Lateral Placement of Truck Wheels Within Highway Lanes

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ABSTRACT

In recognition of the need for representative statistical data on the lateral placement of truck wheels within highway lanes, a video camera was used in a following vehicle to record rear-view images of trucks operating on multilane highways in Texas. Analysis of the data set that resulted from evaluating these images produced four frequency distributions of lateral wheel positions that are definitive for two different truck types and for two roadway alignment conditions. A single frequency distribution could not be used to describe the observed placement patterns with acceptable accuracy. To illustrate the effects of laterally distributed traffic loading on the design thickness of rigid pavements, computations were made for 1, 10, and 20 million repetitions of loads concentrated at the pavement edge and for the same number of loads distributed laterally in accordance with a representative frequency distribution. A thickness reduction of about 15 percent could be realized if the lateral distribution of loads were incorporated into the design process.

Increasing numbers of trucks on the highways coupled with the tendency to move heavier loads on each truck indicate a need for improved traffic data and for more refined pavement design procedures that take into account the magnitude of critical wheel loads that will be applied to pavement structures, their frequency of occurrence, and their lateral distribution among and within the lanes of multilane highways. Most pavement design procedures currently in use employ estimates of the directional and the lanewise distribution of mixed traffic loading, but none of the procedures accounts directly for the effects of varying lateral placement of wheel loads within the lane.

To illustrate the relative importance of lateral load placement in rigid pavement design, it is worthwhile to recall Westergaard's analysis of stresses in the pavement slab. In his work, Westergaard (1) considered three cases of load application: (a) corner, (b) edge, and (c) interior location. For typical highway pavements, his equations indicate that the maximum tensile stress in the slab due to edge loading will be approximately 1.5 times that for interior loading and that maximum deflections will be about three times as great for the respective loading positions. Pickett and Ray, cited in Yoder and Witczak (2), extended Westergaard's original theoretical work and developed influence charts for solving the general equations. Their work also shows that wheel loads applied at the pavement edge cause considerably higher stresses in the slab than do the same loads positioned laterally further away from the edge.

A pavement design procedure should recognize the stochastic nature of lateral wheel load placement within the lane, generally between these extreme locations, and account for the cumulative effects of different levels of stress and different numbers of repetitions of the various stresses that result. None of the popular pavement design procedures evaluates the effects of lateral wheel placement directly. The AASHTO Interim Guide (3), which is widely used for design purposes, estimates the overall effects of various amounts of mixed traffic through an empirical correlation of the observed pavement performance at the AASHO Road Test with the known amount of controlled truck traffic that was applied to pavement test sections there. The actual lateral distribution of truck traffic at the road test was not incorporated as a variable into the definitive cause and effect equations that were developed.

Few statistical data are available on the lateral placement of truck wheels within the traffic lane. Most research studies that have produced quantitative information about wheel placement have been directed toward identifying driver behavior patterns and determining the relationship between vehicle width and the effective width of the highway lane (4-6). An extensive series of studies on lateral placement of vehicles in highway lanes was conducted by the Bureau of Public Roads in the 1950s using a segmented switch on the road surface (7). This gave incremental measurements of wheel location only at a single point along the roadway. Photographic techniques have been used to record the varying lateral position of vehicles moving along the roadway (8-10), but none of these studies has concentrated on characterizing the patterns of truck wheel placement within the lane on multilane highways. This information is needed for pavement design and performance evaluation.

With the overall objective of defining a representative frequency distribution for the lateral placement of truck wheels with respect to the pavement edge on multilane highways in Texas, video photography was chosen as the most appropriate means for obtaining an adequate data set under actual traffic operating conditions. A sampling plan was devised, and a practicable data reduction procedure was developed. Analysis of the video-taped data showed that a single frequency distribution could not be used to represent the various patterns of lateral placement of truck wheels within the lane with acceptable accuracy; therefore, four different frequency distributions were defined. Each distribution describes the observed pattern of lateral wheel placement for a particular set of traffic and roadway alignment circumstances that can be easily identified when designing or evaluating sections of pavement. To demonstrate the applicability of this type of traffic loading information in design, a series of computations was made. Results of these computations are given later in this paper. Significant reduction in the design thickness of rigid pavement slabs was indicated when stress calculations were based on the observed lateral distributions of wheel loads rather than on the assumption that all loads would occur at the pavement edge.

DATA COLLECTION AND REDUCTION

Because a continuous record of wheel placement for individual trucks as they traveled along the roadway was desired, a video camera mounted in a following van was used to record the rear-view image of trucks on two selected multilane (in each direction) highways. The sampled sections included a 26-mi segment of I-35 near Austin and a 16-mi segment of US-59 north of Houston. About 6 hr of video recordings of the movements of some 50 different trucks on carefully chosen sections of these highways with various alignments, cross sections, and pavement types were obtained during daylight hours. The time during which each individual truck was followed varied from about 2 to 20 min. An attempt was made to include various types of trucks in the sample, roughly in proportion to the percentages registered in Texas. Measurement of the lateral distance between the right edge of the truck tire image and the left side of the pavement edge line was made from the replayed images on a video monitor with the aid of a grid placed on the curved screen. The known width of the lane between the marked edge lines and lane lines was used to scale the measurements. A detailed description of the construction of the grid, which was used to correct for the inherent distortion in the video image, and the measuring technique that was used for data reduction is given elsewhere (11). It was also possible to note from the video images other factors such as traffic, pavement condition, and ramps or shoulders that might have influenced the driver's choice of lateral position at any given time.

ANALYSIS OF DATA

The objective of the analysis was to use the available data to define a representative frequency distribution, or a set of frequency distributions, of lateral placement of truck wheels on sections of multilane highways in Texas. The resulting frequency distributions were to be presented in a form that could be used in pavement design with relative ease.

In addition to the video image of the rear view of trucks that were followed, a visual image of the date and time (in 1-sec increments) was recorded. Thus the wheel placement pattern of each truck could be enumerated at exact 1-sec intervals throughout the time that the truck was followed. To reduce all the recorded data at each 1-sec interval was prohibitive and unnecessary; therefore, a systematic data sampling procedure was devised. The sampling rates were 5- to 10-sec intervals on roadway sections with straight horizontal alignment and 2- to 5-sec intervals on sections with horizontal curvature. A uniform small-interval sampling rate was not always feasible because the broken lane line markings sometimes did not appear in the video image at the selected time for sampling. An evaluation of the selected sampling rates, as described in detail elsewhere (11), showed that the rates were entirely adequate to place the observed wheel position properly in the appropriate 1-ft interval that would subsequently be recommended for inclusion in a pavement design procedure.

TABLE 1 Observations of Truck Wheel Placement

Truck Identification No.	Type	Total Time Followed (sec)	No. of Observations
1	3-S2	417	44
2	2-axle	501	61
3	3-S2	241	19
4	3-S2	560	68
5	2-axle	326	35
6	3-axle	242	29
7	3-S2	664	86
8	3-S2	382	51
9	3-S2	751	88
10	3-axle	435	42
11	2-axle	622	89
12	2-axle	255	39
13	2-axle	425	42
14	3-S2	641	33
15	3-S2	1,027	89
16	3-S2	925	95
17	3-S2	583	62
18	2-axle	223	23
19	3-axle	396	39
20	3-S2	370	38
21	3-S2	110	29
22	3-axle	105	19
23	3-S2	120	14
24	3-axle	180	15
25	3-S2	460	44
26	3-S2	311	26
27	3-S2	349	33
28	3-S2	601	83
29	3-S2	282	35
30	3-S2	421	39
31	3-S2	109	17
32	3-S2	372	36
33	3-S2	943	159
34	3-S2	652	73
35	3-S2	611	75
36	3-S2	482	54
37	3-S2	461	57
38	3-S2	574	63
39	3-S2	423	33
40	3-S2	867	95

Table 1 gives all the individual trucks that were observed, the truck type, the time during which each was followed, and the number of measurements of wheel placement that were made from the video recordings. Table 2 gives a summary of the overall characteristics of lateral wheel placement in terms of mean position away from lane edge and observed variance. To determine whether the duration of the selected observation time on every truck was adequate, each data set was tested for stability. Statistics of interest concerning a time-varying phenomenon such as lateral wheel placement are said to be stable in a statistical sense if they are not affected significantly when the time origin of the data set is shifted. All the selected observation times and the duration of time that each truck was followed proved to be adequate for estimating mean values and variance of the lateral placement of truck wheels within the highway lane because the stability tests did not reveal significant differences.

A number of factors can possibly cause the lateral placement of truck wheels to vary at any given location and time. The factors that were evaluated in this study are given in Table 3 along with the chosen levels of each factor. An analysis of variance (ANOVA) procedure was used to identify which of the factors and which levels contributed signifi-

TABLE 2 Overall Characteristics of Lateral Wheel Placement for Trucks Observed

Truck Identification No.	Mean Placement (ft)	Variance (ft^2)
Truck Type: 3-S2		
1	1.09	0.76
3	1.26	1.02
4	0.96	0.65
7	1.71	0.73
8	1.19	0.74
9	1.40	0.77
14	0.72	1.05
15	1.27	0.75
16	1.92	1.17
17	1.38	0.97
20	1.87	1.10
21	0.76	0.89
23	2.7	0.9
25	1.61	0.9
26	1.52	1.06
27	0.81	0.77
28	1.03	0.73
29	1.38	0.94
30	1.46	0.68
31	0.96	0.65
32	1.62	0.88
33	1.62	0.67
34	1.15	0.76
35	1.80	0.66
36	1.81	0.66
37	1.34	0.68
38	1.97	0.88
Truck Type: 3-Axle and 2-Axle		
2	1.6	0.76
5	2.09	1.0
6	1.5	0.89
10	0.61	0.79
11	2.28	0.53
12	1.98	0.69
13	1.97	1.15
18	1.23	0.62

TABLE 3 Factors and Levels Included in Sample

Factors	Levels
Truck type	Single unit
	2-axle
	3-axle
	Tractor and semitrailer
	3-S2
	2-S1
Geometry	Straight
	Downgrade
	Upgrade
	Left curve, level
	Right curve, level
	Left curve, downgrade
	Right curve, downgrade
	Left curve, upgrade
	Right curve, downgrade
Pavement surface	Rigid pavement (concrete)
	Flexible pavement (asphalt)
Lanes	Inside lane
	Center lane
	Outside lane

cantly to explaining the observed variability in lateral wheel placement. Truck type and section geometry were found to be significant influencing factors, but pavement surface type and lane location were not. Two types of trucks--single unit and tractor and semitrailer--were found to have significantly different frequency distributions of lateral wheel placement. Also, two categories of roadway geometry--straight sections and sections with horizontal curvature (regardless of vertical alignment)--exhibited different patterns of lateral wheel placement. The details of the statistical analysis are again given elsewhere (11).

It was necessary to establish four representative frequency distributions for lateral truck wheel placement within the highway lane. Table 4 gives the percentages of truck wheel placements that were observed to fall within the indicated 1-ft intervals with respect to the right pavement edge for each condition. Because no significant difference was found between the placement patterns in the Austin and in the Houston areas, it may be assumed that the tabulated values are representative of general conditions throughout the state. An expanded data set would be needed to substantiate this assumption, however.

TABLE 4 Frequency Distribution of Lateral Wheel Placements for Different Truck Types and Roadway Alignments

Wheel Placement[a] (midpoints of interval) in ft	Tractor and Semitrailer on Straight Sections	Tractor and Semitrailer on Curved Sections	Single-Unit Trucks on Straight Sections	Single-Unit Trucks on Curved Sections
-1.0	1[b]	0.5	3	2
0.0	12	14	16	20
1.0	38	35	20	25
2.0	38	34	41	36
3.0	10	16	19	16
4.0	1	0.5	1	1

[a] Wheel placement is measured between the right-hand edge of the rear tire and the inside edge of the lane or edge line.

[b] Numbers in the table denote the percentage of observation within each class interval.

EFFECTS OF LATERAL WHEEL PLACEMENT ON DESIGN THICKNESS OF RIGID PAVEMENTS

Design procedures for highway pavements have been developed on the assumption that wheel loads are applied at some standard or average lateral location within the lane. The general AASHO Road Test equation (3), for example, characterizes traffic loading only in terms of the number of single or tandem axle loads and their respective magnitudes. The actual lateral positions of the test truck wheels that occurred during the road test were not incorporated into the equation as a variable. In extending this general empirical equation to handle conditions other than those that existed at the road test, a relationship was developed only between the observed number of axle load applications of various types, which produced a given terminal serviceability index at the road test, and the ratio of the modulus of rupture to the maximum tensile stress in the concrete slab as calculated by Spangler's equation for corner loading. Thus the AASHO design equations and nomographs do not allow for direct evaluation of the effects of varying lateral distribution of traffic wheel positions within the lane.

The lateral distribution of truck wheel loads of different magnitudes and number of repetitions across the pavement surface produces various levels of stress, and therefore damaging effects, at any selected point in the pavement slab. To illustrate the relative effect of such lateral distribution of load, design thicknesses for two loading conditions have been determined--one for the edge loading condition and another for the laterally distributed loading condition.

A finite element program (12) was used to calculate the stresses, due to loads positioned at various points on the surface of the slab, at different points in a concrete pavement slab. By running the program several times, with an 18-kip single axle load positioned at a different place each time, the various stress levels that would result at any selected point in the slab from each load position were identified. Then the cumulative damaging effect of repeated applications of these various stress levels at a critical point in the slab was assessed. A pavement thickness that could accommodate a laterally distributed loading frequency pattern without exceeding selected strength-to-stress ratios was finally determined by successive approximation. For comparison, the thickness required for repeated applications of an 18-kip single axle load, all in the conventional edge loading position, was determined using the same procedure.

Slab Model

A 12-ft by 12-ft slab was considered for evaluation purposes. The slab was divided into 144 square elements so that each node was 1 ft away from the adjacent node. The loads were imposed at the nodes, and each node had associated with it a certain slab stiffness and a subgrade stiffness. Figure 1 shows a schematic of the arrangement of nodes and the position of the wheel loads. The edge and corner conditions of the slab were simulated by reducing the stiffness of the slab and the spring support to one-half or one-quarter of the original stiffness, respectively, at the appropriate nodes. A computation was then carried out by the program to determine the stresses (both tensile and compressive) at all the nodal points for each selected loading condition.

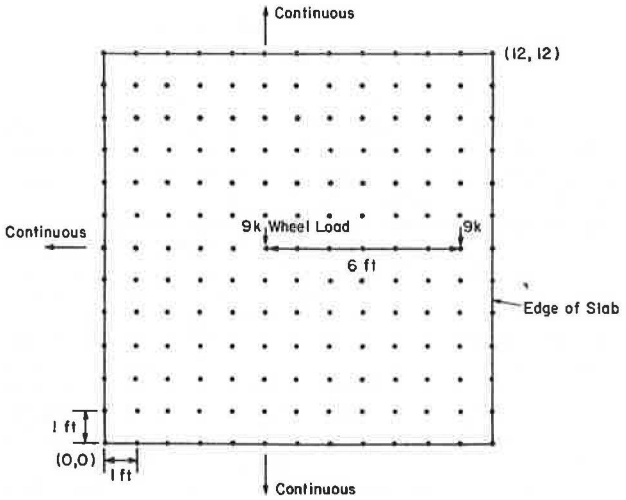

FIGURE 1 Finite element modeling of a slab subjected to an 18-kip axle load.

Use of Vesic's Fatigue Model

Vesic and Saxena (13) used the AASHO Road Test data to develop a fatigue model that incorporated several different loading configurations on rigid pavements of various thicknesses. A concrete slab 30 ft long and 12 ft wide with a transverse joint in the center was modeled in their analysis. Single axle and tandem axle loads were positioned laterally as shown in Figure 2 (inset) and were shifted in nodal increments toward the joint. The resulting maximum tensile stresses were then plotted against the distance of the load from the joint. Figure 2 shows a sample curve. Similar curves were developed for various magnitudes of loads and pavement thicknesses. The lateral placement of the outer wheel was always assumed to be 2.5 ft away from the pavement edge (average wheel path) because AASHO Road Test data were reported only for this condition.

The maximum tensile stress that occurred for different load magnitudes and for different pavement thicknesses was then plotted against the number of repetitions accommodated before the pavement reached a present serviceability index of 2.5 (data available from AASHO Road Test). Vesic and Saxena found that a unique relationship could be described as follows:

$$N_t = 225{,}000\,(f_c/\sigma)^4$$

where

N_t = number of replications of an equivalent 18-kip single axle load needed to reduce the present serviceability index to a value (t),
f_c = modulus of rupture (strength) of the concrete, and
σ = maximum tensile stress in the concrete due to axle loading.

This fatigue model has been used to approximate the effect of distributing wheel load repetitions laterally across the pavement and to calculate the cumulative damage. The slab model used for this purpose was 12 ft by 12 ft, and no joints were present. The basic load position case--that of applying all the repetitions near the edge of the slab--to a certain extent is similar to the critical loading condition of Vesic and Saxena with the axle near the joint. The lateral shift case (i.e., shifting the load repetitions laterally inward from the edge of the slab) compares with Vesic's and Saxena's shifting of the loading configuration longitudinally, away from the transverse joint. Thus a stress distribution curve for the several loading configurations in this analysis might resemble Vesic's and Saxena's stress distribution curves shown in Figure 2. No empirical data concerning the fatigue effects of loads positioned at various lateral positions in the lane are known to exist. Thus an effort was made in this evaluation to adhere as closely as possible to Vesic's and Saxena's loading configuration so that their fatigue model could be used to compare the cumulative damage that might occur to the pavement for laterally distributed loads. The actual loading configurations and the modeling procedure are described in further detail next.

Thickness Required for Repeated Application in the Edge Loading Position (Case 1)

Vesic's and Saxena's fatigue model (13), as shown previously, was used to relate the number of replications to the allowable stress ratio. The terminal serviceability index (t) was set at 2.5. The following assumptions were made in applying this model:

- That the stress ratio is an adequate indicator of the effect of the number of load repetitions on reducing the present serviceability index and
- That the model is valid regardless of where the loads are positioned and where the maximum tensile stresses occur.

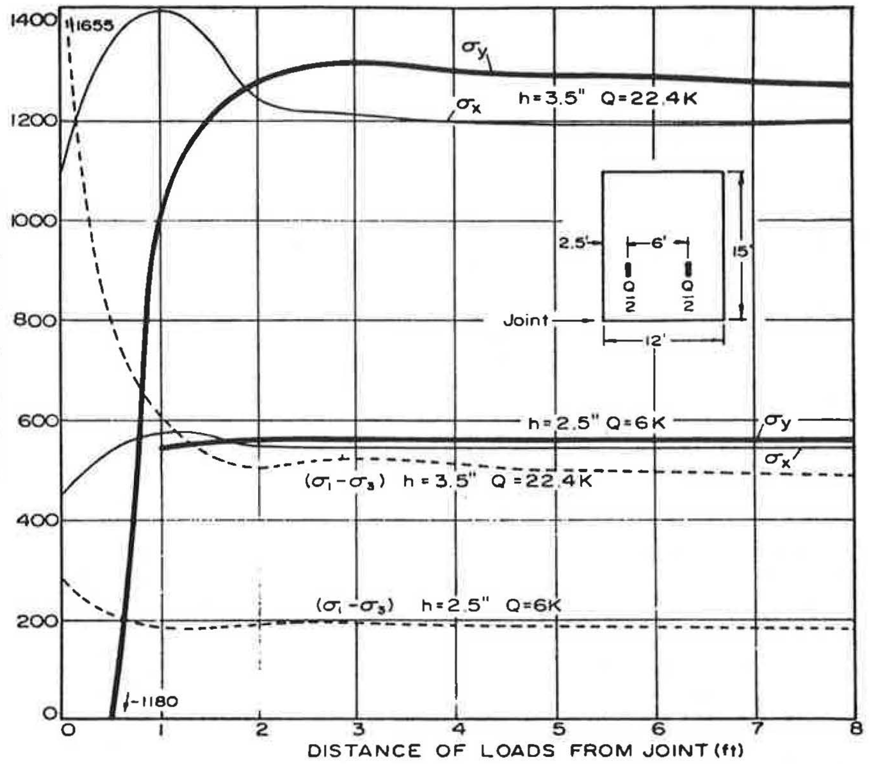

FIGURE 2 Maximum tensile stress as a function of load position for Vesic's model *(13)*.

With these assumptions, the following procedure was carried out:

- Taking the number of replications of the standard 18-kip single axle load that would occur at the edge loading position before failure, the allowable stress ratio was calculated from the fatigue model.
- A modulus of rupture (strength) of concrete was taken as 650 psi, and the maximum allowable tensile stress was calculated from the stress ratio.

The same finite element model (12) that was employed by Vesic and Saxena (13) was then used to calculate the maximum tensile stress in a slab of some trial thickness caused by an 18-kip single axle load being placed at the center of the slab longitudinally with the center of the outside wheel 1.0 ft from the edge of the slab. This maximum tensile stress (under the outside wheel) was compared with the maximum allowable tensile stress from the fatigue model; then another trial thickness was chosen so as to make the calculated stress more nearly equal to the allowable stress for fatigue loading. By making successive adjustments in slab thickness, these stresses were made approximately equal. The resulting thickness was that which would be needed to sustain the chosen number of applications of an 18-kip single axle load in the edge loading position (Case 1) while reducing the present serviceability index to a value of 2.5.

Thickness Required for a Laterally Distributed Application of Loads (Case 2)

The percentages given in Table 4 represent the frequency of application of heavy axle loads in the right lane of multilane highways at the designated transverse locations in 1-ft intervals. Because the distances indicated in the table were measured to the outer wheel edge and the load is considered to be applied at the center of the dual wheels, the modeled loading position is 1 ft to the left of the wheel position placement that is shown in the table.

The lateral loading pattern used for comparison with edge loading is similar to that for tractor and semitrailer trucks on straight alignment and is distributed as follows:

- Right wheel 1 ft from the edge line: 10 percent of total applications (edge loading); loading coordinates were (5,6) and (11,6) each wheel carrying 9 kips.
- Right wheel 2 ft from the edge line: 40 percent of applications; loading coordinates were (4,6) and (10,6).
- Right wheel 3 ft from the edge line: 40 percent of applications; loading coordinates were (3,6) and (9,6).
- Right wheel 4 ft from the edge line: 10 percent of applications; loading coordinates were (2,6) and (8,6).

The first step was to determine the magnitudes and the locations of stresses in the slab caused by the different loading positions. The stresses under nodes (11,6), (10,6), (9,6), and (8,6) were tabulated. The following values for pavement material characteristics were used in the computer program:

$E = 5 \times 10^6$ psi = modulus of elasticity for concrete,
$k = 100$ psi/in. = modulus of subgrade reaction, and
$\mu = 0.15$ = Poisson's ratio for concrete.

An example of stresses for an 8-in. slab thickness is given in the following table.

Loading Position		Tensile Stress Under Node (psi) for Position			
Left Wheel	Right Wheel	(11,6)	(10,6)	(9,6)	(8,6)
(5,6)	(11,6)	-330.6	-215.9	-155.9	-133.4
(4,6)	(10,6)	-208.4	-281.9	-189.8	-141.7
(3,6)	(9,6)	-135.8	-180.2	-265.2	-180.0
(2,6)	(8,6)	-93.8	-118.8	-169.4	-258.6

To account for the accumulated damage due to these several loadings, the following procedure incorporating Minor's hypothesis was used.

Assuming that maximum cumulative damage for 10 million load applications occurs under node (10,6), where 40 percent of the load repetitions occur, the possible number of replications for the different stress levels were calculated as follows:

1. Stress at (10,6) due to loading at nodes (10,6) and (4,6) = -281.9 psi.
2. Additional stress at (10,6) due to loading at nodes (11,6) and (5,6) = -215.9 psi.
3. Additional stress at (10,6) due to loading at nodes (9,6) and (3,6) = -180.2 psi.
4. Additional stress at (10,6) due to loading at nodes (8,6) and (2,6) = -118.8 psi.

Each of these stresses has associated with it a certain number of possible applications of load, which can be calculated from the Vesic fatigue model. The possible replications and the corresponding actual replications are

	Possible	Actual
1 =	6,350,000	4,000,000
2 =	18,500,000	1,000,000
3 =	38,100,000	4,000,000
4 =	Very large	1,000,000
Total		10,000,000

The cumulative linear damage hypothesis (Minor's hypothesis) states that the sum of the ratio of actual to theoretical (or possible) application for each type of load must be equal to unity before failure occurs. Assuming that failure refers to the pavement reaching a present serviceability index of 2.5, the cumulative damage is as follows:

$$\begin{aligned}&(4{,}000{,}000/6{,}350{,}000) + (1{,}000{,}000/18{,}500{,}000)\\&\quad + (4{,}000{,}000/38{,}100{,}000) + \text{negligible} = 0.63\\&\quad + 0.05 + 0.10 + \text{negligible} \simeq 0.80\end{aligned}$$

Note that the cumulative damage index for an 8-in. slab thickness was arrived at after trying several other thicknesses. The actual procedure calls for evaluating the cumulative damage for different thicknesses until the sum of the ratios is close to unity. In this case further iteration is possible until the cumulative damage equals exactly 1, but only minor change in the thickness would be required.

This procedure has been used to determine thicknesses needed to accommodate 1, 10, and 20 million replications of the standard 18-kip single axle load both for the edge loading case and for the laterally distributed loading case using the material properties stated previously. For comparison, design thicknesses have also been determined from the AASHTO Interim Guide (3) nomographs. These values are given in Table 5.

TABLE 5 Design Thicknesses in Inches for Different Lateral Loading Positions and Design Procedures

	Total No. of 18-Kip Axles (millions)		
Condition	1	10	20
All loads edge location, Vesic fatigue model	7.0	9.1	10.0
Laterally distributed loads, Texas study of tractor and semitrailer trucks, straight alignment, Vesic fatigue model (see Table 4)	6.0	7.8	8.5
AASHTO Interim Guide *(3)*	5.9	8.8	9.9

SUMMARY

Theoretical considerations have shown that there is a considerable difference in the stresses calculated for the edge loading case and for the interior loading case in the design of rigid highway pavements. In practice, wheel loads are distributed laterally across the lane in accordance with a frequency distribution pattern. Field studies, using a video recorder in a following vehicle, produced a data set of representative truck wheel placements on multilane highways in Texas. Analysis of these data resulted in frequency distributions of wheel placement for two truck types and for two horizontal alignment conditions. To illustrate the possible application of these distributions in pavement design, a procedure was devised for evaluating the cumulative critical stress replications in a pavement slab. For one case, all load replications were applied in the edge loading position and a finite element program was used to calculate the resulting stresses. For another case, the finite element program was used to determine the various maximum tensile stresses at different points in the pavement slab and a fatigue model by Vesic and Saxena (13) was used to relate the stresses to allowable load repetitions. Using Minor's linear damage hypothesis, a comparison of the thicknesses required for 1, 10, and 20 million load replications showed that reduction in the design pavement thickness of between 14 and 16 percent could be realized when loads were distributed laterally according to a representative frequency distribution. These results indicate that the lateral distribution of load repetitions has significant effects on the stress conditions in rigid pavements and that design procedures should incorporate means for recognizing the variability in lateral wheel position within the lane. A computer program can be easily devised to perform the calculations needed for determining design thickness in accordance with the procedures described.

REFERENCES

1. H.M. Westergaard. Computations of Stresses in Concrete Roads. Proc., HRB, National Research Council, Washington, D.C., Vol. 5, Part 1, 1925, pp. 90-112.
2. E.J. Yoder and M.W. Witczak. Principles of Pavement Design. 2nd ed. John Wiley and Sons, Inc., New York, 1975.
3. AASHTO Interim Guide for Design of Pavement Structures. American Association of State Highway and Transportation Officials, Washington, D.C., 1974.
4. W.P. Walker. Influence of Bridge Width on Transverse Positions of Vehicles. Proc., HRB, National Research Council, Washington, D.C., Vol. 21, 1941, pp. 361-365.
5. A. Taragin. Transverse Placement of Vehicles as Related to Cross Section Design. Proc., HRB, National Research Council, Washington, D.C., Vol. 23, 1943, pp. 342-350.

6. A. Taragin. Effect of Roadway Width on Traffic Operations--Two Lane Concrete Roads. Proc., HRB, National Research Council, Washington, D.C., Vol. 24, 1944, pp. 292-318.
7. Vehicle Speed and Placement Survey on Two Lane Rural Highways. Road Design Division, Texas Highway Department, Austin, March 1957.
8. D.H. Weir and C.S. Sihilling. Measures of Lateral Placement of Passenger Cars and Other Vehicles in Proximity to Inner City Buses on Two Lane and Multi-Lane Highways. Final Report. Environmental Design and Control Division, FHWA, U.S. Department of Transportation, Oct. 1972.
9. E.J. Miller and G.N. Stuart. Vehicle Lateral Placement on Urban Roads. Journal of the Transportation Engineering Division, ASCE, Vol. 108, Sept. 1982.
10. E. Ellard. Vehicle Size-Lane Width Interaction: A Pilot Project. M.S. thesis. University of Toronto, Toronto, Canada, 1975.
11. P.R. Shankar. Lateral Placement of Truck Traffic in Highway Lanes. Ph.D. dissertation. University of Texas at Austin, 1984.
12. J.J. Panak and H. Matlock. A Discrete-Element Method of Analysis for Orthogonal Slab and Girder Bridge Floor Systems. Research Report 26-25. Center for Highway Research, University of Texas at Austin, May 1972.
13. A.S. Vesic and S.K. Saxena. Analysis of Structural Behavior of AASHO Road Test Rigid Pavements. NCHRP Report 97. HRB, National Research Council, Washington, D.C., 1970.

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ILLI-PAVE Mechanistic Analysis of AASHO Road Test Flexible Pavements

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ABSTRACT

The stress-dependent, finite element pavement model known as ILLI-PAVE was used to study the performance of AASHO Road Test flexible pavement sections. Analyses were conducted to identify significant relationships between the appearance of fatigue cracking in the asphalt concrete (AC) surface and the AC strain and subgrade deviator stress predicted by ILLI-PAVE. Deflection and temperature data from the road test were used with ILLI-PAVE to "back calculate" seasonal variations in subgrade support and load-induced pavement stresses and strains. The structural response-performance relationships identified explain the observed behavior of the AASHO Road Test pavement sections in a realistic fashion. Seasonal damage factors and weighting factors based on these relationships provide a mechanistic explanation of the seasonal effects that is consistent with experience. These results demonstrate that ILLI-PAVE is a powerful tool for pavement design and analysis. It provides an adequate and valid representation of the structural behavior of conventional flexible pavements and can be used to effectively evaluate nondestructive test (NDT) data and determine the structural characteristics of existing pavement systems. ILLI-PAVE, therefore, will serve as a sound basis for the development of mechanistic procedures for the design of new flexible pavements and for the selection of rehabilitation strategies for existing flexible pavements.

In a preliminary effort to select transfer functions for a mechanistic flexible pavement design procedure, the performance of the flexible pavement sections of Lane 1, Loop 4 of the AASHO Road Test was studied. The mechanistic design procedure is to be based on the structural response predictions (stresses, strains, and deflections) of the stress-dependent, finite element pavement model known as ILLI-PAVE. This model was selected on the basis of previous studies by Figueroa (1) and Hoffman and Thompson (2) that showed that ILLI-PAVE provided reliable and realistic predictions of the structural behavior of pavement. Simplified equations, referred to as ILLI-PAVE structural response algorithms, were