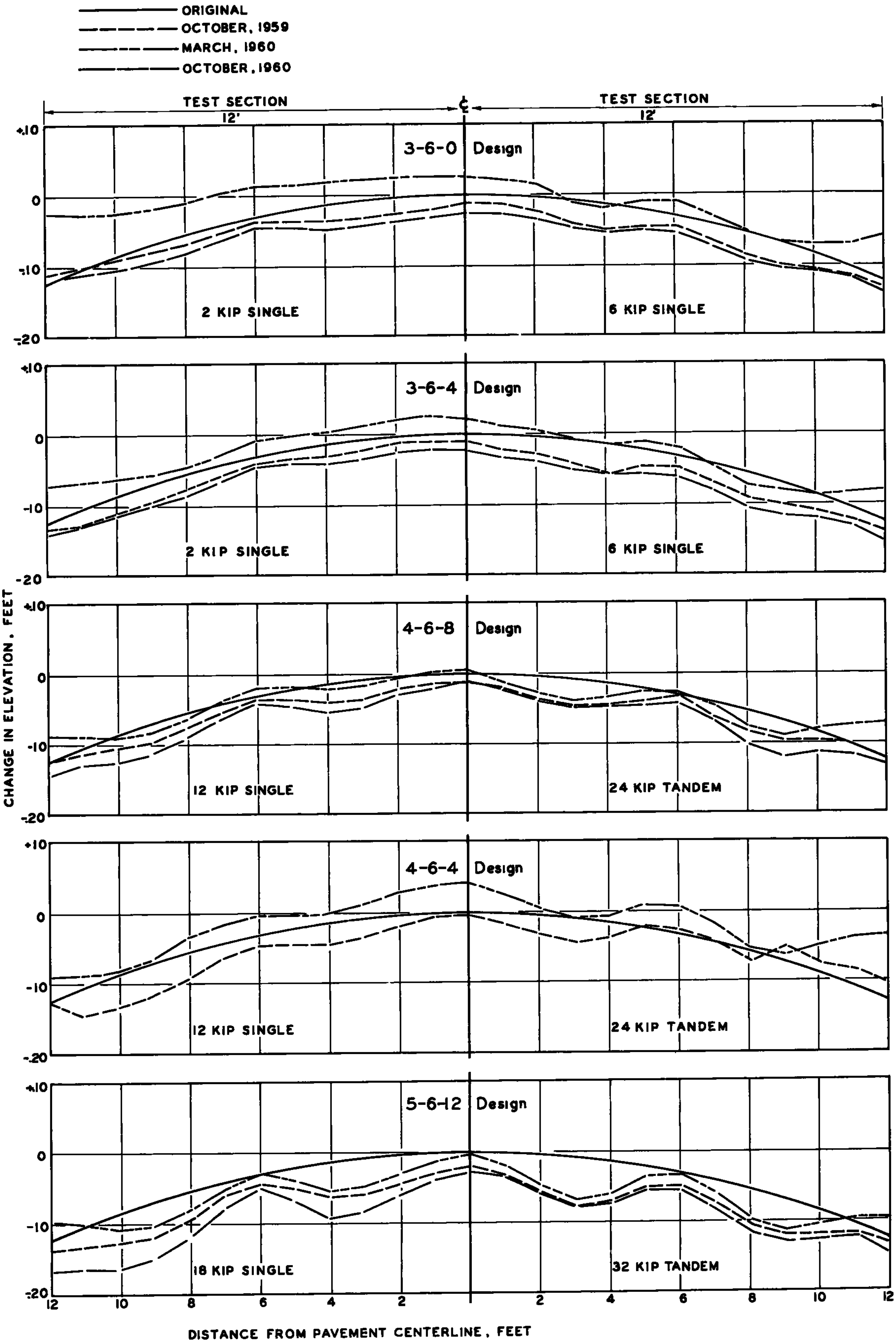

Figure 1. Transverse profiles of pavement surface.

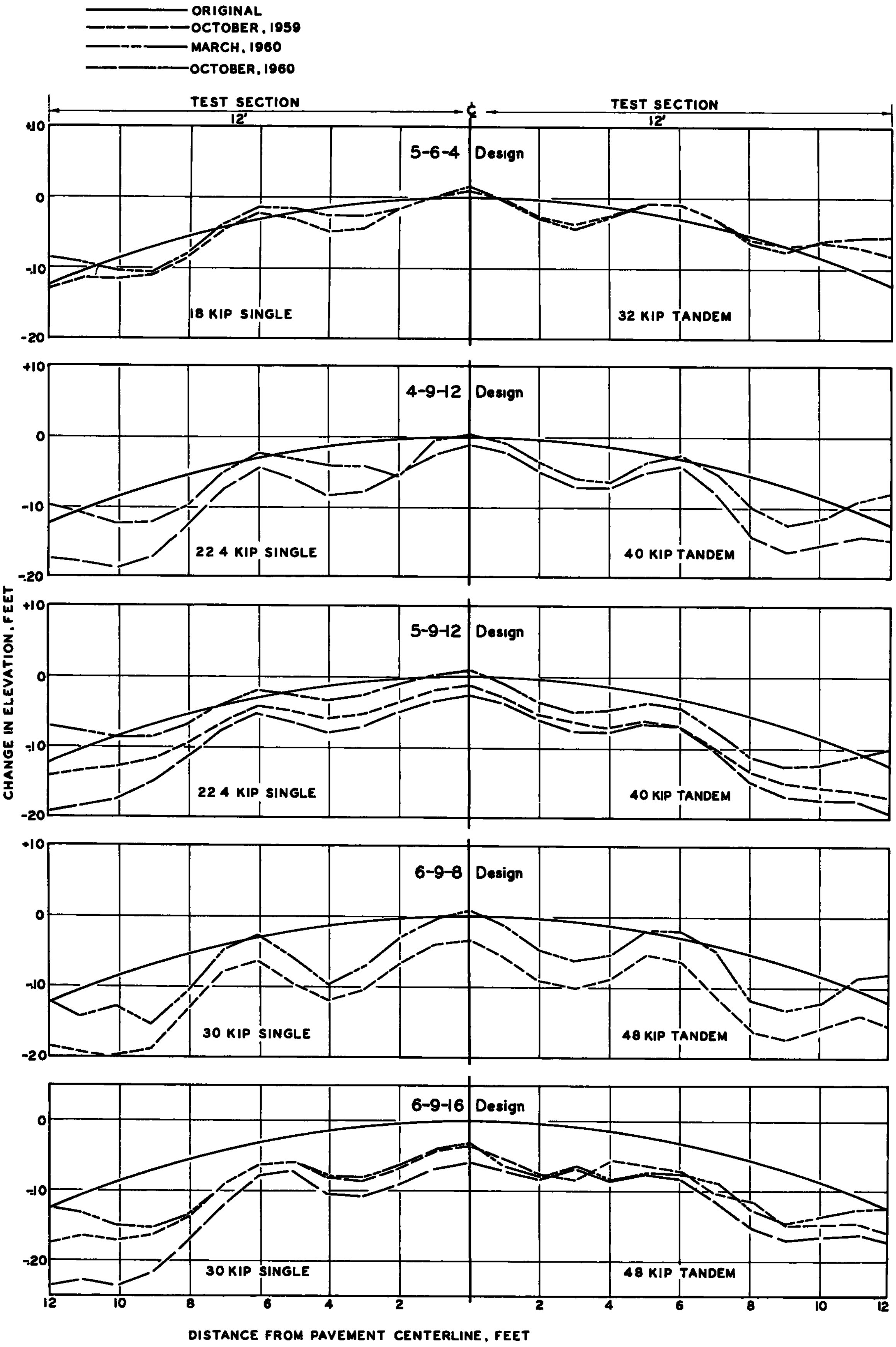

Figure 2. Transverse profiles of pavement surface.

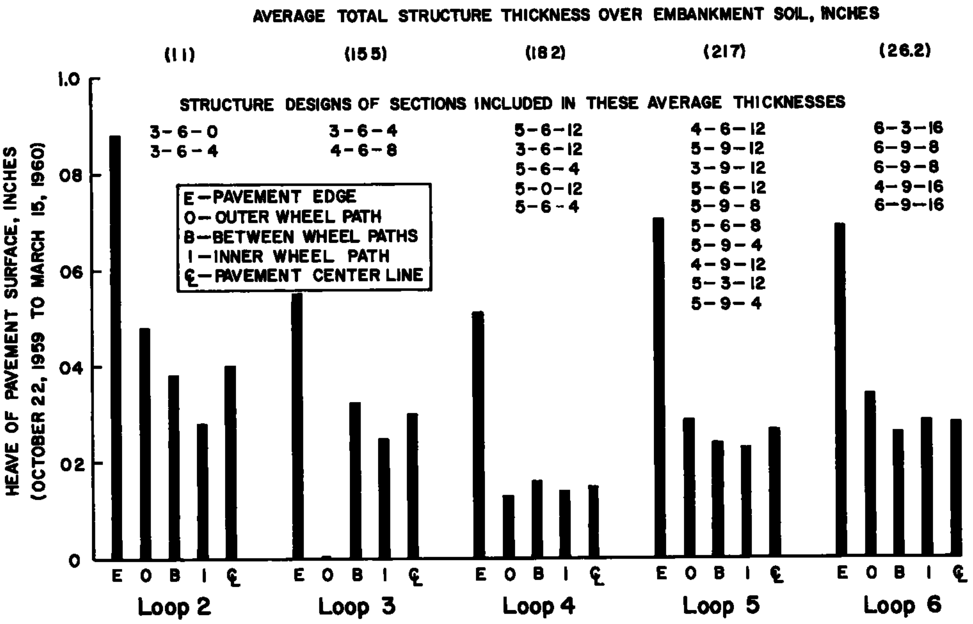

Figure 3. Heave of pavement surface.

heaving is concerned. In this connection, it seemed logical to expect that heaving due to the surcharge weight of the pavement would decrease as its thickness increased, even though the depth of penetration of frost into the embankment soil was much the same beneath the thick and thin pavements. There was a suggestion of an effect of thickness of the pavement on heaving in case of the ten sections of Loop 5 and of the five sections of Loop 6. However, as stated before and shown in Figure 3, heaving actually increased (almost doubled in the interior of the pavement) going from Loop 4 (18.2 in., average thickness of the five sections) to Loops 5 and 6 (21.7 and 26.2 in., average thickness of the 10 and 5 sections, respectively).

Data concerning the condition of the embankment soil in the spring for Loops 3, 4, 5 and 6 in 1960 and for Loops 2 and 4 in 1961 are given in Table 1. The computed value of saturation of the soil for Loop 2 (OWP, spring 1961) was the highest (82.3 percent). Also, its density was appreciably lower (109.2 pcf) and its moisture content higher (17.1) than these values for the other loops.

TABLE 1

CONDITION OF EMBANKMENT SOIL, SPRING MONTHS

Loop	1960					1961				
	Number of Sections	Moisture Content (%)	Density (pcf)	Saturation (%)	CBR	Number of Sections	Moisture Content (%)	Density (pcf)	Saturation (%)	CBR
(a) OUTER WHEELPATH										
2	—	—	—	—	—	6	17.1	109.2	82.3	1.8
3	3	15.1	113.3	80.7	2.5	—	—	—	—	—
4	3	14.1	115.4	79.6	4.0	2	14.1	116.8	81.3	5.0
5	3	16.1	110.2	79.5	2.7	—	—	—	—	—
6	3	13.1	115.1	73.4	6.6	—	—	—	—	—
All		14.6	113.5	78.4	—	—	—	—	—	—
(b) BETWEEN WHEELPATHS										
2	—	—	—	—	—	6	16.8	108.6	79.6	2.8
3	3	15.0	112.5	78.5	2.7	—	—	—	—	—
4	3	14.3	113.8	78.9	3.7	2	13.8	116.0	79.6	3.8
5	3	16.2	109.4	78.3	3.0	—	—	—	—	—
6	3	13.9	115.1	77.9	3.9	—	—	—	—	—
All		14.9	112.7	78.4	—	—	—	—	—	—

Information on the frost potential of the embankment soil reported by the Corps of Engineers shows that when frozen in the laboratory the material at 72 percent saturation, 114-pcf density and 13 percent moisture exhibited no heave. However, at 85 percent saturation, 15.5 percent moisture and at the same density the soil heaved about 1.7 percent. Because soil conditions in Loop 2 were somewhat more adverse than those in the other loops (nearly 85 percent saturation was noted) a greater degree of heaving was to be expected in this loop.

Additional data regarding vertical movements of the flexible pavement structure are shown in Figures 4 and 5. They were obtained from measurements taken in the fall and spring periods of the traffic testing phase. The seasonal changes in elevation in the wheelpaths of the pavement surface and of the top of the embankment soil in ten test sections are shown. Although some heaving took place within the pavement structure during the winter, the greater part of the uplift observed at the top of the pavement originated in the embankment soil and the major part of the settlement of the pavement surface that occurred subsequently was the result of movement within the structure. This is in agreement with the finding of the trench studies.

During 1959 a number of trenches were cut into sections whose condition had deteriorated to the point where their removal from the test was imminent. In fact, the serviceability of some of the sections that were trenched at this time had dropped below 1.5, the level at which they were normally removed from test. The purpose of this work was to develop some preliminary information concerning the amount of wheelpath rutting at the top of each of the component structure layers as well as to obtain information on the existing condition and strength of the materials.

While the trenches were being cut, precise levels were taken at 1-ft intervals on the top of each of the layers. The trenches were 3 ft in width and the levels were taken on both faces. In addition, cores for density determinations were taken of the surfacing course, and in-place density, CBR and moisture content determinations of the granular materials and embankment soil were made. Also in some cases plate load tests were made on the embankment soil.

Transverse profiles of three of the 1959 trenches are shown in Figure 6, two from Loop 6 and one from Loop 4. Those in Loop 6 were cut when the serviceability of the pavements was about 1.5, and that in Loop 4 when its serviceability was about 0.5, when failure was in a more advanced stage. In the Loop 6 sections, although pronounced rutting had developed in both wheelpaths of the pavement surface, very little of it was apparent in the embankment soil. If sections that were failing at a rapid rate were not maintained, rutting or distortion of the pavement in the wheelpaths eventually extended into the embankment soil as was the case in the 5-3-4 section (Fig. 6).

Further information was obtained from trenches cut into 12 sections in the spring and summer of 1960 and from an additional 27 trenches cut in the fall of 1960. Pertinent data from this program of tests are summarized in Figures 7 and 8. The means of the sections trenched in each loop are for measurements made in the outer wheelpath and between the wheelpaths. In addition to the change of thickness data for the pavement layers, the depth of rut reflected in the subgrade is indicated for the outer wheelpath (Fig. 7). A comparison of the magnitude of the embankment rut to the total pavement thickness change serves as definite evidence that most of the observed surface rut can be attributed to changes in thickness of the pavement layers.

Comparison of the as-constructed densities and the densities measured in the trenches in the three programs provides a means for assigning portions of the change in thickness of each component to densification. The amount of change of thickness that would be expected due to the measured change in density is shown for each loop and each structural component in the solid bars of Figures 7 and 8 (densities of base and subbase were not determined in case of the fall group of trenches). The hatched bars show the total observed thickness change for each loop and structural component. The fall 1960 trenches (near the end of the traffic test) indicated that only about 25 percent of the thickness change in the surfacing in the outer wheelpath of these sections could be assigned to densification of the material. The summer trenches indicated that about 25 percent of the thickness change in the subbase under the outer wheelpath and less than 50 percent of the thickness change in the base material of these sections could be assigned to densification. Figure 8 shows data taken from between the wheelpaths summarized by loops. Here densification of the asphaltic concrete accounted for all of the total thickness change in the surfacing material. The base course in nearly all the trenches became thicker rather than thinner between the wheelpaths without undergoing much change in density. Presumably the material was forced into this position from the wheelpath locations. There was considerable reduction in subbase thickness accompanied by a reduction on the average in subbase density.

The data from all the trenching studies led to the conclusion that changes in thickness of the components of the flexible pavements in the wheelpaths at the AASHO Road Test were due primarily to lateral movement of the materials.

More consistency in the behavior of the sur-

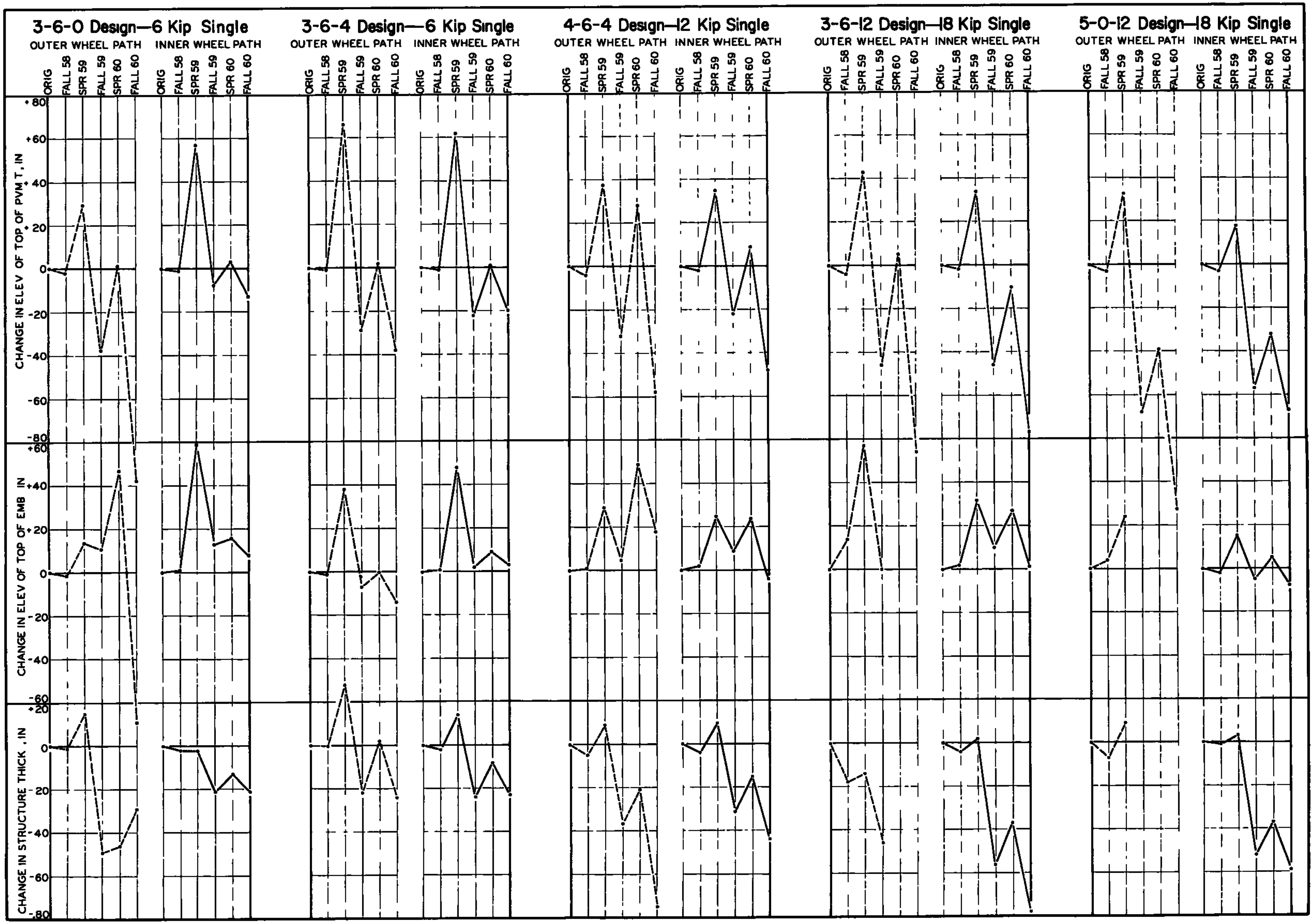

Figure 4. Vertical movement data from settlement rod measurements.

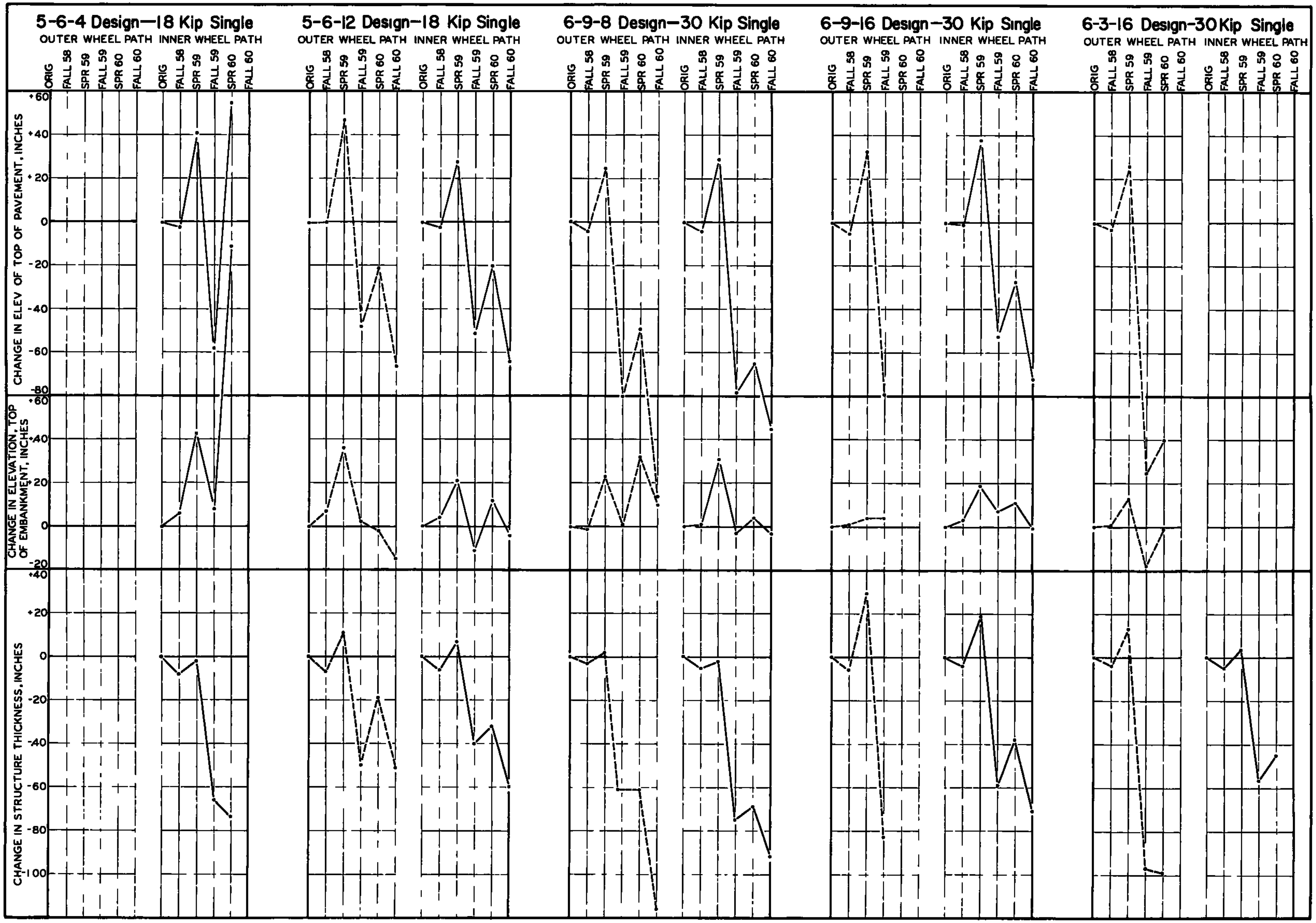

Figure 5. Vertical movement data from settlement rod measurements.

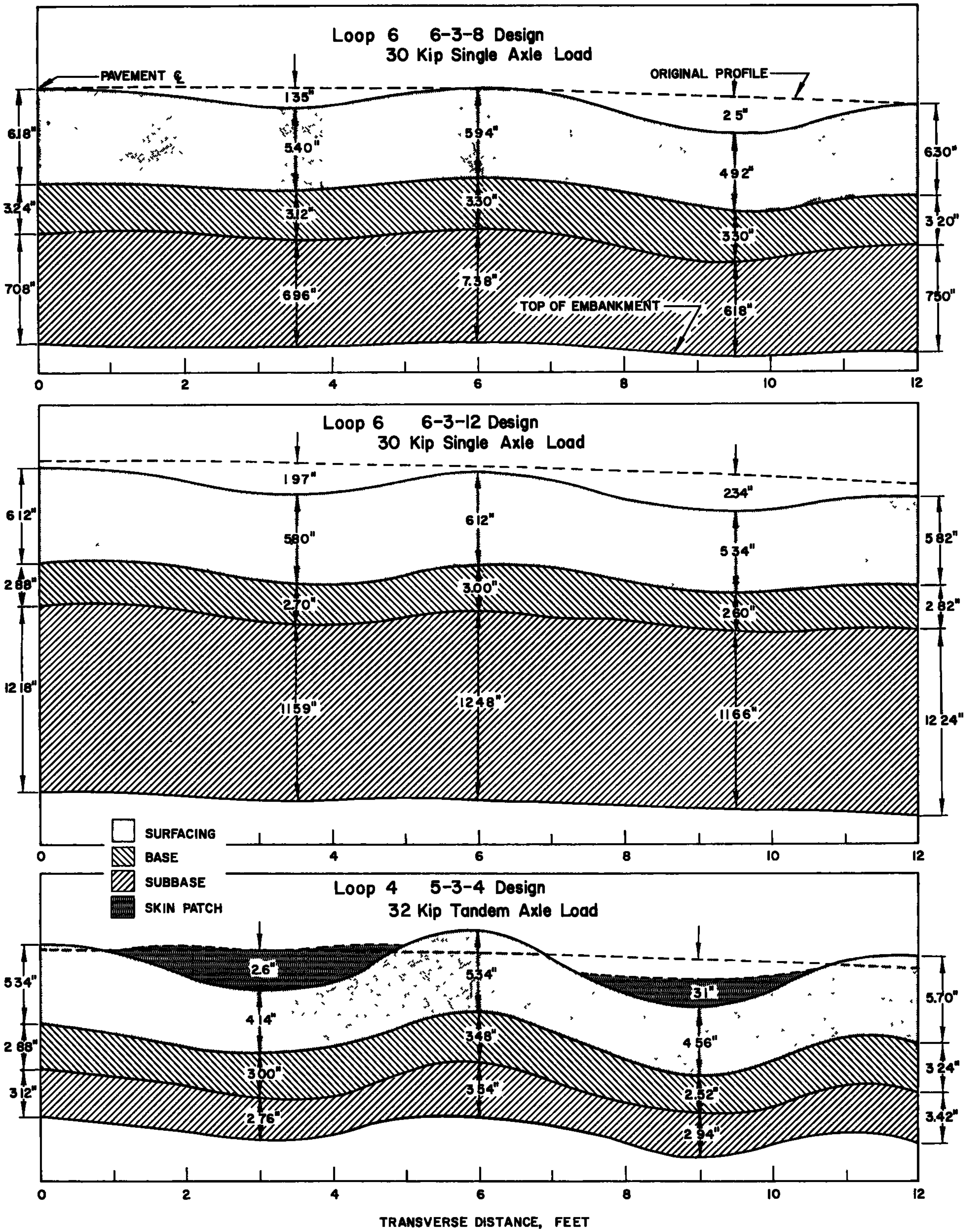

Figure 6. Transverse profiles, 1959 trench study.

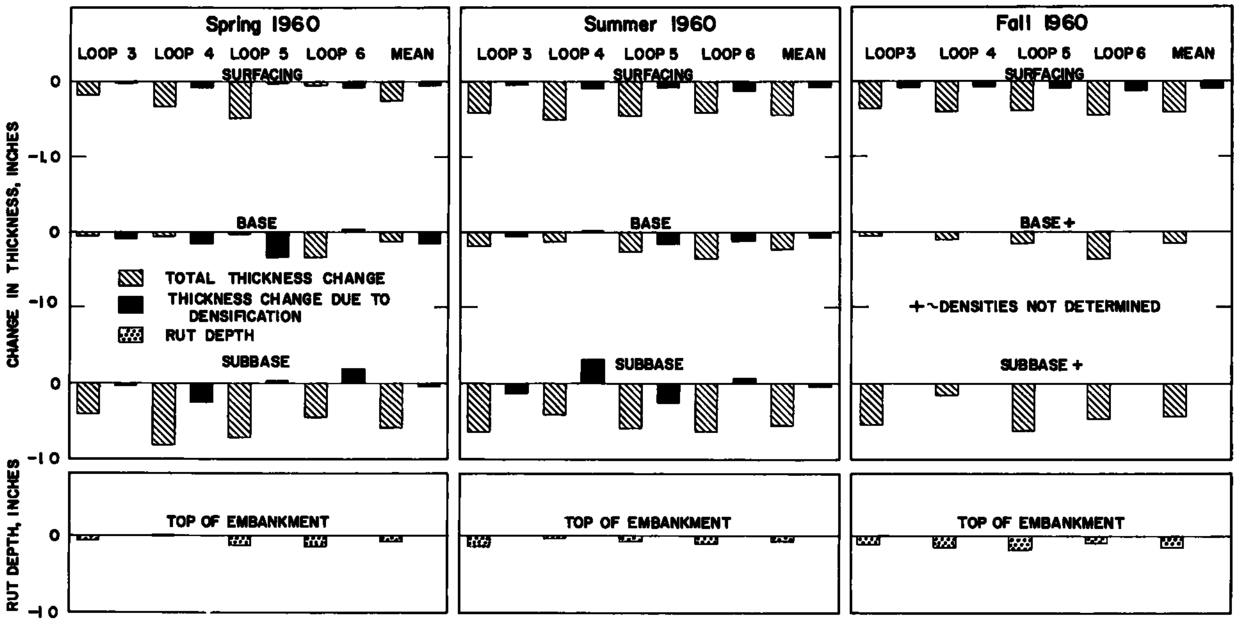

Figure 7. Summary of layer thickness changes in outer wheelpath, 1960 trench study.

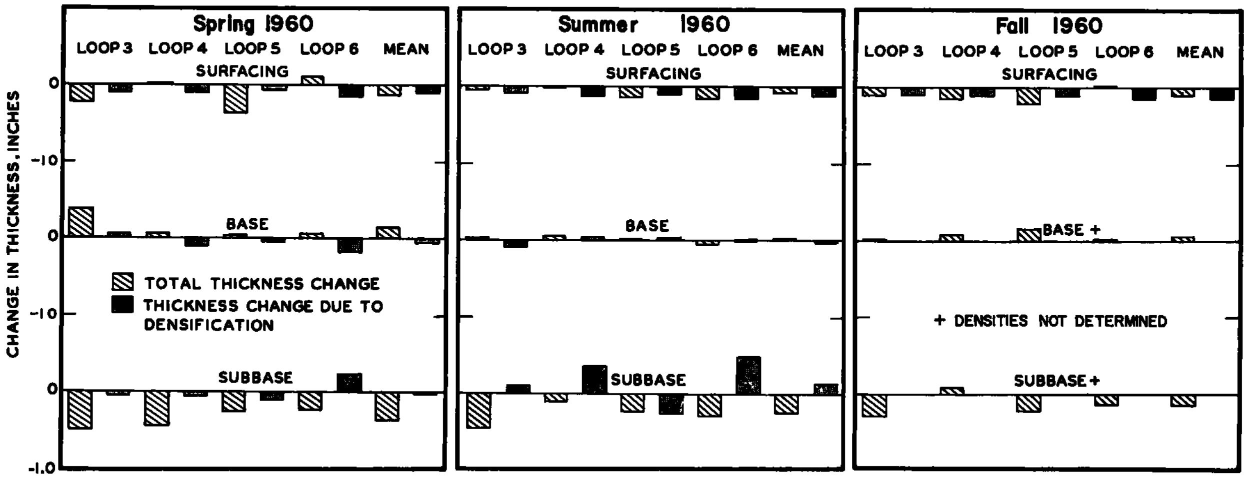

Figure 8. Summary of layer thickness changes between wheelpaths, 1960 trench study.

facing than of the base and subbase components was found. In fact, the thickness of the surfacing of all the sections that were trenched had decreased in 94 percent and the density had increased in 98 percent of the cases investigated. For the base course these values were 75 and 76 percent and for the subbase course 42 and 94 percent, respectively. This suggests that there may have been either less experimental error associated with the conduct of these tests or more physical uniformity of the surfacing material than in the case of the granular materials.

It should be pointed out in connection with the data in the figures that the sum of the thickness changes in each layer plus the rut measured on the top of the embankment soil does not always equal the depth of the existing rut on the pavement surface. This is because any uplift of the surfacing on either side of the rut will add to the depth of the rut. If this is ignored, however, an approximation of the extent to which changes of thickness of each of the layers of the pavement contributed to the rut can be made. For example, in the 51 sections trenched in 1960, changes in thickness of the surfacing, base, subbase, and the rutting on the surface of the embankment soil contributed 32, 14, 45, and 9 percent, respectively, to the total rut.

Figure 9 shows the increase in the density of the asphaltic concrete with axle applications for the thickest pavement designs in the factorial experiment, Loops 5 and 6. As a refer-

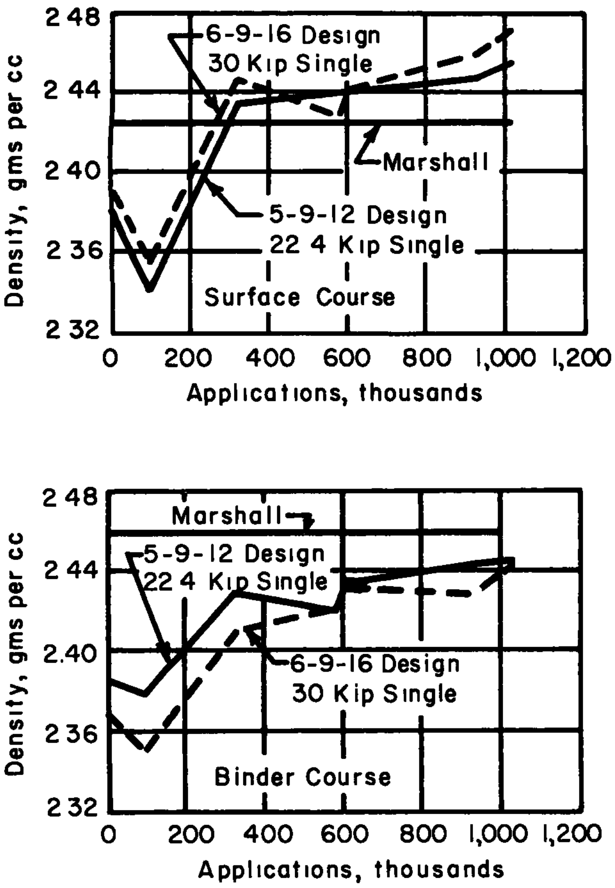

Figure 9. Increase in density of asphaltic concrete.

ence, the 50 blow Marshall density is shown as the horizontal line on each plot. Initial data were taken from the as-constructed density measurements. Later, data were obtained from special tests during the period of test traffic.

Since rut depths were measured every two weeks throughout the period of traffic testing, it was possible to develop plots for the many different designs of pavement showing the progression of rutting with axle applications. Typical examples of these plots, for designs that survived the 1,114,000 axle applications of the test loads, are shown in Figure 10. All plotted points are means of the rut depth in the inner and outer wheelpaths. The data indicate that a greater increase in the progression of rutting occurred for the first year of test traffic than for the second year. This is considered as strong evidence that the rate of the rut development was decreasing with load applications.

A great deal more structural deterioration of the flexible pavement sections occurred during the spring months (March, April and May) than during other seasons of the year. In fact, 80 percent of the sections were removed from the test during the two spring periods, 57 percent the first (1959) and 23 percent the second (1960). In contrast only 6 percent of the sections were removed from test during the two summer periods (June, July and August), an equal percentage (3) in both 1959 and 1960.

Considerable data (Table 2) concerning the condition of the pavement components in the spring and summer seasons of 1960 were obtained from the trench studies.

Based on the average values of the 12 sections that were trenched, the following observations can be made:

1. No difference in moisture content of the embankment soil occurred in the two periods and the density of the material was actually somewhat greater in the spring, 113.5 pcf, than in the summer, 112.8 pcf. However, the strength of the soil as measured by the CBR and the plate load tests was greater in the summer, 5.6 vs 4.0 and 163.8 vs 141.5 psi per in., respectively. The only apparent explanation for the higher indicated strength in the summer is that the material was in a drying cycle at the time.

2. A somewhat lower moisture content of the crushed stone base occurred in the summer than in the spring, 3.6 vs 4.3 percent, but as was the case of the embankment soil, the base course density was slightly higher in the spring than in the summer, 143.8 vs 142.4 pcf, respectively. However, based on the average values in Table 2, the strength (CBR) of the material in the summer was considerably greater than in the spring, 131.3 vs 86.9.

3. Little difference in the moisture content and density of the subbase occurred in the two seasons, but a pronounced difference occurred in the CBR of the material, 24.2 vs 49.7, the higher value in the summer being over twice that during the spring.

Apparently the presence of slightly more moisture in the granular materials in the spring months was to a high degree responsible for their low strength and was a major contributing factor for the poor performance of the flexible pavement sections at this time.

SURFACE CRACKING

An important element of the serviceability and the performance of flexible pavements was cracking of the surfacing material. Although cracks may not in themselves have much effect on the ability of the pavement to serve traffic, they serve as indications that something about the pavement design is inadequate and that failure is likely to occur at an earlier date than would be the case if no cracking appeared.

For purpose of classification, cracking was divided into three categories, namely: Class 1, Class 2, and Class 3. Class 1 cracking was the earliest type observed and consisted of fine, disconnected, hairline cracks. As distress in-

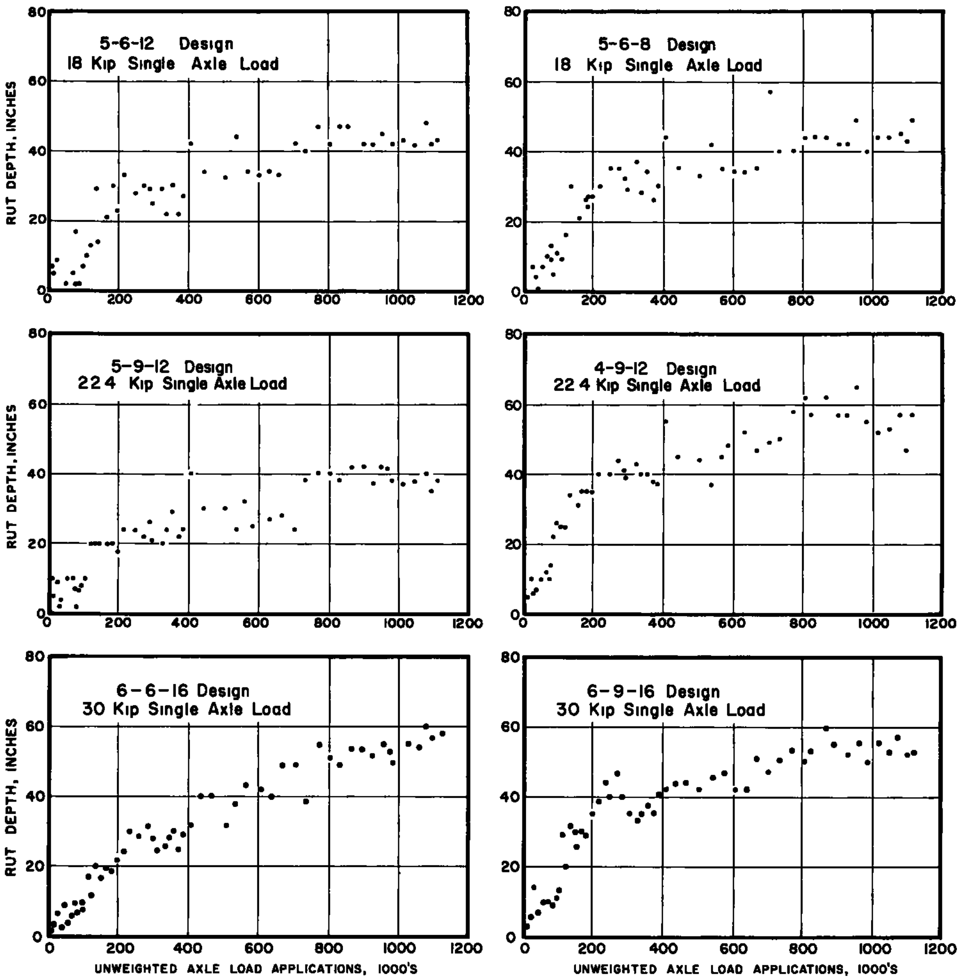

Figure 10. Effect of axle load application on depth of rut; typical sections from main factorial experiment.

creased, the cracks lengthened and widened until cells were formed into what is commonly called alligator cracking. Such cracking was called Class 2 cracking. A small amount of surface spalling at the crack was usually evident.

When the segments of the Class 2 cracks spalled more severely at the edges and loosened until the cells rocked under traffic, the situation was termed Class 3 cracking.

Mathematical analysis of the occurrence of surface cracking resulted in the development of an equation from which the number of axle load applications sustained by the pavement before Class 2 cracking developed could be computed for any design or load. By including a deflection term in the equation a somewhat better prediction of performance could be obtained. The analysis and equations are described in detail in HRB Special Report 61E.

A bar graph showing the time of appearance of Class 2 cracking as it occurred in the test sections of the main factorial experiment is shown in Figure 11. Most cracking occurred

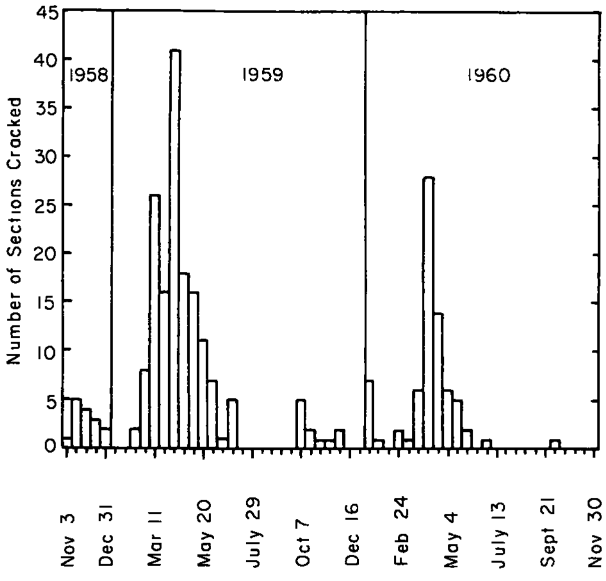

Figure 11. Time of appearance of Class 2 cracking.

TABLE 2

CONDITION DATA OF PAVEMENT COMPONENTS, (FROM TRENCHING PROGRAM, 1960)

		Outer Wheelpath								Between Wheelpaths					
Loop	Design	Moisture Content (%)		Density (pcf)		CBR		k_F (psi/in.)		Moisture Content (%)		Density (pcf)		CBR	
		Spring[1]	Summer	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer
							(*a*) EMBANKMENT								
3	4–3–8	15.4	15.0	113.8	113.9	2.0	6.2	115	138	15.3	13.8	112.1	112.8	2.7	6.4
	4–6–4	14.5	14.2	112.5	113.7	2.8	6.8	108	143	14.4	13.7	112.0	115.2	2.6	5.0
	4–6–8	15.5	15.6	113.5	111.6	2.7	3.6	139	149	15.2	15.0	113.3	111.7	2.8	3.8
	Mean	*15.1*	*14.9*	*113.3*	*113.1*	*2.5*	*5.5*	*121*	*143*	*15.0*	*14.2*	*112.5*	*113.2*	*2.7*	*5.1*
4	5–6–12	14.5	13.8	114.7	114.7	4.3	6.8	132	169	14.1	13.6	114.3	113.7	4.5	6.3
	5–6–8	14.1	14.9	114.4	112.8	3.5	5.9	131	138	14.3	14.8	114.3	110.5	3.0	4.1
	5–3–12	13.8	14.9	117.0	113.8	4.3	2.4	134	154	14.5	15.0	112.8	110.7	3.5	3.6
	Mean	*14.1*	*14.5*	*115.4*	*113.8*	*4.0*	*5.0*	*132*	*154*	*14.3*	*14.5*	*113.8*	*111.6*	*3.7*	*4.7*
5	5–9–12	15.2	15.2	112.6	111.2	3.2	5.3	153	183	15.2	15.1	111.1	109.8	3.7	5.4
	5–6–12	15.9	15.2	110.3	110.1	2.6	2.6	154	164	16.5	14.8	107.3	110.6	2.2	3.0
	5–9–8	17.2	16.6	107.7	106.8	2.3	4.0	127	132	16.8	15.8	109.8	109.9	3.0	3.4
	Mean	*16.1*	*15.7*	*110.2*	*109.4*	*2.7*	*4.0*	*145*	*160*	*16.2*	*15.2*	*109.4*	*110.1*	*3.0*	*3.9*
6	6–6–16	13.4	12.4	118.1	115.3	6.6	8.2	192	196	14.1	12.4	115.6	114.7	4.1	8.2
	6–9–12	13.1	14.3	115.9	114.7	5.9	9.7	131	159	13.6	13.8	115.9	113.1	4.4	5.8
	6–9–16	12.8	13.3	111.3	114.6	7.2	5.2	181	240	13.9	13.6	113.8	114.3	3.3	4.8
	Mean	*13.1*	*13.3*	*115.1*	*114.9*	*6.6*	*7.7*	*168*	*198*	*13.9*	*13.3*	*115.1*	*114.0*	*3.9*	*6.3*
Over-all Mean		*14.6*	*14.6*	*113.5*	*112.8*	*4.0*	*5.6*	*141.5*	*163.8*	*14.9*	*14.3*	*112.7*	*112.2*	*3.3*	*5.0*
							(*b*) SUBBASE								
3	4–3–8	4.9	4.4	134.0	136.2	23.7	47.3			5.1	4.2	132.8	132.0	22.6	24.2
	4–6–4	5.5	4.6	137.4	137.9	9.2	30.0			5.6	5.0	134.6	131.0	8.8	22.6
	4–6–8	5.2	4.7	128.3	132.7	21.4	34.2			5.3	4.6	134.5	130.4	24.6	56.0
	Mean	*5.2*	*4.6*	*133.2*	*135.6*	*18.1*	*37.2*			*5.3*	*4.6*	*134.0*	*131.1*	*18.7*	*34.3*
4	5–6–12	4.8	5.2	143.4	129.0	23.2	49.8			4.8	4.6	135.9	126.0	14.9	65.8
	5–6–8	5.3	4.8	—	130.4	21.6	54.4			5.6	4.6	—	131.4	22.7	49.5
	5–3–12	5.4	4.6	—	132.9	9.4	45.6			5.2	4.8	—	132.5	16.8	26.3
	Mean	*5.2*	*4.9*	*143.4*	*130.8*	*18.1*	*49.9*			*5.2*	*4.7*	*135.9*	*130.0*	*18.1*	*47.2*
5	5–9–12	5.8	4.8	131.2	139.9	26.8	62.2			5.9	5.1	139.3	139.7	26.7	28.8
	5–6–12	5.9	4.5	134.7	134.8	18.2	42.6			6.2	5.0	134.0	137.3	14.9	29.7
	5–9–8	6.3	5.4	135.3	136.9	26.2	74.7			7.2	5.8	132.6	134.8	18.8	52.9
	Mean	*6.0*	*4.9*	*133.7*	*137.2*	*23.7*	*59.8*			*6.4*	*5.3*	*135.3*	*137.3*	*20.1*	*37.1*
6	6–6–16	5.7	4.8	131.3	138.6	39.1	10.3			6.0	4.8	134.2	131.0	23.2	74.2
	6–9–12	5.6	4.5	134.8	130.3	35.7	85.4			5.8	5.0	135.2	136.0	28.7	39.0
	6–9–16	5.8	5.4	141.3	142.5	36.2	60.3			6.2	5.4	136.8	132.6	28.8	44.2
	Mean	*5.7*	*4.9*	*135.8*	*137.2*	*37.0*	*52.0*			*6.0*	*5.1*	*135.4*	*133.2*	*26.9*	*52.5*
Over-all Mean		*5.5*	*4.8*	*136.5*	*135.2*	*24.2*	*49.7*			*5.7*	*4.9*	*135.2*	*132.9*	*21.0*	*42.8*

(*c*) Base

3	4-3-8	4.1	3.3	143.4	148.2	55	142	4.1	3.4	144.7	146.3	58	163
	4-6-4	4.3	3.5	145.8	146.4	80	145	4.5	3.6	142.7	144.2	72	149
	4-6-8	3.8	3.4	149.1	141.0	150	103	4.2	3.4	141.2	148.0	85	90
	Mean	*4.1*	*3.4*	*146.1*	*145.2*	*95.0*	*130.0*	*4.3*	*3.5*	*142.9*	*146.2*	*71.7*	*134.0*
4	5-6-12	4.4	4.0	146.3	145.0	86	200	4.6	4.1	144.3	142.7	79	155
	5-6-8	4.3	3.9	149.0	133.6	55	109	4.8	3.6	144.9	136.6	67	85
	5-3-12	4.2	3.4	137.2	142.0	78	124	4.4	4.0	139.8	138.2	42	71
	Mean	*4.3*	*3.8*	*144.2*	*140.2*	*73.0*	*144.3*	*4.6*	*3.9*	*143.0*	*139.2*	*62.7*	*103.7*
5	5-9-12	4.4	3.7	147.8	141.9	78	150	4.5	3.9	139.2	140.3	76	128
	5-6-12	4.8	3.5	140.5	144.9	92	150	5.0	4.0	143.2	140.2	52	116
	5-9-8	4.3	3.6	146.9	140.2	87	150	4.6	3.8	138.1	136.8	53	97
	Mean	*4.5*	*3.6*	*145.1*	*142.3*	*85.7*	*150.0*	*4.7*	*3.9*	*140.2*	*139.1*	*60.3*	*113.7*
6	6-6-16	4.0	3.1	141.5	142.2	69	82	4.3	3.4	142.5	140.2	76	98
	6-9-12	4.3	3.6	136.2	142.0	65	104	4.8	3.5	142.2	142.0	66	77
	6-9-16	4.2	3.8	141.4	141.9	148	116	4.3	3.8	144.4	138.1	119	150
	Mean	*4.2*	*3.5*	*139.7*	*142.0*	*94.0*	*100.7*	*4.5*	*3.6*	*143.0*	*140.1*	*87.0*	*108.3*
Over-all Mean		*4.3*	*3.6*	*143.8*	*142.4*	*86.9*	*131.3*	*4.5*	*3.7*	*142.3*	*141.2*	*70.4*	*114.9*

during periods when the pavement structure was in a relatively cold state. The peak period for the appearance of Class 2 cracking was in April for both spring seasons.

SUMMARY

On an average, the pavement in the various loops heaved approximately 0.4 in. during the winter with the edges rising about 0.6 in. and the interior portion about 0.3 in. Most of this heaving was attributed to expansion of the embankment soil.

No consistent or orderly effect of the over-all thickness of pavement upon the magnitude of heaving was found.

Rutting of the pavement was due principally to decreases in thickness of the component layers.

Based on average data from 51 trenched sections, a rut on the surface of the pavement was attributed to changes in thickness of 32 percent, 14 percent, and 45 percent, respectively, in surfacing, base and subbase, and to a rut in the embankment soil equal to 9 percent of the total.

Only 20 percent of the change in thickness of the surfacing and 4 percent of the change in subbase thickness was accounted for by increases in density of the materials. In the case of the base only 30 percent of the change in thickness determined in the summer of 1960 was accounted for by increases in density. However, the increase in the density determined in the spring of 1960 accounted for all of the decrease in thickness of the material.

A great deal more structural deterioration took place during the spring months than during the summer months.

The decrease in the indicated strength of the embankment soil during the spring months was not attributed to a decrease in its density, nor to an increase in its moisture content.

The decrease in the strength (CBR) of the crushed stone base course during the spring period was attributed to an increase in its moisture content.

The marked decrease in the CBR of the gravel sand subbase material during the spring was not explained by change in its moisture content.

In sections that survived the test, the rate of development of rutting during the first year of traffic generally exceeded the rate observed during the second year.

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[1] Road Test Report 2 (Materials and Construction), Table 2-C, gives the *R*-value at 300-psi exudation pressure as 21. Hveem stability tests run on in-place samples obtained in the spring of 1959 gave *R*-value in the range 7 to 10, corresponding to an exudation pressure of 220 psi.