Effect of Lane Widening on Lateral Distribution of Truck Wheels

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Past field studies of lateral distribution of trucks on highway pavements are limited in their relevance to current design practices and truck size limits. In particular, little information is available on the effect of widened concrete slabs on lateral distribution of trucks. The Illinois Department of Transportation has constructed test sections of "widened-lane" pavements with 18-in. and 20-in. slab extensions on I-57. Truck wheel placements on these test sections were compared with those observed on nearby conventional 12-ft pavement slabs in a recent study conducted at the University of Illinois. Continuous filming of truck wheel positions was performed with an 8-mm camera mounted on bridges over the highway. Wheel positions were determined to within approximately 0.5-in. precision by scaling distances measured on the films to known dimensions on the pavements. The mean placement of the wheels of over 900 trucks observed on the control sections was about 22 in. from the slab edge. About 2.5 percent of the wheels passed within 6 in. of the slab edge. On the widened-lane sections, the mean placement of truck wheels was about 2 in. closer to the lane edge (marked by the paint stripe) but still 38 to 40 in. away from the slab edge. No slab edge loadings were observed among more than 1,300 observations of truck wheel placements on the widened-lane pavement sections. The results suggest that lane widening is likely to be a cost-effective design improvement for concrete highway pavements that otherwise would be vulnerable to transverse fatigue cracking as a predominant mode of failure.

STATEMENT OF THE PROBLEM

Structural damage to concrete highway pavements is caused primarily by truck loads applied at the outer slab edge. Field observations of concrete highway pavement performance (*1*) have confirmed the findings of many analytical studies that have identified the outer edge as the critical location for fatigue damage accumulation. The major structural distresses observed nationwide are transverse cracking and corner breaks on jointed pavements and punchouts on continuously reinforced pavements, all of which are fatigue failures produced by edge loadings. Load-related longitudinal cracking is far less prevalent on highway pavements than on airfield pavements.

The importance of fatigue cracking to the performance of concrete pavements has prompted a two-pronged effort by researchers to study truck edge loads. Analytical studies employing plate theory (Westergaard's equation) (*2,3*), influence charts (*4*), and, more recently, finite element programs (*5,6*) have concentrated on quantifying the magnitude of the stress under an edge load and the reduction of this stress with increasing distance of the load from the edge. These and other studies have encouraged design modifications to reduce edge stresses, including increased slab thickness, reduced transverse joint spacing, tied concrete shoulders, and widened lanes, paved a foot or more wider than the standard 12-ft traffic lane width (*7–10*). Field studies, meanwhile, have attempted to observe the lateral wander of truck wheels around their mean wheelpath location and to quantify the portion of truck loadings that truly may be considered edge loads (*11–19*). These field studies have been conducted by using a variety of data collection methods on various types of roads and have addressed a variety of concerns (not only pavement thickness design but also vehicle operations and roadway geometry). Unfortunately, those field studies that are the oldest and least relevant to current roadway designs and truck characteristics persist in being the most influential to many concrete pavement design procedures and state design policies. In addition, very little field information is available to assess the effect of widened lanes on lateral distribution of truck traffic.

The Illinois Department of Transportation (DOT) has constructed an experimental pavement section with a widened lane design on Interstate 57. The University of Illinois recently conducted a field study and analysis of lateral distribution of truck traffic on the widened-lane pavement sections and on nearby sections of standard designs. The findings of this study are reported in this paper.

SUMMARY OF PAST FIELD STUDIES

Before World War II, when most roads in the United States had traffic lanes less than 12 ft wide, the Bureau of Public Roads studied the effect of roadway width on vehicle operations. Based on observations of some 95,000 vehicles at 47 sites in 10 states, Taragin reported in 1945 (*11*) that vehicle encroachment onto shoulders was much greater for lane widths of 11 ft or less than for 12-ft widths. Largely on the basis of these findings, the 12-ft lane width became the norm in postwar roadway construction and remains so today. Relationships among lane width, vehicle placement, and pavement distress on two-lane highways in Texas were studied by Scrivner in 1955 (*12*). Further research on lateral placement of vehicles on two-lane rural highways with and without paved shoulders was reported in 1957 by the Texas Highway Department (*13*).

Taragin's 1958 study (*14*) on lateral placement of trucks on two-lane and four-lane divided highways drew on data for nearly 20,000 trucks collected at 119 sites in 17 states between

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1948 and 1956. For two-lane highways with 12-ft lanes, lateral displacements from the outer edge of truck dual wheels to the edge of the pavement were reported to have means of 26.4 in. and 10.8 in. for pavements with unpaved and paved shoulders, respectively. Similar results were obtained for 10-ft and 11-ft lanes, leading Taragin to conclude that paved shoulders that clearly contrasted the traffic lane in appearance increased the effective width of each lane by a foot or more.

The mean displacement on four-lane divided highways with unpaved shoulders was 33.6 in.; no data for four-lane divided highways with paved shoulders were reported. If paved shoulders were assumed to have the same effect on four-lane highways as on two-lane highways (i.e., an outward shift of about 15 in.), a mean displacement of 18 in. could be inferred from Taragin's study.

The early Texas and Bureau of Public Roads studies relied on point sampling of vehicle placements by taking measurements directly from the pavement surface. In a 1972 study of the effect of intercity buses on nearby passenger cars, Weir and Sihilling described a system for continuous photographic monitoring of vehicles using cameras mounted inside buses (*15*). Although conducted for purposes unrelated to pavement design, this study introduced following moving vehicles as a means for observing their positions in traffic lanes. Data for Emery's 1975 lateral displacement study for the Georgia DOT (*16*) were collected by observers in passenger cars who followed trucks for 10 mi at a time and visually estimated the trucks' wheel positions every 10 seconds. The mean lateral displacement of the truck wheels from the lane edge was reported as 17.6 in.

Canner and Hale's 1980 study for the Minnesota DOT (*19*) was the first to compare truck positions on pavements with widened slabs or tied concrete shoulders with those on conventional 12-ft-wide slabs with bituminous shoulders. Canner and Hale used the same data collection method as Emery: following trucks for 10 mi and estimating their positions every 10 seconds. Truck positions were recorded and reported in 8-in. intervals, a level of precision felt by the researchers to be coarse, but sufficient for the purposes of the study. The mean lateral displacements computed from the information reported for the sections included in the Minnesota study are shown in Table 1.

The tied concrete shoulder apparently caused trucks to shift their positions 3 to 4 in. closer to the lane edge than to the bituminous shoulders, even though the concrete shoulder had rumble strips. Slab widening apparently caused an even greater shift (about 10 in.) toward the lane edge. Rumble strips on one of the widened slab sections did not appear to significantly affect this shift.

TABLE 1 MEAN LATERAL DISPLACEMENTS FROM MINNESOTA STUDY (*19*)

Section	Lane (ft)	Slab (ft)	Shoulder	Rumble strip	Mean (in.)
I-90	12	12	AC	No	26
I-94	12	12	AC	No	27
I-35	12	12	AC	No	26
TH 169	12	12	AC	No	26
I-90	12	12	PCC	Yes	23
I-94	12	15	AC	No	16
TH 52	12	15	AC	Yes	17

NOTE: All displacements are measured from the lane edge (paint stripe). Means computed to whole inch; measurement accuracy about ±4 in.

Time-lapse photography was used by Miller and Stewart in 1982 (*17*) to monitor traffic on lanes of various widths in Toronto. They found this technique to be superior to other methods of collecting lateral distribution data. Lee et al. returned to the truck-following method in a 1983 study of truck positions on Texas highways (*18*). Trucks were monitored by using a video camera mounted in a van, and measurements were made by displaying the videotape on a 19-in. monitor. Of the sources of error encountered in this procedure, among the more serious was image distortion caused by curvature of the monitor screen, for which some compensation was attempted. No mean lateral displacement was reported in the study.

Statistical analysis of the data collected in these past studies has been limited in nearly all cases to presenting histograms of the data, calculating the mean wheel location, and reporting the percentage of vehicles encroaching on the shoulder. However, it is commonly assumed in concrete pavement thickness design that lateral placement of truck wheels is approximately normally and symmetrically distributed about the mean location. This assumption permits calculation of the percentage of truck passes constituting edge loads using normal distribution z-tables. Although this assumption may be valid for aircraft wheels distributed about the centerline of a wide runway or taxiway, there is less reason to believe that it is valid for highway traffic. For example, Emery's data were shown in a 1976 study by Darter to be approximately normal, whereas Taragin's data were not (*20*). The median (50th percentile) value of Taragin's data for two-lane highways with paved shoulders is approximately 18 in., in contrast to the reported mean value of 10.8 in. This type of discrepancy suggests that lateral distributions of highway traffic may be significantly asymmetric, which raises the question of whether it is appropriate to use normal distribution tables to compute edge loadings.

LEGISLATION AFFECTING TRUCK WIDTHS

Previous studies on lateral distribution of trucks must also be viewed in light of legal truck widths in force at the time the data were collected. Width limits were controlled by individual states' regulations between 1913 and 1956, with 96 in. (8 ft) being the maximum in nearly all states. The first federal truck size and weight limits were contained in the Federal-Aid Highway Act of 1956, which set 96 in. as the truck width limit on all interstate highways (with a grandfather clause allowing wider limits already set by a few states to stand) (*21*). The 96-in. limit remained in effect until 1983, when the Surface Transportation Assistance Act of 1982 took effect, increasing the limit to 102 in. (8.5 ft). Only one of the above studies was published after that time, and it is likely that data for that study were collected before the law changed and trucks with wider wheel spacings were on the road.

LATERAL DISTRIBUTION ON WIDENED LANES

Another concern associated with applying the findings of past lateral distribution studies to future pavement designs is the

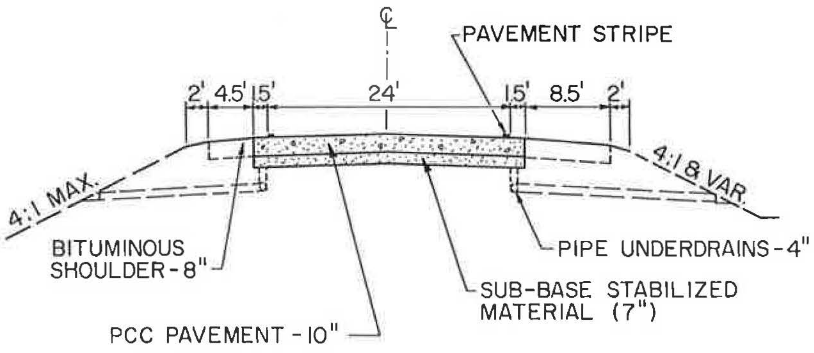

FIGURE 1 Typical cross-section of widened-lane pavement on I-57 near Effingham, Ill.

scarcity of data for pavements with widened lanes or tied concrete shoulders. Some researchers have suggested that widened lanes and concrete shoulders do not provide the strong visual delineation of the shoulder from the traffic lane, which bituminous shoulders provide, and thus do not discourage shoulder encroachment as effectively as bituminous shoulders. Colley et al. (*9*) state that "it is highly improbable that a painted white stripe located 406 mm (16 in.) from the pavement edge will prevent encroachment." The Minnesota DOT's study (*19*) seems to support this assertion; however, the crude measurement method employed in this study casts doubt on the significance of any differences observed.

FIELD DATA COLLECTION

Widened Lane and Conventional Pavement Sections

In 1987, the Illinois DOT constructed a 4.1-mi section of widened-lane pavement on Interstate 57 north of Effingham in east central Illinois. The original 10-in. jointed reinforced concrete pavement (JRCP), which was built in 1964, was recycled and reconstructed as a 10-in continuously reinforced concrete pavement (CRCP) with a 7-in. cement-stabilized subbase and longitudinal edge drains. Figure 1 shows a typical cross-section detail from the widened-lane pavement. The traffic lanes are striped 12 ft wide, but the design calls for the slab to be paved 18 in. wider on each side. Measurements taken during this study showed the pavement to be 18 in. wider in the southbound direction, but 20 in. wider in the northbound direction. A typical cross-section for a conventional Illinois interstate pavement is shown in Figure 2 for comparison. Eight control sections (northbound and southbound) were selected at four sites on I-57 in Champaign, Douglas, and Coles counties. The control sections, as well as the widened-lane sections, had little or no horizontal curvature.

Field Data Collection and Data Reduction

The lateral distribution data collected for this study were obtained by using an 8-mm camera mounted on bridges over the highway. A variety of camera positions and angles were tried in an effort to identify the set-up that gave the best view of truck wheels in the outer lane and allowed measurement of their positions to the greatest degree of precision. Two-inch-square holes spaced 2 in. apart were cut in a cardboard template 2 ft long, which was used to paint marks on the pavement. The template was placed perpendicular to the outer lane edge stripe and the pavement was marked 60, 120, and 200 ft downstream from the bridge. The positions of truck wheels passing over the paint marking could be determined with a precision of less than 1 in. at the 120-ft and 200-ft locations. Better precision (0.5 in. or better) was obtained at

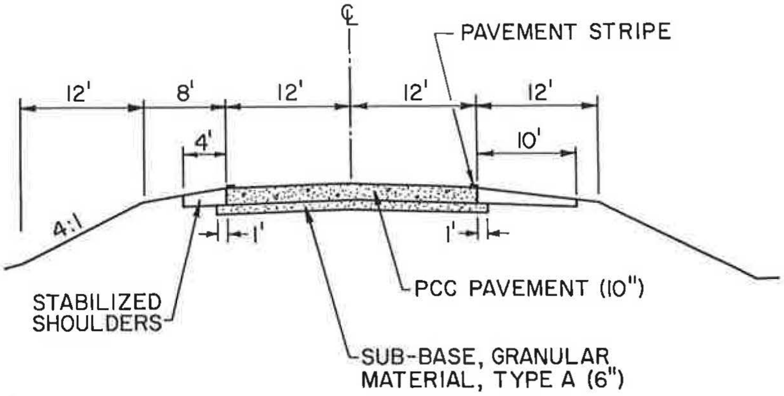

FIGURE 2 Typical cross-section of control sections on I-57 between Champaign and Effingham, Ill.

the 60-ft location, so a camera angle directed at the pavement 60 ft from the bridge was selected for use at all of the test sites.

The position of the camera on the bridge was also selected after much trial and error, at positions ranging from one aligned with the paint stripe to one several yards farther away from the paint stripe. The camera position that provided the best view of truck wheels passing over the template without significant visual distortion was one above the outer edge of the outer shoulder, 10 ft from the paint stripe. This location resulted in a camera position at a slight angle from the traffic lane as well as at a downward angle to the roadway. To check for distortion and the possible need for a correction factor, a scale striped in 2-in. increments was placed across the lane, and actual distances on the scale were compared to distances measured on film. From this comparison it was determined that lateral distortion was not significant.

A variety of filming methods were tested before a satisfactory one was identified. Continuous filming of all traffic on the highway was tried first and consumed a lot of camera film. Next the camera was operated with its automatic timer feature active and an operator-controlled trigger, so that as a truck approached the operator could start the camera and take a series of time-lapse images of the truck. Even at the fastest shutter speed available, however, truck wheels were not always filmed at the spot on the pavement at which the camera was aimed. The most satisfactory method eventually proved to be having the operator watch for an approaching truck and trigger the camera to film continuously for the several seconds during which the truck passed under the bridge and through the camera's field of view.

Data collection was not performed on days when, in the operator's judgment, a significant cross-wind was present that might influence truck positions. Only tractor-semitrailers were filmed; no data were collected for single-unit trucks or passenger cars. Using the methods described, a total of 1,304 trucks were filmed on the two widened-lane sections and 912 trucks were filmed on the control sections. The trucks' positions were determined by projecting the movie films onto a screen and measuring the distance from the side of the outer wheel to the edge of the pavement. The distances measured on the films were scaled to actual distances by constant factors determined from the actual measured widths and filmed widths of the paint stripe and the widened slabs.

STATISTICAL ANALYSIS

Normality of Control Section Data

The lateral distribution data collected on the control sections are summarized in Table 2. In most cases, the data did not appear to be normally distributed. Examples of this are shown in Figure 3 using data from control sections 1 and 5. In each case, the actual data frequencies are indicated by bars, and the theoretical frequency of a normal distribution with the same mean and variance is indicated by a curve. Most of section 1's actual frequencies to the left of the mean are less than the theoretical frequency, whereas most of the actual frequencies to the right of the mean exceed the theoretical frequency. The mean of these data is 20.09 in., whereas the median is about 18 in. Section 1 exhibited the most pronounced skew; among the other control sections, the median was skewed an inch or less from the mean. No consistent leftward or rightward skew was observed among the eight control sections.

Normality should not be judged only by skewness, however. The mean of the data for control section 5 (24.34 in.) is very close to the median (24 inches). Nonetheless, the distribution does not appear to be normal. Actual frequencies exceed theoretical frequencies on both sides of the mean and fall short of theoretical frequencies in the vicinity of the mean.

To examine the normality of the control section distributions, chi-square (χ^2) tests were performed on each of the eight data sets. The computed χ^2 values and the theoretical

TABLE 2 SUMMARY OF LATERAL DISTRIBUTIONS MEASURED ON CONTROL SECTIONS OF I-57 IN ILLINOIS

Section	Number	Mean	Std Dev	Location
1	146	20.087	8.479	I-57 SB Champaign Cty Rd 25
2	84	25.716	6.854	I-57 NB Douglas Cty Rd 1250 N
3	48	24.422	7.382	I-57 NB Douglas Cty Rd 600 N
4	136	18.411	8.226	I-57 NB Champaign Cty Rd 25
5	118	24.345	8.259	I-57 SB Coles Cty Locust Rd
6	64	24.071	7.893	I-57 NB Coles Cty Locust Rd
7	146	24.844	8.239	I-57 SB Douglas Cty Rd 600 N
8	170	22.682	8.204	I-57 SB Douglas Cty Rd 1250 N
Total	912	22.659	8.396	

Notes: Mean displacements are distances from the slab edge, in inches.

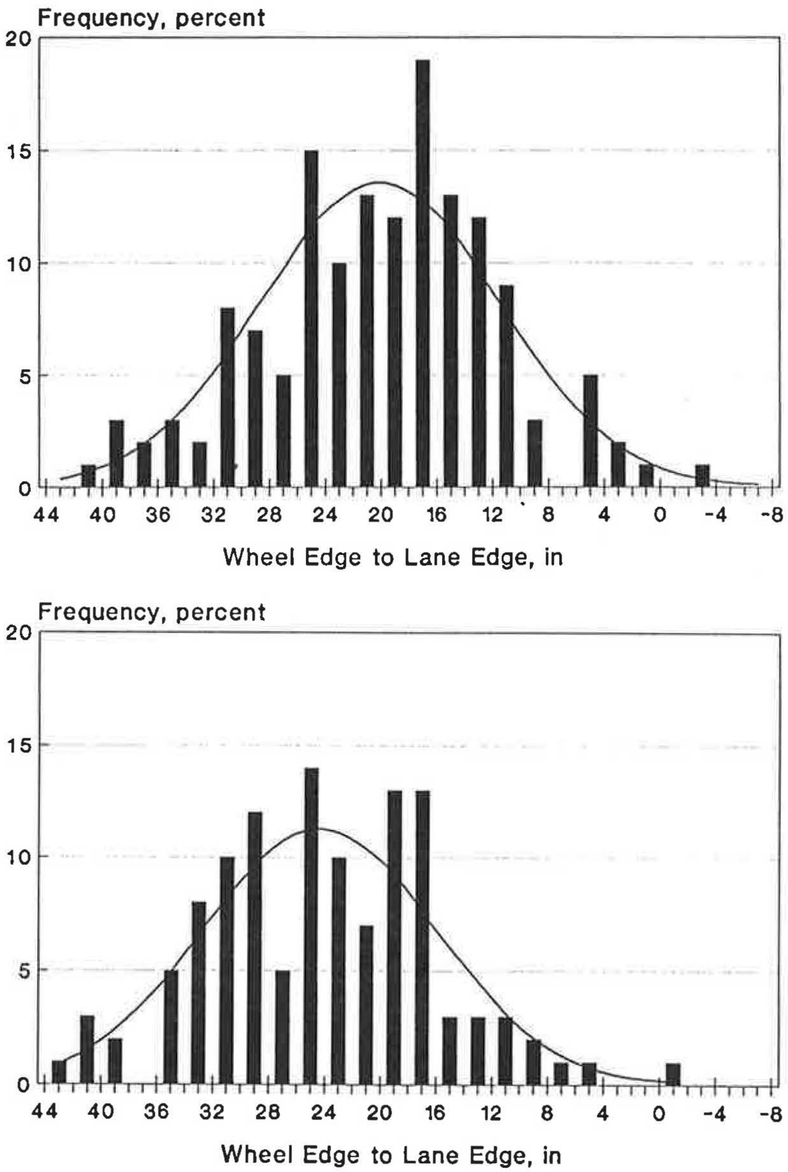

FIGURE 3 Actual versus theoretical distribution of wheel positions for control sections 1 (*top*) and 5 (*bottom*).

values at a significance level of $\alpha = 5$ percent are shown in Table 3. For seven of the eight data sets, the computed values exceed the theoretical values, implying that those seven data sets exhibit a significant departure from a normal distribution. The observed significance level of each test, also reported in Table 3, showed that five of the eight data sets would be judged not normal even at a significance level of $\alpha = 1$ percent.

Equality of Variances on Control Sections

Any significant differences among the means of the eight control sections can be identified by an analysis of variance, provided that the data sets meet the assumptions required for use of the F-statistic. Ideally, the data sets compared should be independent and normally distributed and have a common

TABLE 3 RESULTS OF CHI-SQUARE TESTS FOR GOODNESS OF FIT OF CONTROL SECTION DATA TO NORMAL DISTRIBUTION

Section	χ^2_{calc}	K	$\chi^2_{K-3,\alpha=5\%}$	Observed Significance
1	23.08	14	19.67	98
2	18.84	10	14.07	>99
3	18.28	6	7.81	>99
4	22.91	14	19.67	98
5	24.00	13	18.31	>99
6	27.97	8	11.07	>99
7	26.54	15	21.03	>99
8	20.67	15	21.03	93

NOTE: The null hypothesis H_0 that the data are normally distributed $N(\mu,\sigma^2)$ is rejected with 95 percent confidence if the calculated value χ^2_{calc} exceeds the theoretical value $\chi^2_{K-3,\alpha=5\%}$, where K is the number of intervals and α is the level of significance. The observed significance level corresponds to the level at which χ^2_{calc} equals the theoretical value of $\chi^2_{K-3,\alpha=5\%}$.

TABLE 4 TEST FOR HOMOGENEITY OF VARIANCE OF CONTROL SECTIONS

Given: J sample variances $s_1^2, s_2^2, \ldots s_J^2$, of relatively large (> 25) samples $n_1, n_2, \ldots n_J$ from populations with possibly different means and variances, all unknown

Null hypothesis H_o: $\sigma_1^2 = \sigma_2^2 = \ldots = \sigma_J^2$
Alternate hypothesis H_a: at least two σ_i^2 are unequal

Let:

Y_{ij} = i^{th} observation in j^{th} sample
$\bar{Y}_j$ = j^{th} sample mean

$$G = \Sigma (n_j - 1) \left[\ln s_j^2 - \frac{\Sigma (n_j - 1) \ln s_j^2}{\Sigma (n_j - 1)} \right]^2 / k^2$$

$k = 2 + [1 - (1 / \bar{n})] m$
$\bar{n} = (\Sigma n_j) / J$

$$m = \frac{(\Sigma n_j) \ \Sigma \Sigma (Y_{ij} - \bar{Y}_j)^4}{[\Sigma \Sigma (Y_{ij} - \bar{Y}_j)^2]^2} - 3$$

If H_o is true and all n_j are reasonably large, G has approximately a χ^2 distribution with J-1 degrees of freedom. A formal test of H_o at a significance level α is:

Reject H_o if $G > \chi^2_{\alpha,J-1}$

Do not reject H_o if $G \leq \chi^2_{\alpha,J-1}$

For the 8 control section data sets:

See Table 1 for observations and sample variance of each data set.

$m = 0.092$
$\bar{n} = 912 / 8 = 114$
$k = 2 + [1 - (1 / 114)] 0.092 = 2.0912$
$k^2 = 4.373$
$G = 2.92$
$\chi^2 = 14.07$

$2.92 \leq 14.07$

Therefore do not reject H_o, assume variances are homogeneous.

variance. Although the control section distributions already have been shown to be nonnormal, an analysis of variance from a previous study (*22*) still may be used to compare their means, provided that their variances are homogeneous:

> If the number of observations in each group is reasonably large, inferences made about means assuming normality remain valid for nonnormal populations, all other things being equal. . . In particular, the F test is essentially unaffected if the underlying populations are all of the same form.

To ensure that the data sets are of the same form, a test of the equality of their variances can and should be conducted. Unfortunately, the most commonly used tests for comparing variances are severely affected by nonnormality. One test for homogeneity of variance that applies to large samples and is insensitive to departures from normality is given by Layard (*23*). Applied to the eight sets of control section data, Layard's test confirms that the variances are homogeneous, as shown in Table 4. The *F*-statistic is therefore appropriate for use in comparing the means of the data sets.

Comparison of Control Section Mean Displacements

The results of the analysis of variance, given in Table 5, confirm that significant differences do exist among the eight control section means at a significance level of $\alpha = 5$ percent.

The seven degrees of freedom provided by the eight data sets permit up to seven specific comparisons to further investigate differences in the control section means. However, only five comparisons were judged to be of interest. It should be noted that since they are not independent (all being related by the mean square error), these comparisons cannot be tested individually at a particular significance level α and all be simultaneously considered valid at that same level of α. The five individual comparisons were therefore made at a significance level of $\alpha = 1$ percent, so that their simultaneous confidence level is $(1 - \alpha)^5 = (0.99)^5 = 0.951$ = approximately 95 percent.

One of the comparisons made was between the pair of sections 1 and 4 and the remaining six sections, since these two means (20.1 and 18.4 in.) are noticeably less than those

TABLE 5 ANALYSIS OF VARIANCE OF CONTROL SECTIONS

Source	Degrees Freedom	Sum of Squared Errors	Mean Square Error	F calc	F theor
Total	911	64,156			
Trtmnt	7	5,515	788	12.14	2.01
(1)	1	4,647	4,647	71.63	6.63
(2)	1	198	198	3.05	6.63
(3)	1	1,225	1,225	18.88	6.63
(4)	1	564	564	8.69	6.63
(5)	1	523	523	8.06	6.63
Error	904	58,631	64.86		

Notes: Some significant difference among the eight treatment means is indicated by F_{calc} (12.14) greater than $F_{0.05,7,\infty}$ (2.01).

Significant comparisons are indicated by F_{calc} (see table) greater than $F_{0.01,1,\infty}$ (6.63). These comparisons are made individually with 99 percent confidence; their simultaneous confidence level is $(0.99)^5$ = 95 percent.

Comparisons:

(1) { 1, 4 } versus { 2, 3, 5, 6, 7, 8 }
(2) { 1 } versus { 4 }
(3) { 8 } versus { 1, 4 }
(4) { 8 } versus { 2, 3, 5, 6, 7 }
(5) { 2 } versus { 8 }

of the other six sections. Table 5 shows that these two sections are significantly different from the other control sections.

The mean of section 8 (22.7) is about 2 in. greater than that of section 1, but about 2 in. less than those of the remaining five sections. As Table 5 shows in two comparisons, the difference in means between section 8 and these two groups is significant.

At two of the four bridge locations, the means of the data measured in opposite directions appeared to be noticeably different. As noted above, the means of sections 1 and 4 (southbound and northbound at Champaign County Road 25) differ by 1.5 in. The means of sections 2 and 8 (northbound and southbound at Douglas County Road 1250 N) differ by a full 3 in. As Table 5 shows in two comparisons, the difference between the means of 1 and 4 was not statistically significant, whereas the difference between the means of 2 and 8 was significant. At the two other locations used in the study, the difference in means by direction was so slight (0.4 in. between sections 3 and 7, 0.2 in. between sections 5 and 6) that comparisons did not seem warranted.

The analysis of variance tests only for significant differences in means and does not compare entire distributions. The cumulative percent frequency distributions for the eight control sections shown in Figure 4 illustrate the notable difference between sections 1 and 4 and the remaining six sections, but does not make obvious the differences found among the other sections. The points at which the curves cross the 50 percentile line in Figure 4 correspond to the *median* values of the distributions, and not the *mean* values.

Lateral Distributions on Widened-Lane Sections

A summary of the data collected on the widened-lane sections is given in Table 6. Five rolls of film were shot on each test section, each roll on a different day. A total of 691 trucks were observed on the southbound section, which is widened 18 in., and 613 trucks were observed on the northbound section, which is widened 20 in. The mean displacements reported in Table 6 are measured from the edge of the slab and can be converted to displacements from the lane edge by subtracting 18 and 20 in., respectively. When this is done, the values for the two sections appear similar. Mean displacements from the lane edge range from 17.0 to 23.2 in. on the southbound section, with an overall mean of 20.09 in., and mean displacements range from 18.3 to 21.5 in. on the northbound section, with an overall mean of 20.55 in.

Of the 691 trucks observed on the southbound section, the smallest measured distance from the slab edge was 10.9 in., a 7.1-in. encroachment over the lane edge stripe but still well outside the range in which it could be considered an edge loading. On the northbound section, the smallest measured wheel distance from the slab edge among 613 observations was 17.1 in., an encroachment of 2.9 in. over the lane edge stripe.

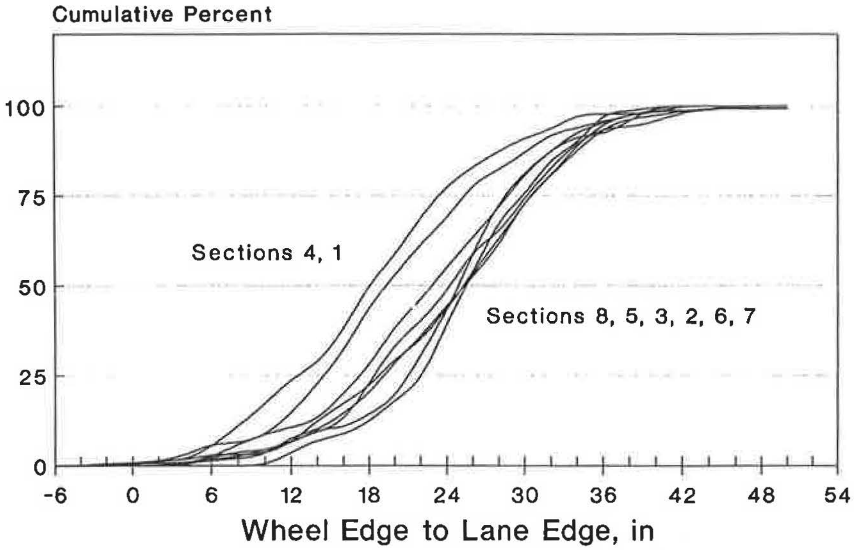

FIGURE 4 Cumulative percent frequency distributions for control sections.

Widened-Lane Lateral Distributions Compared by Direction

The variances of the northbound and southbound widened-lane lateral distributions were confirmed to be homogeneous by using Layard's test. The similarity in the means (20.55 and 20.09 in.) suggests, and an analysis of variance confirms, that no significant difference exists between the distributions observed in the two directions.

CONCLUSIONS AND RECOMMENDATIONS

The findings of past field studies on lateral distribution of trucks on conventional 12-ft lanes should be examined carefully and applied with caution. All of the past field studies on lateral distribution were conducted before enactment of legislation permitting 8.5-ft truck widths, and some were conducted using approximate data collection methods. The method employed for this study, filming truck wheels on the pavement at fixed spots, was felt to provide sufficiently accurate and precise measurements.

The mean lateral displacement of truck wheels from the pavement edge on conventional 12-ft-wide lanes ranged from 18.4 in. and 25.7 in. on eight pavement sections, with an overall mean of 22.7 in. However, significant differences were observed among the mean displacements, despite the pavement sections being of the same geometric design, all located on the same interstate highway, and all within 70 mi of each other. Variance in lateral distribution, however, was consistent among all of the control sections.

Using a mean and standard deviation for lateral distribution of trucks, and assuming the distribution to be normal, a pavement designer can compute the percentage of truck loads in any desired interval of the distribution as the area under the normal curve within this interval. Although conditions will vary depending on the specific design features of the pavement, as a rule of thumb only loads within about 6 inches of the slab edge will produce significantly high stresses at the slab edge. For the eight control sections in this study, the percentage of loads within 6 in. of the slab edge ranged from less than 1 to about 7.5 percent, with an overall average of about 2.5 percent. The designer should keep in mind that whatever quantity for percent edge loads is computed in this fashion may be somewhat overconservative or underconservative if the assumption of a normal distribution is not valid.

The findings of this study clearly show that the paint stripe, and not the slab edge, is the more influential factor in truck wheel placement on widened-lane pavements. The mean lateral distance from the lane edge was only about 2 in. less on 18-in. and 20-in. widened pavement sections than on control sections. With respect to both mean and variance, no statistically significant differences in lateral distributions were detected for the 18-in. and 20-in. widened-lane pavement sections.

Among more than 1,300 observations of truck wheel placements on widened-lane pavement sections, the smallest measured from the slab edge was 10.9 in. There were, in other words, no edge loadings observed among some 1,300 total loadings. The practical significance of this to structural design of concrete pavements is noteworthy: lane widening is likely to be a cost-effective design improvement for pavements whose probable mode of failure will be accumulated fatigue damage manifested by slab cracking. For pavements likely to fail in other ways (e.g., joint deterioration or D-cracking), other design improvements should be investigated.

The trends observed in this study may be fairly typical, but the actual statistics are specific to the sites studied and should not be applied to design of pavements at other sites without great caution. Research into the effects of pavement conditions, shoulder conditions, weather conditions, traffic volume, and other factors on lateral distribution of trucks is strongly encouraged. Meanwhile, pavement designers should view with skepticism any reported national average for truck wheel positions and verify assumed distributions with field observations whenever possible. The methodology used in this study for field data collection is suggested as reasonable for other studies.

TABLE 6 SUMMARY OF LATERAL DISTRIBUTIONS MEASURED ON WIDENED-LANE TEST SECTIONS ON I-57 IN ILLINOIS

18-INCH WIDENED-LANE SECTION:

Film Roll	Number	Mean	Std Dev	Location
1	129	34.978	8.671	I-57 SB Effingham Cty mp 165
2	131	38.528	7.398	(same)
3	127	41.229	9.520	(same)
4	195	38.235	9.071	(same)
5	109	37.336	9.840	(same)
Total	691	38.091	9.077	

20-INCH WIDENED-LANE SECTION:

Film Roll	Number	Mean	Std Dev	Location
1	107	41.376	9.244	I-57 NB Effingham Cty mp 165
2	127	41.466	9.312	(same)
3	145	41.486	9.707	(same)
4	126	38.342	8.590	(same)
5	108	39.949	8.242	(same)
Total	613	40.546	9.375	

Note: All mean displacements are expressed as distance from the side of the wheel to the edge of the concrete slab, in inches. Subtract 18 inches and 20 inches respectively to obtain mean displacement from the lane edge.

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