the range of load, size of tire, and tire pressure tested.

Comparison

When the surface-treated items were compared to similar items having no surfacing, there was significant improvement in the performance of the surface-treated items. Data for unsurfaced items also trafficked by the simulated MX load cart are given in Table 1. As can be seen, item 3 of Lane 1 contained Blend II material at the surface and sustained 1.93 in. of rutting; whereas, item 3 in Lane 3 contained the double surface treatment on Blend II material and sustained only 1.1 in. of rutting. Also, item 4 of Lane 1 had Blend I at the surface and sustained 4.61 in. of rutting; whereas, item 4 of Lane 3 containing a single surface treatment sustained only 1.0 in. of rutting. There was also significant movement of the soil in items 3 and 4 of Lane 1 from underneath the tire to the sides of the traffic lane; this did not occur in the surface-treated items. The important implication of these results is that the application of a surface treatment on the in-place soils at the MX deployment area may be sufficient to carry the anticipated heavy loads and provide an adequately paved road.

CONCLUSIONS

The following conclusions resulted from this analysis:

1. Adequate compaction of soil layers is important to prevent densification.
2. Surface treatments performed satisfactorily under heavy loads.
3. Rutting of soil layers was reduced by the application of surface treatments.

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Development of Rigid and Flexible Pavement Load Equivalency Factors for Various Widths of Single Tires

JOHN P. HALLIN, JATINDER SHARMA, AND JOE P. MAHONEY

An analytical study to compare the effects of axles with single and dual tires on pavement performance is presented. Both rigid and flexible pavements were analyzed using currently available finite-element and elastic-layer analysis programs. The stresses and strains obtained from these programs were used in fatigue failure models to develop equivalency relationships between dual tires and various widths of single tires. Equivalent wheel-load factors were developed for various widths of single tires on both rigid and flexible pavements. These factors can be used to evaluate regulations relating to tire and axle loadings. They also permit conversion of mixed traffic having axles with single tires to equivalent 18-kip dual-tire, single-axle load applications for use in pavement design and evaluation.

An increasing number of trucks are being observed with heavy loads on axles with single tires. Concern over whether current regulations properly consider the relative effects of axles with single tires resulted following observations of serious distress on a highway in northwestern Washington State. In 1979 as the result of a railroad abandonment, transportation of limestone between a quarry and cement plant near Bellingham, Washington, shifted to trucks. The trucking contractor elected to use tandem axles with single 12-in. wide tires on double trailer trucks. This tire and axle configuration was selected to permit the maximum load on the minimum number of tires and comply with tire and axle load regulations. Washington State Department of Transportation regulations permit a maximum tire load of 550 lb/in. of width for tires less than 12 in. wide and 660 lb/in. of width for tires 12 in. wide or wider. The maximum axle loads permitted are 20,000 lb for single axles and 34,000 lb for tandem axles.

It became apparent that the use of single tires in lieu of dual tires should be examined. Thus, the objective of this study was to determine the relationship between axles with single tires and axles with dual tires and pavement performance. The results of the study can be used to answer the question: If axles with single tires are a major contributor to pavement deterioration, what changes are needed in the regulations?

Various rigid and flexible pavement sections were analyzed by using existing finite-element and elastic-layer analysis programs. The maximum calculated stresses and strains resulting from various tire loads were used to determine the fatigue life of the pavement under these loads. Equivalency factors between single and dual tires were then determined based on relative fatigue lives. Dual tires with a width of 10 in. and center to center spacing of 15 in. and single tires with widths of 10, 12, 14, 16, and 18 in. were used in the analysis. The study approach is outlined in Figure 1.

ANALYSIS OF RIGID PAVEMENTS

In the analysis of portland cement concrete pave-

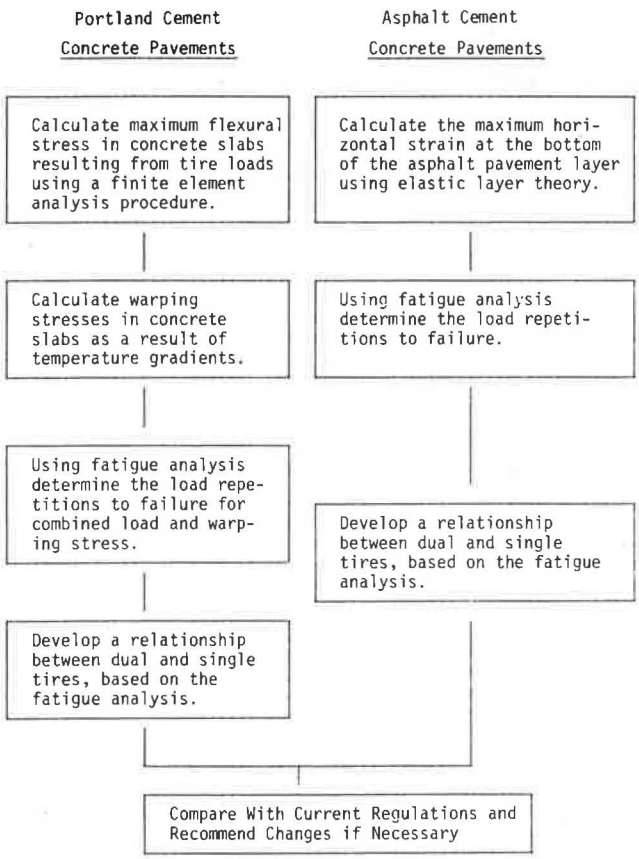

Figure 1. Study approach.

ments, the combined stresses resulting from traffic loads and temperature gradients within the pavement were considered. The magnitude of these stresses is a function of the pavement section, material properties of the concrete, joint design, and subgrade support. Most recently constructed concrete pavements in the Washington State Highway System are 9 in. thick. They are placed on a gravel or asphalt treated subbase 4 in. or more in thickness. The pavements are plain jointed concrete, and aggregate interlock provides the load transfer across the joints. Transverse joints are skewed at a ratio of 2:12 with a random spacing of 9, 10, 14, and 13 ft.

To bracket the range of conditions generally expected, plain concrete pavements with thicknesses of 7, 9, and 12 in. over a foundation with a modulus of subgrade reaction of 100 and 300 psi/in. were analyzed. Material properties of the concrete were modulus of rupture, 750 psi; modulus of elasticity, 4.5×10^6 psi; and Poisson's ratio, 0.15.

Load Stresses

Load-related stresses in concrete pavements were determined by using the ILLI-SLAB finite-element computer program (1). The program is relatively simple and inexpensive to use; and, as reported by Tabatabaie and Barenberg (2), the results agree closely with both theoretical and experimental results.

A large number of variables affect the stresses in concrete pavement. As a first step in the study, the variables that had the greatest effect on tensile stresses in the pavement slab were identified. The following are the basic parameters selected for the identification process: The maximum legal axle loads of 20,000 lb for single axles and 34,000 lb for tandem axles; and tire widths of 10 in. for dual tires, 16 in. for single tires on single axles, and 13 in. for single tires on tandem axles. These tire widths were based on the regulatory requirements for maximum tire load. Because the loaded pavement area modeled in the program is a rectangle, the transverse dimension was the tire width and the longitudinal dimension varied depending on the axle load. The tire contact pressure was 80 psi.

The initial phase of the analysis consisted of determining the magnitude of the tensile stresses in the concrete pavement for single and tandem axles at four load positions. The axle configurations examined were as follows: Case I, a single axle with dual 10-in. tires; Case II, a single axle with single 16-in. tires; Case III, tandem axles with 10-in. dual tires; and Case IV, tandem axles with single 13-in. tires. Four load positions were analyzed: (a) at the joints with the vehicle centered in the lane; (b) at the joint with the right wheel at the pavement edge; (c) at the midpoint of the slab with the right wheel at the pavement edge; and (d) at the midpoint of the slab with the right wheel 12 in. from the pavement edge. The results clearly showed that the mid-panel edge loadings caused the most stress and that maximum tensile stress was located at the bottom edge of the mid-panel slab. The mid-panel edge loadings, shown in Figure 2, were selected for use in this study.

A single axle, mid-panel edge load, 9-in. pavement, and a modulus of subgrade reaction of 100 psi/in. were selected for the analysis of the sensitivity of load-related stresses to variations in tire pressure, single tire width, and joint spacing. These were varied as follows:

1. Tire contact pressures of 70, 80, 90, and 100 psi were analyzed for both 10-in. dual tires and 16-in. single tires. The results, shown in Figure 3, indicate that the variation in edge stress is about 1 percent for tire contact pressures between 70 and 100 psi.
2. The effects of tire width were analyzed using a 20-kip single axle load with 10-, 12-, 14-, 16-, and 18-in. wide single tires. The results, shown in Figure 4, indicate a definite relationship between tire width and pavement stresses.
3. Joint spacings of 13, 15, and 20 ft were analyzed to determine the effect of joint spacing on pavement edge stress. The results, shown in Figure 5, indicate a maximum variation of less than 3 percent.

Based on the preceding a decision was made to use a tire contact pressure of 80 psi and a joint spacing of 13 ft in this analysis of pavement stresses.

Warping Stresses

Differences in temperature between the top and bottom surfaces of a concrete slab will cause the slab to warp. The weight of the slab and its contact with the subgrade restricts the movement of the slab and stresses are developed. Measurements by Teller and Southerland (3) show that the temperature differential between the pavement layers is much larger during the day than during the night. Furthermore, during the day the temperature of the upper surface of the concrete slab is higher than the temperature at the bottom of the slab placing tensile stresses at the bottom of the slab. This is important, because the maximum load-related tensile stresses also occur at the bottom of the concrete pavement slab.

To evaluate warping stresses, the temperatures at the top and bottom of the slab were computed from Weather Bureau data using a procedure developed by Barber (4). Maximum pavement temperatures were cal-

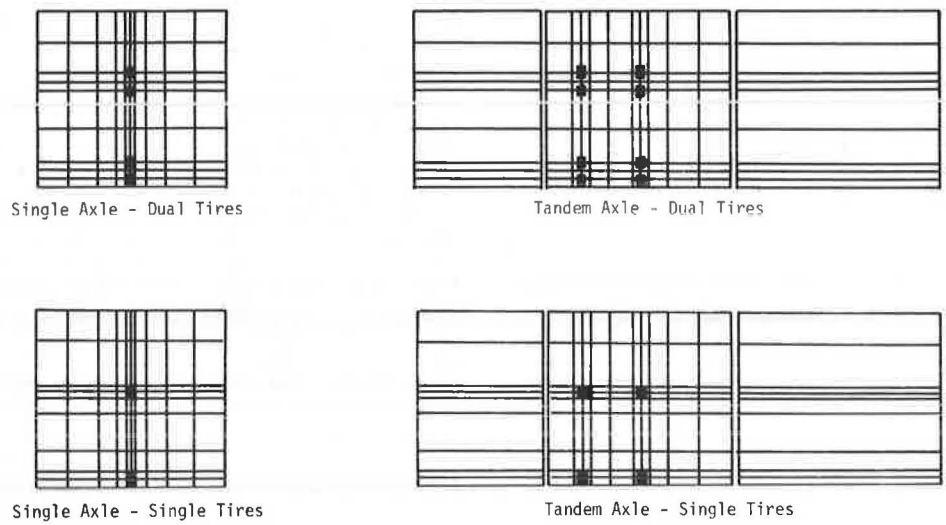

Figure 2. Loading cases used in the finite-element analysis of concrete pavement.

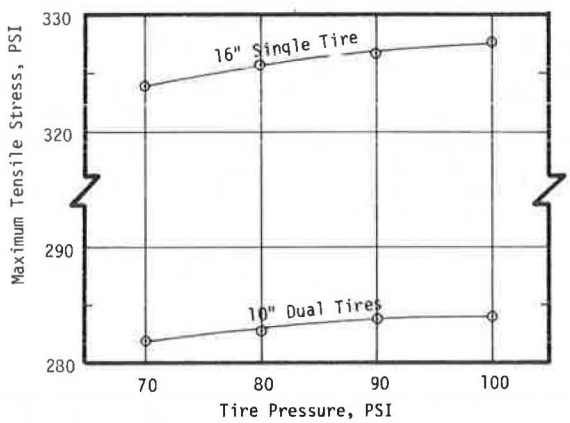

Figure 3. Effect of variations in tire pressure on edge stress.

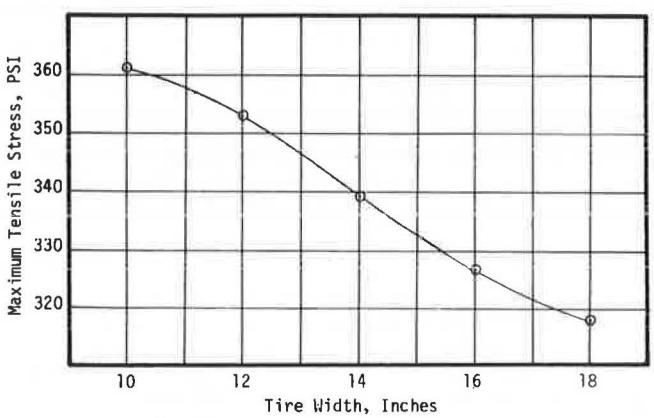

Figure 4. Effect of the width of a single tire on edge stress.

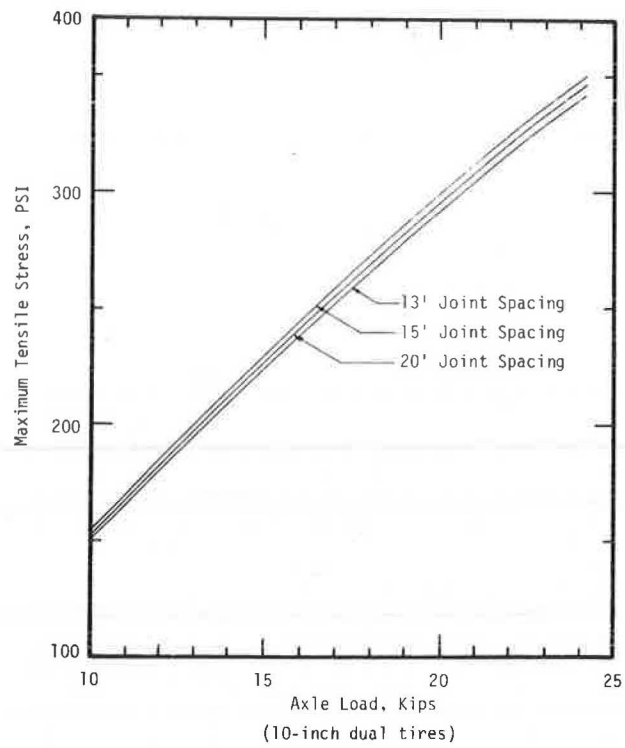

Figure 5. Effect of joint spacing on load-related edge stress.

culated for 7-, 9-, 10-, and 12-in. slabs in eastern and western Washington. Temperatures were calculated for each slab thickness, and the difference in gradients between eastern and western Washington was only about 5 percent. Therefore, to reduce the number of computations, only the western Washington pavement temperatures were used for the analysis.

To determine the maximum combined load and warping stresses, the warping stresses were calculated at the bottom center of the longitudinal pavement edge. This was where the maximum load-related edge stresses were found. Two methods for computing warping stress were considered: a procedure presented by Bradbury (5), which is based on Westergaard's work, and a set of regression equations developed by Darter (6) using data developed from a finite-element analysis.

The two methods were compared using pavement temperatures for July, which was the month with the highest temperature gradient. The following variables were used in the analysis: moduli of subgrade reaction (K) of 50, 100, 200, and 300 psi/in. and pavement thicknesses of 7, 9, and 12 in. Figure 6 shows the stresses calculated for a 9-in. pavement. For higher K-values the Bradbury analysis gave much

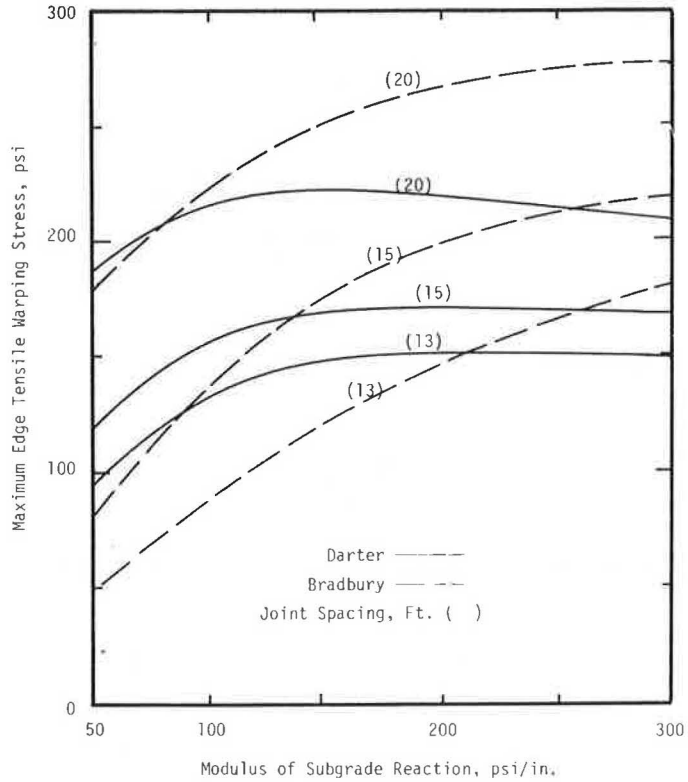

Figure 6. Warping edge stress during July for 9-in. pavements located in western Washington.

higher stresses than the Darter equations. However, the warping stresses calculated by the Bradbury procedure were generally higher than the measured stress because full restraint of the slab is assumed. Whereas, the finite-element program used by Darter allows the slab to curl in a weightless condition, then the restraining weight of the slab is added.

Based on a comparison of the two procedures and a review of previous work, the Darter equations, subject to the conditions in the following discussion, were selected to compute edge-warping stresses for this study. It was noted that above a modulus of subgrade reaction of approximately 200 psi/in. the warping stress tended to decrease. Majidzadeh, Ilves, and McComb (7) reported that when analyzing warping stresses using a coupled finite-element and elastic-multilayer subgrade program, no appreciable differences in warping stresses were noted for changes in subgrade support conditions. It was concluded that Darter's equations would be used to compute warping stresses for subgrades with K-values of 200 psi/in. and below. For K-values above 200 psi/in., the warping stress calculated for 200 psi/in. would be used. This assumed that for very weak subgrades, the subgrade yields as the slab warps. This provides uniform support over the length of the slab and reduces stress.

Fatigue Analysis

The fatigue relationship used was the one proposed by Vesic (8):

$$N_{2.5} = 225{,}000\,(MR/\sigma)^4 \qquad (1)$$

where

$N_{2.5}$ = load repetitions to a serviceability index of 2.5,
MR = modulus of rupture of the concrete, psi, and
σ = tensile stress, psi.

The tensile stress was the combined load and warping stress. The fatigue analysis assumed that load repetitions were uniformly distributed over the year. The mean maximum monthly warping stress was used, which assumes that the load repetitions occurred during the day. It was felt that this assumption was adequate for comparison of tire sizes and configurations. Allowable repetitions for a specific axle load and pavement section was based on the following relationship:

$$\sum_{i=1}^{12} (n/Ni) = 1 \qquad (2)$$

where

n = 1/12 of the total load repetitions, and
Ni = the allowable number of load applications for each month, based on the combined load stress and warping stress for that month.

Figure 7 shows the fatigue relationships developed for single axles on a 9-in. pavement.

Equivalency Relationships

The fatigue curves were used to determine the percent of a dual tire axle load that an axle with a specific width of single tire could carry and have an equivalent number of repetitions to a serviceability index of 2.5. It was found that each pavement depth and modulus of subgrade reaction had an individual relationship. These are shown in Figure 8.

Equivalent wheel-load factors were developed for dual tires on single axles and 10-, 12-, 14-, 16-,

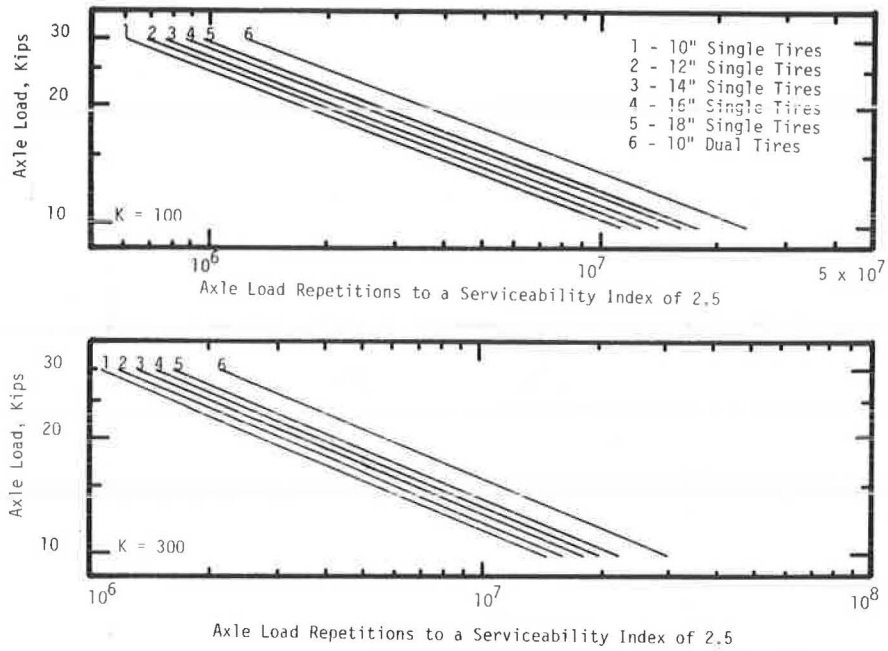

Figure 7. Axle load repetitions to a serviceability index of 2.5 for single-axle edge loading (cases I-C, II-C) on a 9-in. pavement.

and 18-in. wide single tires on single axles. The factors were developed for 7-, 9-, and 12-in. pavements with subgrade K-values of 100 and 300 psi/in. The following relationship was used to develop the equivalent wheel-load factors:

$$F_i = N_{18}/Ni \quad (3)$$

where

F_i = equivalent wheel load factor, 18-kip dual-tire, single axles;
N_{18} = repetitions to a serviceability index of 2.5 for an 18-kip dual-tire, single-axle load; and
N_i = repetitions to a serviceability index of 2.5 for the axle load being evaluated.

The equivalent wheel-load factors for single axles with single tires on a 9-in. pavement with a subgrade K-value of 100 psi/in. are given in Table 1.

ANALYSIS OF FLEXIBLE PAVEMENTS

The use of currently available analysis procedures to compare the effects of various widths of single tires with dual tires on flexible pavement performance presents an interesting problem. This is because the various elastic-layer and finite-element analysis procedures developed for flexible pavements use uniform circular loads. As a result, the width of the tire being modeled is a function of tire contact pressure and load. In a previous study, Terrel and Rimsritong (9) compared the relative damaging

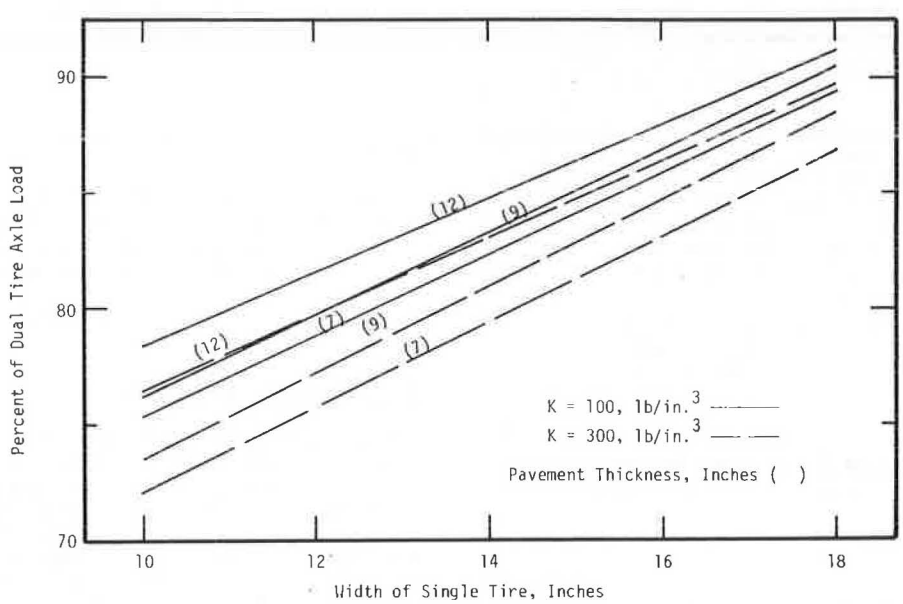

Figure 8. Percentage of dual-tire axle loads that an axle with single tires can carry for equivalent pavement life.

Table 1. Traffic equivalence factors for single axles with single tires, rigid pavement 9-in. thick, and modulus of subgrade reaction = 100.

Axle Load (kips)	Equivalent 18-kip Dual-Tire, Single-Axle Loads				
	Single Tire Width				
	10 in.	12 in.	14 in.	16 in.	18 in.
10	0.4251	0.3848	0.3407	0.2950	0.2728
12	0.6922	0.6266	0.5548	0.4803	0.4442
14	1.0453	0.9463	0.8378	0.7254	0.6709
16	1.4939	1.3524	1.1973	1.0367	0.9588
18	2.0469	1.8530	1.6405	1.4204	1.3137
20	2.7130	2.4561	2.1744	1.8827	1.7412
22	3.5005	3.1690	2.8056	2.4292	2.2466
24	4.4176	3.9992	3.5406	3.0656	2.8352
26	5.4719	4.9537	4.3857	3.7972	3.5119
28	6.6711	6.0394	5.3468	4.6294	4.2815
30	8.0227	7.2630	6.4301	5.5674	5.1490
32	9.5339	8.6310	7.6413	6.6161	6.1189
34	11.2118	10.1500	8.9861	7.7805	7.1958
36	13.0634	11.8262	10.4701	9.0653	8.3841
38	15.0954	13.6658	12.0988	10.4755	9.6882
40	17.3146	15.6748	13.8774	12.0155	11.1125

effects of various widths of single tires and dual tires. To simulate tire widths for various wheel loads, they varied the contact pressure. This resulted in contact pressures that were not representative of contact pressures encountered in the field.

The development of equivalency factors for axles with single tires in this study is an extension of the earlier study by Terrel and Rimsritong. Two additional modeling techniques were evaluated to determine if tire contact pressure or shape have a significant effect on the tensile strains at the bottom of the pavement.

Method of Analysis

The pavement sections analyzed were 3, 6, and 9.5 in. of asphalt concrete pavement on 8 in. of crushed aggregate base. The material properties used are given below.

Asphalt Concrete: The resilient modulus of asphalt concrete is a function of its temperature. Resilient modulus versus temperature relationships have been developed for Washington State University Test Track pavement (9). Assuming an average temperature of 68°F, a resilient modulus of 400,000 psi was selected. The Poisson's ratio was assumed to be 0.3.

Crushed Aggregate Base: The resilient modulus of untreated aggregates is a function of the confining stress. Repeated-load triaxial testing of crushed aggregate base on a project at the Washington State University Test Track resulted in the following relationship (9):

$$MR = 2843\theta^{0.6} \quad (4)$$

where

MR = resilient modulus, and
θ = bulk stress ($\sigma_1 + 2\sigma_3$ in the triaxial test).

This relationship and a Poisson's ratio of 0.4 were used for crushed aggregate base in the analysis for this study.

Subgrade: A wide range of modulus values for subgrade materials are encountered on highway construction in the state of Washington. Terrel and Rimsritong used a value of 6,500 psi and a Poisson's ratio of 0.45. For uniformity, these values were used in this study.

The maximum horizontal strain at the bottom of the asphalt concrete layer was calculated for various tire sizes and axle loads using the Elastic Theory Iterative Method-Dual Wheel Option (PSAD2A) computer program. This program, developed at the University of California at Berkeley, is capable of calculating stresses and strains due to dual wheel configurations. In addition, for layers with stress-dependent resilient modulus values, the modulus can be determined by an iterative process.

To compare axles with single tires to axles with dual tires, a fatigue distress model was used. Fatigue distress is assumed to be the cracking that results from repeated load applications and is a function of the horizontal strain at the bottom of the asphalt concrete layer. Fatigue analysis was used, because cracking is the principal form of asphalt pavement distress in Washington State (10). The fatigue model selected for this study was developed by Finn et al. (11). The model predicts the number of repetitions resulting in fatigue cracking equal to or less than 10 percent of the wheelpath.

$$\log N_f = 15.947 - 3.219 \log(\epsilon/10^{-6}) - 0.854 \log(E^*/10^3) \quad (5)$$

where

N_f = repetitions to failure,
ϵ = maximum tensile strain at the bottom of the asphalt bound layer, inches, and
E^* = resilient modulus, psi.

The following three techniques were used for modeling tire widths.

1. Constant Radius-Variable Pressure Method. This procedure was the method used by Terrel and Rimsritong. Three single tire widths were evaluated, 10, 15, and 18.5 in. The width of each dual tire was 10 in. The tire widths were maintained by varying the tire pressures. The maximum horizontal strains at the bottom of the asphalt pavement layer were determined and the fatigue life for various axle loads on the three pavement sections calculated. Figure 9 shows the relationship developed between axle loads and repetitions to failure for a 6 in. asphalt pavement section.

2. Double Circle-Constant Pressure Method. This method and the single circle-constant pressure method, to be discussed next, use the assumption that the axle load versus repetitions to failure curves for various single tire widths are parallel to the curve for dual tires. To determine the slope of the fatigue curves, curves were developed for dual tires using two methods: applying the wheel load through a circle with a constant radius and applying the load using a constant contact pressure of 80 psi. The slopes of the two curves were very close for the 9.5-in. asphalt pavement. However, the difference in slopes increased as the depth of the asphalt pavement section decreased.

It was concluded that the average slope would be an adequate representation of the slope of the fatigue curve. For dual tires, the average curve was fit through the intersection of the constant contact pressure and constant radium lines. An example of these curves for a 6-in. pavement section is shown in Figure 10. It is interesting to note that the intersection of these curves lies between 20- and 25-kip axle loads, which is in the load range commonly analyzed using the elastic layer programs.

To model tire width using the double circle method, two adjacent loading circles with a contact pressure of 80 psi were used. The radius of the circle was chosen so that four times the radius equalled the desired tire width. The total area, of two circles, was calculated and multiplied by the

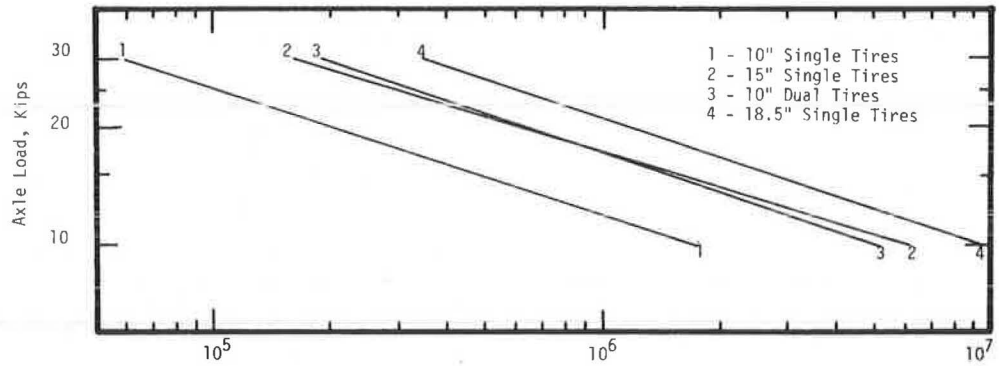

Figure 9. Axle load repetitions to failure for single axles on a 6-in. asphalt concrete pavement over an 8-in. crushed aggregate base—constant radius method.

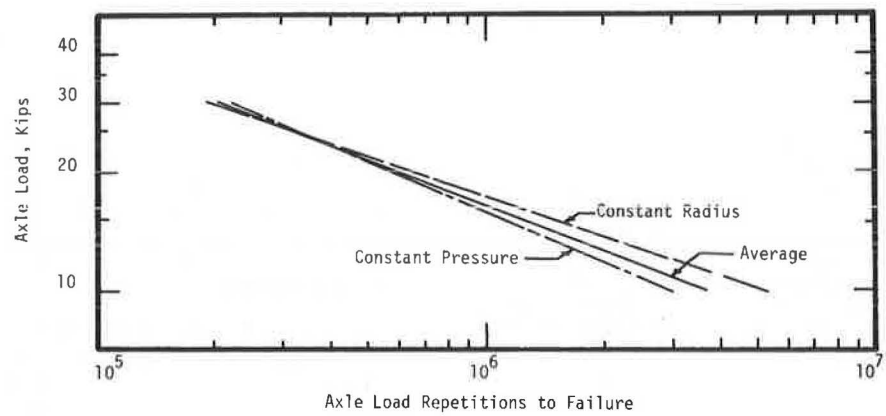

Figure 10. Fatigue relationship for single axles with dual tires (6-in. asphalt concrete pavement over 8 in. of crushed aggregate base).

contact pressure. This represented the simulated load on the single tire. The maximum horizontal strain at the bottom of the pavement layer was determined and the repetitions to failure calculated. The point representing axle load versus number of repetitions to failure was plotted and a fatigue curve fit through the point. Calculations were made for simulated tire widths of 10, 12, 14, 16, and 18 in. The resulting relationship for a 6-in. asphalt pavement section is shown in Figure 11.

3. Single Circle-Constant Pressure Method. This method is similar to the double circle method. In this case, the diameter of the circle was chosen to equal the width of the tire to be simulated. The

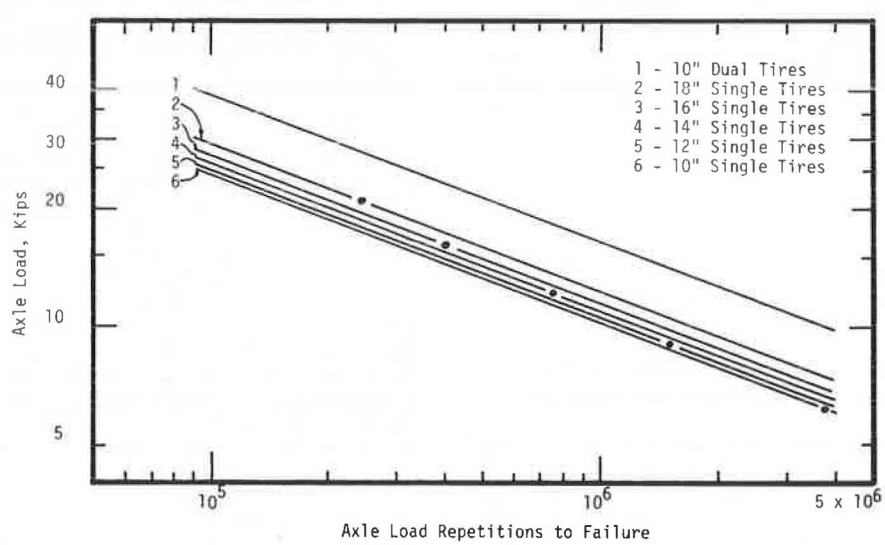

Figure 11. Axle load repetitions to failure for single axles on a 6-in. asphalt concrete pavement over an 8-in. crushed aggregate base—double circle method.

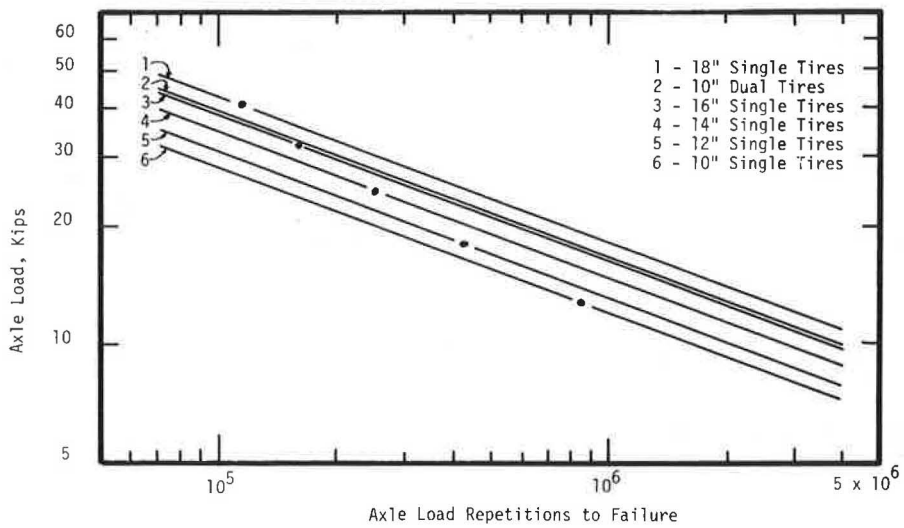

Figure 12. Axle load repetitions to failure for single axles on a 6-in. asphalt concrete pavement over an 8-in. crushed aggregate base—single circle-constant pressure method.

wheel load was equal to the area of the circle times the contact pressure, which was held constant at 80 psi. The maximum horizontal strain at the bottom of the asphalt pavement section was determined and repetitions to failure calculated. A fatigue curve was then fit through the point using the same method as in the double circle method. Fatigue curves were developed for 10-, 12-, 14-, 15-, and 18-in. wide tires. The curves for a 6-in. asphalt pavement section are shown in Figure 12.

Equivalency Relationships

For each method and pavement thickness, the percent of dual axle load that an axle with single tires could carry and have an equivalent fatigue life was determined. The equivalency relationships for a 6-in. asphalt concrete pavement are shown in Figure 13. Because of the wide range between the double-circle and the two single-circle methods, a comparison with actual field measurements was needed.

There have been only a limited number of investigations to measure the actual effects of dual tires versus single tires on pavement performance. At the AASHO Road Test an investigation was conducted to determine the performance and deflections for a number of pavement sections under loadings of several pieces of military transport equipment (12). These included the study of the use of low pressure, low silhouette (LPLS) tires on tractor and semitrailer units and the effects of the use of the GOER, a self propelled cargo or fluid transporter resembling a conventional two-axle tractor scraper. Both the LPLS and GOER tires were approximately the same width as the dual tires used for comparison.

Zube and Forsyth (13) reported on a study by the California Division of Highways in 1963 to determine the single-wheel, single-axle loading that would produce the same destructive effect as a dual-wheel, single-axle loading of 18,000 lb. The width of the single tire was approximately 12 in. At one test site they measured the horizontal strain at the bottom of the pavement section under both dual and single tire loadings.

Based on an analysis of the data from the AASHO Road Test and the California study it was concluded that an axle with a single tire equal in width to the dual tires on a 3-in. asphalt pavement section should be able to carry 120 percent of a dual tire

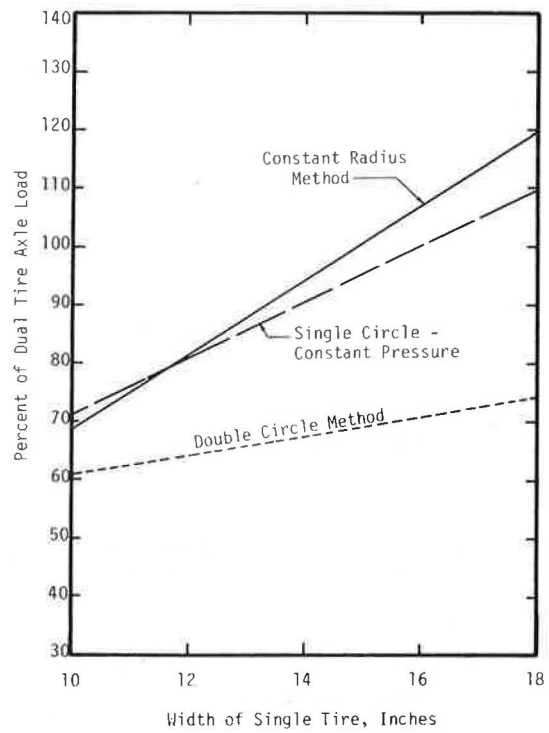

Figure 13. Percentage of dual-tire axle load that an axle with single tires can carry for equivalent fatigue life (6-in. asphalt concrete pavement).

axle load and have an equivalent destructive effect in fatigue, whereas an axle with 12-in. wide tires on a 3-in. asphalt pavement section should be able to carry 62 percent of a dual-tire axle load. Figure 14 shows these points connected with a straight line on a plot of the equivalency relationships developed for single versus dual tires on a 3-in. pavement. The line appeared to fall midway between the single and double circle lines. Therefore, an average relationship was developed between the single methods and the double-circle method.

The results shown in Figure 15 indicate that the average single-tire to dual-tire equivalency is close to the equivalency developed using available

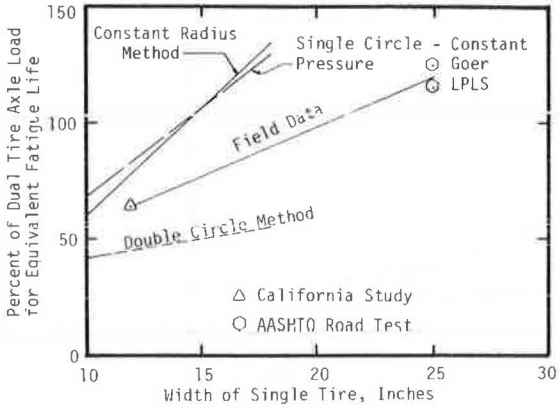

Figure 14. Comparison of methods for computing the equivalency of single tires to dual tires with field data for a 3-in. asphalt concrete pavement.

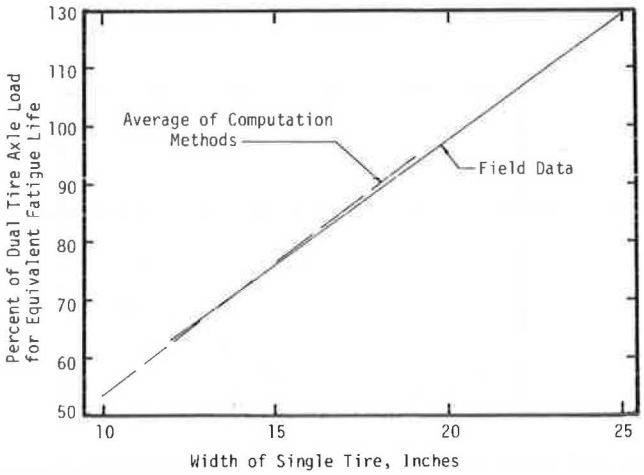

Figure 15. Comparison of the average between the single-circle and double-circle computation methods and available field data for 3-in. asphalt concrete pavement.

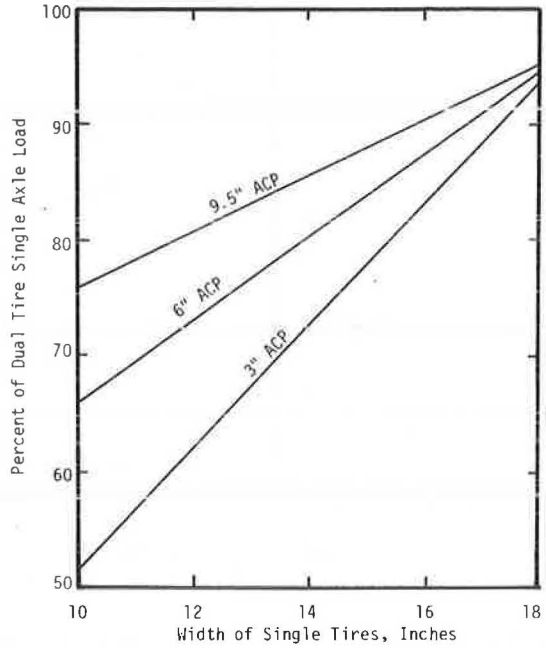

Figure 16. Average equivalency of single axles with single tires to single axles with dual tires for 9.5-, 6-, and 3-in. asphalt concrete pavements.

Table 2. Traffic equivalence factors for single axles with single tires, asphalt concrete pavement, and SN = 4.

Axle Load (kips)	Equivalent 18-kip Dual-Tire, Single-Axle Loads: Single Tire Width 10 in.	12 in.	14 in.	16 in.	18 in.
10	0.6309	0.4790	0.3731	0.2969	0.24050
12	1.0286	0.7809	0.6082	0.4840	0.39210
14	1.5549	1.1805	0.9195	0.7317	0.59277
16	2.2243	1.6887	1.3153	1.0466	0.84793
18	3.0502	2.3157	1.8038	1.4353	1.16279
20	4.0458	3.0715	2.3925	1.9038	1.54232
22	5.2237	3.9658	3.0891	2.4580	1.99136
24	6.5962	5.0077	3.9007	3.1038	2.51455
26	8.1750	6.2064	4.8343	3.8468	3.11643
28	9.9718	7.5705	5.8969	4.6923	3.80141
30	11.9979	9.1087	7.0951	5.6457	4.57379
32	14.2643	10.8293	8.4353	6.7121	5.43778
34	16.7818	12.7406	9.9241	7.8968	6.39749
36	19.5610	14.8505	11.5675	9.2045	7.45695
38	22.6123	17.1670	13.3719	10.6403	8.62014
40	25.9458	19.6978	15.3432	12.2089	9.89093

Note: SN = 4 represents 5 to 8 in. of ACP over aggregate base.

field data. For this reason, it was decided to use an average between the single-circle and double-circle equivalencies for all three pavement sections. These are shown in Figure 16. Admittedly, there is little data to support the use of the average relationship; and field studies will be undertaken to improve this relationship. These studies will include measurements of deflections under axles with single and dual tires using extensometers installed in the pavement structure.

The fatigue curves for dual tires and the equivalency relationships in Figure 16 were used to develop equivalent wheel-load factors for 10-, 12-, 14-, 16-, and 18-in. wide tires on flexible asphalt concrete pavement (ACP) sections with approximate AASHTO structural numbers of 2, 4, and 6. The equivalency factors were calculated using the relationship in Equation 3. The equivalency factors for a pavement section with an SN of 4 are given in Table 2.

CONCLUSIONS

Load equivalency relationships have been developed that can be used to determine the effects of axle loads, with various widths of single tires, on both rigid and flexible pavements. These relationships can be used to evaluate regulations relating to tire width and axle loading configurations. They also permit conversion of mixed traffic, including axles with single tires, to equivalent 18-kip dual-tire, single-axle load applications for use in pavement design and evaluation.

A summary of size and weight limits published by the American Trucking Associations (14) indicate that at least 24 states have regulations that control maximum tire loads. Ten additional states have regulations that limit the load on axles with single tires. Of the states having regulations limiting the maximum tire load, 19 permit tire loads in excess of 550 lb/in. of tire width. This includes six states that permit tire loads of 800 lb/in. of width. The relative effects of single versus dual tires on pavement performance were compared with the regulations for maximum tire loads.

This comparison for a 20,000 lb dual-tire axle load is shown in Figure 17. The comparison supports the requirement of 550 lb/in. of tire width. However, tire loads above 550 lb/in. of tire width are not supported. For example an axle with 14-in. single tires on a 9-in. concrete pavement with a subgrade K = 100 can carry approximately 82 percent of a dual-tire axle load or a maximum of 16,400 lb for an equivalent fatigue life, whereas regulations permitting 660 lb/in. of tire width would allow an axle load of 18,400 lb and regulations permitting 800 lb/in. of tire width would allow the maximum 20,000 lb axle load.

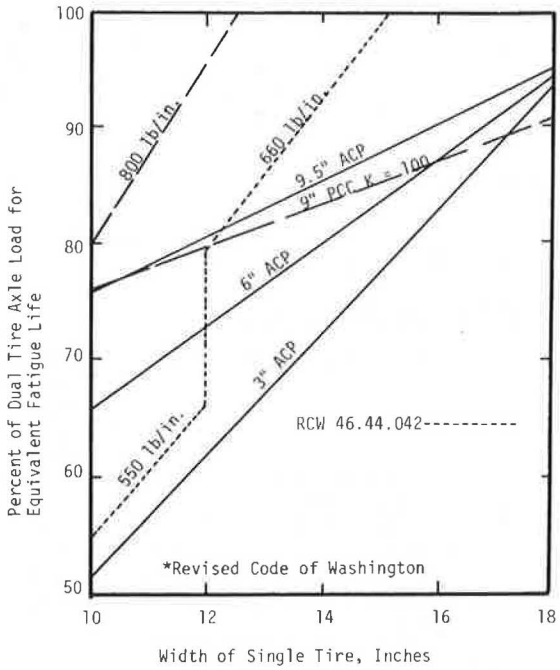

Figure 17. Comparison of the regulatory requirements for maximum tire loads with the dual and single tire relationships for equivalent fatigue life where the dual tire axle load equals 20,000 lb.

ACKNOWLEDGMENT

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