Abridgment

Condition Surveys in the Strategic Highway Research Program Long-Term Pavement Performance Study and Pavement Condition Rating for Preoverlay Conditions

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The long-term pavement performance (LTPP) research study, a component of the Strategic Highway Research Program (SHRP), represents a $50 million effort to collect field observations of pavement structures from across the United States and Canada. The procedures to be used for rating the condition of LTPP test sections before overlay are discussed. The methods should be used in classifying the condition of a test section as "good" or "bad"; such information is needed as an input variable to the asphalt concrete overlays on asphalt and concrete pavement factorial experiments. These experiments were defined for recruiting in-service test sections for inclusion in the SHRP LTPP study. The distress-monitoring approach being adopted for the long-term monitoring of in-service SHRP pavement sections is then described. The categories and types of distress data to be collected periodically are described, together with uniform and practical distress definitions and monitoring procedures. Finally, information on the contents of survey forms and maps to be used during the process is provided.

The rapid deterioration of U.S. pavements noted during the last few years underscores a need for developing and conducting comprehensive research on the long-term performance of pavement. In addressing this problem, the Strategic Highway Research Program (SHRP) undertook, in 1987, major research in six primary areas, one of which was the long-term pavement performance (LTPP) study (*1*). The objectives of the study included evaluation of existing design methods; development of improved strategies and design procedures for the rehabilitation of existing pavements; development of improved design equations for new and reconstructed pavements; determination of the effects of loading, environment, material properties and variability, construction quality, and maintenance levels on pavement distress and performance; and establishment of an international long-term pavement data base to support these objectives for both present and future needs. The LTPP data base will include information from more than 1,000 in-service test sections [general pavement studies (GPS)] and from specially constructed pavements [special pavement studies (SPS)] to study the influence of design factors in pavement performance. From the GPS portion of LTPP, 769 projects have been approved. Of these test sections, 48 are planned asphalt concrete overlays of asphalt concrete pavements (GPS 6B), and 22 are planned asphalt concrete overlays of portland cement concrete (PCC) pavements (GPS 7B). The target number of projects to be approved for inclusion in these categories of GPS is 150 and 200, respectively.

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The first part of this paper deals with the rating procedures recommended for classifying the preoverlay condition of the LTPP test section included in the GPS factorials 6B and 7B. Because the objective of the rating methods is to characterize preoverlay conditions of GPS 6B and 7B as "good" or "bad" (information needed as input to the previous factorials), and because limited field distress data are collected for this purpose, the proposed methods are modified rating procedures. The second part of the paper deals with long-term pavement distress evaluation, a part of the LTPP monitoring data set. It presents the categories and types of distress data to be collected periodically in both rigid and flexible LTPP test sections using manual or automatic survey procedures.

The Texas Research and Development Foundation (TRDF), with the Center for Transportation Research (CTR) of the University of Texas at Austin as subcontractor, has been selected by SHRP for SHRP LTPP technical support (Project P001). Two pavement distress–related manuals have been completed thus far by the P001 team (*2,3*). The manuals will be used during the periodic monitoring of the LTPP test sections.

FIELD DATA AND RATING PROCEDURES FOR PREOVERLAY CONDITIONS

The GPS 6B and 7B factorials use the pavement condition before overlay as input. Because a limited type of distress data was collected for assessing the pavement condition as good or bad, a rating method for each pavement type (asphalt and PCC) was designed to (*a*) use the maximum possible distress information collected from the LTPP test sections, (*b*) examine whether the measurement units used for monitoring the distress extent during the preoverlay condition surveys could be converted with acceptable assumptions to the units defined by the rating methods, and (*c*) compare the relative weights given by each method with each distress type for a specific pavement (asphalt or PCC) with results obtained from previous studies regarding the influence of each distress type in a pavement's performance.

After examining 21 flexible and 17 rigid pavement condition manuals proposed by different highway and other agencies involved in the process of rating pavements, indices based on weighted values of distress types and severity levels were selected (because profile measurement or riding comfort ratings were not available). Distress data from approximately 20 LTPP test sections were used for examining the agreement of the rating method response with the field rater's evaluation. The type of distress data collected for this purpose is reported below.

The following distress information is collected before overlays in GPS 6B. *Alligator and block cracking* and *raveling/weathering* are measured in square feet of affected area for each corresponding severity level (low, medium, and high) noticed in the pavement surface. *Patch deterioration* is recorded as the number of patches and square feet of affected area for each severity level. *Pumping* is included in the survey form but has not yet been reported for any of the LTPP test sections surveyed so far. The number of *transverse cracks* in the pavement test section at each severity level must be monitored. *Bleeding* is considered only when it is extensive enough to cause a reduction in skid resistance and must be recorded in square feet of affected area. *Rutting* must be monitored as the *average rut depth* within the entire section.

The following distress information is collected before overlays in GPS 7B. *Longitudinal and "D" cracking* are measured in linear feet of affected area for each corresponding severity level noticed in the pavement surface. *Joint seal damage* and *transverse cracking* are measured in number within each severity level noticed in the pavement, whereas *patch or slab replacement deterioration* is measured in both number and square feet at each severity level. *Average faulting* is monitored only in severity level, whereas the highest severity of *pumping* is considered. Finally, the number of *corner breaks* present in the test section is monitored. Further details regarding distress types and their corresponding severity levels can be found in the distress identification manual (*2*).

The rating method of the Ohio Department of Transportation and the Pavement Condition Index (PCI) defined by Paver (*4*) were selected for the set of rating procedures evaluated for this purpose—principally because they use the maximum amount of detailed distress data obtained through the condition surveys developed for this part of the LTPP study and because minor assumptions for data conversion are required. The proposed methods are described below.

PAVEMENT CONDITION RATING PROCEDURE FOR GPS 6B FACTORIAL EXPERIMENT

The rating procedure for GPS 6B is based on a simplified version of the PCI of Paver (*4*). It was selected after extensive review of the available literature and after trying various methods with field condition data from approximately 20 LTPP test sections. The results of the analysis indicated that field ratings and the ratings obtained using the method outlined below were the same for most cases available for study. It is recommended that the methodology described be used only for the GPS 6B factorial experiment. The procedure is based on seven of the eight distress types described above. The simplifications, assumptions, and modifications made to the PCI method follow.

Conversion of Field Data from Extent to Density of Distress

The field data must be transformed from extent measurements (square feet, number, linear feet, etc.) to density of distress. In most cases this is straightforward. For example, if there is 110 ft^2 of medium-severity alligator cracking within a section, the density is 110 ft^2/6,000 ft^2 $\times$ 100 percent = 1.83 percent. [The area of the LTPP test section (or sample unit) is 500 ft long $\times$ 12 ft wide, or 6,000 ft^2.] In other cases (transverse cracking, rutting, and pumping), the following assumptions must be made.

Assumptions

Transverse cracking is recorded as the number of cracks at various severity levels. However, the weight value curves for this distress were developed for transverse cracking density, defined as (extent in linear feet)/(test section area in square feet) $\times$ 100 percent. The assumption is that each transverse crack is, on the average, as long as the lane width, that is, 12 ft. The number of transverse cracks is multiplied by 12 ft to calculate the total extent, in linear feet, for each severity level.

Rutting is recorded as average rut depth; the area affected is not given. The assumption is then made that rutting exists in both wheel paths. Each wheel path is 18 in. wide; 18 in. $\times$ 2 wheel paths = 36 in., or 3 ft. It is also assumed that rutting exists along the total length of the test section, that is, 500 ft. Thus, the area affected can be estimated as 3 ft $\times$ 500 ft = 1,500 ft^2 of average rut depth.

Only severity levels are recorded for pumping in the field survey form, and there is no information as to the extent of this distress throughout the test section. For these reasons, it was decided that test sections with pumping will be evaluated on an individual basis (i.e., if a borderline good/bad test section exhibits pumping, it will be placed in the bad category). As mentioned, however, pumping has not been reported for any of the LTPP test sections for which field data are available. In other words, pumping is not a common distress in the asphalt pavements monitored for the LTPP study.

Rating Procedure

Two steps are involved in calculating the final condition index of an asphalt pavement test section: (*a*) the distress information observed on the pavement surface is recorded in the distress survey forms and (*b*) the field data are transformed in distress density and severity levels. The distress density is determined as follows. For distresses measured in square feet,

density = (extent of distress/test unit area) × 100 percent

where extent of distress and test unit area are both measured in square feet. For distresses measured in linear feet (transverse cracking), the same formula is used, but extent of distress is measured in linear feet and test unit area is measured in square feet.

After the density of each distress type–severity level combination is determined, the weight values are obtained from the distress weight curves (*4*). A total weight value is computed by summing all individual distress weight values. Once the total distress weight value is computed, the adjusted weight value can be determined from the corresponding curves. During the determination of the adjusted weight value, if any individual weight value is higher than the adjusted weight value, the adjusted weight value is set equal to the highest individual weight value. The index *I* is computed using the relation *I* = 100 − adjusted weight value. The index number that separates between pavement sections in bad or good condition is 55.

PAVEMENT CONDITION RATING PROCEDURE FOR GPS 7B FACTORIAL EXPERIMENT

The rating procedure for GPS 7B is based on a simplified pavement condition rating (PCR) index developed and used by the Ohio Department of Transportation (*5*). It was selected after reviewing the literature and trying various methods using available field condition data from approximately 20 LTPP test sections. The procedure is based on seven of the eight distress types described above. The results indicate that field ratings and the ratings obtained using the method outlined below were the same for most cases. It is recommended that the methodology be used only for the GPS 7B factorial experiment. The simplifications, assumptions, and modifications made to the PCR method follow.

Assumptions

The weight values defined by this method are a function of the density of distresses in percentage of slabs affected or percentage of joints affected. To determine the weight values, the total number of slabs or joints in the test section must be known. The assumption of slabs 25 ft long and 12 ft wide in the 500-ft test section results in 20 slabs (500/25) with 21 joints. As for flexible pavements, it is assumed that the total test section is 500 ft long × 12 ft wide, or 6,000 ft^2. These assumptions hold for continuously reinforced concrete pavements (CRCPs), because most procedures for rating this type of pavement consider imaginary slabs of approximately 25 ft. Faulting is recorded as average faulting with the area affected not given. The assumption is then made that faulting exists in 50 percent of the test section, that is, one slab is level, whereas the following one presents faulting. The extent of pumping in the test section is assumed to be proportional to the severity level observed, because only this information is monitored. For example, when low severity is observed, the extent is assumed to be 10 percent of the section's total length (i.e., occasional); for medium severity the corresponding extent is assumed to be 10 to 25 percent (i.e., frequent); and for high severity, the area affected is extensive (more than 25 percent). The extent weight for the corner break distress is defined differently from that of the original rating method (i.e., occasional = 1 corner break/mi, frequent = 2 or 3 corner breaks/mi, and extensive = more than 3 corner breaks/mi). It is believed that these limits are conservative and, moreover, not practical considering the type and size of the LTPP test sections. The extent for corner breaks is redefined as follows: occasional, < 4 corner breaks/500 ft; frequent, 4 to 8 corner breaks/500 ft; and extensive, > 8 corner breaks/500 ft. Because no information is reported in the preoverlay condition surveys regarding the severity level of this distress, it is assumed that severity level and extent are related as follows: occasional corresponds to low-severity, frequent to medium-severity, and extensive to high-severity distress.

Conversion of Field Data

The field data must be transformed from extent measurements (square feet, number of slabs or joints affected, etc.) to density of distress. For example, if there are 10 joints with seal damage of medium severity on the section, then the density is 10/21 × 100 percent = 47.61 percent, where 21 is the number of joints in each test section. Longitudinal cracking is monitored in linear feet, and the rating procedure uses the percentage of slab affected. To determine the percentage of slabs affected, the number of linear feet observed is divided by the length of each slab (25 ft) to obtain the number of slabs affected. The result is then divided by 20, the number of slabs in the LTPP test section. Patching is reported in number and square feet, whereas the patching density in this method is percentage of slabs affected. However, percentage of slabs affected is the same as the percentage of total area, because

$$\begin{aligned}\text{Percentage of slabs} &= \frac{\text{no. of slabs affected}}{\text{total no. of slabs}}\\ &= \frac{\text{no. of slabs affected}}{\text{total no. of slabs}} \times \frac{\text{area of each slab}}{\text{area of each slab}}\\ &= \frac{\text{area affected}}{\text{total test section area}}\\ &= \text{percentage of area affected}\end{aligned}$$

Rating Procedure

Two steps are involved in calculating the final condition index of a PCC pavement test section: (*a*) the distress information observed on the pavement surface is recorded in distress survey forms and (*b*) the field data are then transformed in distress density and severity levels. The distress density is determined as follows:

For distresses measured in square feet,

density = (extent of distress/test unit area) × 100 percent

where extent of distress and test unit area are measured in square feet. For distresses measured in number (e.g., corner breaks),

density = number/500 ft

For distresses measured in the number of joints or slabs affected,

density = (no. of joints or slabs/total no. of joints or slabs) × 100 percent

The density of transverse cracking is defined as average crack spacing (CS) between intermediate transverse cracks as given by the following expression:

$$CS = L/(Z + 1)$$

where

CS = average crack spacing,
Z = average number of transverse cracks per slab (see example below), and
L = transverse joint spacing (in accordance with previous assumption of slab length of 25 ft).

Example: For a test section with 16 low-severity transverse cracks, the parameters Z and CS are evaluated as follows: $Z = 16/20 = 0.8$, where 20 is the number of slabs in the test section, and $CS = 25/(0.8 + 1) = 25/1.8 = 13.8$. The extent of each distress type used by the rating procedure is shown in Table 1.

After the density of each distress type–severity level combination is determined, the weight value for each distress type is obtained by multiplying the distress weight by the severity and the extent weights (*5*). This PCR procedure permits the addition of weight points when multiple distresses occur in the pavement section. Because the procedure assumes that several distresses will be observed in a given survey, the method tends to overestimate the PCR value when only a few (one or two) distresses are observed. It is unlikely that the condition of a pavement with extensive, high-severity distress of any type would be considered good. Therefore, some adjustments to the PCR method appear necessary when only one or two severe distresses are observed for a pavement section. The suggested adjustment factors for these conditions are as follows:

- If one distress type is observed, multiply the weight value by 2.0.
- If two distresses are observed, multiply the sum of weight values by 1.5.
- If more than two distress types are observed, no adjustment is necessary.

The index I is computed using the relation $I = 100 -$ total weight value. The index number that separates between PCC pavement sections in bad or good condition is 75.

PAVEMENT DISTRESS DATA COLLECTION OF LTPP TEST SECTIONS

The main objective of pavement distress data collection is to provide practical, uniform, comprehensive, and reliable pavement condition information. The characteristics described must be reflected in all pavement data collection steps. The infor-

TABLE 1 EXTENT OF DISTRESS TYPES USED BY RATING PROCEDURE

	Extent			
Distress	Occasional	Frequent	Extensive	Percent of
Patching	<5%	5-20%	>20%	Slabs
Pumping	<10%	10-25%	>25%	Section length
Faulting	<20%	20-50%	>50%	Section length
D-Cracking	<20%	20-50%	>50%	Transverse Joints
Joint Sealant Damage	<20%	20-50%	>50%	Joints
Transverse Cracking	cs>15	10<cs<15	cs<10	-
Longitudinal Cracking	<5%	5-20%	>20%	Slabs
Corner Breaks	<4/500 ft	4-8/500 ft	>8/500 ft	-

mation collected from such surveys should be stored in the LTPP data base, where it can be used to define the pavement's present condition and its condition trend under specific load and environmental conditions to develop pavement performance prediction models. A review of the pavement monitoring literature revealed as many techniques and procedures as there are highway agencies involved in this process. Because the objective of the LTPP study is to produce an international pavement data base, preliminary studies were made by TRDF and CTR to recommend and define a uniform condition survey to be used in the LTPP test sections. The LTPP monitoring data will be collected in the outside lane in one direction of traffic for highways in North America. The data are to be collected on 500-ft-long test sections.

IDENTIFICATION AND DEFINITION OF DISTRESS DATA

Pavement distress represents any undesirable manifestation of defects in the pavement surface capable of affecting pavement serviceability, structural capacity, or appearance. The review of the literature revealed a lack of uniformity in terminology and classification of pavement defects. Because one of the objectives of the LTPP study is to create an international data base for use in all regions of North America and elsewhere, there was a need to

- Standardize defect terminology for defining distress type, severity, and extent to obtain a uniform data base,
- Include distress types that have a significant influence on pavement performance as determined from previous studies,
- Obtain consistency between classification of distresses as well as use detailed measurements to minimize errors, and
- Standardize graphical and visual descriptions of distress types and severity levels to minimize different interpretations between raters.

The distress data to be collected in the LTPP test sections are presented in the *Distress Identification Manual for the Long-Term Pavement Performance Studies* (*2*). Because asphalt concrete pavements, jointed (plain and reinforced) concrete pavements (JCPs), and CRCPs present some noncommon defect manifestations, the distresses for each pavement type are presented separately.

The distresses for pavements with asphalt concrete surfaces have been grouped into the following general categories: cracking, patching and potholes, surface deformation, surface defects, and miscellaneous distresses. Cracking includes alligator (fatigue), block, edge, longitudinal, and transverse cracking, as well as reflection cracking of joints for the overlaid sections. The extent of these distresses must be determined for each severity level using the corresponding measurement units described in the manual (*2*). The extent of the patching and pothole distresses must be monitored within each severity level defined. Rutting and shoving constitute the surface deformation distresses. No severity levels are defined for either, and they must be monitored according to the descriptions in the manual (*2*). Bleeding, polished aggregate, and raveling/weathering constitute the surface defects type. Miscellaneous distresses include water bleeding and pumping (to be recorded in any of the three severity levels) and lane-to-shoulder drop-off, which has no severity levels.

For the JCPs, the following categories of defects have been considered: cracking, joint deficiencies, surface defects, and miscellaneous distresses. Corner breaks and durability "D" cracks, as well as longitudinal and transverse cracks, are included in the cracking category. The extent of these distresses has to be recorded separately for each severity level using measurement units defined in the manual (*2*). The joint deficiencies category includes joint seal damage of transverse joints and spalling of longitudinal and transverse joints. Map-cracking and scaling, polished aggregate, and popouts are included in surface defects. Of these distresses, only map-cracking and scaling must be monitored for each severity level defined. The last category for JCPs, miscellaneous distresses, includes blowups, faulting of transverse joints and cracks, lane-to-shoulder drop-off and separation, patch/patch deterioration, and water bleeding and pumping; only the last two distresses must be monitored by severity levels.

For CRCPs, the last pavement type considered in the LTPP studies, the following distress groups have been included: cracking, surface defects, and miscellaneous distresses. For this type of pavement the following defects are included under cracking: durability "D" cracks and longitudinal and transverse cracks. The surface defects category for CRCPs includes map-cracking and scaling, polished aggregate, and popouts. The considerations related to such distresses are similar to those reported previously for surface defects of JCPs. The last group, miscellaneous distresses, includes blowups, construction joint deterioration, lane-to-shoulder drop-off, lane-to-shoulder separation, patch/patch deterioration, punchouts, spalling of longitudinal joint, and water bleeding and pumping. The extent of these defects in the pavement surface must be monitored using one of the three severity levels available, with the exception of blowouts, lane-to-shoulder drop-off, and lane-to-shoulder separation, for which no severity levels have been defined.

METHODS FOR FIELD SURVEY OF LTPP PAVEMENT SECTIONS

Two pavement distress surveying techniques have been selected for use in the LTPP study: a visual or manual survey procedure and an automatic technique using the PASCO multifunction survey vehicle. The visual surveys are intended for use as a backup when it is not possible to schedule a visit by the PASCO vehicle. If PASCO has surveyed the test section within 3 months before maintenance-rehabilitation work, it is not necessary to perform the visual distress survey, which, however, will be performed in remote areas not directly accessible to PASCO (e.g., Hawaii and Puerto Rico). About 700 GPS test sections have been surveyed to date with the PASCO equipment.

The manual (*2*) should be used as a standard guide for interpretation, identification, and rating of observed pavement distresses. The *Manual for Field Distress Surveys* (*3*) provides instructions, data forms, and maps for use in visual collection of defect information for pavements with asphalt concrete pavements (chapter 2), JCPs (chapter 3), and CRCPs (chapter 4). In the visual pavement distress survey, raters walk along the pavement section and manually draw a map showing the type and exact location of all defects present on the pavement surface—a procedure similar to the one used for the AASHO road test (*6*). The severity level of each distress is identified and recorded on the maps and the data sheets included in the field manual (*3*). The field maps are used to show the exact location of each defect type on the test section. Five sheets are used for mapping; each sheet contains two 50-ft maps that represent 100 ft of the LTPP section. The defects are drawn on the map at the appropriate locations using the various distress symbols defined in the manual (*3*). Once the distress is drawn, it is labeled and numbered using the relative symbols and corresponding severity levels (L, M, or H) if applicable. Any distresses that are not described in either manual should be photographed and videotaped. Their location and extent should be shown and labeled on the map. If bleeding, polished aggregate, or raveling/weathering occur in extended areas over an asphalt-concrete-surfaced pavement test section, the total extent is not mapped. For JCP sections and CRCPs, if map-cracking or scaling, polished aggregate, or popouts occur in large areas over the test section, the total extent must also not be mapped. Instead, the location, extent, and severity level (if applicable) of all these distresses must be noted in the space for comments at the bottom of each map. These distresses should be mapped only if they occur in localized areas. Lane-to-shoulder drop-off for both CRCP and JCP and lane-to-shoulder separation for CRCP are not mapped but are recorded in the corresponding sheets. The data sheets or forms included in the field manual (*3*) provide space for recording the state ID number, the SHRP ID (state code plus SHRP Section ID), the survey date, and the results of distress surveys on different sheets for each pavement type. Except where otherwise indicated, entries have to be made for all distress data elements. If a particular type of distress does not exist, a zero should be entered in the appropriate space. All data sheets and maps are to be completed in the field.

The PASCO multifunction survey vehicle (*7*) was selected for surveying the LTPP test sections. The photographs and other images of the pavement surface collected by this vehicle will be interpreted later in the office. This vehicle is used to speed the field data collection and provide a permanent visual record of the pavement condition. Cracking, patching, and other distresses are recorded using the ROADRECON-70. The vehicle travels at speeds between 3 and 53 mi/hr (5 and 85 km/hr). A continuous photographic record of the pavement surface is made using a 35-mm slit camera. The system synchronizes film feed speed and camera aperture with the speed of the vehicle to equalize image density and photographic reduction. Road widths of up to 16 ft (5 m) can be filmed. Photography is performed at night using on-board lights set at an angle to the road surface so that shadows are produced at cracks and other defects in the surface, making interpretation easier. Interpretations of the distresses are made by a technician viewing the developed 35-mm film enlarged 10 times on the ROADRECON Film Digitizer. A grid pattern is overlaid on the film to aid in qualification of the distress for input into a computer data base.

Rut depth surveys can be carried out at speeds up to 50 mi/hr (80 km/hr) using the ROADRECON-75 system (*7*). A pulse camera mounted on the vehicle photographs hairline optical bars projected onto the road. The camera shutter and hairline projector are synchronized according to the distance covered by the projection vehicle, so that the system is able to create a photographic record of rutting at variable distance intervals. The film is projected onto a digitizing table and traced with a computer "mouse," enabling the wave patterns to be processed into a transverse profile of the pavement surface.

SUMMARY

The simplified rating procedures presented in this paper should be used in defining whether the preoverlay condition of a test section can be classified as "good" or "bad." In the LTPP study this information was used in the GPS experimental factorials 6B and 7B for recruiting in-service test sections for inclusion in the SHRP data base.

The distress surveys conducted as part of this long-term study will be used to quantify the condition of a pavement annually by classifying the amount and extent of distress present. The information to be collected from such a survey has been described, along with the manual and automatic survey procedures. The primary objective of the distress identification and field surveys discussed is the provision of a uniform basis for collecting distress data, and it is expected that the definitions and procedures used in the SHRP-LTPP study will be adopted by highway agencies interested in developing condition surveys.

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