A Computerized Analysis of Rutting Behavior of Flexible Pavement

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Rutting is one mode of failure in flexible pavements. Described herein are laboratory models that predict rutting in asphaltic concrete, dense-graded aggregate, and a subgrade soil. These models have been programmed to predict a rut depth for a particular pavement structure using a given set of traffic and environmental conditions. A number of rutting charts have been developed and an example is presented herein that can be used to estimate rutting in a particular structure after an assumed number of equivalent axle loads. Such charts can also be used for overlays on flexible and rigid pavements. A comparison is made between thickness designs using rutting and fatigue as failure criteria.

The behavior of asphalt-bound layers, unbound aggregate bases, and foundation soils (subgrades) may be affected by such variables as gradation, asphalt and moisture contents, type of aggregate, density, method of compaction, temperature, magnitude and frequency of loading, and duration of each load cycle. There are also other less significant variables. The complex interaction of all of these variables yields a composite behavior for a particular pavement structure that could become manifest in some form of distress or even complete "failure."

Flexible pavements are susceptible to rutting, but it is not well known where and to what extent rutting takes place within a pavement structure. Rutting is a result of the lateral distribution (generally approximated by a normal distribution) or scatter of wheel passes across the wheelpaths. A large percentage of wheel passes occur within relatively narrow paths on the pavement surface. It is the distribution of traffic that causes accumulated deformations to occur, producing ruts. If these ruts are to be estimated or predicted for design purposes, the behavior of the materials must be known or parameterized.

To determine where in the pavement structure and to what extent rutting occurs and to determine the factors that control rutting, a comprehensive laboratory testing program was performed. Various traffic and environmental parameters were controlled in the study; and from the data, mathematical models that described the rutting behavior of an asphaltic concrete, a dense-graded aggregate, and a subgrade soil were formulated. A traffic and a temperature model were also formulated to provide necessary input to the rutting models. These models have been collected and programmed in a computer program entitled PAVRUT. By using this program, an estimated rut depth can be calculated for any flexible pavement, assuming that the volume and characteristics of the traffic stream and the properties of the paving materials are known.

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MODELS

Asphaltic Concrete Rutting Models

To predict accumulation of rutting in the field under repeated service loads, it was necessary to determine the susceptibility of an asphaltic concrete mixture to deformation. The mixture contained crushed limestone aggregate and was graded as shown in Figure 1. It contained 5.2 percent asphalt. Samples were compacted in a split mold that had a double plunger (top and bottom). The material was heated to 300°F (149°C), and the proper quantity of material was weighed into a heated mold. The material was compressed under a 5,000-lb (2273-kg) load until the proper height was obtained. The average temperature at the time of compaction was 280°F (138°C). The average height was 3.0 in. (76 mm) and the average diameter was 2.0 in. (51 mm). Twenty-seven unconfined repeated-load tests were performed on an asphaltic concrete base (asphalt cement grade was AC-20). The tests were run at three temperatures: 45°F (7°C), 77°F (25°C), and 100°F (38°C). Three vertical pressures were used at each temperature: 80 psi (551 kPa), 50 psi (345 kPa), and 20 psi (138 kPa). A detailed discussion of methodology, equipment, and analyses for those tests is given elsewhere *(1, 2)*.

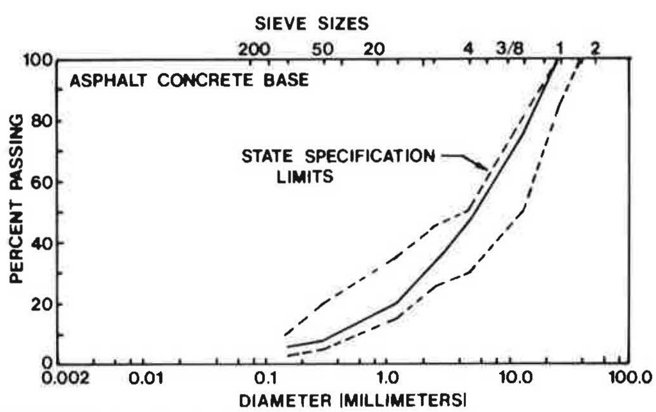

FIGURE 1 Gradation of asphalt concrete base.

Figure 2 is an example of the repeated-load data. A least-squares regression analysis of all data resulted in an equation that described plastic deformation (rutting) as a function of temperature, stress, and load repetitions:

$$\log \varepsilon_p = C_0 + C_1 (\log N) - C_2 (\log N)^2 + C_3 (\log N)^3 \quad (1)$$

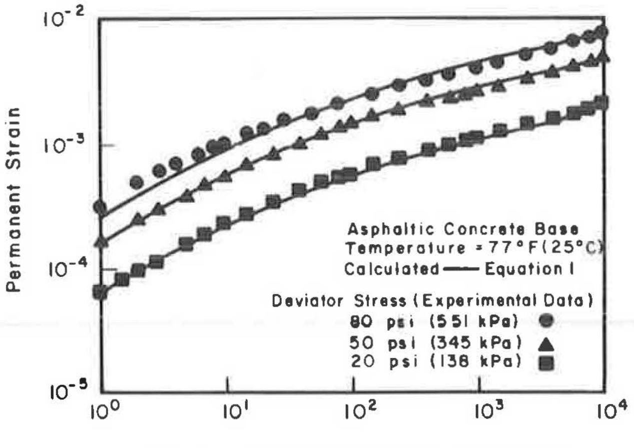

FIGURE 2 Permanent strain as a function of number of load cycles (asphaltic concrete).

where

ε_p = permanent strain,
N = number of stress repetitions,
C_3 = 0.00938,
C_2 = 0.10392,
C_1 = 0.63974,
C_0 = $(-0.000663\ T^2 + 0.1521\ T - 13.304) + [(1.46 - 0.00572\ T)(\log \sigma_1)]$,
T = temperature (°F), and
σ_1 = stress (psi).

Dense-Graded Aggregate Rutting Model

The algorithm in this model also was developed from data obtained from a series of repeated-load tests on laboratory-compacted specimens of dense-graded aggregate. The dense-graded aggregate was crushed limestone. The gradation is shown in Figure 3. To prepare samples at various moisture contents, it was necessary to determine the moisture-density relationship according to AASHTO Standard T-180. The maximum dry density was 150 lb/ft^3 (2403 kg/m^3); optimum moisture content was 4.7 percent. The repeated-load tests were performed at moisture contents of 1.7, 3.6, and 5.3 percent. The specimen size was 6 in. (152 mm) in height and 2.8 in. (71.1 mm) in diameter. Confining pressures of 5 psi (34 kPa), 10 psi (69 kPa), and 15 psi (103 kPa) were used and deviator stresses of 10 psi (69 kPa), 20 psi (138 kPa), and 30 psi (207 kPa) were applied at each confining pressure. A total of 27 tests were run.

As in the case of asphaltic concrete, analysis of the repeated-load test data (an example is shown in Figure 4) resulted in a third-degree polynomial describing the plastic deformation as a function of stress level, confining pressure, moisture content, and load repetitions:

$$\log \varepsilon_p = C_0 + C_1 (\log N) + C_2 (\log N)^2 + C_3 (\log N)^3 \tag{2}$$

where

ε_p = permanent strain,
N = number of stress repetitions,
C3 = $0.0066 - 0.004 (\log w)$,
C_2 = $-0.142 + 0.092 (\log w)$,
C_1 = 0.72
C_0 = $[-4.41 + (0.173 + 0.003\ w)(\sigma_1)] - [(0.00075 + 0.0029\ w)(\sigma_3)]$,
w = moisture content (percent),
σ_1 = deviator stress (psi), and
σ_3 = confining pressure (psi).

Subgrade Rutting Model

As in the cases of asphaltic concrete and dense-graded aggregate, the algorithm in this model was developed from a series

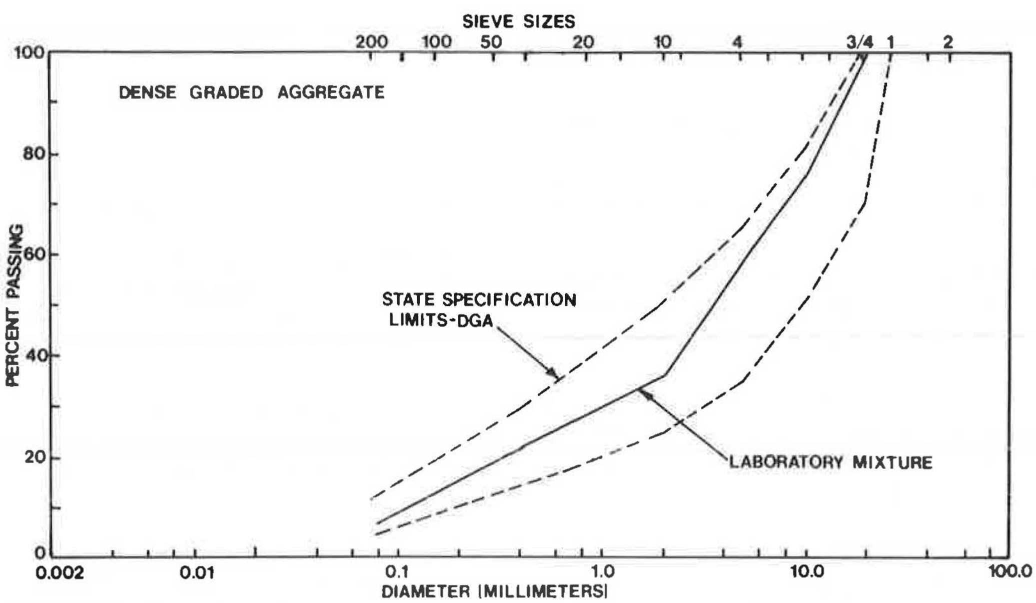

FIGURE 3 Gradation of dense-graded aggregate.

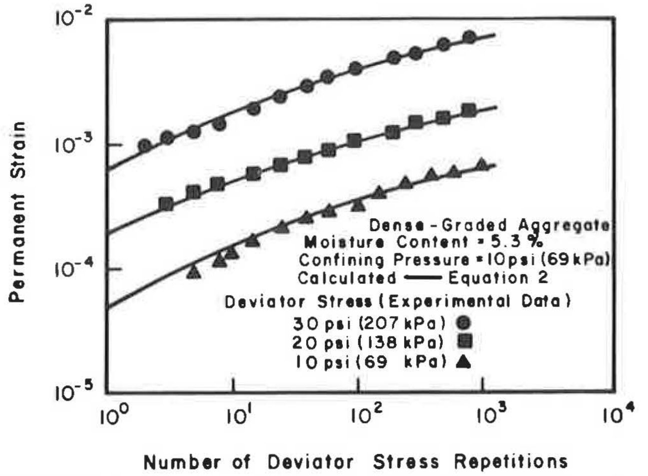

FIGURE 4 Permanent strain as a function of number of load cycles (dense-graded aggregate).

of repeated-load tests on laboratory-compacted soil specimens.

The gradation of the particular soil used in this study is shown in Figure 5. Results of the moisture-density test (AASHTO T-180) indicated a maximum dry density of 130.8 lb/ft^3 (2093 kg/m^3) at an optimum moisture content of 9.7 percent.

Two series of specimens were tested: one at 8.2 percent moisture and the other at 9.4 percent. Specimen size was 6 in. (152 mm) in height and 2.8 in. (71.1 mm) in diameter. Three confining pressures [5 psi (34 kPa), 10 psi (69 kPa), and 15 psi (103 kPa)] were used in each series. At least three specimens were tested at each confining pressure with deviator stresses of 2.5 psi (17 kPa), 5 psi (34 kPa), and 10 psi (69 kPa).

There was considerable scatter in the data, and results were not always repeatable. This was attributed largely to the high degree of variability of the material. An example of the repeated-load tests data is shown in Figure 6. Because of scatter, each curve in this figure is an average of two or more tests; and, for that reason, no data points are shown. A permanent deformation model was derived for the subgrade material using a linear-regression analysis on points taken from those average curves:

$$\log \varepsilon_p = C_0 + C_1 (\log N) + C_2 (\log N)^2 + C_3 (\log N)^3 \quad (3)$$

where

ε_p = permanent strain,
N = number of stress repetitions,
C_3 = 0.007 + 0.001 w,
C_2 = 0.018 w,
C_1 = $10^{(-1.1+0.1w)}$,
C_0 = $[(-6.5 + 0.38\ w) - (1.1 \log \sigma_3)] + (1.86 \log \sigma_1)$,
w = moisture content (percent),
σ_1 = deviator stress (psi), and
σ_3 = confining pressure (psi).

If desired, the subgrade rutting model may be used to calculate rutting as a function of California bearing ratio (CBR) rather than moisture content. The following relationship was developed from laboratory CBR tests on subgrade material at various moisture contents:

$$w = 10^{[0.8633 - 0.05645(\log_{10} CBR)]} \quad (4)$$

Equation 4 can be substituted for w in the previous equations when using CBR.

Temperature Model

This model is used to calculate the temperature of the asphaltic concrete at any depth for any typical hour of the year. This temperature is used to calculate strain in the asphalt concrete

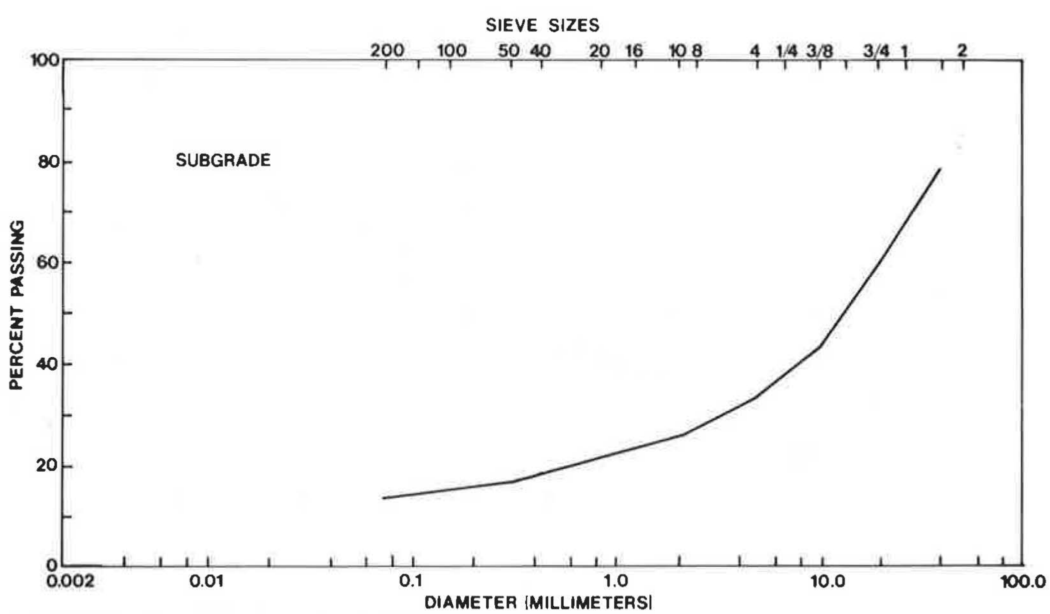

FIGURE 5 Gradation of subgrade soil.

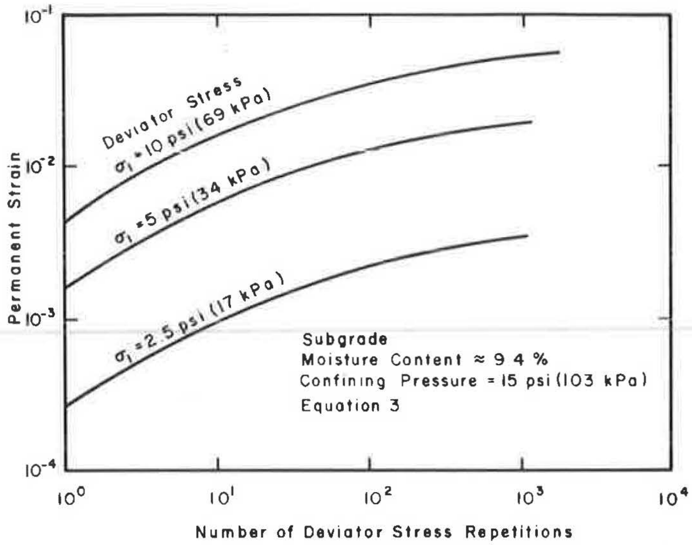

FIGURE 6 Permanent strain as a function of number of load cycles (subgrade).

and also to calculate the modulus of elasticity of the asphaltic concrete.

In 1969 Southgate and Deen *(3)* described an in-depth analysis of temperature-versus-depth data collected by Kallas *(4)* in 1964 and 1965 at The Asphalt Institute laboratory at College Park, Maryland. Charts similar to the one shown in Figure 7 were developed. In those charts (a total of 28), pavement temperature at some depth was plotted as a function of the pavement surface temperature plus the mean air temperature for the previous 5 days. Those relationships were developed by running a regression analysis on data from Kallas for most hours of the day (one chart for each hour).

To use information presented in Southgate and Deen's charts in the program, it was necessary to develop a mathematical model describing the relationship between the dependent variable (pavement temperature at some depth) and the independent variables (slope and zero intercept of the depth curves from all of Southgate and Deen's charts and pavement surface temperature plus the 5-day mean air-temperature history). As illustrated in Figure 7, the depth curves were straight lines; therefore, an equation of the following form should describe the relationship:

$$T = A + BX \tag{5}$$

where

- T = temperature at some depth (°F),
- A = zero intercept of depth curves,
- B = slope of depth curves, and
- X = pavement surface temperature plus 5-day mean air-temperature history (°F).

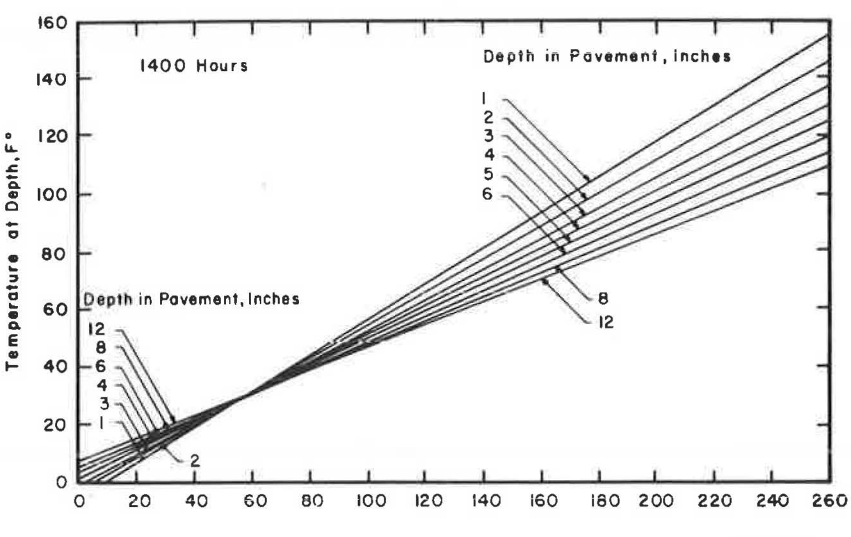

FIGURE 7 Pavement temperature at depth as a function of pavement surface temperature plus 5-day mean air-temperature history.

However, Variables A, B, and X are, in themselves, very complicated functions. As may be noted in Figure 7, Variables A and B are dependent on hour of the day and depth in the pavement. Variable X is dependent on month of the year and hour of the day.

To define Variables A and B, all values for A and B reported by Southgate and Deen were plotted as functions of hour and depth. Linear-regression analyses were performed, yielding functions that were fifth-degree polynomials in hour of the day and third-degree polynomials in depth in pavement. The following two equations describe Variables A and B:

$$\begin{aligned} A = {} & (-0.8882061 - 5.409584\ H + 1.419966\ H^2 \\ & - 0.1436045\ H^3 + 0.006001302\ H^4 \\ & - 0.000087823\ H^5) + (-2.312872 + 3.643902\ H \\ & - 1.000187\ H^2 + 0.1082190\ H^3 - 0.004867211\ H^4 \\ & + 0.00007657193\ H^5)\ (D) + (0.3188233 - 0.4041188\ H \\ & + 0.1103354\ H^2 - 0.01201035\ H^3 + 0.0005488345\ H^4 \\ & - 0.000008829082\ H^5)\ (D)^2 + (-0.01064115 \\ & + 0.01438466\ H - 0.00390228\ H^2 + 0.00042378\ H^3 \\ & - 0.0000194274\ H^4 + 0.0000003144042\ H^5)\ (D)^3 \end{aligned} \tag{6}$$

and

$$\begin{aligned} B = {} & (0.5449503 + 0.01836149\ H - 0.01005689\ H^2 \\ & + 0.00157948\ H^3 - 0.00008601361\ H^4 \\ & + 0.000001517039\ H^5) + (-0.004002625 + 0.0112879 \\ & H - 0.001222558\ H^2 - 0.0001705093\ H^3 \\ & + 0.00001952838\ H^4 - 0.0000004628811\ H^5)\ (D) \\ & + (0.0007371035 - 0.001401982\ H + 0.0002543963\ H^2 \\ & + 0.000001147628\ H^3 - 0.000001274846\ H^4 \\ & + 0.00000003690588\ H^5)\ (D)^2 + (-0.00007334696 \\ & + 0.00007449587\ H - 0.00001665841\ H^2 \\ & + 0.0000008755230\ H^3 + 0.00000000193508\ H^4 \\ & - 0.0000000006176451\ H^5)\ (D)^3 \end{aligned} \tag{7}$$

where H is the hour of the day and D is the depth in the pavement (inches).

Variable X in Equation 5 also was defined from data reported by Southgate and Deen. Figure 8 shows the relationship between pavement surface temperature and hour of day, normalized to 132°F (the average temperature at 1300 hr for the month of July). A regression analysis on those data yielded the following "best-fit" equation:

$$T_n = -0.316 + 0.0814\ H + 0.0125\ H^2 + 0.00155\ H^3 + 0.0000230\ H^4 \tag{8}$$

where T_n is the normalized pavement surface temperature.

However, Equation 8 does not adequately describe the "linear" portion of the curve, from Hour 1 to Hour 6. Therefore, an additive correction factor (C_n), derived from a graphic solution, must be applied to Equation 8:

$$C_n = 10^{(-0.0757 - 0.0221\ H^2)} - 10^{(-2.96 + 0.058\ H^2)} \tag{9}$$

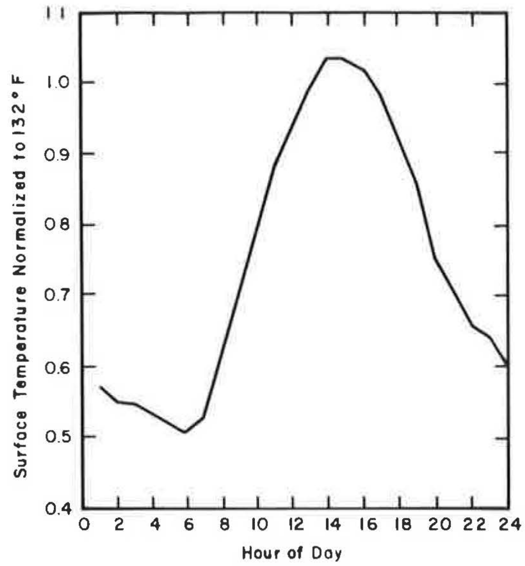

FIGURE 8 Pavement surface temperature normalized to 132°F (temperature at 1300 hr in July) as a function of hour of day *(1)*.

Combining Equations 8 and 9 gives the corrected pavement surface temperature in degrees Fahrenheit:

$$T_c = 132\ (T_n + C_n) \tag{10}$$

Equation 10 was based on temperatures for the month of July. Therefore, it must be corrected for each month. Figure 9, which was derived from Figure 22 of Southgate and Deen's report *(3)*, shows the relationship between normalized pavement surface temperature (°F) at 1300 hr and month of the year. As in Figure

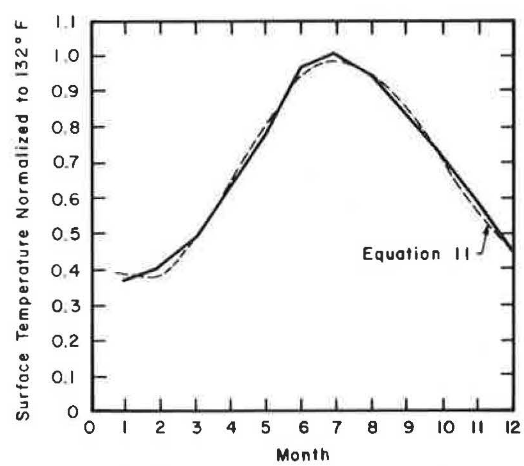

FIGURE 9 Pavement surface temperature normalized to 132°F (temperature at 1300 hr in July) as a function of month of year *(1)*.

8, the average pavement surface temperature at 1300 hr for the month of July (132°F) was set equal to 1.0. A regression analysis on that data gave the following result:

$$T_{nm} = 0.603192 - 0.35332\ M + 0.152582\ M^2 - 0.017904\ M^3 + 0.00062937\ M^4 \tag{11}$$

where T_{nm} is the normalized pavement surface temperature as a function of month and M is the month of the year (January = 1, December = 12).

Equation 10 can now be corrected for month of year:

$$ST = T_c \times T_{nm} \tag{12}$$

where ST is the pavement surface temperature for any month and hour of the year.

The 5-day mean air-temperature history is the last factor to be considered when defining Variable X in Equation 5. Figure 10 is a plot of the average daily temperature for each month, for the years 1970 through 1977. This was developed for locations with latitudes around 39 degrees North. Two linear "fits" were made to approximate the data. The first equation gives the mean daily temperature for the months of January through August:

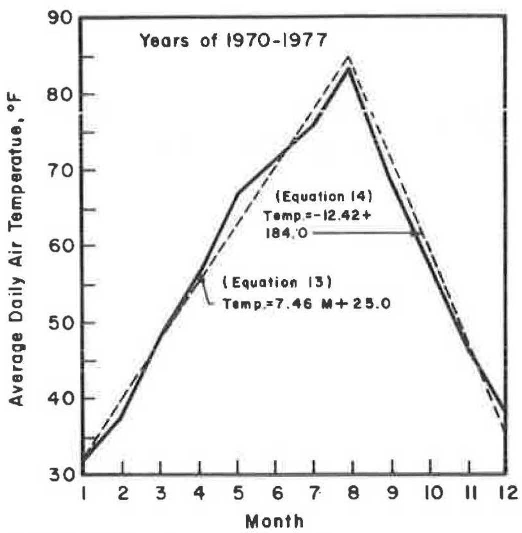

FIGURE 10 Average daily air temperature as a function of month of year.

$$T_{DA} = 7.46\ M + 25.0 \tag{13}$$

The second equation may be used to calculate the same variable for September through December:

$$T_{DA} = -12.42\ M + 184 \tag{14}$$

As noted earlier, Southgate and Deen's charts were based on the 5-day mean air-temperature history. However, in making the previous analysis, it was assumed that the average daily temperature of any 5-day period in the month would be reasonably close to the monthly mean. Although Southgate and Deen have shown that this is not entirely true, it appeared that the error introduced would not be significant (Figure 11). Variable X of Equation 5 has now been defined and can be written as

$$X = ST + T_{DA} \tag{15}$$

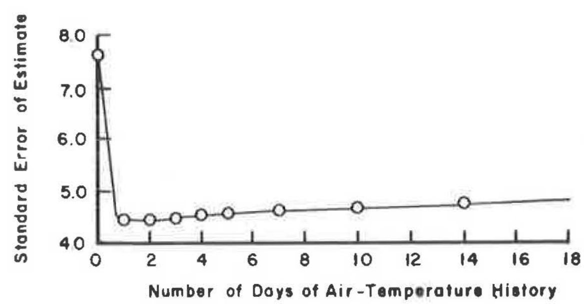

FIGURE 11 Standard error of estimate versus number of days of antecedent air temperatures for 6-in. depth at 1300 hr.

Modulus Models

The modulus of elasticity of asphaltic concrete was derived from Figure 19 of Southgate and Deen's report *(3)*. A regression analysis was performed on that data, yielding the following result:

$$\log E = 10.46 - 2.676 \log T \tag{16}$$

where E is the modulus of elasticity (psi) and T is the pavement temperature (°F) calculated from Equation 10.

The modulus calculated for dense-graded aggregate is actually a resilient modulus obtained from repeated-load tests. Definition of resilient modulus, how it was obtained, and the effects of confining pressure and moisture content on its magnitude are explained in detail elsewhere *(1)*. Again, regression analyses on the laboratory data gave the following equation for resilient modulus:

$$\log M_r = (5.4624 - 2.729 \log w) + (0.175 + 1.10 \log w)(\log \sigma_3) \tag{17}$$

where

M_r = resilient modulus (psi),
w = moisture content (percent), and
σ_3 = confining pressure (psi).

The equation describing the modulus of subgrade materials as a function of moisture content and confining pressure was developed from regression analyses of data obtained from resonant column tests on the material *(1)*:

$$\log E_r = 5.331 + 0.00070\ \sigma_3 + (0.11246 - 0.010060\ \sigma_3 + 0.000310\ \sigma_3^2)w - (0.02496 - 0.001880\ \sigma_3 + 0.00005490\ \sigma_3^2)w^2 \tag{18}$$

where E_r is the modulus of elasticity (psi) from the resonant column test. Moduli calculated with this model may be used to calculate stresses in the pavement structure.

Traffic Model

Traffic volumes by month and by hour of day for rural roads in Kentucky were reported by Herd et al. *(5)*. Figures 12 and 13

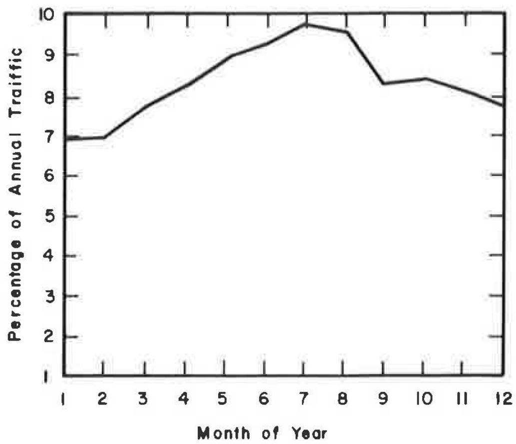

FIGURE 12 Percentage of annual traffic volume occurring in each month of the year.

were developed from their data. Figure 12 shows the percentage of total annual volume that occurs in each month, and Figure 13 illustrates the percentage of daily volume that occurs in any hour for a typical day. Although it is not entirely correct, for the sake of simplicity, it was assumed that the traffic pattern was the same for all days of any particular month.

To determine the volume for a particular hour of a particular month, it is necessary to multiply the percentage value from Figure 12 by the percentage value from Figure 13. This product is then multiplied by the number of days in a month (30 was assumed) and then by the annual volume.

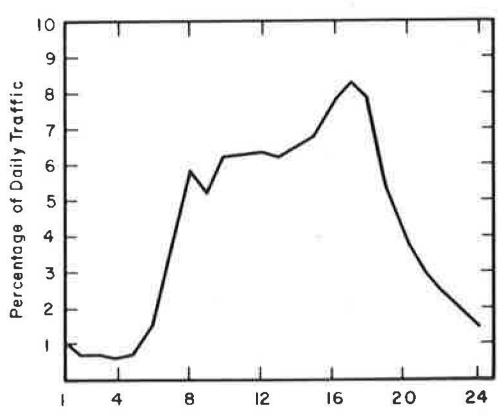

FIGURE 13 Percentage of daily traffic volume occurring in any hour of a typical day.

The total number of vehicles, however, is not the primary concern; the number of wheel passes is the major factor. To determine this, it was imperative to classify the traffic stream by types of vehicles. Traffic data for Kentucky indicated that approximately 20 percent of the traffic stream for rural roads was truck traffic. Furthermore, the same data showed that the average truck had 3.92 axles. Therefore, to obtain wheel passes, 80 percent of the hourly volume was multiplied by 2.0 (axles) for automobiles and 20 percent was multiplied by 3.92 (axles) for trucks to obtain the total number of wheel passes per hour.

All wheel passes do not occur at the same location on the pavement. It has been shown *(6)* that, in general, the distribution of wheel passes across any section of pavement approximates a normal distribution pattern (bell-shaped curve) or a sinusoidal function. This broadens the rut while reducing the depth. To account for such a pattern, the number of wheel passes was reduced to a number equal to the root mean square of the peak of the sinusoidal curve (0.707).

PROGRAM PAVRUT

All previously described models have been programmed as subroutines in PAVRUT.

There are 8,769 hr in a 365-day year. To be entirely correct, it would be necessary to calculate stresses, temperatures, and traffic volumes for each hour of the year; determine, from those calculations the amount of rutting in each layer for that particular hour; and, finally, sum all rutting values for 8,760 hr to obtain the total rut accumulated in 1 year. However, this would consume an extremely large amount of computer time. Therefore it was assumed that each month would have a "typical" day as far as traffic and temperature were concerned. Consequently, traffic and temperatures were determined for each hour of each typical day of the year. This means the program must cycle through each subroutine 288 times for each layer (12 typical days times 24 hr per day). In other words, to calculate rutting for one pavement, the program will cycle through most subroutines a total number of times equal to 288 multiplied by the number of layers.

The program will solve for rutting in a flexible pavement system that has up to 15 layers. However, the program requires a large amount of computer time, and the amount of time required increases rapidly with each additional layer to be analyzed.

Two classes of vehicles (such as automobiles and trucks) can be input for each problem with a different wheel load and tire pressure for each vehicle class. However, if only one class of vehicle is used, the program assumes that 20 percent of the annual volume is truck traffic.

It should be noted that the distribution of stresses in the pavement is calculated using layered elastic theory. A subroutine entitled COFE was used from the Chevron N-layer program to calculate stresses *(5)*.

An example output is shown in Figure 14. Each layer is identified. Layer thickness, magnitude of vertical compressive stress at the midpoint of the layer, depth of the midpoint of the layer, and moisture contents for dense-graded aggregate and subgrade are shown. In addition, the permanent deflection for each layer is printed. Finally, the total pavement deflection is printed.

To date only four field sites have been checked with estimated rut depths from the program. Figure 15 shows the results. There appears to be generally good agreement between measured and estimated rut depths, although in two cases the program slightly underestimated the rut depth.

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****************************************************************************
*                                                                          *
*          10,000,000 EAL - RUN 21 - 20 10 18  CBR-7.5                     *
*                                                                          *
****************************************************************************

     LAYER NUMBER     1     ASPHALT CONCRETE
     ------------------     LAYER THICKNESS        20.00
                            FIRST STRESS           22.60
                            ANSWER DEPTH           10.00
                            LAYER DEFLECTION     0.3098E 00

     LAYER NUMBER     2     DENSE-GRADED AGGREGATE
     ------------------     LAYER THICKNESS        10.00
                            FIRST STRESS            1.79
                            ANSWER DEPTH           25.00
                            MOISTURE CONTENT        3.00
                            LAYER DEFLECTION     0.3240E-01

     LAYER NUMBER     3     SUBGRADE
     ------------------     LAYER THICKNESS        18.00
                            FIRST STRESS            1.07
                            ANSWER DEPTH           39.00
                            MOISTURE CONTENT        7.00
                            LAYER DEFLECTION     0.1967E 00

    TOTAL PAVEMENT DEFLECTION    0.5389E 00
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FIGURE 14 Example printout.

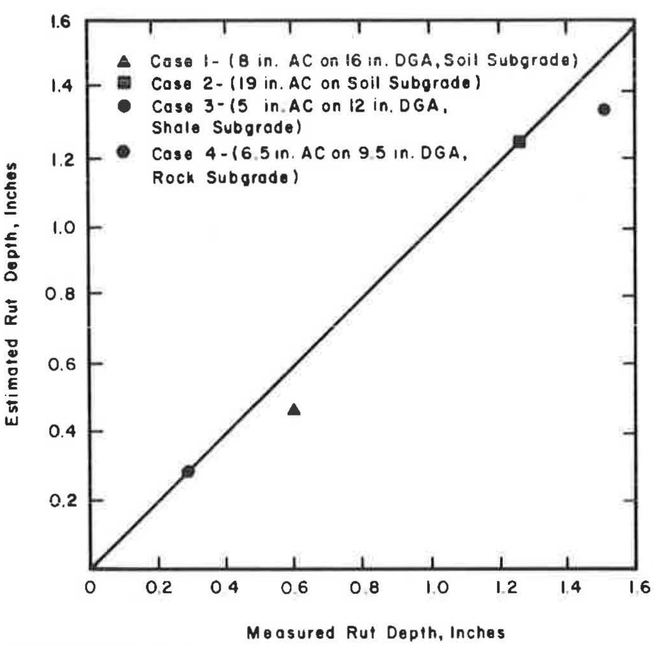

FIGURE 15 Estimated rut depths versus measured rut depths.

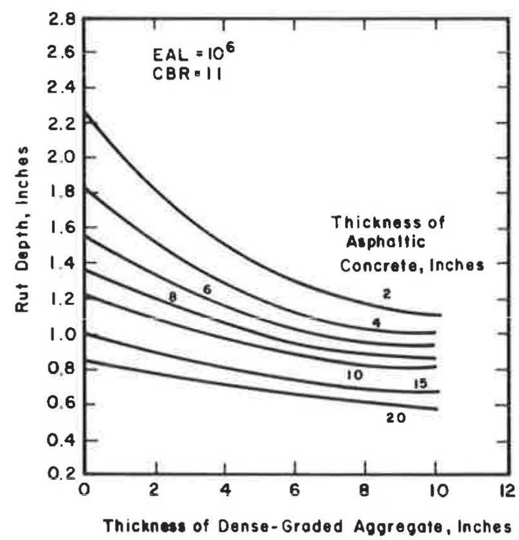

FIGURE 16 Rut depth chart.

EXAMPLE PROGRAM USES

The program may be used for any number of analyses, and three examples are given here. Figure 16 is a rut depth chart that was developed from the program. This chart permits a designer to estimate the amount of rutting for any particular pavement structure. Rutting also may be estimated for an in-service pavement. If the accumulated equivalent axle loads (EALs) are known, the remaining rutting life of a pavement may be estimated from such charts.

Figure 17 shows the relationship between rut depth and thickness of asphaltic concrete layers expressed as a percentage of total pavement thickness. All designs in Figure 17 are "equivalent" with respect to adequacy to resist failure by fatigue. As would be expected, CBR is quite influential in determining rut depth. Also, a somewhat surprising result, at EALs of 10^7, the more conventional designs of 33 or 50 percent asphaltic concrete thicknesses appear to be the better designs to minimize rutting. Although this hypothesis has not yet been tested extensively, it is suspected that the relationship shown in Figure 17 is related to the distribution of stresses in the pavement layers. Figure 18 shows a typical distribution of stresses with depth for a conventional design and for a full-depth design. Stresses decrease more rapidly in the asphaltic layers of

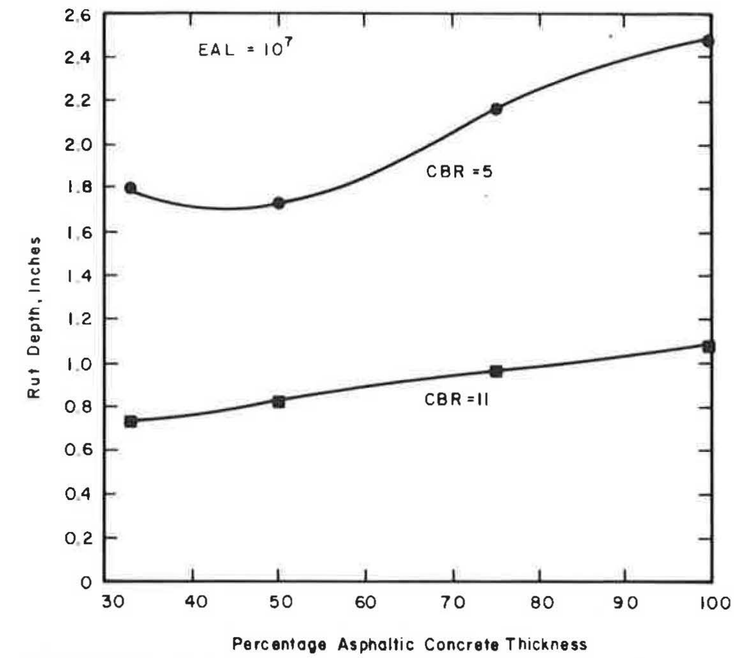

FIGURE 17 Rut depth as a function of the percentage of asphaltic concrete thickness.

the conventional design than in the more homogeneous full-depth design. This distribution tends to keep the higher stresses in the upper, stiffer layers of the conventional design. Stresses were calculated assuming linear elastic materials; therefore it is not clear how a nonlinear model of elasticity would affect the stress distribution and, consequently, the relationship shown in Figure 17.

In Kentucky, pavements are designed using fatigue as the failure criterion. However, rutting could, hypothetically, be used as a failure criterion. Figure 19 shows thickness design curves using a rut depth of 0.5 in. as the failure criterion. Up to 10^6 EALs, very thin pavements are required. However, from 10^6 to 10^7 EALs, the thickness required increases exponentially

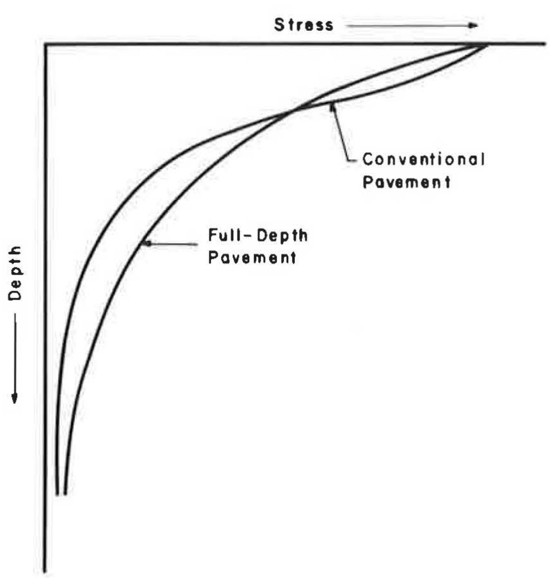

FIGURE 18 Typical stress distributions.

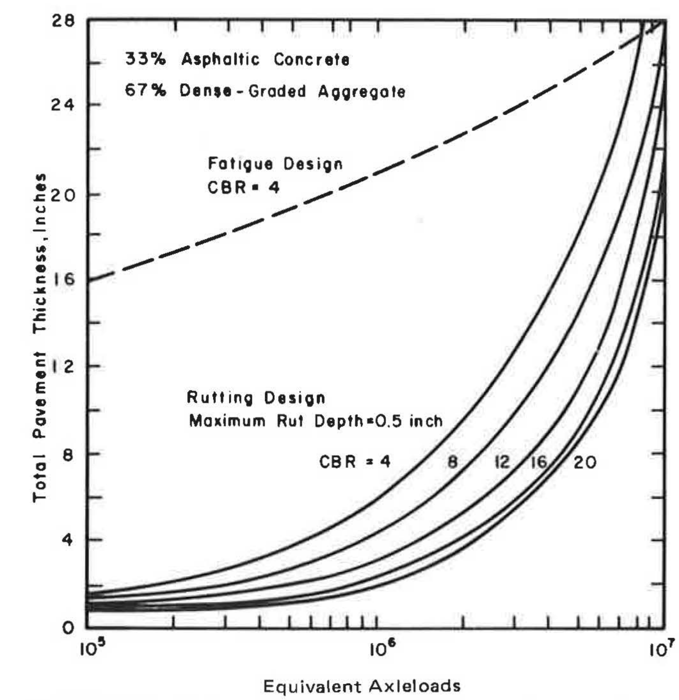

FIGURE 19 Thickness design curves for maximum rut depth of 0.5 in.

and becomes almost asymptotic at 10^7 EALs. From this it could be concluded that it is highly impractical to attempt to build a pavement thick enough to prevent a 0.5-in. rut depth for more than 10^7 EALs. For comparison, the thickness design curve presently used in Kentucky and based on the fatigue failure criterion is shown as the dashed line (for CBR = 4) in Figure 19. At an EAL of 8.4×10^6, the two failure criteria yield "equivalent" designs.

CONCLUSIONS

Based on a limited number of cases, the PAVRUT program appears to be reasonably accurate in predicting rut depths. Caution must be exercised in extrapolating the output to any flexible pavement because the models in the program are based on only one material.

Equivalent designs based on a fatigue failure criterion are not equivalent designs when using the rutting failure criterion.

In this study the more conventional designs (33 or 50 percent asphaltic concrete thickness) appear to function better from the standpoint of rutting than do full-depth asphaltic concrete pavements. Again, it must be emphasized that this conclusion is based on the behavior of only one material for each layer.

Rut depth charts developed from the PAVRUT program appear to be useful tools for determining the rutting potential of a particular flexible pavement structure. Such charts may be used to plan stage construction to minimize rutting and thus provide smoother pavements, which are also resistant to failure due to fatigue, for longer periods.

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