Pavement Management System for Concrete Roadways in Virginia: Phase I—Condition Ratings

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This paper traces the development of a proposed rating system reviewed by a subcommittee of the Virginia Department of Transportation for use in evaluating the service condition of Virginia's portland cement concrete pavements. The service condition is assessed in terms of distress roughness, that is, that portion of a pavement's poor ride characteristics directly attributable to the occurrence of certain key distress types. The key distresses identified for jointed concrete pavements are permanent patching, lane and shoulder separation, transverse-joint faulting, transverse-joint seal damage, and scaling, map cracking, or crazing. For continuously reinforced pavements, spacing of transverse cracks, lane and shoulder separation, and scaling, map cracking, or crazing were identified. Field surveys of the occurrence of these distresses provide the necessary data for estimating distress roughness through the use of prediction equations that have been established from the standard statistical analysis of pavement section distress data and roughness measurements. The use of distress roughness to reflect a pavement's service condition provides a common basis for comparison of pavement sections. This, in turn, enables managers to set priorities for pavement rehabilitation. These rating procedures and a comprehensive system for managing portland cement concrete pavements will be implemented in a subsequent project.

As new highway construction has slowed and the nation's existing roads continue to age, it has become increasingly obvious that all those years of emphasis on construction and deemphasis on maintenance has left engineers with a rather formidable task: to continue to provide acceptable levels of service to the traveling public through maintenance of an aging and deteriorating roadway system within the limits of increasing budgetary restraints. Early efforts to meet these needs soon showed that existing maintenance policies were inadequate in the wake of the overwhelming needs. A new approach was needed to help maintenance dollars do the most good. This new approach was pavement management.

The fundamentals of pavement management can be traced to the results obtained from the American Association of State Highway Officials' road tests published in the early 1960s (*1,2*). During these tests, subjective ratings of the condition of pavements were made by a panel of road users. These ratings were on a scale of 0 to 5 (very poor to very good). Later these ratings were transformed into a more objective index of serviceability based on the occurrence of certain distress types. The term "pavement management," however, did not come into use until the late 1960s and early 1970s.

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There are probably as many variations of the definition of pavement management as there are pavement management users, but, generally, pavement management is an ordered and objective approach to providing the most serviceable pavements possible to the traveling public at the lowest cost.

In Virginia formal pavement management efforts began in the mid-1970s. Maintenance and research personnel worked together to develop a flexible pavement condition rating system designed for use by field engineers to assist in determining when maintenance activities should be performed. This system was demonstrated and refined in 1979–1980 and applied to all the flexible pavements in the Interstate system in 1981 (*3*).

With the pavement condition rating system as its foundation, the Virginia Department of Transportation (VDOT) pavement management system (PMS) began its development. The potential benefits to VDOT for implementing such a system were (*4*)

- Improved performance forecasting and monitoring,
- Objective support for funding requests,
- Identifiable consequences of various funding levels,
- Improved administrative credibility,
- A basis of cost allocation to highway users, and
- Improved engineering input for policy decisions.

These benefits along with a legislative mandate led to full support from management to proceed with full development and implementation of a comprehensive PMS.

Concentrated efforts have carried Virgina's PMS considerably beyond simple pavement condition ratings. The pavement management data base is used in both priority programming and projecting long-range pavement maintenance needs. Funding allocations based on condition data have led to a significant redistribution of average pavement condition among the various VDOT districts (*3*).

Great strides have clearly been taken in the management of Virginia's flexible pavements; however, management of rigid pavements has been conspicuously missing. Manpower limitations forced the pavement management efforts to be directed where they could do the most good. VDOT has responsibility for 62,753 mi of roads, the majority of which (53,653 mi) is contained in three systems—Interstate, primary, and secondary. Virginia's PMS is currently applied to these three systems, and of that mileage, 41,646 mi is paved (i.e., hard surfaced). Portland cement concrete pavements (PCCP) make up only 463 mi (just over 1 percent) of the paved roads (*5*). Quite reasonably, then, Virginia's PMS has been developed around flexible pavements.

In addition to lack of manpower and the relatively small quantity of PCCP, the complex nature of the performance of these pavements makes them more difficult to analyze and model than flexible pavements. All of these hindrances cannot reduce the importance of PCCP to Virginia's highway system. This importance is clearly illustrated by the fact that 26 percent of Virginia's highest-volume roads, the Interstate system, is built of PCCP. The ability of these pavements to withstand today's high traffic loadings and high tire pressures along with their long design life emphasizes the need to manage them properly.

The benefits of pavement management certainly apply to rigid pavements as well as flexible pavements. The short-term benefit will be the assimilation into an organized data system of scattered, outdated information on Virginia's concrete pavements. In the long term, the development and integration of a PMS for concrete pavements with the comprehensive PMS currently in operation would draw the department toward completion of the system. So with all these factors in mind, VDOT endorsed pursuing the development and implementation of a PMS for concrete roadways. As a first step, this project was initiated in April 1984.

PURPOSE AND SCOPE

The purpose of this project was to develop a system for evaluating the service condition of Virginia's existing PCCP. This system includes procedures for collecting data on the pavement sections and subsequently deriving numerical ratings of the condition of the sections from the data obtained. The project is the first step in developing a functional PMS for concrete pavements. The system will be implemented and integrated with VDOT's comprehensive PMS in a subsequent project.

The rating system developed is applicable to all types of concrete pavement (jointed plain, jointed reinforced, and continuously reinforced) in the Interstate, primary, and secondary highway systems in Virginia. The development of the system centers on the PCCP in the Interstate system.

APPROACH

Background

A review of some literature on the PMS in other states shows that some type of pavement field evaluation is conducted on both flexible and rigid pavements in order to collect basic pavement condition data (*6–9*). This literature, along with Virgina's experience with flexible pavement management, clearly indicates that the first and most important step in the establishment of a PMS for concrete pavements is the development of a procedure that would enable managers to assess the present service condition of the existing pavements. Ideally, this evaluation would yield numerical ratings of the service condition that would be relatively easy to determine. These ratings should permit consistent comparisons of pavement sections so that priorities for rehabilitation can be established.

The determination of the service condition of a pavement centers on the user's perception of serviceability, that is, the comfort of smoothness of the ride. Unfortunately, this is an extremely subjective quantification process. The preference of Virginia engineers has been to derive serviceability from the pavement's engineering characteristics as exhibited by the manifestations of certain distresses and the way they relate to ride quality (*4,10*). Therefore, the approach selected for this project was to collect pavement condition data through field surveys and compare them with the pavement's ride characteristics in order to determine a numerical condition rating.

Researchers at the University of Illinois developed the Concrete Pavement Evaluation System (COPES) under the National Cooperative Highway Research Program's Project 1-19 (*11*). This system was designed for state and nationwide use in evaluating concrete pavement performance and is capable of efficiently collecting, processing, and evaluating large amounts of pavement data to improve design, materials, construction, and maintenance of concrete pavements. Although COPES is far more comprehensive than VDOT needs at this time, its field-tested procedures for assessing pavement distress certainly provide excellent guidelines for the development of similar procedures for Virginia's PCCP.

Condition Surveys

Because of the relative complexity of distress occurrences and their causes in portland cement as compared with bituminous concrete pavements, it was anticipated that, if the survey was to be effective, rigid pavement distress surveys would have to be considerably more detailed than the "windshield survey approach" often employed when flexible pavements are rated. More detailed surveys would cause difficulty during implementation because of the increased manpower requirements for such surveys. Therefore, the project sampling approach set forth in COPES, surveying sample sections instead of entire projects, was adopted in order to maintain detail without increasing manpower needs.

Uniform Sections

A pavement's characteristics and environment greatly affect the types and occurrences of distress; therefore, one of the first steps in establishing a sampling plan was to divide the PCCP mileage into uniform sections. COPES defines a uniform section as one having the following characteristics uniformly along its entire length:

- Structural design,
- Joint and reinforcement design,
- Truck traffic,
- Number of lanes,
- Subgrade conditions,
- Construction by the same contractor,
- Opened to traffic the same year,
- Pavement materials,
- General distress occurrence,
- Maintenance applied, and
- Same local government jurisdiction.

It was decided that the original construction project limits would effectively meet these criteria of uniformity. In some cases, however, a portion of a particular project may have been overlaid with bituminous concrete at some point in its life. The limits of these projects would have to be adjusted to matching surface type. The lengths of all projects in the Interstate system range from 0.3 to 10.68 mi.

Sampling Plan

A statistical sampling plan was employed to reduce actual survey time. Each uniform section was divided into smaller sample units. Then the survey was conducted on a certain number of the sample units and the results of the survey from these units were used as estimates to represent the condition of the entire uniform section.

How many sample units must be measured to obtain statistically representative results? According to COPES, analysis has shown that normally one sample unit must be surveyed for every 10 in the uniform section to obtain a reasonable degree of accuracy in the pavement survey. Therefore, a 10 percent sample should be sufficient, or a 0.1 = mi sample for each mile in each uniform section.

As far as selecting which sample units to measure, the simpler and much preferred of the two valid methods mentioned in COPES is simply to sample 0.1 mi at each mile marker or post within the limits of the uniform section, adjusting as necessary to avoid sampling bridges and approaches. This method was selected for use with the realization that changes would be necessary for rating the primary PCCP because there are no mile markers on the primary system.

Distress Types

The initial distress surveys that were conducted on the sample units closely followed the survey procedures outlined in COPES. The comprehensive nature of the procedures would best enable the raters to document all distresses that affect the assessment of the pavement's serviceability. This approach would be appropriate for the development of the system; however, for practical purposes the final rating procedures were expected to be reduced to documenting only those distresses determined to have a direct influence on pavement service condition.

Because COPES was designed with national application in mind, before the initial surveys were conducted, the COPES distress types were carefully reviewed and those less likely to be applicable to Virginia—such as durability cracking and studded-tire damage—were eliminated from the survey. The respective jointed concrete pavement (JCP) and the continuously reinforced concrete pavement (CRCP) distress types initially surveyed are as follows:

1. JCP distress types surveyed:
   - Permanent patching
   - Transverse joint faulting
   - Lane and shoulder separation
   - Transverse cracking
   - Longitudinal cracking
   - Transverse joint spalls
   - Longitudinal joint spalls
   - Shoulder condition
   - Transverse joint seal damage
   - Temporary patching
   - Pumping
   - Map cracking and scaling
   - Wheelpath wear
2. CRCP distress types surveyed:
   - Permanent patching
   - Lane and shoulder separation
   - Transverse cracking
   - Longitudinal cracking
   - Longitudinal joint spalls
   - Shoulder condition
   - Temporary patching
   - Pumping
   - Map cracking and scaling
   - Wheelpath wear

Note that jointed plain and jointed reinforced pavements were surveyed in the same way.

Shoulder condition, transverse-joint seal damage, temporary patching, pumping, and map cracking and scaling were all rated on separate occurrence or condition scales. The area of permanent patching was estimated, whereas transverse-joint faulting and lane and shoulder separation were measured. Finally, transverse cracking, longitudinal cracking, transverse-joint spalls and longitudinal-joint spalls were each quantified and then rated according to the severity of occurrence. For more detailed information on how these distresses were initially quantified and rated, see a previous report (*11*).

Data Collection

For the most part, condition surveys were conducted with a two-man team. Before they left the office, the team prepared slightly modified COPES condition survey data sheets. These sheets were partially filled in at the office from construction project information. The set of sheets for each project was composed of a background sheet and a set of rating sheets, including a section sketch and a distress rating and summary sheet for each sample section to be rated.

Upon arriving at the project, the survey team drove over the entire length of the project in each lane at the posted speed. At the end of each pass a consensus ride rating was determined using a rating of 5 to 4 as very good, 4 to 3 as good, 3 to 2 as fair, 2 to 1 as poor, and 1 to 0 as very poor. Also during the ride-rating passes, the driver verified the project limits or made necessary adjustments required by changes resulting from rehabilitation. The passenger noted when structures fell within the proposed sample sections, which required altering the sample section location.

Next, the team returned to the beginning of the project and drove to the first sample section and pulled the vehicle well onto the shoulder. The vehicle's flashers were turned on and a rotating caution light was placed on top of the car. The team left the vehicle and walked the entire 0.1-mi sample length of the section. One team member measured the area of permanent patching and transverse-joint faulting and counted and rated all transverse-joint spalls. The other team member sketched the occurrence of longitudinal and transverse cracks, permanent and temporary patches, longitudinal-joint faulting, and any other notable section specifics. In addition, this person measured lane and shoulder separation, counted and rated longitudinal-joint spalls, and rated transverse-joint seal damage and pumping. A consensus on shoulder condition, map cracking and scaling, and wheelpath wear was arrived at after the team returned to the vehicle.

When projects in areas with particularly high traffic volume were rated, it was preferable to conduct the surveys with a three-man team, for safety reasons. The third member of the team became the driver, and his ride rating is included in the team's consensus. While the actual survey was being conducted, the driver remained in the car and followed the raters along the shoulder at a distance of 100 to 150 ft. The vehicle then effectively became a barrier between the raters and the traffic.

The majority of the surveys on the approximately 262 mi of Interstate PCCP were conducted from April 1984 through July 1985. The amount of time it took to survey each sample section varied from 15 to 45 min. The time depended on the pavement design (20-ft jointed, 61.5-ft jointed, continuously reinforced, etc.), the condition of the pavement, the traffic volume, the size of the crew, and the experience of the crew.

Finally, Mays meter roughness data were collected for the traffic lane of each project during the summer of 1985. Although most of the distresses were surveyed for the two outermost lanes, time constraints prohibited measuring roughness in more than just the traffic lane. For purposes of the statistical analysis, collecting data on roughness for only the traffic lane was not seen as a drawback because by far the greatest concentration and highest severity of distress was found to occur in that lane.

SURVEY RESULTS

Data Reduction

Once all of the pavement projects had been surveyed and roughness had been measured, the distress data from the sample sections were converted to project averages. Quantified sample section distresses became project average quantities per mile, and rated distresses became average project ratings. For example, for a 3-mi project the three sample sections yielded values of 100, 200, and 300 ft per mi of low-severity transverse cracking. The sample sections also showed that the transverse-joint seal damage was rated low (2), medium (2), and high (3). The average project values for low-severity transverse cracking and transverse-joint seal damage would be 200 ft per mi and 2.3, respectively.

Finally, descriptive, roughness, and distress data for each project were used to construct a condition data base. All this information was entered on floppy disks in spreadsheet format. This format permitted easy data manipulation, updating, and analysis.

Data Analysis

The objective of analyzing the data was to determine the influence of occurrence or severity, or both, of each distress type on the pavement's condition. A pavement's condition or serviceability can be assessed in terms of its ride quality, which essentially constitutes the users' perception of its serviceability. Therefore, by establishing relationships between distress types and ride quality, a pavement's serviceability may be established from the measurement and rating of its distresses.

Although the rating team's assessment of each project's ride quality was available, the much more objective roughness values obtained using the Mays meter were selected to be used as the dependent variable during this critical stage of establishing the basic relationships between distress types and ride quality. The rating teams' values actually represented the public's "seat-o-meter" perception; however, because the team's rating was found to be highly correlated ($R^2 \approx 0.92$) to the actual roughness measurements, little accuracy would be lost with the use of either.

Standard statistical techniques were employed to analyze the data. Because of the inherent differences in the design, performance, and distress between JCP and CRCP, each type of pavement was examined separately. Early analysis showed no need for continued examination of some of the distress data. Some of the distress types (especially the medium- and high-severity classifications) occurred with such infrequency that no meaningful relationships could be established. Likewise, some distresses, such as wheelpath wear and temporary patching, occurred with such little variability (i.e., they occur in practically all sections) that they also needed no further consideration. Although shoulder condition was always rated and showed plenty of variability, because it had no direct bearing on the roughness of the traffic lane, it was also eliminated from further analysis. For the same reason, all distresses surveyed on the inner lane were also eliminated. The distress types with enough variability or number of occurrences, or both, for analysis are as follows:

1. JCP:
   - Permanent patching
   - Transverse joint faulting
   - Lane and shoulder separation
   - Transverse cracking (low)
   - Transverse joint spalls (low)
   - Scaling, map cracking, or crazing
   - Transverse joint seal damage
   - Pumping
2. CRCP:
   - Permanent patching
   - Lane and shoulder separation
   - Transverse cracking (low)
   - Scaling, map cracking, or crazing
   - Pumping

Although the more severe occurrences of some distresses should not be considered separate variables in the remainder of the analyses, it was decided that the quantities of these occurrences should not be omitted. Therefore, the quantities for such distresses would be the sum of the quantities at each distress level. For example, transverse cracking equals low transverse cracking plus medium transverse cracking plus high transverse cracking. The author attempted to weigh the quantities of medium and severe occurrences relative to the low occurrences in an effort to better reflect the effect of these occurrences, but found that no statistically significant improvement in the relationship was gained. Thus, the quantities used represent the sums.

The results obtained from the analysis of the project-average data were excellent and yielded some strong statistical relationships. However, in light of the objective of the analysis, some questions were raised as to the appropriateness of using project-average data. The survey results often showed that the occurrence and severity of distress types varied considerably among sample sections within a given project. The effect of the same section exhibiting a great deal of distress could be greatly lessened when averaged with other project sections. Likewise, the effect of these distresses on project ride quality would be reduced. For that matter, the measured roughness of the distressed section would also be reduced when averaged with the other sections in order to determine a project roughness: how can the relationship between distress occurrence and roughness be determined when the direct association between a sample section and its corresponding roughness can be lost when averaged with other sections exhibiting variable levels of distress and roughness?

It seemed that the initial analyses might not have established the most direct relationship between specific distress occurrence and roughness as originally intended. So it was decided that the analyses would be rerun on a section-by-section basis within a given project in order to eliminate the effects of averaging.

Extensive data base changes were required. First, the Mays meter data were recalculated from mile market to mile marker within the limits of each project. Next, the project-average distress data were expanded to data for each sample section for each project and extrapolated to 1 mi (mile marker to mile marker).

Analyses performed on the revised data base yielded very similar results statistically, but the distress types with the strongest relationship to roughness did change somewhat. Because the more accurate determination of the relationships should have been obtained from the revised data base, the distresses selected from these analyses were chosen for use in the condition equations. These statistically significant distresses are as follows:

1. JCP:
   - Permanent patching
   - Lane and shoulder separation
   - Transverse joint faulting
   - Transverse joint seal damage
   - Scaling, map cracking, or crazing
2. CRCP:
   - Transverse cracking
   - Lane and shoulder separation
   - Scaling, map cracking, or crazing

It is something of a misnomer to refer to permanent patching as a distress itself, because patching is simply recorded as the square feet of patching found in the section. The strength of the correlation between patching and roughness, however, clearly indicates that patching increases roughness. This leads to the conclusion that the condition of most patches is less than satisfactory. Similarly, the transverse cracking in CRCP (which is all of low severity) can hardly be considered a distress, because such cracks are there by design. On the other hand, the closer the crack spacing (i.e., the greater the amount of transverse cracking), the more likely localized distresses like edge punchouts and irregular cracking are to occur. These distresses can have a significant influence on roughness. Also, although lane and shoulder separation and joint seal damage do constitute distresses, they do not directly affect roughness. Nevertheless, the well-documented effects of the damage that can result when water is permitted to enter the pavement support system show that these types of distress most certainly affect roughness indirectly.

After the significant distresses were identified, a method of using them to calculate a value that would represent pavement condition and permit comparisons of the relative condition of pavement sections needed to be devised. For flexible pavements a condition index referred to as the distress maintenance rating (DMR) is used. The DMR uses a base score of 100, from which deductions are made based on the occurrence and severity of certain key distress types. Frequency of occurrence is determined by the percentage of the section affected. The ratings are "none," "rare," "occasional," and "frequent." Guidelines given for each distress classify each as "not severe," "severe," or "very severe." The ratings given to each distress are up to the judgment of each rating team. Once rated, each distress is assigned a rating factor from 0 to 9 as shown in Table 1. These factors are then multiplied by the relative weight of each distress (relative to its influence on pavement condition) in order to determine how many points to deduct. This procedure is fully explained by McGhee (*12*).

Unfortunately, this approach is not directly applicable to the distress data collected for PCCP. The quantification process varies with each distress and only one severity level is recorded (Table 2). Thus another approach must be employed.

Using the coefficients determined for each distress type from the multiple linear regressions performed on the data, roughness prediction equations can be derived. The equations for JCP (Equation 1) and for CRCP (Equation 2) are as follows:

$$\text{Distress roughness} = (0.002 \times \text{patching}) + (60.56 \times \text{lane-shoulder separation}) + (95.23 \times \text{joint faulting}) + (29.76 \times \text{joint seal damage}) + (66.41 \times \text{scaling}) \quad R^2 = 0.93 \tag{1}$$

$$\text{Distress roughness} = (46.96 \times \text{lane-shoulder separation}) + (0.039 \times \text{transverse cracking}) + (21.28 \times \text{scaling}) \quad R^2 = 0.87 \tag{2}$$

The excellent correlation coefficients (R^2) for both equations clearly indicate the ability of the distress measurements and ratings to predict distress roughness. It must be kept in mind, however, that this predicted roughness is actually only the portion of the pavement's roughness that is a direct result of distress manifestation. Poor workmanship, depressions and swells, and so forth are obviously not taken into account. This point was readily illustrated when the predicted roughnesses were compared with the Mays meter roughnesses. The two pavement sections with the lowest distress roughness had two of the highest Mays meter values. Futher investigation quickly revealed that poor workmanship was involved. There was very little distress present; in fact, the pavement was less than 5 years old.

Because the objective of the ratings is to determine the relative need for major rehabilitation among pavement sections, the fact that distress roughness is used is certainly acceptable because major rehabilitation should be needed only as a result of pavement distress. In the example cited, the rehabilitation required would simply be pavement grinding. Although these two sections would not be identified by the prediction equation as being in need of attention, the displeasure with the ride quality invariably expressed by the traveling public would quickly bring the need to the attention of the engineer. Also, it should be noted that projects like these two are the exception and not the rule.

It appears that data obtained from pavement condition surveys for the distresses in Table 2 can be used with the distress roughness prediction equations derived earlier to establish values that will permit managers to make consistent comparisons of pavement sections so that priorities for rehabilitation can be established. The priorities would be established by giving sections with the highest distress roughness the highest priority.

At this point no threshold values for distress roughness (i.e., values beyond which rehabilitation is considered a necessity) have been ascertained nor have attempts been made to convert distress roughness values to a 100-point scale in order to permit direct comparison with flexible pavement sections in terms of DMRs. It is anticipated that both of these issues will be addressed when the system is implemented.

Subcommittee Review

In order to make a final review of the proposed rating procedures developed herein, a subcommittee of engineers experienced with Virginia's concrete pavements was formed. This subcommittee's task was to review the findings of this study and make suggestions for improvements. The members were encouraged by the fact that there would finally be a rating system for concrete pavements. After reviewing the significant distress types, they recommended including some additional distresses in the survey. Although this additional information would not significantly improve the prediction of distress roughness, the engineers would know more about the pavement deterioration and would be better able to determine the appropriate rehabilitation alternatives. For JCP they believed that pumping and transverse-joint spalling should be included, and in addition to measuring the area of permanent patching, the condition of the patch should be rated based on the amount of cracking, spalling, and faulting present. For CRCP the subcommittee added pumping, irregular cracking, and localized distress (e.g., spalling, potholes, and punchouts). As for transverse cracking, they believed that low-severity cracks should not be counted and only medium to severe cracks should be included.

Virginia's CRCPs are young relative to the JCPs and are generally found in areas with lower traffic volume; therefore,

TABLE 1 RATING FACTORS FOR FLEXIBLE PAVEMENTS

Frequency of Distress	Not Severe (NS)	Severe (S)	Very Severe (VS)
None (N)	0	0	0
Rare (R) less than 10%	1	2	3
Occasional (O) 10% - 40%	2	4	6
Frequent (F) over 40%	3	6	9

TABLE 2 DISTRESS MEASUREMENTS AND RATINGS FOR PCCP

Distress	Measurement/Rating
Permanent Patching	Square Feet
Lane/Shoulder Separation	Inches
Transverse Joint Faulting	Inches
Transverse Joint Seal Damage	1-3 (Low-High)
Scaling, etc.	0-3 (Low-High)
Transverse Cracking	Linear Feet

they do not really exhibit much distress. None of the surveys conducted on the CRCP showed a single linear foot of medium or severe transverse cracking. Therefore, if low-severity cracking were eliminated, essentially all cracking would be eliminated. Removing cracking from the prediction equation would have rather undesirable effects on the prediction results, which are questionable to begin with because of the infrequency of distress ocurrence found on these pavements; consequently, low-severity transverse cracking will remain in the rating procedures.

Finally, it was agreed that only the traffic lane needs to be rated because the highest occurrence and severity of distress tend to be found there. All details of the proposed condition survey procedure and rating sheets, including the subcommittee's recommendations, are available from the author.

Other issues were discussed by the subcommittee. The establishment of an ongoing roughness testing program was given some priority in an attempt to identify projects that do not show much distress roughness before the traveling public brings these projects to the engineers' attention. It was also mentioned that thresholds for each distress type should be set that would by themselves trigger the need for some type of immediate rehabilitation. These and other issues will be addressed under the implementation of these procedures.

CONCLUSIONS

The findings presented in this paper appear to support the following conclusions:

1. A workable procedure for conducting condition surveys has been established.
2. Equations have been developed for the prediction of a value referred to as "distress roughness" for both jointed and continuously reinforced PCC pavement sections from the data collected from the condition surveys.
3. Distress roughness ratings provide a common means by which different pavement sections of the same type may be compared and given a priority.
4. Because of the relatively good condition of the CRCP surveyed, the accuracy of the developed equation for assessing roughness directly caused by distress is somewhat less than that of the equation developed for JCP. However, both equations are acceptable for use in establishing serviceability ratings.

RECOMMENDATIONS

In light of the completion of the development phase of this system and the shift to implementation, the following recommendations are offered.

1. The implementation of this rating system should be actively pursued, and to that end the subcommittee of engineers established to assist with the development of the system should remain active to assist in its implementation.
2. The PCCP in the primary system should be incorporated into the system as soon as possible.
3. Efforts should be undertaken to establish threshold distress roughness values.
4. A training program and manual should be created in order to turn the rating system over to the field personnel.
5. The ratings should be monitored in much the same way as flexible ratings are monitored.
6. The system needs to be interfaced with the flexible system so that direct comparisons between surface types can be made.
7. Because of the unequal distribution of PCCP throughout the state, implementation of this system must address the resulting disparity in manpower needs among the districts.

ACKNOWLEDGMENTS

The author gratefully acknowledges the assistance received from many people on this project. This research was conducted under the general guidance of Howard H. Newlon, Jr., Director of Research, and was funded by the Federal Highway Administration.

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Publication of this paper sponsored by Committee on Pavement Management Systems.