Research Report
UKTRP-82-23

STRAIN ENERGY ANALYSIS OF PAVEMENT DESIGNS FOR HEAVY TRUCKS

by

Herbert F. Southgate
Chief Research Engineer

Robert C. Deen
Director

and

Jesse G. Mayes
Chief Research Engineer

Kentucky Transportation Research Program
University of Kentucky

in cooperation with the
Kentucky Transportation Cabinet
and the
U.S. Department of Transportation
Federal Highway Administration

Prepared for Presentation
Annual Meeting
Transportation Research Board
January 1983

November 1982

INTRODUCTION

The first portion of this paper summarizes classical concepts of work, or strain energy, as applied to the analysis of stresses, strains, and deflections under various vehicular load configurations on pavement systems. Controlling equations for strain energy density are presented. When considering strain energy density, strain energy, or work, all components of stresses or strains must be taken into account so that total internal behavior can be evaluated. Previously, pavement thickness design systems have been developed using only a single component of strain, typically at the bottom of the asphaltic concrete layer or at the top of the subgrade. Strain energy concepts permit modifications to thickness design systems to account for the net effect of all components of strains or stresses.

The second portion of this paper illustrates the significance of detailed analyses. Effects of loads and load distributions on vehicles are summarized. One startling result shows the large increase in fatigue rate due to unequal distribution of loads between the two axles of a tandem group relative to the fatigue under an equal load distribution.

A third part of this paper deals with pavement thickness designs for heavily loaded trucks exceeding legal load limits. The effects of those vehicles on interstate pavements are compared to the effects of more normally loaded vehicles.

STRAIN ENERGY

The "work" done by a force when its point of application is displaced is the product of that force (parallel to the direction of movement) and the displacement. When work is done on some systems, the internal geometry is altered in such a way that there is a potential to "give back" work when the force is removed, and the system returns to its original configuration. This stored energy is defined as strain energy. Strain energy per unit volume at a given point in the body is the strain energy density at that point.

Strain energy density is a function of the Young's modulus of elasticity and Poisson's ratio of the material and the nine strain (or stress) components; however, it is independent of the coordinate system. Stress and strain components, referenced to a local cylindrical coordinate system, for each load are calculated by the Chevron program *(1)*. The classical equation for strain energy density derived by Sokolnikoff *(2)* is as follows:

$$W = \Sigma \; \Sigma \; [(1/2)\, \lambda\nu\, \epsilon_{ii} + G\, \epsilon_{ij}\epsilon_{ij}]$$

$$= (1/2)\, \lambda\nu^2 + G(\epsilon^2_{11} + \epsilon^2_{22} + \epsilon^2_{33} + 2\epsilon_{12} + 2\epsilon^2_{23} + 2\epsilon^2_{13}), \qquad [1]$$

in which W = strain energy density, or energy of deformation per unit volume;

ϵ_{ij} = i, jth component of the strain tensor;

$G = E/[2(1 + \mu)]$, the "modulus of rigidity" or the "shear modulus";

E = Young's modulus;

μ = Poisson's ratio;

$\lambda = E\mu/[(1+\mu)(1-2\mu)]$; and

$\nu = \epsilon_{11} + \epsilon_{22} + \epsilon_{33}$.

Strain energy density may be calculated using stress components by the equation

$$W = -\mu\Theta^2/2E + [(1+\mu)/2E](\sigma^2_{11} + \sigma^2_{22} + \sigma^2_{33}) +$$

$$[(1+\mu)/E](\sigma^2_{12} + \sigma^2_{23} + \sigma^2_{31}), \qquad [2]$$

in which $\Theta = \sigma_{11} + \sigma_{22} + \sigma_{33}$ and

σ_{ij} = i, jth component of the stress tensor.

Inspection of Equation 1 shows that the term $E/[2(1+\mu)]$ is contained by means of the terms λ and G. Also, it is noted that the strain components are squared. Having calculated strain energy density, "work strain" *(3)* may be obtained from

$$\epsilon_W = (2\ W/E)^{0.5} \qquad [3]$$

in which ϵ_W = work strain. The associated "work stress" is given by $E\epsilon_W$.

INTERPRETATIONS OF WORK STRAIN

Admittedly, work strain is not a true strain because Poisson's ratio has not been eliminated prior to taking the square root; however, it is of the same order of magnitude as any of the strain components. Calculating the work strain is a minor effort since all terms of the equations are either required input to, or calculated output of, the Chevron N-layer *(1, 4)* program. Work strain is also the composite, or net effect, of all strain components and thus is an indicator of the total strain behavior. Figure 1 illustrates there is a direct correlation between a strain component and work strain.

USES FOR WORK STRAIN

Some thickness design systems for flexible pavements are based partially upon tensile strain criteria at the bottom of the asphaltic concrete layer. Kentucky's proposed system *(5, 6, 7)* is based in part upon the tangential strain component. The tangential component is generally the largest in magnitude, but the radial component often is nearly as large. Only the tangential component has been utilized because laboratory test data yields one component of tensile strain. The net effect of all components of strain (work strain) can be correlated with any component of strain. Thus, design systems based upon one component of strain may be converted to a design system that utilizes the net effect of all component strains. The load-damage factor relationships presented in this paper are based on work strain. All comments concerning component strains also apply to component stresses.

FATIGUE CONCEPTS

The equivalent axleload (or EAL) approach involves the expression of all axleload weights that pass over a pavement during its design life in terms of some reference axleload. The reference axleload weight selected in Kentucky was 80 kN (18,000 pounds). Any axleload could have been selected, and the change from one axleload reference to another should not change the results of a design process. The 80-kN (18,000pound) axleload was probably selected because it represented, at the time the EAL concept was developed, the typical legal axleload limit recognized in many states. The 80-kN (18,000-pound) axleload was also the reference used at the AASHO Road Test in the early 1960's. The passage of one 80-kN (18,000-pound) axleload results in the application of one EAL (or equivalent axleload). An 89-kN (20,000-pound) axleload results in the application of 1.7 EAL's; the 89-kN (20,000-pound) axleload would cause 1.7 times the damage to the pavement as would one 80-kN (18,000-pound) axleload. The EAL for a given group of axles, thus, represents the damage factor (load equivalency) for that particular group. Figure 2 illustrates how the damage factor for selected axle groups varies with increasing loads on those groups. The load-damage factor relationships shown in Figure 2 were developed from analyses using the Chevron N-layer computer program, which is based upon elastic theory. Pavements analyzed were the hundred possible combinations of thicknesses, of which 67 were built and tested, at the AASHO Road Test. The tire loads and axle spacings were those used on the test vehicles at the AASHO Road Test. The load-damage factor relationship is expressed by

$$DF = 10^{[a + b (\log Load) + c (\log Load)^2]}, \qquad [4]$$

in which DF = damage factor and

a, b, c = coefficients by regression analyses.

Table 1 contains the numerical values for the coefficients in Equation 6 for each axle configuration. The coefficients have been published previously *(8)* for the two- and four-tired single axle and eight-tired tandem axle groups.

Figure 3 illustrates how the damage factor increases due to an increasing difference of load distribution between the axles of a tandem group. The significance or prevalence of unevenly distributed loads between the two axles of a tandem is indicated by an examination of individual axleloads for 335 vehicles of the 3S2 (five-axle semitrailer) configuration listed in the 1976 W6 Tables for Kentucky. Appropriate damage factors were applied to those individual axleloads. Figure 4 shows the large difference between uniform and nonuniform load distributions using factors from Figure 2 and those adjusted by Figure 3 for nonuniform load distributions. AASHTO *(9)* damage factors also were applied to the same vehicle loads. Figure 4 shows that there is very little difference in the summation of EAL's based on AASHTO damage factors and the energy based factors adjusted for nonuniform loading.

As an example, it has been found that only about 10 percent of the tandem axle groups observed in Kentucky have loads uniformily distributed between the two axles. Analyses indicate that the nonuniform distribution between the axles in a tandem group can account for as much as a 40-percent increase in the damage to a pavement. The frequency of tandems for which the difference between the axles exceeded 8.9 kN (2,000 pounds) was three of 10 tandems on semitrailers and two of 10 tandems on the tractors. The use of "floating" axles also may be undesirable unless means are provided by which the floating axle carries its proper share of the load. It has been observed that loads carried by floating third axles may vary from a very low portion of the total load, providing very little benefit from the additional axle and shifting the additional load to the two remaining axles in the group, to an unduely large percentage of the load. Both conditions increase the damage significantly over the situation when the load is distributed uniformly among all axles.

Experience has indicated that the elastic theory and work concept used in Kentucky predict reliably the number of EAL's a given pavement system can support in its lifetime. Conversely, it is possible to design a pavement that will adequately resist the damage of a specified number of EAL's. However, the problem of predicting the rate at which EAL's will accumulate remains. This involves estimates of the numbers and types of vehicles that will be using a section of highway as much as 30 years in advance. To illustrate the problem, a section of KY 15 was designed to carry a given number of EAL's. The pavement, however, failed after only 8 months. Analyses showed that the pavement did in fact carry the EAL's for which it was designed. Unfortunately, the opening of a high-volume and heavy-traffic generator (a coal producing operation) was not foreseen, and the rate of accumulating EAL's was underestimated.

HEAVY LOAD DESIGN

In almost any state, there is some commodity being transported on overloaded trucks. In Kentucky, coal and limestone are two such primary commodities. In other states, industries that generate overloaded trucks might be logging, pulp wood, minerals, ores, and grains and other agricultural products. Many county roads in Illinois, for example, have only one paved lane, and that lane leads to a grain elevator.

Three truck configurations in Kentucky coal fields routinely have gross loads shown in Table 2. Table 2 also shows the corresponding damage factors obtained from Figure 2. Classification counts in 1981 on one of the main coal-haul non-interstate routes were used to obtain the percentages of the three configurations. Note that another 111 kN (25,000 pounds) can be carried on the 3S3 than on the 3S2, yet produces slightly less total damage per trip.

Table 3 shows the design EAL's required for just the three truck configurations of Table 2. Two of the thickness design charts contained in the proposed Kentucky thickness design system *(6)* are shown in Figures 5 and 6. Assuming a design CBR of 5.2, which is typical for many Kentucky soils and the same soil used at the AASHO Road Test, the required thicknesses are given in Table 3 for the various combinations of truck volumes and design periods. Kentucky assigns a terminal serviceability of 3.5 for pavements expected to support 4 million or more 80-kN (18,000-pound) EAL in the design life.

COMPARISON WITH INTERSTATE TRAFFIC

Interstate traffic is a mixture of loaded and empty trucks, as reflected by loadometer studies. Average damage factors *(5, 6)* had been calculated and have been applied to eight classification counts made in 1981 at two locations. The volume of truck traffic was 28.3 percent on I 65 and 39.0 percent on I 71. However, the number of trucks was nearly the same on each route and almost identical regardless of which quarter of the year the count was made. Thus, truck traffic was fairly constant. Table 4 shows that the daily and annual EAL's for these two routes were nearly the same. Table 3 shows that approximately 200 heavily loaded trucks per day can cause the same fatigue as all trucks using I 65 or I 71.

A second comparison was made on the basis of net tonnage and the associated accumulation or fatigue. Table 5 gives the tare weight for typical vehicles for both the heavily loaded trucks and those normally found on interstates and other routes. This permits a theoretical comparison of net tonnage hauled by the two groups of vehicles. The following assumptions were made:

1. The number of trucks was taken from I-65 data in Table 4 for the corresponding classifications in Table 2. This represents typical useage on interstates.
2. The remainder of the traffic stream would be constant for both comparisons and therefore are not included in this example problem.
3. Each axle group is loaded to the legal maximum.
4. For an interstate, 365 days are assumed for EAL calculations because truck traffic does not appear to vary significantly on any given day. However, for coal or similar commodities, there are market slumps and bad-weather days that reduce the total number of working days to approximately 300.

The following methodology was used to calculate the net loads:

1. Legally loaded trucks for the three classifications reported for I 65 were used to calculate the fatigue for one year. The fatigue for one year for 100 heavily loaded trucks also was calculated. The ratio of the two fatigue calculations multiplied by the original 100 heavily loaded trucks produces the total number of heavily loaded trucks required to produce the same fatigue as the trucks reported on I 65.
2. For each classification of legally loaded trucks, the number of trucks per day were multiplied by the net load and accumulated. The product of the number of heavily loaded trucks and their net loads was also calcuated.
3. The total net load per day for the legally loaded trucks was divided by the total net load for the heavily loaded trucks.

For the same fatigue, calculations shown in Figure 7 indicate that the number of heavily loaded trucks is approximately 10 percent of the number of legally loaded trucks. Furthermore legally loaded trucks would transport approximately 7.7 times more payload than would the heavily loaded trucks with only about one-fourth (1/3.72 from Figure 7) of the fatigue damage.

DETERIORATION OF PAVEMENTS

Many Kentucky pavements have been subjected to heavily loaded vehicles. Some observations of their effect upon pavements follow.

Pavements designed for light to medium traffic will deteriorate rapidly under heavy loads and the paved surface of a rural secondary road may be broken up and even disappear in one to two years. During construction of 11 km (7 miles) of KY 15, two unanticipated strip mine operations were opened. Eight months later, a 102-mm (4-inch) asphaltic concrete overlay was placed to eliminate severe rutting and some cracking. The overlay was required and laid prior to the official opening of the new construction to traffic.

On an experimental full-depth asphaltic concrete pavement with cross sections ranging from 254 to 457 mm (10 to 18 inches), cold weather temperature cracking was observed in the passing lane. Those transverse cracks were 1.2 to 1.8 m (4 to 6 feet) apart in some areas. The cracks were evident in the outer lane only at the outer and centerline paint stripes. Evidently, the heavily loaded trucks kneaded the pavement surface together. At this time, it is not known if the cracks extend below the surface layer.

On a 432-mm (17-inch) full-depth asphaltic concrete pavement on the Daniel Boone Parkway, there is a long steep grade that shows progressively deeper rutting as the top of the hill is approached. The change in rutting was pronounced and occured over a fairly short length where drivers downshift into a lower gear. The amount of rutting then remained relatively constant over a considerable distance. When the driver shifted to even a lower gear, another significant increase in rutting occurred and remained constant over a considerable length. The lengths of "constant rutting" decreased as the truck approached the top of the hill. Rutting varied from 6.4 mm (0.25 inches) at the bottom of the grade to 76 mm (3 inches) at the top of the hill. To help understand the cause of the rutting, two experiments were conducted. First, a full-depth trench was excavated across the climbing lane containing the severe rutting. Inspection of the cross section showed that rutting occurred only in the top 152 mm (6 inches) and all construction interfaces below the 152-mm (6-inch) depth were parallel and straight. Above 152 mm (6 inches), construction interfaces were undulating and layer thicknesses varied due to differential densification under traffic. Also in the upper layers, the normally random orientation of aggregate particles was totally reoriented such that the particles were parallel to each other. The second experiment consisted of making two shallow saw cuts across the lane. One was prependicular to the centerline, and the other was on a 45° angle with the lower end of the cut at the shoulder. Both cuts were filled with small-diameter glass beads used in highway paint stripping. Four weeks later these cuts were inspected. Both cuts in both wheel track areas had been displaced downgrade by 16 mm (0.6 inches). Thus, the high torque at the tire pavement interface caused a downward flow of the surface mix. The lack of stability of the bituminous mixture was determined to be caused primarily by a soft grade of asphaltic cement. An overlay with a stiffer grade of asphaltic cement was placed.

SUMMARY

Pavements can be designed for heavily loaded trucks, but the rate of accumulating fatigue is greatly accelerated. The accumulation of fatigue for heavy trucks is highly disproportionate to the amount of payload transported. For the same fatigue and assumed proportions of trucks, the number of trucks loaded to the legal maximum axleloads is approximately ten times the number of heavily loaded trucks. For the same fatigue, legally loaded trucks can transport approximately 8.2 times more payload than can heavily loaded trucks.

Pavements designed for "normally" loaded trucks may deteriorate rapidly and severely when subjected to heavily loaded trucks. Observed deterioration varies from accelerated rutting, both in depth and time, to severe breakup of the paved surface.

REFERENCES

1. J. Michelow, *Analysis of Stresses and Displacements in an N-Layered Elastic System under a Load Uniformly Distributed on a Circular Area,* Chevron Research Corporation, 1963.

2. I. S. Sokolnifoff, **Mathematical Theory of Elasticity**, Second Edition, McGraw-Hill Book Company, 1956.

3. R. C. Deen, H. F. Southgate, and J. G. Mayes, *The Effect of Truck Design on Pavement Performance,* **Proceedings**, Association of Asphalt Paving Technologists, February 1980.

4. H. Warren and W. L. Dieckmann, *Numerical Computation of Stresses and Strains in a Multiple-Layered Asphalt Pavement System,* Chevron Research Corporation, 1963.

5. H. F. Southgate, R. C. Deen, J. H. Havens, and W. B. Drake, *Kentucky Research: A Flexible Pavement Design and Management System,* **Proceedings**, Fourth International Conference, Structural Design of Asphalt Pavements, University of Michigan, 1977.

6. J. H. Havens, R. C. Deen, and H. F. Southgate, *Design Guide for Bituminous Concrete Pavement Structures,* Kentucky Transportation Research Program, College of Engineering, University of Kentucky, Report No. KTRP-81-17, August 1981.

7. H. F. Southgate, R. C. Deen, and J. H. Havens, *Development of a Thickness Design System for Bituminous Concrete Pavements,* Kentucky Transportation Research Program, College of Engineering, University of Kentucky, Report No. KTRP-81-20, November 1981.

8. *Traffic Factors Used in Flexible Pavement Design,* **Research Circular Number 240,** Transportation Research Board, April 1982.

9. **Interim Guide for Design of Pavement Structures**, American Association of State Highway and Transportation Officials, 1972.

ACKNOWLEDGMENT

This study was conducted at the University of Kentucky Transportation Research Program and in part was sponsored cooperatively by the Kentucky Transportation Cabinet and the Federal Highway Administration. The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the University of Kentucky, the Kentucky Transportation Cabinet, nor the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

TABLE 1. REGRESSION COEFFICIENTS TO CALCULATE DAMAGE FACTORS FOR VARIOUS AXLE CONFIGURATIONS

Log (Damage Factor) = a + b (Log Load) + c [Log Load]^2

	COEFFICIENTS		
AXLE CONFIGURATION	a	b	c
Two-Tired Single Front Axle	-3.540112	2.728860	0.289133
Four-Tired Single Rear Axle	-3.439501	0.423747	1.846657
Eight-Tired Tandem Axle	-2.979479	-1.265144	2.007989
Twelve-Tired Tridem Axle	-2.740987	-1.973428	1.964442
Sixteen-Tired Quad Axle	-2.589482	-2.224981	1.923512
Twenty-Tired Quint Axle	-2.264324	-2.666882	1.937472
Twenty-Four Tired Sextet Axle	-2.084883	-2.900445	1.913994

TABLE 2. DAMAGE FACTORS FOR TYPICAL HEAVY TRUCK CONFIGURATIONS

CONFIGURATION	GROSS LOAD (kips)	FRONT AXLE		TANDEM		TRIDEM		TOTAL DAMAGE PER TRIP	NUMBER OF TRUCKS PER 100 TRUCKS	TOTAL DAMAGE PER 100 TRUCKS
		LOAD (kips)	DAMAGE FACTOR	LOAD (kips)	DAMAGE FACTOR	LOAD (kips)	DAMAGE FACTOR			
Single Unit Three-Axle Dump	96	20	3.2	76	57.0			60.2	25	1,505
Five-Axle Semi-Trailer 3S2	115	15	1.15	2@ 50	2@ 4.65			10.5	70	732
Six-Axle Semi-Trailer 3S3	140	15	1.15	50	4.65	7.5	4.50	10.3	5	51
Total EAL										2,288

TABLE 3. PAVEMENT THICKNESS DESIGNS FOR HEAVY LOADS

NUMBER OF TRUCKS PER DAY	DESIGN YEARS	DESIGN EAL $P_t = 3.5$	DESIGN THICKNESS PERCENT* 50	100
100	1	617,760	-	-
	5	3,088,800	18.2	11.8
	10	6,177,600	20.1	13.1
	20	12,355,200	22.1	14.5
200	1	1,235,520	-	-
	5	6,177,600	20.1	13.1
	10	12,355,200	22.1	14.5
	20	24,710,400	24.2	15.8

Assumptions:
Sundays = 52
Holidays = 8
Bad Weather = 5

Total Non-work = 65
Working days per year = 365 - 65 = 300

*50 percent -- half of pavement thick- is asphaltic concrete, half is unbound granular base

*100 percent -- full-depth asphaltic concrete

TABLE 4. VEHICLE CLASSIFICATION COUNTS AND CORRESPONDING EAL FOR TWO SITES ON KENTUCKY INTERSTATES

			SINGLE UNIT TRUCKS			SEMI-TRAILER TRUCKS				
	AUTOS & PICKUPS	TWO AXLES FOUR TIRES	TWO AXLES SIX TIRES	THREE AXLES	FOUR AXLES	THREE AXLES	FOUR AXLES	FIVE AXLES	SIX AXLES	TOTAL
AVERAGE DAMAGE FACTOR	0.0501	0.0605	0.2953	0.6386	0.6386	0.6353	0.7514	0.6267	0.6000	
VOLUME: TOTAL OF FOUR DAILY COUNTS										
I 65	51,026	52	2,435	272	15	266	1,442	15,319	67	70,894
I 71	32,392	356	2,015	426	137	372	945	15,889	150	52,682
EAL's										
I 65	2,556.4	3.1	719.1	173.1	9.6	169.0	1,083.5	9,600.4 Average	40.2	14,355.0 3,588.8
Annual EAL = 365 x 3,588.8 = 1,309,895										
I 71	1,622.8	21.5	595.0	272.0	87.5	236.3	710.0	9,957.6 Average	99.6	13,602.6 3,400.6
Annual EAL = 365 x 3,400.6 = 1,241,235										

TABLE 5. GROSS, EMPTY, AND NET WEIGHTS OF SELECTED VEHICLE CONFIGURATIONS

	NORMAL TRUCKS				HEAVILY LOADED TRUCKS			
CLASSIFICATION	EMPTY WEIGHT (kips)	GROSS WEIGHT (kips)	NET WEIGHT (kips)	DAMAGE FACTOR PER TRIP	EMPTY WEIGHT (kips)	GROSS WEIGHT (kips)	NET WEIGHT (kips)	DAMAGE FACTOR PER TRIP
Three- Axle Single-Unit	20	46	26	1.18	30	96	66	60.2
Five-Axle Semi-Trailer	30	80	50	1.80	30	115	85	10.45
Six-Axle Semi-Trailer	32	96	64	1.74	34	140	106	10.30

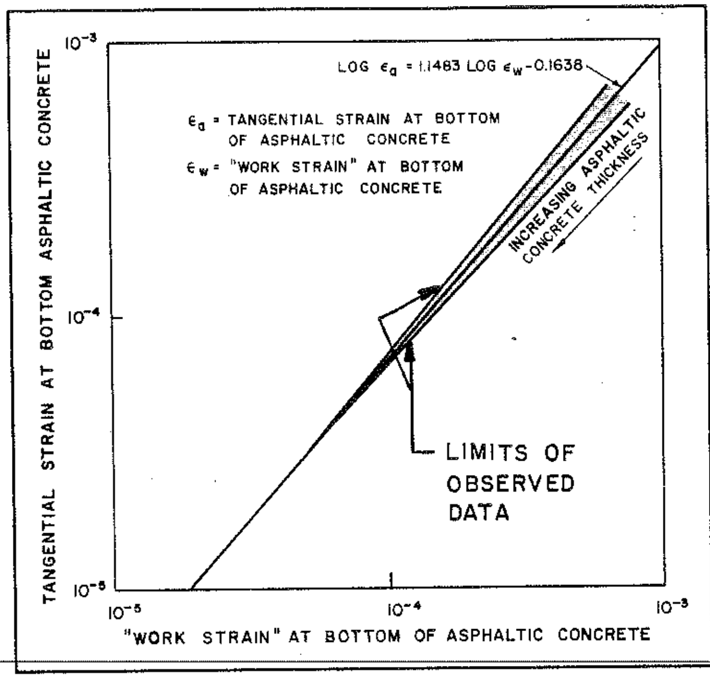

Figure 1. Tensile Strain versus "Work Strain."

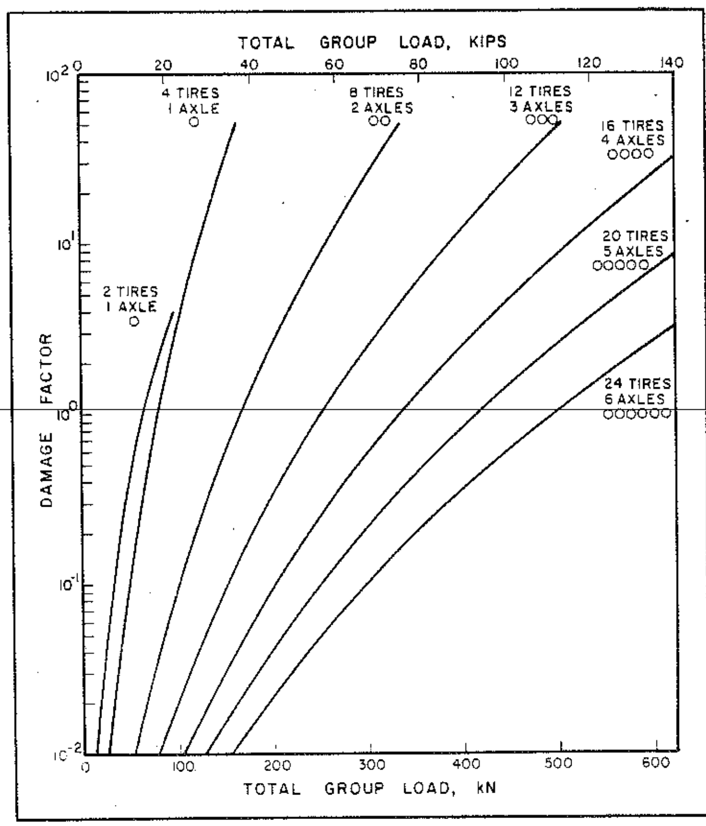

Figure 2. Variation of Damage Factor for Selected Axle Groups as Load on Axle Group is Changed.

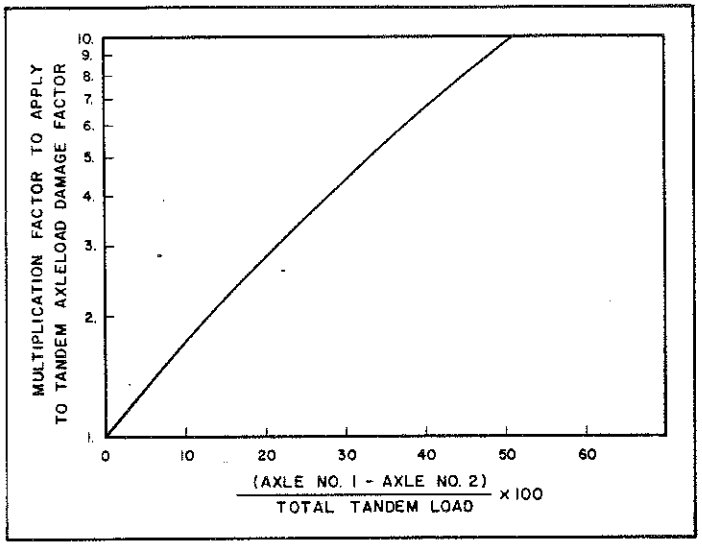

Figure 3. Multiplying Factors Increasing Damage Factors due to Nonuniform Load Distribution between Axles of a Tandem.

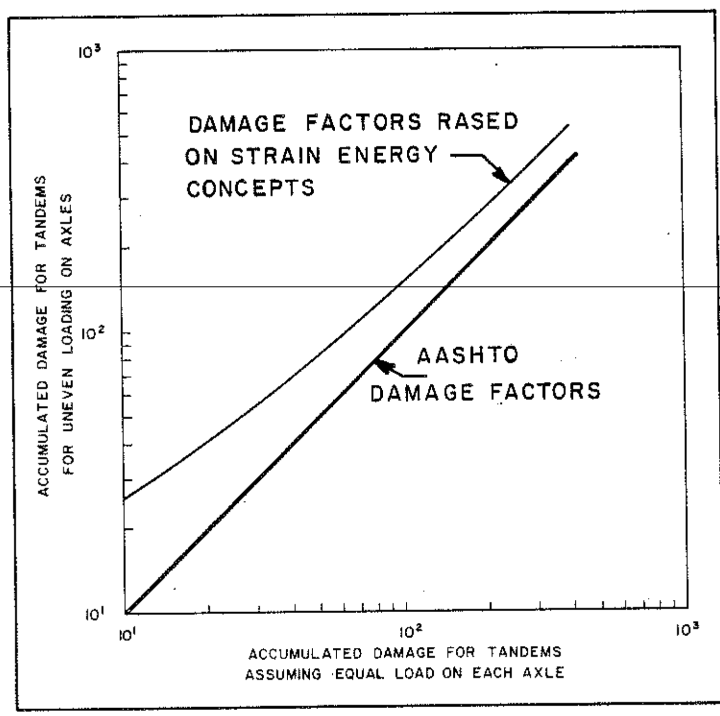

Figure 4. Accumulated Fatigue of 335 Vehicles from 1976 W6 Tables for Kentucky.

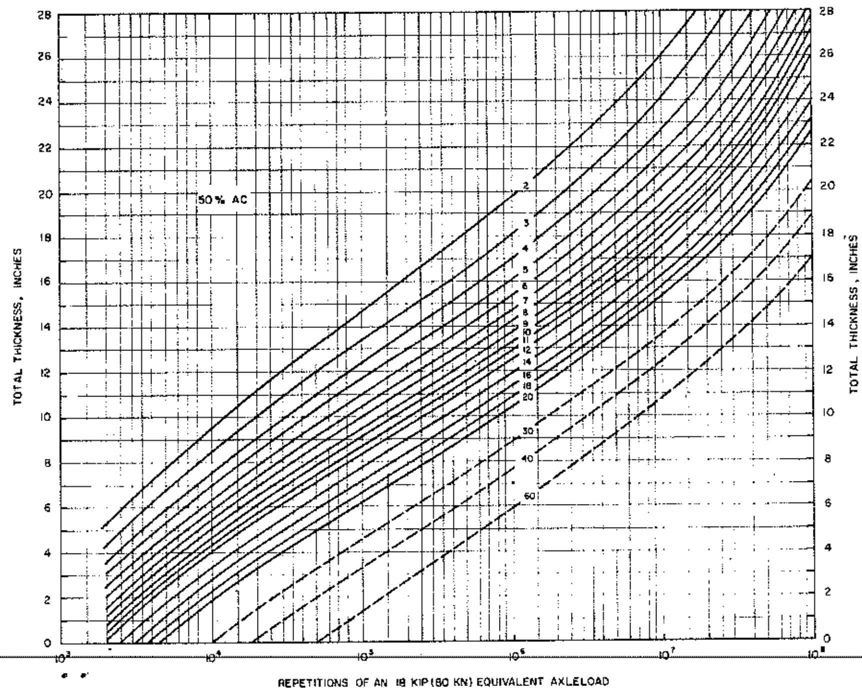

Figure 5. Thickness Design Curves for Pavement Structures Having 50 Percent Asphaltic Concrete Thickness of the Total Pavement Thickness.

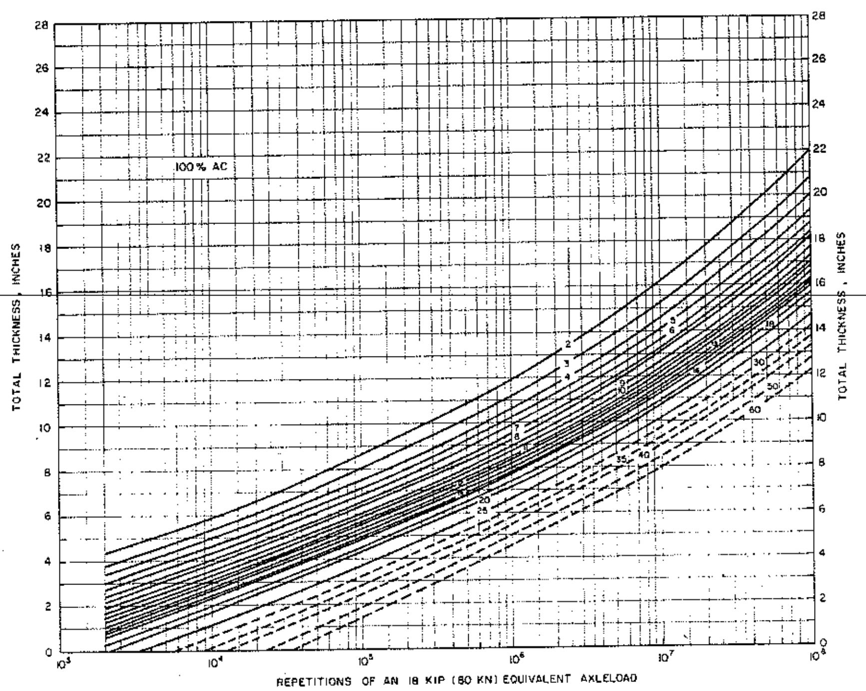

Figure 6. Thickness Design Curves for Pavement Structures Having 100 Percent Asphaltic Concrete Thickness of the Total Pavement Thickness.

Figure 7. Example Calculation Sheet to Compare Fatigue and Payloads

CLASSIFICATION	NUMBER OF TRUCKS*	NET WEIGHT** (kips)	TOTAL NET WEIGHT (kips)	AVERAGE DAMAGE FACTOR**	TOTAL EAL
NORMALLY LOADED TRUCKS (per day for 365 days per year)					
Three-Axle Single Unit	68	26	442	1.18	80.24
Five-Axle Semi-Trailer	3,830	50	191,500	1.80	6,894
Six-Axle Semi-Trailer	17	64	1,088	1.74	29.58
Totals	3,915		193,030		7,003.82 x 365
					2,556,394 EAL/year
HEAVILY LOADED TRUCKS (per day for 300 days per year)					
Three-Axle Single Unit	25	--	--	60.2	1,505
Five-Axle Semi-Trailer	70	--	--	10.45	731.5
Six-Axle Semi-Trailer	5	--	--	10.30	51.5
Totals	100				2,288 x 300
					686,400 EAL/year

$$\text{Ratio of EAL} = \frac{\text{Normal Trucks}}{\text{Heavy Trucks}} = \frac{2{,}556{,}394}{686{,}400} = 3.72 \text{ for equivalent fatigue damage}$$

Number of Heavy Trucks

3.72 x 25 =	93.1	66	6,145
3.72 x 70 =	260.7	85	22,159
3.72 x 5 =	20.7	106	2,194
Totals	374.5		30,498

$$\text{Ratio of Net Load} = \frac{\text{Legally Loaded}}{\text{Heavily Loaded}} = \frac{193{,}030 \times 365}{30{,}498 \times 300} = 7.7$$

* Daily Volume -- one-fourth of volumes in Table 4
** From Table 5