Study of Rutting in Flexible Highway Pavements in Oklahoma

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Field and laboratory observations indicate three major modes of rutting in flexible pavements. For the bituminous materials of a pavement, these are (a) post-construction differential densification of one or more of the pavement layers (4; 7, pp. 58-80), (b) shear failure or lateral displacement of material in one or more layers from beneath the wheel paths (2; 8, pp. 21-39), and (c) surface wear or erosion of surface material under traffic (5, 6). In addition, densification (consolidation) or shear failures or both in the nonbituminous base and subgrade materials will influence the total amount of rutting. In a specific case, each of these factors may act singularly or in various combinations.

The primary objective of this research was to investigate rutting on high-quality flexible pavements and to detect if possible evidence of contribution of bituminous-bound pavement materials to this type of failure. This research did not deal directly with the influence or contributions to rutting of the subgrade soils and non-asphalt-bound base materials.

A transverse profile gauge was developed to plot the profile of the pavement surface perpendicular to the centerline. Rut depths could be scaled directly, and humps outside the wheel-path locations could be detected from the transverse profile tracings. Heaving or humping adjacent to ruts was considered an indication of outward or lateral creep of material from beneath the wheel paths.

Cores of the asphalt-bound pavement materials, 10.16 cm (4.00 in) in diameter, were recovered at selected points across the pavement. The core samples were subdivided into surface course; leveling course; and upper third, middle third, and bottom third of the base course. The percentage density values of the respective subdivisions of the core samples were determined and compared. Significant differences in the percentage density values between materials in the wheel-path locations and those outside the wheel paths were considered as evidence of differential densification.

Stereo photography (6) was employed to obtain quantitative estimates of differential wear in the wheel-path locations. Also a visual rating of the pavement surface condition was made at each test site to provide additional data for the study of these locations.

Sixteen test sites were selected on two Interstate Highway systems (I-35 and I-40) in Oklahoma. Performance of four test sites on flexible pavements constructed on each of the following types of base course materials was studied: (a) hot-mix sand asphalt (HMSA), (b) soil-cement base (SCB), (c) stabilized aggregate base course (SABC), and (d) black base (BB).

Although a limited number of test sites were studied, classical statistical methods that use the statistical analysis system (SAS) computer program (1) were employed in the analysis of test data to detect possible performance trends.

TRANSVERSE PROFILE GAUGE

The transverse profile gauge was developed to provide a portable and accurate apparatus for making a continuous profile tracing of the pavement surface. With these profile tracings, the shape of the pavement surface in and adjacent to the wheel-path depressions could be ascertained and the rut depth could be measured to the nearest 0.025 cm (0.01 in). In essence, this apparatus consisted of a supported guide rail, a trolley system, and an X-Y recorder (Figure 1).

The guide rail had a total length of 3.96 m (13.00 ft) and was made from two magnesium alloy carpenter's framing levels. The rail was supported at the center point and at the ends with adjustable height supports and was oriented to span a traffic lane perpendicular to the centerline of the roadway. The two end supports were adjusted to set the rail at a given height above the pavement surface at these points, and the center support was adjusted to remove any midspan deflection. Thus, the rail became a planar surface and served as a guide for the trolley system and as the datum for the measurements.

The trolley system consisted of an aluminum suspension plate with four nylon rail-track wheels machined to

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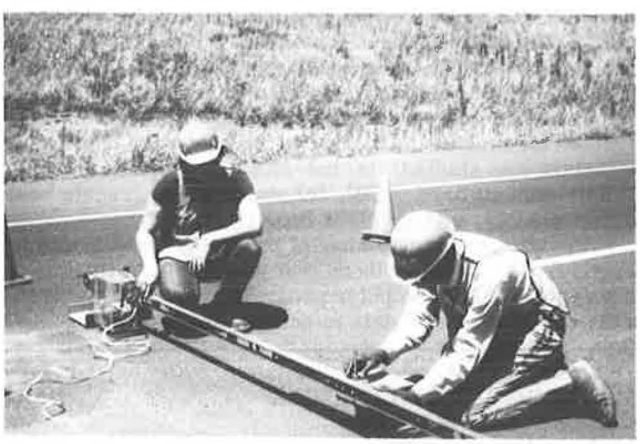
fit the top and bottom flanges of the guide rail. A 12.70-cm-diameter (5.00-in-diameter) rubber-rimmed actuating wheel made of Teflon was attached to a short pivot arm hinged to the bottom of the suspension plate. The pivot arm also supported a helical potentiometer, whose shaft was connected to the axle of the actuating wheel, and a bracket connection for one end of a linear potentiometer. The other end of this linear potentiometer was attached to the suspension plate.

The actuating wheel contacted and rolled along the pavement surface as the trolley system traversed the guide rail. The helical potentiometer scaled the horizontal displacement, and the linear potentiometer scaled the vertical displacement of the actuating wheel. These displacements were recorded as a continuous transverse profile trace of the pavement surface by an X-Y recorder. A more complete description of the construction and operation of the profile gauge has been reported by Manke and Oteng-Seifah (3).

PROFILE MEASUREMENTS

Lack of an original profile tracing of the pavement surface at a test site made it difficult to determine the total subsidence or upheaval that the surfaces had undergone since the roadway was opened to traffic. For this reason, the observed profile measurements were based on defined datums. That is, rut depth was measured as the maximum vertical displacement of the surface in the wheel path from a straight line whose ends formed tangents to the transverse profile curve at the adjacent points of maximum elevation.

Figure 1. Transverse profile gauge.



It was known from design records that the pavement surface at the test sites had been designed with uniform cross slope for lanes in the same traffic direction. A straight line joining the end support points on a tracing was assumed to be the original surface, and significant upward displacements of the surface above this line were scaled from the profile tracings. The maximum upward displacement was considered as probable heave resulting from lateral displacement of materials.

STEREOPHOTOGRAPHIC INTERPRETATION

Estimates of differential wear in the wheel paths at the test sites were based on the relative projections of the surface aggregates above the matrix. The pairs of photographs were viewed stereoscopically under six power magnification on a fluorescent light table. The aggregate projections were compared with the projection of a wedge-shaped scale placed on the pavement surface when the photographs were taken to obtain the heights of the aggregate projections. Comparison of the surface aggregate projections in the wheel paths with those at locations receiving less wheel coverage was considered a reasonable approach to determining the amount of surface attrition that had occurred.

LABORATORY DENSITY DETERMINATIONS

Core samples of full thicknesses of the asphalt-bound materials were cut from wheel-path and non-wheel-path locations at the selected test sites. As previously stated, these cores were cut into segments corresponding to the respective pavement layers with a concrete saw. Specific gravities of the individual layers could then be determined and differences in density detected. Bulk specific gravities of the core segments were determined by using ASTM method D1188. The maximum specific gravities of the mixtures were determined by using ASTM method D2041.

SUMMARY OF RESULTS

Table 1 gives the contributions of the various modes of

Table 1. Modal contributions to rutting.

				Approximate Contribution to Rutting			
Site Number	Type of Base Course	Age (months)	Maximum Rut Depth (cm)	Densification (%)	Surface Wear (%)	Lateral Creep (%)	Base or Subgrade Deformation (%)
10	HMSA	36	2.515	28	2	70	—[a]
60	HMSA	169	1.090	40	5	55	—[a]
70	HMSA	169	1.458	40	5	55	—[a]
120	HMSA	105	0.965	42	8	50	—[a]
20	BB	82	1.450	58	12	30	—[a]
30	BB	56	1.542	25	2	—[a]	73
40	BB	56	1.633	22	2	—[a]	76
50	BB	86	1.996	8	2	—[a]	90
80	SABC	165	1.450	9	5	—[a]	86
90	SABC	165	1.588	9	13	—[a]	78
100	SABC	156	1.542	18	5	—[a]	77
110	SABC	156	1.224	20	6	—[a]	74
130	SCB	148	0.556	43	8	49	
140	SCB	148	0.734	30	5	65	
170	SCB	169	1.270	14	8	78	—[a]
180	SCB	169	1.214	25	6	69	—[a]

Note: 1 cm = 0.394 in.

[a]Not a major factor; some contribution indicated.

rutting at the test sites. The measurements of rut depth, heave, surface wear, and differential density determined in this study were subject to many inaccuracies primarily because of the lack of initial data on the pavement sections. Thus the tabulated values should be regarded only as indications of the component contributions. Despite this, however, the data from this study consistently showed that the bituminous mixes were responsible for a significant amount of the rutting that occurred on these flexible pavements.

CONCLUSIONS

Based on the test procedures employed and the pavement sections studied, six conclusions are drawn.

1. The transverse profile gauge provides a portable and accurate means of obtaining continuous transverse profile tracings of a pavement surface.
2. In addition to measurements of surface deformations, profile graphs can provide permanent records of these conditions at a specific time in the service life of a pavement and can be used for future studies.
3. Densification contributed a significant amount to the total surface rut depth. On the thicker pavements (sections employing black base or sand-asphalt base), the amount of rut depth ascribed to densification ranged from 8 to 58 percent in the outer lane.
4. Evidence of lateral creep or instability in the bituminous material layers was found at 11 of the 16 test sites. This occurred in high- as well as low-density materials and contributed from 30 to 78 percent of the rutting at these locations. More prominent surface heaves were noticed at sites where the material layers had low densities.
5. Surface wear or attrition in the wheel paths on heavily traveled lanes was an important contributing factor to rutting. Proper consideration should be given to this factor in the design of surface mixtures.
6. Base and subgrade deformations influenced the magnitude of rutting at many of the test sites. Extensive surface cracking and indications of surface subsidence were found at these sites. Consolidation and shear failure in these layers conceal the effects of lateral creep in the bitumen-bound materials.

REFERENCES

1. A. J. Barr and others. A User's Guide to the Statistical Analysis System. North Carolina State Univ., Raleigh, Aug. 1972.
2. C. R. Foster. Dominant Effect of Fine Aggregate on Strength of Dense-Grade Asphalt Mixes. HRB, Special Rept. 109, 1968, pp. 1-3.
3. P. G. Manke and S. Oteng-Seifah. Characteristics of Rutting on High Quality Bituminous Highway Pavements. Oklahoma Department of Highways, Oklahoma City, Research Project 72-03-3, Interim Report 2, Dec. 1975.
4. N. W. McLeod. Influence of Viscosity of Asphalt Cements on Compaction of Paving Mixtures in the Field. HRB, Highway Research Record 158, 1967, pp. 76-115.
5. C. K. Preus. Studded Tire Effects on Pavements and Traffic Safety in Minnesota. HRB, Highway Research Record 418, 1972, pp. 44-54.
6. R. Schonfeld. Photo-Interpretation of Skid Resistance. HRB, Highway Research Record 311, 1970, pp. 11-25.
7. The AASHO Road Test: Report 5—Pavement Research. HRB, Special Rept. 61E, 1962.
8. E. J. Yoder. Principles of Pavement Design. Wiley, New York, 1959.