Comparison of Pavement Surface Distress Measurement Systems

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Two state-of-the-art (late 1989) pavement distress data collection devices were used to evaluate 15 bituminous-surfaced test sections 152 m (0.1 mi) long. The Infrastructure Management Services (IMS) road surface tester was a laser-based system that produced a comprehensive array of rutting and cracking statistics for nominal pavement segments 0.16 km (0.1 mi) long. The PAVEDEX PAS-I system recorded the pavement surface condition on videotape, which was later visually analyzed by PAVEDEX technicians using Kansas Department of Transportation (KDOT) pavement management system network-level distress identification criteria. Data from the two systems were compared with distresses measured and mapped by KDOT engineering technicians using a ground survey. The average maximum rut depth measured by the IMS laser system provided a relatively precise estimate of rut depth severity. Only one linear correlation between IMS cracking data and KDOT distress data was significant at the 5 percent level. Given the comprehensive array of ten IMS cracking width and depth measurements, the absence of linear association with KDOT field data was unexpected. PAVEDEX video data generally detected the presence of transverse and fatigue cracking but had difficulty in assigning the correct KDOT severity code because perceived roughness associated with transverse cracking and differences between hairline and spalled fatigue cracking are used as criteria. Transverse cracks with secondary cracking were interpreted to be block cracking. As a general conclusion, the study indicated that the current KDOT distress rating criteria are not compatible with the capabilities of the two distress measurement systems.

The Kansas Department of Transportation (KDOT) conducts an annual network-level pavement condition survey that requires 4 months and evaluates 17 700 km (11,000 mi) of in-service pavement subdivided into nominal 1.6-km (1-mi) sections. Distress data are collected using a sample of three randomly selected 30.5-m (100-ft) segments in each 1.6-km (1-mi) section of pavement. The randomized selection process is repeated each year, so it is highly improbable that the same segments are evaluated on a year-to-year basis. Therefore, the annual distress survey is based on about a 6 percent sample.

PURPOSE OF STUDY

KDOT is interested in new technology that would reduce distress survey time at perhaps lower cost because the current process is labor intensive as it is based on visual inspections. The use of equipment has the potential to reduce or eliminate both rater-to-rater and time-dependent variations in the field data. Near the end of the survey, visual rating consistency may also become compromised by the tediousness of the process. Furthermore, equipment that can travel at highway speeds eliminates the safety problems associated with temporary work zones that interrupt normal traffic flow.

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Data Collection Equipment and Methodology

Two state-of-the-art (late 1989) pavement distress data collection devices using different technologies were selected for the study. The Infrastructure Management Services (IMS) road surface tester was a laser-based system and produced a comprehensive array of rutting and cracking statistics for nominal pavement segments 0.16 km (0.1 mi) long. The PAVEDEX PAS-I video system recorded the pavement surface condition on videotape. Subsequently, the tapes were visually analyzed by PAVEDEX technicians using KDOT pavement management system (PMS) crack distress criteria. The data were reported for nominal 0.16-km (0.1-mi) pavement segments using the standard format developed for the agency's annual network-level survey. Rutting was not measured by the PAVEDEX system in late 1989.

KDOT Pavement-Type Classifications

Three KDOT PMS pavement types have asphalt concrete surfacing. FDBIT refers to full-design bituminous pavement; construction of the pavement section was based on conventional thickness design and prudent engineering practice. PDBIT is assigned to flexible pavement sections that have evolved through repeated application of surface treatments or overlays. Although contemporary resurfacing mixture and thickness design are based on current engineering practice, the complete pavement cross section has been constructed with only partial reliance on formal design procedures. COMP refers to composite pavements; a bituminous overlay has resurfaced the original rigid pavement.

KDOT Distress Code Definitions

The KDOT PMS uses a distress classification system that includes rutting, transverse cracking, and fatigue cracking. Definitions for the distress classifications discussed in the reported research are as follows:

- Code 1 transverse cracking has no roughness; cracks 6 mm (0.25 in.) wide or wider with no secondary cracking;

or any width crack with secondary cracking less than 1.2 m (4 ft) per lane.

- Code 2 transverse cracking is associated with any width crack with noticeable roughness caused by depression, bump, or wide crack width [in excess of 25 mm (1 in.)] or cracks that have more than 1.2 m (4 ft) per lane of secondary cracking but no roughness.
- Code 3 transverse cracking is assigned to any crack width with significant roughness caused by a depression or bump. Secondary cracking will be more severe than it is in Code 2.

Secondary cracks generally develop parallel and within 150 mm (6 in.) of the main transverse crack as a depression begins to form under the action of traffic. The length of secondary cracking referenced in the distress criteria is the summed length of secondary cracks immediately adjacent to the transverse crack across the full roadway width. Roughness is a subjective evaluation as perceived by the evaluator traveling along the pavement segment. Code 1 fatigue cracking is hairline alligator cracking with nonremovable segments, and Code 2 fatigue cracking indicates spalling of the cracks around the nonremovable segments. The detection of spalling generally requires a close visual examination of the fatigue cracks.

EXPERIMENT DESIGN

The two distress measuring systems were used on 15 bituminous concrete–surfaced pavement segments 152 m (500 ft) long, whose distresses identified by KDOT engineering technicians were meticulously recorded on crack maps. The objective was to compare the data obtained using the two devices with the distress patterns recorded on the crack maps. Statistical significance for correlation studies and analyses of variance was defined using an alpha level of 5 percent.

Test Section Descriptions

The 15 in-service test sections included 5 of each of the three KDOT asphaltic concrete–surfaced pavement types (COMP, PDBIT, and FDBIT). A typical surface distress diagram or crack map is shown in Figure 1.

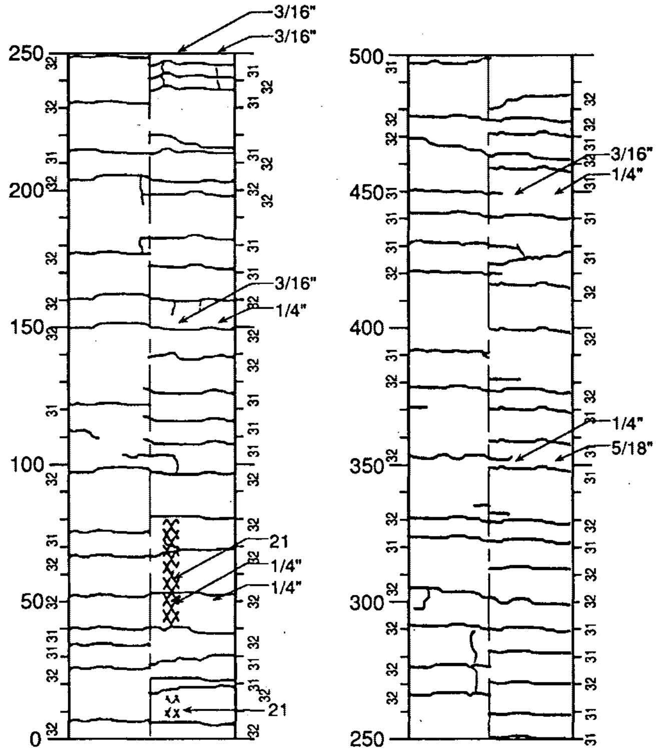

FIGURE 1 Distress diagram (US-54, Woodson County).

Data Set Decriptions

Basic IMS and PAVEDEX data used nominal 0.16-km (0.1-mi) pavement segments that corresponded in length to the 152-m (500-ft) KDOT test sections. In those cases when these segments did not exactly correspond with the KDOT test sections (i.e., the KDOT test section was overlapped by two IMS or PAVEDEX segments), the average IMS or PAVEDEX data for the two segments were used as the appropriate comparative statistics.

The selected IMS data array relating to rutting and surface cracking consisted of the following elements:

- Average rut depth (in.) in left wheelpath;
- Average rut depth (in.) in right wheelpath;
- Average maximum rut depth (in.) in both wheelpaths;
- Crack count [3 to 6 mm deep; 2 to 4 mm wide (0.12 to 0.24 in. deep; 0.10 to 0.16 in. wide)];
- Crack count [3 to 6 mm deep; 4 to 6 mm wide (0.12 to 0.24 in. deep; 0.16 to 0.24 in. wide)];
- Crack count [3 to 6 mm deep; 6 to 12 mm wide (0.12 to 0.24 in. deep; 0.24 to 0.47 in. wide)];
- Crack count [3 to 6 mm deep; 12 to 25 mm wide (0.12 to 0.24 in. deep; 0.47 to 0.98 in. wide)];
- Crack count [greater than 6 mm deep; 2 to 4 mm wide (greater than 0.24 in. deep; 0.10 to 0.16 in. wide)];
- Crack count [greater than 6 mm deep; 4 to 6 mm wide (greater than 0.24 in. deep; 0.16 to 0.24 in. wide)];
- Crack count [greater than 6 mm deep; 6 to 12 mm wide (greater than 0.24 in. deep; 0.24 to 0.47 in. wide)];
- Crack count [greater than 6 mm deep; 12 to 25 mm wide (greater than 0.24 in. deep; 0.47 to 0.98 in. wide)];
- Total crack count (left wheelpath plus right wheelpath) minus the number of cracks detected by both sensors; and
- Total crack count (both inside of wheelpath sensors) minus the number of cracks detected by both sensors.

The relevant PAVEDEX test section data for COMP, PDBIT, AND FDBIT pavement types were as follows:

- Number of Code 1 transverse cracks,
- Number of Code 2 transverse cracks,
- Number of Code 3 transverse cracks,
- Lineal feet of Code 1 fatigue cracking, and
- Lineal feet of Code 2 fatigue cracking.

KDOT test section data discussed in this paper for COMP, PDBIT, and FDBIT pavement types were as follows:

- Average rut depth (in.) in left wheelpath on the basis of five string line measurements taken at 30-m (100-ft) intervals;
- Average rut depth (in.) in right wheelpath on the basis of five string line measurements taken at 30-m (100-ft) intervals;
- Maximum of the two average rut depth measurements (in.) taken in the wheelpaths;
- Number of Code 1 transverse cracks;
- Number of Code 2 transverse cracks;
- Number of Code 3 transverse cracks;
- Number of uncoded transverse cracks;
- Total number of transverse cracks;
- Lineal feet of Code 1 fatigue cracking;
- Lineal feet of Code 2 fatigue cracking; and
- Total lineal feet of fatigue cracking.

RESEARCH RESULTS

The figures use alphanumeric codings to represent the large number of duplicate data points found in the data sets. Numbers 1 through 9 plotted on a scatter diagram represent that number of duplicate data points. For larger numbers, the alphabet is used with A assigned to 10 data points and progressing in alphabetical order to Z, the code for 35 duplicate data points. An asterisk is used if the number of duplicates exceeds 35.

IMS Rutting Data

A correlation analysis between the IMS and KDOT rutting data indicated three significant linear associations:

r (IMS average left wheelpath rutting KDOT average left wheelpath rutting) = 0.66

r (IMS average right wheelpath rutting, KDOT average right wheelpath rutting) = 0.84

r (IMS average maximum rut depth in both wheelpaths, maximum of the two average KDOT rut depths taken in the wheelpaths) = 0.86

The data pairs are graphed in Figures 2 through 4. A line of equality is also shown to assist in data interpretation. Figure 2 shows that the average of the KDOT string line measurements tends to be greater than the IMS laser data for the left wheelpath. A total of 10 of the 15 data points are right of the line of equality. Figure 3 shows the same trend for the right wheelpath with 10 data points to the right of the line of equality. When maximum rut depth values are considered, the bias is less obvious. Only eight data points are to the right of the line of equality in Figure 4. The major conclusion drawn from these data suggests that the IMS average maximum rut depth provides a relatively precise estimate of rut depth severity.

Analysis of variance (ANOVA) was used to determine if the differences between the IMS rut depth data and the KDOT string line measurements were significantly affected by pavement type (e.g., COMP, PDBIT, FDBIT). In these analyses, the differences between IMS and KDOT data using the left wheelpath data, right wheelpath data, and the maximum rut data were tested. All three ANOVAs indicated that pavement type was not a significant factor.

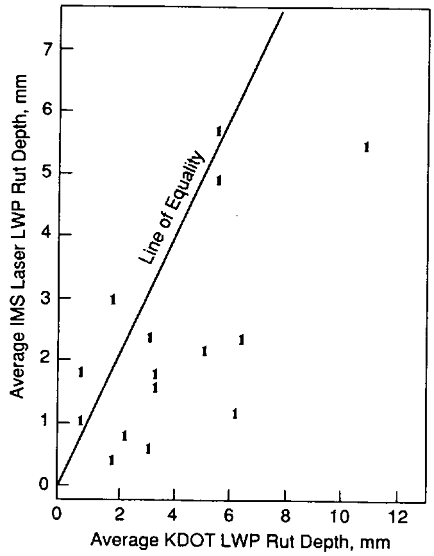

FIGURE 2 IMS average left wheelpath rutting versus average KDOT left wheelpath string line rut depth.

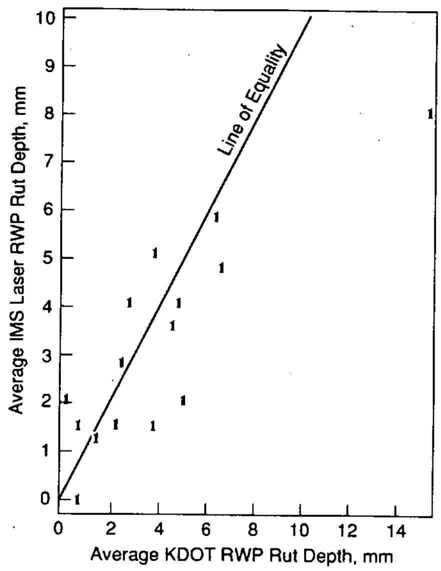

FIGURE 3 IMS average right wheelpath rutting versus average KDOT right wheelpath string line rut depth.

IMS Cracking Data

A similar correlation study was conducted using IMS and KDOT crack data statistics. Only one linear association was significant:

r [total crack count; both wheelpath sensors; 3 to 6 mm deep; 12 to 25 mm deep (0.12 to 0.24 in. deep, 0.47 to 0.98 in. wide), number of Code 1 transverse cracks] = −0.55.

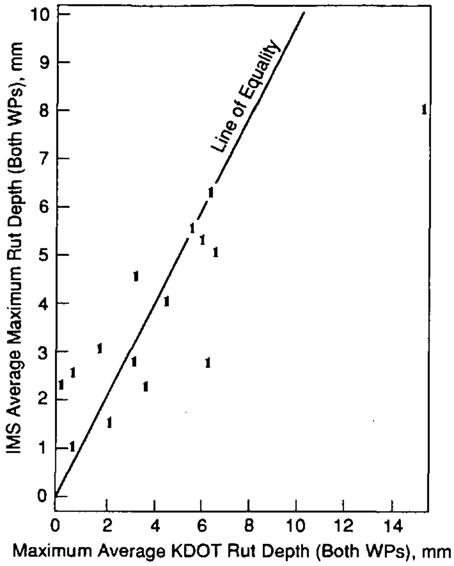

FIGURE 4 IMS average maximum rut depth in both wheelpaths versus maximum of two average KDOT string line rut depths taken in wheelpaths.

As the number of Code 1 transverse cracks increases, the number of IMS-detected wheelpath cracks 3 to 6 mm deep and 12 to 25 mm wide decreases. This appears to be consistent with KDOT severity coding, which considers roughness. Code 1 transverse cracking is not associated with perceptible roughness. As the transverse cracks become wider, roughness increases and a Code 1 severity rating would no longer be appropriate.

Given the comprehensive array of IMS crack width and depth measurements, the absence of a significant number of correlations with KDOT field data was unexpected. This finding suggests that a basic incompatibility exists between the KDOT distress rating criteria and the IMS cracking statistics. The simplicity inherent in visual distress rating criteria does not take advantage of the laser system ability to accurately measure crack widths and depths. If full benefit of a laser-based system is to be realized, a new distress rating system will be needed to replace the existing manual system that is based on visual observation. For example, cracking characteristics such as perceived roughness, spalled cracks, and nonremovable pieces used in the KDOT distress rating system have no "laser meaning." Crack severity and extent will require redefinition in terms of the IMS statistics such as cracking width, depth, and density.

PAVEDEX Cracking Data

PAVEDEX data were analyzed on the basis of two pavement section lengths. Because the basic data used 0.16-km (0.1-mi) pavement section lengths, these data were compared with the KDOT data summed over the entire 152-m (500-ft) test section. In addition, PAVEDEX data were also reported using the 30-m (100-ft) station lengths. This was done because KDOT currently uses randomly selected 30-m (100-ft) segments to collect cracking data during the annual condition survey.

The KDOT test sections were simply subdivided into five 30-m (100-ft) segments, and the appropriate cracking data were summed for each segment. However, PAVEDEX data for each 0.16-km (0.1-mi) section were divided by 5.28 creating five pseudo 30-m (100-ft) segments with identical cracking statistics. These were compared with the five 30-m (100-ft) KDOT segments to study the effect of the potential computational bias on the correlations. PAVEDEX indicated that this computational approach would consistently underestimate the actual lineal feet for a given distress level because of a dilution effect. PAVEDEX also expected the frequency of reported occurrences (i.e., the number of transverse cracks) to be higher than the KDOT data. (D. L. Bender, PAVEDEX, to A. J. Gisi, KDOT, personal communication, Feb. 1990). This bias creates two possible sources of variation between PAVEDEX and KDOT data that do not directly relate to the ability of the technology to detect surface distress.

Although this second analysis increased the number of correlate data pairs by a factor of five, the additional data are not truly independent. The KDOT data for each 30-m (100-ft) segment within the 152-m (500-ft) test section are independent; however, the five pairs of correlates use identical PAVEDEX data. This creates an additional source of computational variation between PAVEDEX and KDOT data, which, again, does not relate to the ability of the technology to detect surface distress.

Correlation Analyses

The statistically significant correlation coefficients (a measure of linear association) involving PAVEDEX distress measurements and KDOT extent-severity codes for the three pavement types are given in the following text. As an aid to interpretation, the correlations are subdivided into three general categories: correlations between (a) like distresses and severity codes, (b) like distresses but different severity codes, and (c) different distresses. The significant correlations associated with both the 30-m (100-ft) and 152-m (500-ft) pavement segment length data bases are shown in the following list. Those linear associations significant for the 152-m (500-ft) pavement segment data base are shown in bold type. If a significant linear association between PAVEDEX (or PDX) and KDOT data existed for the 152-m data set consisting of 15 pairs of correlates, it was also significant using the 30-m (100-ft) pavement segment length data base consisting of 75 pairs of correlates.

Correlation interpretation can be complicated by a nonuniform distribution of data in the factor space. Several of the statistically significant correlations within the 152-m (500-ft) pavement segment data exhibited an elongated data cluster. Many data points were associated with the zero level of one or both of the correlates in conjunction with one or two outlying points. This situation is identified by an asterisk adjacent to the correlation coefficient. Although the correlation may be statistically significant, the engineering inferences are not robust. This finding also placed added importance on the correlations developed from the 30-m (100-ft) data sets.

- Correlations between like distresses and severity codes:

r (number of PDX Code 1 transverse cracks, number of KDOT Code 1 transverse cracks) = 0.29

r (number of PDX Code 2 transverse cracks, number of KDOT Code 2 transverse cracks) = **0.67**, 0.52

r (number of PDX Code 3 transverse cracks, number of KDOT Code 3 transverse cracks) = **0.93***, 0.26

r (lineal feet of PDX Code 1 fatigue cracking, lineal feet of KDOT Code 1 fatigue cracking) = **0.84**, 0.83

- Correlations between like distresses and different severity codes:

r (number of PDX Code 1 transverse cracks, number of KDOT Code 2 transverse cracks) = 0.27

r (number of PDX Code 1 transverse cracks, number of KDOT Code 3 transverse cracks) = 0.23

r (number of PDX Code 1 transverse cracks, total number of KDOT coded and uncoded transverse cracks) = 0.30

r (number of PDX Code 2 transverse cracks, number of KDOT Code 3 transverse cracks) = **0.96**, 0.82

r (number of PDX Code 3 transverse cracks, total number of KDOT coded and uncoded transverse cracks) = 0.24

r (number of PDX Code 3 transverse cracks, number of KDOT Code 2 transverse cracks) = **0.70***, 0.38

r (lineal feet of PDX Code 1 fatigue cracking, total lineal feet of KDOT fatigue cracking) = **0.84**, 0.84

r (lineal feet of PDX Code 2 fatigue cracking, lineal feet of KDOT Code 1 fatigue cracking) = **0.66***, 0.61

r (lineal feet of PDX Code 2 fatigue cracking, total lineal feet of KDOT fatigue cracking) = **0.64***, 0.60

- Correlations between different distresses:

r (number of PDX Code 1 transverse cracks, lineal feet of KDOT Code 1 fatigue cracking) = **−0.53**, −0.48

r (number of PDX Code 1 transverse cracks, total lineal feet of KDOT fatigue cracking) = **−0.53**, −0.49

r (number of PDX Code 2 transverse cracks, lineal feet of KDOT Code 1 fatigue cracks) = −0.25

r (number of PDX Code 2 transverse cracks, total lineal feet of KDOT fatigue cracks) = −0.26

r (lineal feet of PDX Code 1 fatigue cracking, number of KDOT Code 1 transverse cracks) = **−0.55**, −0.33

r (lineal feet of PDX Code 1 fatigue cracking, number of KDOT Code 2 transverse cracks) = −0.31

r (lineal feet of PDX Code 1 fatigue cracking, total number of KDOT coded and uncoded transverse cracks) = −0.37

r (lineal feet of PDX Code 2 fatigue cracking, number of KDOT Code 2 transverse cracks) = −0.23

r (lineal feet of PDX Code 2 fatigue cracking, total number of KDOT coded and uncoded transverse cracks) = −0.24

r (PDX block cracking code, number of KDOT Code 2 transverse cracks) = **0.59**, 0.47

r (PDX block cracking code, number of KDOT Code 3 transverse cracks) = **0.80**, 0.48

r (PDX block cracking code, total number of KDOT coded and uncoded transverse cracks) = 0.38

Discussion of Data

The array of significant positive correlations between like distresses and severity codes suggests that the PAVEDEX data appear to be sensitive to all three severity codes of transverse cracking and to Code 1 fatigue cracking. Increases in PAVEDEX cracking occurrence data were associated with similar increases in KDOT data for both 152-m (500-ft) and 30-m (100-ft) pavement data sets. This finding is encouraging given the difficulty in interpreting video images using KDOT distress rating criteria.

The array of significant positive correlations between like distresses and different severity codes indicates that increases in PAVEDEX transverse and fatigue cracking occurrence data were associated with increases in KDOT data for both 152-m (500-ft) and 30-m (100-ft) pavement data sets, although the severity codes were not consistent. This suggests that the video image interpretation was sensitive to the general presence of transverse and fatigue cracking. Given the difficulty in converting the KDOT severity code criteria (based on perceived roughness and fragment spalling) into an image analysis format, the presence of positive linear associations between numbers of transverse cracks detected and fatigue cracking extent are encouraging, although the KDOT severity codes did not match.

The significant correlations between different distresses were both positive and negative for both 152-m (500-ft) and 30-m (100-ft) pavement data sets. The positive correlations between the PAVEDEX block cracking code and KDOT Code 2 and Code 3 transverse cracks may be caused by the video image analysis misinterpreting extensive interconnected secondary cracking associated with severe transverse cracking as block cracking.

The negative correlations indicate that as the PAVEDEX variable increases, the KDOT variable decreases and vice versa. The negative correlations between lineal feet of fatigue cracking and the number of transverse cracks suggest that extensive fatigue cracking does not occur simultaneously with transverse cracking, which seems to imply a mutual independence of distress types.

However, it may also indicate an interaction involving pavement age that can be explained in terms of causal factors; transverse cracking is an environmental distress caused by cold-weather temperature cycling, whereas fatigue cracking is traffic related. Younger pavements may experience enough temperature cycles for the development of Code 1 (hairline) transverse cracking but may not experience fatigue cracking. Hence, fatigue cracking would not be associated with transverse cracking. Older pavements certainly would experience increased levels of fatigue cracking because of a larger number of axle loads; more severe transverse cracking would also be likely. Hence, for these pavements fatigue cracking would not be associated with the less severe Code 1 (hairline) transverse cracking. The combination of these two explanations could explain the large number of negative correlations between transverse and fatigue cracking.

Direct Data Comparisons

Selected scatter diagrams comparing PAVEDEX and KDOT data for specific distresses and severities with statistically significant correlation coefficients were developed using both data sets. Lines of equality rather than simple linear regression models are shown on each figure to aid in directly comparing KDOT and PAVEDEX data.

Test Section Length of 152 m (500 ft)

Data pairs for Code 1 fatigue cracking are shown in Figure 5. Seven test sections did not exhibit fatigue cracking. PAVEDEX data for one test section indicated Code 1 fatigue cracking, although no fatigue cracking at that severity level was noted by KDOT engineering technicians. It does not necessarily mean that the PAVEDEX data indicated fatigue distress where none existed. The remaining eight data pairs indicate that KDOT cracking data generally exceeded corresponding PAVEDEX data.

For Code 1 transverse cracking, the trend illustrated in Figure 6 indicates that the PAVEDEX number of occurrences is usually greater than the KDOT data. In single cases, the KDOT data did not indicate the presence of Code 1 transverse cracking, although the PAVEDEX data did, and vice versa. For Code 2 transverse cracking, as shown in Figure 7, the general trend is reversed, with KDOT data exceeding PAVEDEX data. For three test sections, KDOT data indicated the presence of Code 2 cracking, whereas PAVEDEX data were void of the distress at that severity level. One section exhibited the reverse.

These data indicate that the PAVEDEX video-based data detected the presence of fatigue cracking with perhaps some difficulty in assigning the correct severity, which is based on differences between nonspalled and spalled cracks. If the data shown in Figures 6 and 7 are taken together, it is apparent

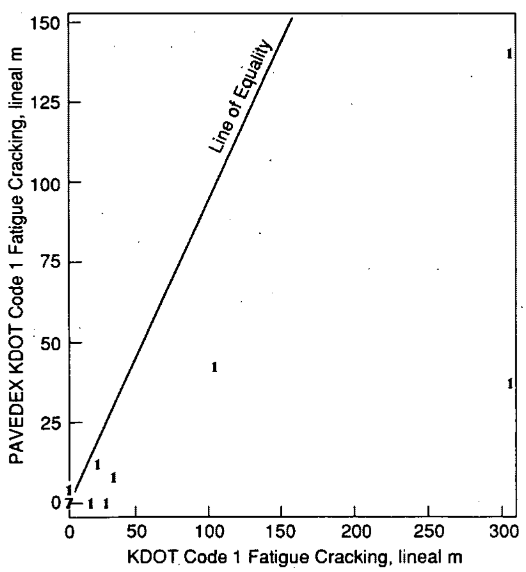

FIGURE 5 KDOT Code 1 fatigue cracking measured by PAVEDEX versus KDOT Code 1 fatigue cracking, 152-m test sections.

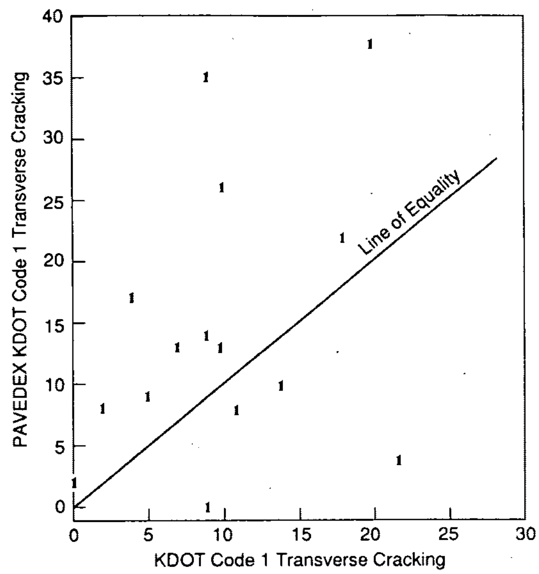

FIGURE 6 Number of KDOT Code 1 transverse cracks measured by PAVEDEX versus number of KDOT Code 1 transverse cracks, 152-m test sections.

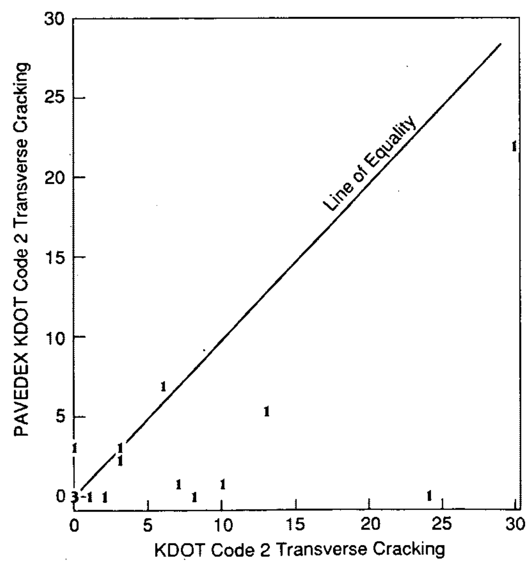

FIGURE 7 Number of KDOT Code 2 transverse cracks measured by PAVEDEX versus number of KDOT Code 2 transverse cracks, 152-m test sections.

that although the PAVEDEX data were sensitive to the presence of transverse cracking, the severity was generally underestimated. This is not surprising since the difference in KDOT severity criteria between Code 1 and Code 2 transverse cracking is a function of perceived roughness rather than a visual characteristic.

Test Section Length of 30 m (100 ft)

Figures 8 through 10 plot data using a 30-m (100-ft) pavement segment as the basis. Recall that within the five data pairs developed for each 152-m (500-ft) KDOT test section, the PAVEDEX data cannot be considered statistically independent and may also indicate a computational bias.

Figure 8 illustrates the PAVEDEX Code 1 transverse cracking data and the KDOT Code 1 transverse cracking data plotted with respect to a line of equality. Given the technique used to subdivide the PAVEDEX data into five pseudo 30-m (100-ft) segments, a single value of PAVEDEX data associated with several different KDOT values produced the obvious horizontal alignment within the data set plotted in the figure. Furthermore, it is apparent that the PAVEDEX data tend to overestimate the number of transverse cracks as compared with the KDOT crack mapping data.

Figure 9 indicates that the PAVEDEX data for Code 2 transverse cracking tends to underestimate the KDOT Code 2 transverse cracking data. The "L" plotted at (0,0) signifies 21 data points.

These two figures taken together suggest that the PAVEDEX video analysis classified many KDOT Code 2 transverse cracks as Code 1 cracks. This classification would overestimate the number of Code 1 cracks and underestimate the number of Code 2 cracks. These trends are similar to those observed in Figures 6 and 7. The potential effect of computational bias (i.e., overestimation of the number of transverse cracks), if it exists, is not apparent. Although the correlation for Code 3 cracking was statistically significant, not enough Code 3 data were obtained from the test sections for a meaningful discussion of a scatter diagram.

Figure 10 illustrates the relationship between the PAVEDEX Code 1 fatigue cracking data and KDOT Code 1 fatigue cracking data. The asterisk plotted at (0,0) indicates over 35 points. These data clearly indicate that the PAVEDEX data underestimate the lineal feet of Code 1 fatigue cracking as measured by KDOT field personnel. Furthermore, seven of the data

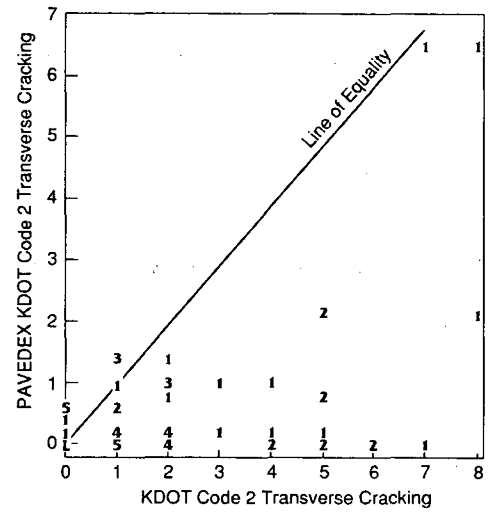

FIGURE 9 Number of KDOT Code 2 transverse cracks measured by PAVEDEX versus number of KDOT Code 2 transverse cracks, 30-m test sections.

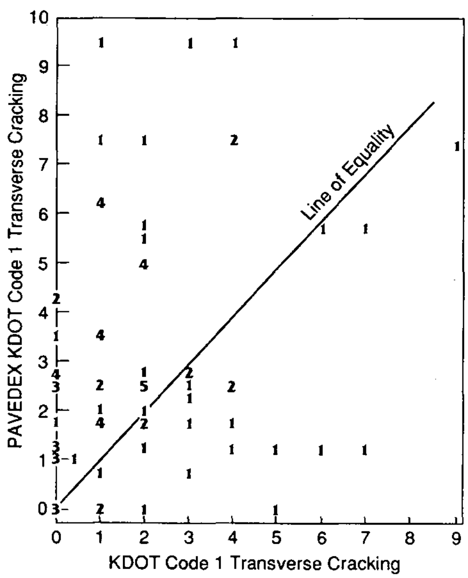

FIGURE 8 Number of KDOT Code 1 transverse cracks measured by PAVEDEX versus number of KDOT Code 1 transverse cracks, 30-m test sections.

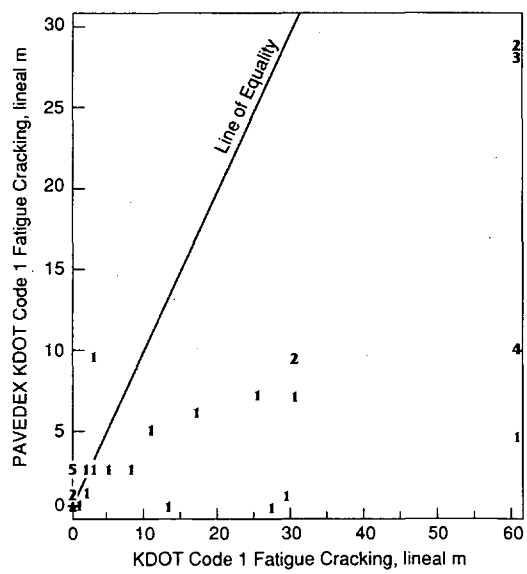

FIGURE 10 KDOT Code 1 fatigue cracking measured by PAVEDEX versus KDOT Code 1 fatigue cracking, 30-m test sections.

points that fall above the line of equality indicate the presence of Code 1 fatigue cracking in the PAVEDEX data but not in the KDOT data. This does not necessarily mean that PAVEDEX detected nonexistent fatigue cracking, but that PAVEDEX assigned a higher severity code to the distress than KDOT. This would not be unexpected since the difference between Code 1 and Code 2 fatigue cracks relates to the presence of spalling, and video image interpretation was inconsistent in assigning the correct distress severity.

Crack Analysis—Significance of Pavement Type

A one-way ANOVA was performed using pavement type as the independent variable. The response variables were the differences between compatible PAVEDEX and KDOT data related to fatigue and transverse cracking.

Test Section Length of 152 m (500 ft)

None of the ANOVAs indicated that pavement type was a significant factor. Therefore, pavement type (COMP, PDBIT, and FDBIT) did not influence the relative precision of the PAVEDEX unit in identifying the number of specifically coded (by severity) transverse cracks or lineal feet of specifically coded (by severity) fatigue cracking in both wheelpaths.

Test Section Length of 30 m (100 ft)

Pavement type was a significant factor affecting the differences between KDOT and PAVEDEX Code 1 transverse cracking, Code 1 fatigue cracking, and Code 2 fatigue cracking measurements. Since the null hypothesis is an equality of means (differences in this case) for each pavement type, the mean differences for the significant distresses were as follows:

Distress	*COMP*	*PDBIT*	*FDBIT*
Code 1 TC	2.50	0.30	0.56
Code 1 FC	1.20	−58.26	−15.08
Code 2 FC	0.00	25.68	−3.80

The transverse cracking data are numbers of cracks; the fatigue cracking data are in lineal feet. The differences were developed by subtracting KDOT data from PAVEDEX data. Positive quantities mean that KDOT data were larger than PAVEDEX data and vice versa. These data illustrate the magnitude of variation in the mean differences over the three pavement types and the basis for the statistical significance of pavement type in the analysis of variance. It is not clear whether pavement type or some other unknown concomitant factor, such as the computational technique used to create PAVEDEX data for 30-m (100-ft) segments, caused this variation in the differences between the PAVEDEX and KDOT data. No apparent physical reason associated with pavement type was evident from examination of the KDOT crack map data. However, these findings may suggest that subdivision of the PAVEDEX data using 0.16-km (0.1-mi) pavement segment length into smaller units should be done with caution.

CONCLUSIONS

1. The average maximum rut depth measured by the IMS laser system provided a relatively precise estimate of rut depth severity.
2. The differences between IMS rutting data and KDOT field measurements were not affected by KDOT PMS pavement type (COMP, FDBIT, PDBIT).
3. Only one correlation between IMS cracking data and KDOT cracking distress measurements was significant. Given the comprehensive array of IMS crack width and depth measurements, the absence of linear association with the field data was unexpected.
4. PAVEDEX video data appeared to be sensitive to the presence of transverse and fatigue cracking, as suggested by numerous statistically significant correlations with KDOT field measurements. However, the video interpretation had difficulty in assigning the correct severity code because the KDOT PMS distress rating system uses perceived roughness associated with transverse cracking and spalling associated with fatigue cracking as criteria. This may also indicate a technician training deficiency.
5. The PAVEDEX video data interpretation also appeared to classify severe transverse cracking with secondary distress as block cracking. This could also be a training deficiency.
6. The differences between PAVEDEX cracking data and KDOT field measurements were not affected by KDOT PMS pavement type (COMP, FDBIT, PDBIT) if analyzed on the basis of a 152-m (500-ft) pavement segment length, but KDOT pavement type was significant if the data were analyzed on the basis of a 30-m (100-ft) pavement segment length.

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