# DEVELOPMENT OF PAVEMENT CONDITION INDICES FOR THE VIRGINIA DEPARTMENT OF TRANSPORTATION

# PHASE II

# RIGID PAVEMENTS


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# ABSTRACT

This report documents work done by the Virginia Department of Transportation (VDOT) over the past 5 years to develop pavement condition indices compatible with Virginia conditions. The work began with attempting to choose indices that would be similar in "look and feel" to a Virginia index used to quantify flexible pavement windshield data since the early 1980s and called a Distress Maintenance Rating (DMR)[(1)]. The DMR was used principally in the establishment of needs lists on a "worst first basis". In turn, that list was used in the development of resurfacing schedules. Expanding the approach to rigid pavements was a major effort in view of the entirely different set of pavement distresses and causative mechanisms.

The purpose of the study was to develop pavement condition indices suited to the management of Virginia rigid pavements. Included were indices to describe pavement surface and/or structural distresses as well as joint faulting. Pavement types to be included in index development were jointed concrete pavements (JPCP) and continuously reinforced concrete pavements (CRCP).

A guiding principle of the index development effort was to arrive at indices that would be acceptable to VDOT users of the pavement management system. This meant the indices needed to describe critical pavement condition features in such a way that field personnel would understand what those indices tell them about the condition of their pavements. Further, those personnel need to be comfortable with the use of those indices in planning pavement maintenance and rehabilitation activities on a project basis. At the same time, central office pavement management personnel needed to be able to use the indices to describe network as well as project pavement conditions and to use those indices in optimization and other studies directed at the best use of available funds. Because of the need to consider maintenance and rehabilitation options separately for jointed and CRC pavements the decision was made early that several indices would be required. The indices developed were the slab distress rating (SDR) and the joint faulting index (JFI) for jointed pavements and the concrete distress rating (CDR) and the concrete punchout rating (CPR) for CRC pavements.

The general approach to index development was to borrow from existing work to the extent practical and to modifying existing approaches to gain the look, feel, and acceptability mentioned above. In addition to the previous DMR work in Virginia, a major resource was the PAVER work done by the Corps of Engineers[(2)]. A first cut at index development was to use the PAVER curves of deduct values relating to each level of each distress where applicable. Then, to the extent possible, shape the indices to achieve the "look and feel" of the indices used to management flexible pavements in the state. The efforts to achieve that goal led to numerous modifications to the PAVER deduct values and curves.

After the completion of first stage development efforts equations of best fit were derived for the modified values. These equations serve to feed VDOT pavement management software for rigid pavements. Trial runs of the various indices, use of the deduct equations in VDOT pavement management software, and sensitivity analysis of the indices have been undertaken to ensure that deduct values and the resulting indices meet the test of reasonableness. The completion of these trials awaits the availability of Portland cement concrete (PCC) pavement images to be collected in late 2002. Those images will be processed and the PCC indices applied as appropriate. Final adjustments to deduct curves and equations will follow the completion of the trials.

# INTRODUCTION

## HISTORICAL OVERVIEW OF PAVEMENT MANAGEMENT IN VIRGINIA

Formal pavement management in the Virginia Department of Transportation began in the late 1970s as documented in the first research report spelling out the need for a pavement management system[(3)]. Clearly, pavements had been managed before formal pavement management came into common use. That earlier management however had been largely informal and budget rather than needs driven.

As a part of the earlier pavement management process, a hot mixed asphalt concrete (HMAC) pavement windshield pavement condition rating procedure had been developed and used for the allocation of funds among the districts and down to the county level. The rating procedure also was used for priority programming of the primary and interstate resurfacing schedules. The process, however, did not address long range project or network needs and had no optimization module. A basic element of the rating procedure was a condition index called the distress maintenance rating (DMR)[(1)]. The DMR was a deduct based index where a perfect pavement was assigned a value of 100. The DMR included only various pavement surface distresses as parameters. The major distresses considered were cracking, raveling, pushing, rutting, flushing, and patching with cracking and patching given the most severe deduct weights. Pavement surface distresses were evaluated on the basis of both frequency of occurrence and the severity of the distress to arrive at the deduct points for a given distress.

The fact that none of the earlier work was directed at the evaluation of PCC pavement led to the initiation of the work described in the present report.

## PAVEMENT MANAGEMENT DEVELOPMENTS IN THE 1990S

### <u>AUTOMATED DATA COLLECTION</u>

In the mid-1990s VDOT began to collect pavement distress data through the use of videotaped images. To make use of data collected from those tapes, VDOT also made interim use of the pavement condition index (PCI) defined and used by the U.S. Army Corps of Engineers[(2)]. After several trial years, the PCI was deemed too general for Virginia conditions so that a VDOT specific method was considered necessary.

For the first three years videotape distress data was collected there were no standards for distress data collection and reduction such that procedures tended to change each year. The result was that there was no stable basis for the development of pavement performance curves and for other long-range data uses.

To overcome some of the problems associated with the absence of standards, in 1997 pavement management staff undertook the development of a manual "A Guide to Evaluating Pavement Distress Through the Use of Video Images"[(4)]. The manual provided general distress evaluation rules as well as detailed procedures for the rating of asphalt concrete pavements, overlays of jointed PCC pavements, jointed PCC pavements and continuously reinforced concrete pavements (CRCP). Procedures spelled out in the manual were applied to data collected in 1998 and became a part of contract documents for the data collected in 1999. It is notable that the VDOT manual was developed in response to recognized fundamental differences in the evaluation of pavements through the use of imaging rather than through direct pavement observation by trained observers. Those fundamental differences relate to the fact that not all distresses are readily captured on or discerned from images and that it is very difficult to evaluate levels of distress severity from images. The VDOT distress evaluation manual is believed to be one of the first of it type to be developed.

### NEW PM SOFTWARE

Also in 1995 a contract was awarded to develop new pavement management software for the department. This personal computer based software is to replace old mainframe software in use for many years within the department.

The software has the capability of single year project prioritization, multi-year work planning, funding optimization studies, and feedback analysis. The software offers many new analysis capabilities and a departure from the single year and "worst first" approach to programming pavement maintenance and rehabilitation. During 1999 the software underwent user testing and VDOT personnel received preliminary training in its use.

Full use of that software clearly requires the development and implementation of meaningful and reliable measures of pavement condition and the availability of data collected in accordance with the applicable standards.

## PURPOSE AND SCOPE

The purpose of the study was to develop pavement condition indices suited to the management of rigid pavements in Virginia. Pavement types to be included in index development were both plain and reinforced jointed concrete pavements (JPCC) and continuously reinforced concrete pavements (CRCP). The present document addresses the development and use of only those rigid pavement distresses. Indices used to define the condition of hot mix asphalt concrete pavements (HMAC) flexible pavements are the subjects of an earlier report[(5)].

A guiding principle of the index development effort was to arrive at indices that would be acceptable to VDOT users of the pavement management system. This meant the indices needed to describe critical pavement condition features in such a way that field personnel would understand what those indices tell them about the condition of their pavements. Further, those personnel need to be comfortable with the use of those indices in planning pavement maintenance and rehabilitation activities on a project basis. At the same time, central office pavement management personnel needed to be able to use the indices to describe network as well as project pavement conditions and to use those indices in optimization and other studies directed at the best use of available funds.

# ADDITIONAL BACKGROUND

## PAVEMENT CONDITION INDEX OVERVIEW

Pavement condition indices typically provide aggregated measures of several related pavement features. Typical indices assign a rating of 100 to pavements having no discernable distress or other characteristics that detract from engineering or user perception of pavement condition or functionality. Deducts from the perfect score typically relate to the type and degree of a given feature and to how extensively it occurs. Because several features are combined in an index, a good measure of overall pavement condition may result although extreme values of some features may be masked.

Two major classes of pavement condition parameters are represented by indices. These are pavement surface distress parameters and parameters relating to pavement longitudinal or transverse profile. The first typically are visually evaluated, from direct observation or from pavement images, while a vehicle passing over the pavement measures the second. Such vehicles are instrumented to provide a known plane of reference and to measure deviations of the pavement surface from that plane. Measurements are typically through the use of high speed ultrasonic or laser based transducers, which send a signal from the plane of reference to the pavement surface and measure the rebound of that signal from the surface. The time required for the signal to travel to the pavement surface and back is directly related to the distance between the reference plane and the surface.

Highway agencies use both types of indices in the priority programming of pavement activities and in multi-year planning of those activities as well as in the analysis of funding optimization through the definition of network and project level pavement performance curves.

## NEED FOR VIRGINIA SPECIFIC INDICES

The early VDOT approach was but a first step toward "true" pavement management because the DMR considered only surface distress and was not related to the various distress causes or to the consequences of those distresses and their causes in making pavement management decisions. Further, it was used only to identify the worst distressed pavements and to program them for maintenance on a “worst first” basis.

Modern pavement management systems recognize that addressing the worst pavement first often is not the best use of available funds. It may at times be much more cost effective to repair a pavement in relatively good condition because that repair may prolong the "remaining life" of the pavement far beyond the life expected if the same pavement was permitted to continue to deteriorate.

Fortunately, proper design and use of several different indices of pavement condition permit the pavement manager to identify those pavements that could benefit from timely treatment. At the same time, those indices may indicate those pavements where deferred maintenance will not be overly detrimental or costly.

While Virginia no doubt suffers the same types of PCC pavement distresses as other agencies, the commitment to automated condition data collection and to PCC indices similar in "look and feel" to those used for flexible pavements lead to the development of PCC condition indices specific to Virginia.

## INTERNATIONAL ROUGHNESS INDEX

The standard measure of ride quality for VDOT is the International Roughness Index (IRI) also used by the Federal Highway Administration in the nationwide monitoring of the Highway Performance Monitoring System (HPMS) used in the distribution of Federal Highway Funds to the states(6). Roughness as defined by ASTM Designation E867 is "The deviation of a surface from a true planar surface with characteristic dimensions that affect vehicle dynamics and ride quality." While an important measure of pavement condition, the IRI is one of several condition indicators not within the scope of the present report.

## PAVEMENT CONDITION REPORTS

The flexible pavement condition indices described in reference (5) form the basis for two reports of interstate and primary pavement condition in Virginia. For the first, in 1998(7) indices were determined from pavement condition data captured on videotapes and manually reduced following the procedures given in reference (4)). The second report in 2002 (8) used windshield data structured and collected in a manner consistent with the requirements of reference (5). The Department found it necessary to resort to windshield surveys of flexible pavements in 2000-2002 due to the absence of automated data caused by contractual problems.

No formal report of PCC pavement condition has been issued due to delays in implementing condition indices for those pavements. However, the Richmond and Hampton Roads districts did manually collect data on their PCC pavements during 2001, as discussed later. Because of unforeseen inconsistencies in the data collection process those data did not meet the QA requirements imposed and, therefore, are considered to be unusable. That experience led to revisions in the process and to the conclusion that PCC pavement condition data should be collected by automated means (photos, digital images, etc.) and processed through image review in the office.

# INDEX DEVELOPMENT PROCEDURE

## IDENTIFICATION OF CRITICAL DISTRESSES

One of the first steps in developing new indices was to identify the pavement condition factors that enter into maintenance and rehabilitation decisions. With input from numerous VDOT personnel with experience in building and maintaining PCC pavements it was concluded that there are four major classes of distress leading to most maintenance and rehabilitation decisions. These are (1) cracking and other surface distress of all PCC pavements, (2) faulting of jointed pavements, (3) “punchouts” of CRCP pavements, and (4) the roughness (or smoothness) of the pavement surface. Unlike the case with flexible pavements, PCC pavement distresses were not readily grouped as load related and non-load related. Therefore, there was no effort to devise indices relating to load related and non-load related distresses.

The PCC pavement distresses deemed critical by Department personnel for both jointed and CRC pavements are given in Table 1. These distresses are described in detail in Appendix A while the rating procedures used are given in *A Guide To Evaluating Pavement Distress Through the Use of Video Images*[(4)]. The details of data collection in terms of what data will be collected and how it is to be collected are given in that document. Therefore, the details of inputs to VDOT specific indices also are fixed by that document and can be noted in the data delivery format given in Appendix C.

**Table 1**
**Summary of Portland Cement Concrete Pavement Distresses**

| Jointed Pavements | CRC Pavements |
|---|---|
| Corner Breaks | Transverse Cracking |
| Linear Cracking | Longitudinal Cracking |
| Divided Slabs | Punchouts and Spalled "Y" Cracks |
| Joint Spalling | Clustered Cracking |
| Joint Seal Condition | Longitudinal Joint Spalling/Seal Condition |
| Blowups | PCC Patching |
| PCC Patching | Asphalt Patching |
| Asphalt Patching | - |

## INDEX DEFINITIONS

## JOINTED PCC PAVEMENTS

There are two indices used to describe jointed pavements. These are (1) the slab distress rating (SDR), and (2) the slab faulting index (SFI). The two indices are intended to characterize the major conditions, other than roughness, that cause maintenance or rehabilitation decisions on jointed PCC pavements. Thus, the SDR addresses distresses visible on the surface of the slab, especially from pavement images. The SFI is a function of a measured value (not visible from pavement images) representing differential elevations between the two sides of a joint. In the absence of SFI values Virginia has often used the IRI as a proxy since faulting is a prima facie contributor to pavement roughnessand greater faulting results in a higher IRI.

The slab distress rating (SDR) components are:

Corner Breaks
Transverse Joint Spalls
Longitudinal Joint Spalls
Transverse Cracking
Longitudinal Cracking
Divided Slabs
PCC Patches
AC Patches

It should be noted that blowups as given in Table 1 are not listed as SDR components as they were deemed so severe as to require immediate repair to maintain traffic. Further, joint seal condition is not defined as a deductible distress and is not included for that reason.

As described later, distress density is typically expressed as a percentage of slabs affected similar to the PAVER approach.[2]

## CRC PAVEMENTS

In the case of CRCP the data are collected continuously (i.e., no slabs or pseudo-slabs as described later for jointed pavements) as with AC pavements. Unless otherwise noted, the extents of distress are based on area and expressed in terms of the percentage of the pavement section. There are two indices; (1) the concrete punchout rating (CPR), and (2) the concrete distress rating (CDR). The components are:

CPR – punchouts
cluster cracking
asphalt concrete patching

CDR – transverse cracking
longitudinal cracking
PCC patching
longitudinal joint spalling

## DEVELOPMENT OF DEDUCT VALUES

## JOINTED PAVEMENTS

### Corner Breaking Used as an Example

Others have shown that the degree to which a given pavement distress is detrimental to pavement performance is a function of both the extent and the severity of that distress [(1)(2)]. Distress deduct values are related to that detrimental effect and typically are non-linear, i.e., there is not a one-to-one correspondence between distress frequency and severity and the deduct values assigned for the distress. An example is given in Figure 1 where a variation of the PAVER deduct curves for corner breaking of jointed pavement slabs is displayed [(2)].

Values on the horizontal axis are distress density in terms of the percentage of pavement slabs affected while the vertical axis is the corresponding deduct values. The percentage of slabs affected is characteristic of the PAVER approach to PCC pavement evaluation. In PAVER, pavement projects with slabs less than 25 ft. long are evaluated on the basis of about 20 slabs per sample section. Pavements with slab lengths exceeding 25 ft. are divided into imaginary or pseudo slabs of less than 25 ft and each sample section is evaluated on the basis of about 20 of these pseudo slabs. VDOT has chosen to use the percentage of slabs affected approach, but does not divide pavements into pseudo slabs. The major reason for not using the pseudo slab approach is the perceived difficulty in applying that approach to pavements where distresses are captured on videotapes or through digital imaging, the desired VDOT methodology. As will be seen later, some adjustments to the PAVER deduct values are necessitated by the fact that there are numerous Virginia pavements with slab lengths greater than 25 ft.

Figure 1 will be used as an example of how the shapes of PAVER curves were used as the basis for VDOT deduct curves for corner breaking. Deduct curves for other jointed PCC pavement distresses were developed in a similar manner as given in Appendix B.

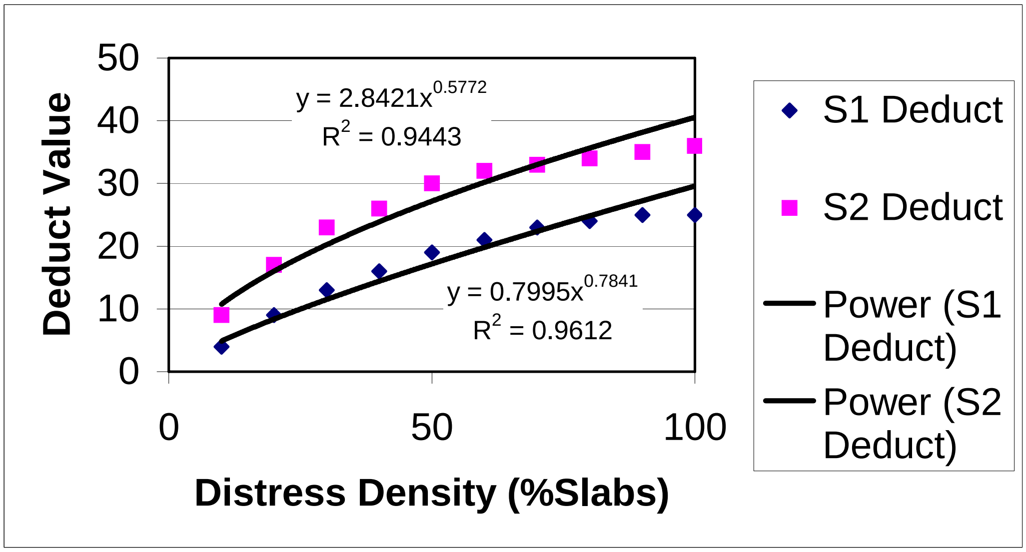



Figure 1- VDOT Deduct Curves for PCC Corner Breaks

To develop the VDOT curves, the shapes of the PAVER corner break curves were used to address two levels of severity. While PAVER addresses three levels, the thinking was that it would be very difficult to discern more than two levels from pavement images. Therefore, the PAVER curve was used directly for a lower level severity (L) while the higher level (H) was defined as an average of the medium and high PAVER deducts (PAVER values in Table 2).

Early evaluation of the PAVER values indicated they were much more drastic than deemed appropriate for Virginia conditions. Sensitivity analysis showed that the difficulty arose due to the earlier decision to use actual rather than imaginary slab lengths in the Virginia procedure. Because of that, a relatively small number of distressed slabs can result in a large percentage distressed which, in turn, leads to a large deduct value. Because typical Virginia slab lengths often approximate twice the recommended PAVER pseudo slab length of 25 ft. adjusted deducts equal to ½ the PAVER values are given as VDOT deducts in Table 2.

The rationale for the above process was that the shape of PAVER curves would be a reasonable approximation of the shape of a corner break curve on a scale other than the pavement condition index (PCI) used in PAVER. On the other hand, the deduct values were derived through consideration of the flexible pavement deducts VDOT personnel had become accustomed to using. In this case, the rationale was that VDOT personnel would more readily accept and use indices seeming similar to the values they had been using.

| Distress | PAVER Deduct Values | | VDOT Deduct Values | |
|---|---|---|---|---|
| Density | Severity | | Severity | |
| % Slabs | L | H | L | H |
| 0 | 0 | 0 | 0 | 0 |
| 10 | 8 | 18 | 4 | 9 |
| 20 | 17 | 33 | 9 | 17 |
| 30 | 25 | 45 | 13 | 23 |
| 40 | 32 | 53 | 16 | 27 |
| 50 | 38 | 59 | 19 | 30 |
| 60 | 42 | 64 | 21 | 32 |
| 70 | 45 | 68 | 23 | 34 |
| 80 | 48 | 69 | 24 | 35 |
| 90 | 49 | 70 | 25 | 35 |
| 100 | 50 | 71 | 25 | 35 |

**Table2 - VDOT First Generation Deduct Values for Corner Breaking**

Regression equations of "best fit", shown in Figure 1, provided a VDOT deduct equation for corner breaking. The equation as used in the VDOT pavement management software is a combination of the two "best fit" equations from Figure 1:

*Corner Breaks:* Deduct = 0.8*(SEV1_%Slabs)^0.8 + 2.8 *(SEV2_%Slabs)^0.6

As a generalization for this report it is important to note that "best fit" equations may at times seem a misnomer as there are occasions where something other than a power curve might fit slightly better. However, the power type curve was chosen because of the ease of use in the VDOT pavement management software and because it provided a very close fit to most curves finally chosen to characterize distress deducts. Further, it seemed best not to be switching curve types from one distress to another as might happen with the very "best" fit.

Jointed Pavement Distresses Other Than Corner Breaks

All other jointed pavement distresses were addressed in much the same way as corner breaks although some deduct values have had to be adjusted after field trials to be discussed later. Each of these distresses is discussed briefly below.

*Transverse and Longitudinal Joint Spalls*

Again, the procedures for data collection are documented in the VDOT manual(4) and distress density is defined in terms of the percentage of slabs distressed. Early experience had shown that it is difficult to discern the severity level of joint spalling from pavement images. Therefore, it was decided that only one level would be used and that it would be based on the average of the medium (M) and high (H) levels of PAVER deducts. Those initial deducts were later modified to reflect the long slabs prevalent in Virginia by using one-half the combined M and H PAVER deducts. The deduct curve is given in Figure 2.

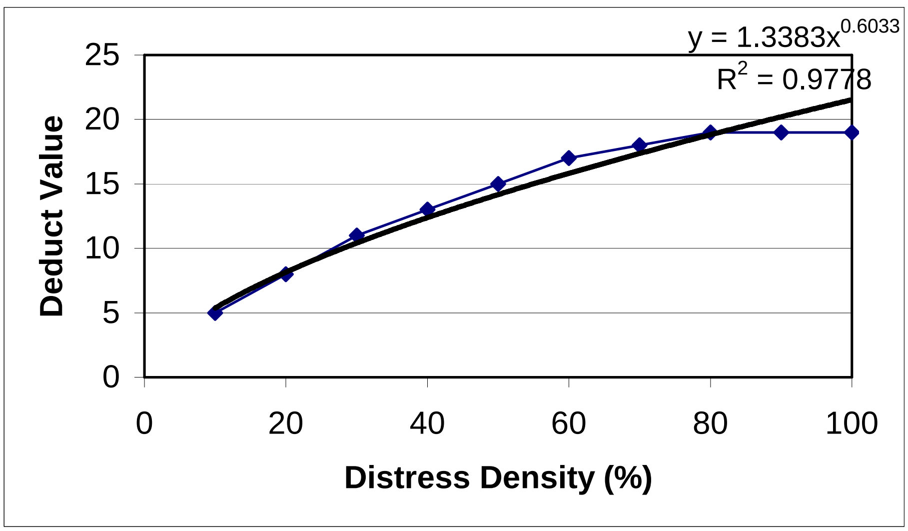



**Figure 2 – VDOT Deduct Curves for Joint Spalling**

The best fit power equation transformed to VDOT terminology is:

*Joint Spalling: Deduct* = 1.3*(%Slabs_SJ.)^0.6

*Transverse and Longitudinal Cracking*

Again, the procedures for data collection are documented in the VDOT manual(4) and distress density is defined in terms of the percentage of slabs distressed. Because of the difficulty in discerning very fine cracks from images, the VDOT procedure calls for only two levels of distress severity. In the case of longitudinal and transverse cracking the PAVER "linear cracking" deducts at the M and H levels were used. As discussed above, the PAVER deducts were adjusted to ½ their values to accommodate the long VDOT slabs. The deduct curves are given in Figure 3.

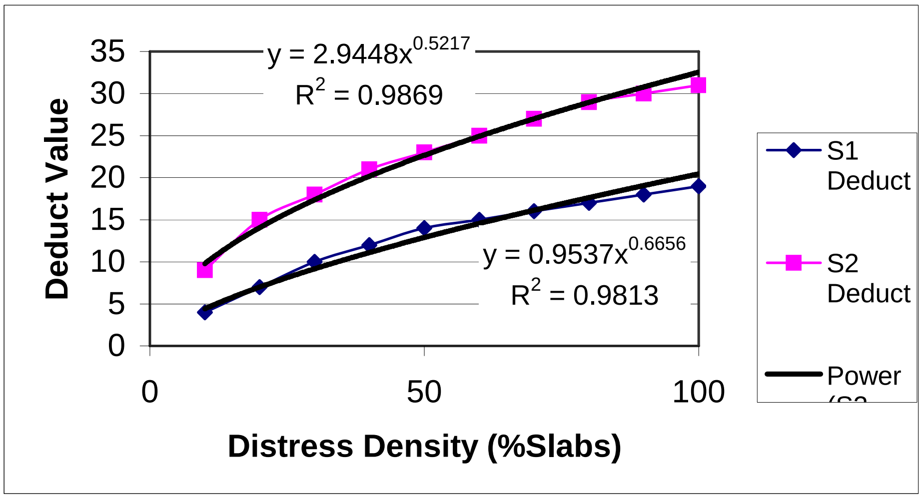



**Figure 3 – VDOT Longitudinal and Transverse Cracking Deduct Curves**

The best fit power equation transformed to VDOT terminology is:

*Slab Linear Cracking:* Deduct = 1*(SEV1_%Slabs)^0.7 + 2.9*(SEV2_%Slabs)^0.5

*Divided Slabs on Jointed Pavement*

Divided slabs were considered by VDOT staff to be sufficiently serious that the full PAVER deduct values were used rather than adjusting for slab length. Also, only one severity level is used so that the deduct curve given in Figure 4 is the power expression of the PAVER high severity level.

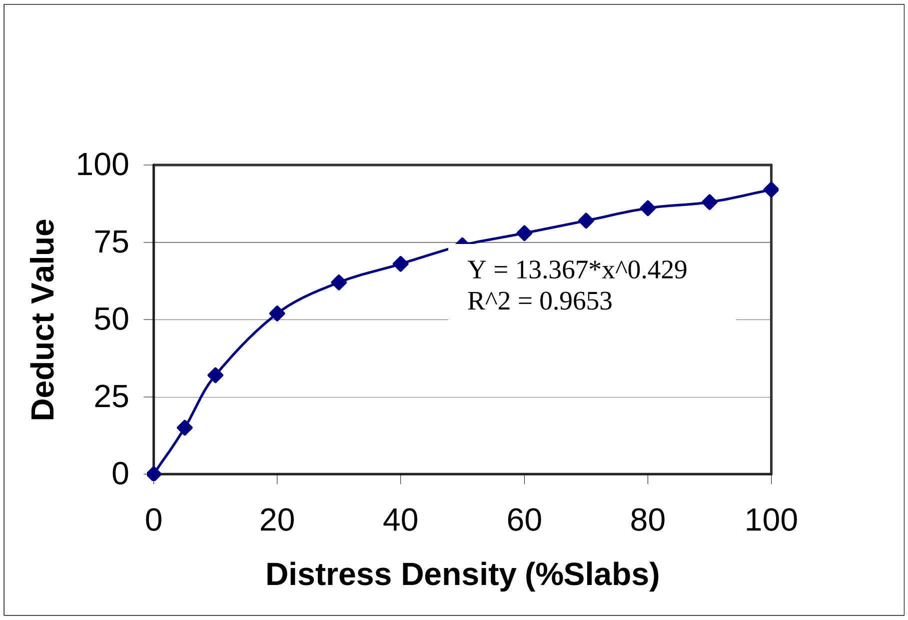



**Figure 4 – VDOT Divided Slab Deduct Curve**

The VDOT software equation is:

*Divided Slabs*: Deduct = 13.4*(%DIV_SLABS)^0.4

*PCC Patching on Jointed Pavement*

Similarly, for PCC patching of jointed pavements the PAVER deducts for low, medium, and high severity distress are used directly (no adjustment for long slabs). The corresponding deduct curves are given in Figure 5 with the software equation following.

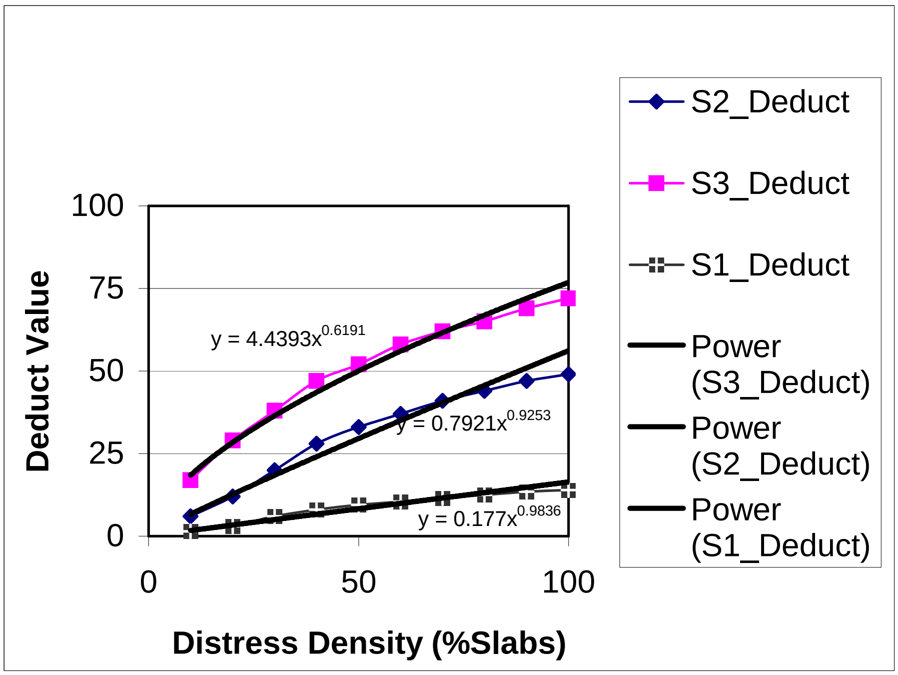



**Figure 5 – VDOT PCC Patching Deduct Curves**

*PCC Patches:* Deduct = 0.18*(SEV1_%Slabs)^0.98 + 0.79*(SEV2_%Slabs)^0.92 + 4.4*(SEV3_%Slabs)^0.62

*Asphalt Concrete (AC) Patching of Jointed Pavements*

Since PAVER does not differentiate between asphalt concrete and PCC patching of concrete pavement it was decided that the previous deduct curves would again be used directly. However, only the medium severity PAVER deducts were used and they were adjusted for long slabs by applying only ½ the PAVER deducts. Early experience with Virginia pavements showed those deducts to be insufficient so that other adjustments were made in mid-2002. Those adjustments amounted to the use of the most severe PAVER patching deduct and the decision was made to not adjust for long slabs. Thus, the AC patch deduct curve is identical to the high severity PCC patching curve. The deduct curve is given in Figure 6 with the equation following.

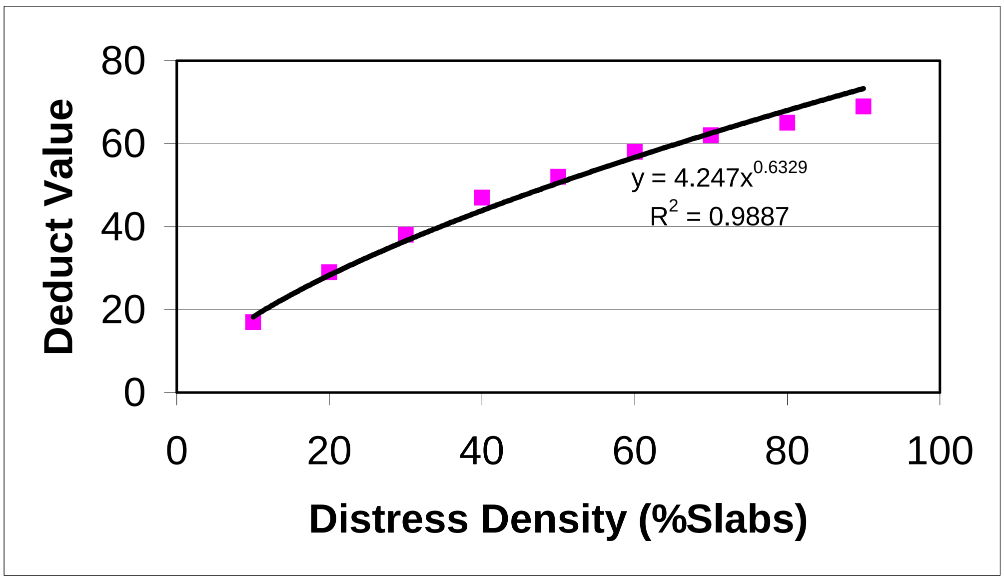



**Figure 6 – Asphalt Concrete Patching of Jointed Pavements**

*AC Patching:* Deduct = 4.3*(%SLABS)^0.63 (Revised 6/02)

*Reduction Factor for Multiple Distresses*

There is general agreement that pavement distresses are somewhat interconnected. In other words, the effect of one distress on pavement performance is not mutually exclusive of other distresses. Therefore, if multiple distresses are present and the individual deducts are algebraically summed, the combined effects may result in an unrealistically low index value. For that reason, it is necessary to reduce the combined deduct to a reasonable value whenever multiple distresses are present in the pavement. Deduct values are directly related to the amounts of various distresses present. The more the individual distresses, the higher will be individual deducts and the higher will be the combined effect of the distresses.

The need for a reduction factor for jointed concrete pavements is apparent from another perspective. For jointed concrete pavements distress density is expressed in terms of the percentage of slabs affected by the distresses rather than in terms of the actual quantities. Further, even a small amount of distress on a given slab causes that slab to be classed as distressed. VDOT collects and stores data based on 0.1-mile incremental sections. Slab lengths of jointed concrete pavement in Virginia vary from 15 to 61 feet. So, depending on the length of the slabs, the 0.1 mile long section may have as few as 9 slabs. In such a case, if, for example, only two slabs are affected with 3 different types of distresses (say, transverse cracking, joint spalling and corner breaking) the corresponding distress densities would be about 22% for each distress type. The percentage will be higher if more slabs are affected by more distresses and those cases will be very common for jointed pavement. The same effect for asphalt concrete and continuously reinforced concrete pavements (CRCP) is considered to be minimal because for both of those cases the actual quantities of the distresses are measured and used to compute pavement condition index. Thus, VDOT staff made the decision to apply the multiple distress correction for jointed concrete pavements only.

VDOT studied several options to seek an appropriate correction factor. The U.S Corps of Engineers (COE), while developing the pavement management system PAVER[(2)], addressed this issue by introducing a parameter called the maximum number of deducts. Correction curves for various maximum numbers of deducts were developed. According to the PAVER method, the individual deducts are algebraically summed to get an initial or uncorrected deduct. This value is corrected using the correction curves developed for various numbers of deduct elements. This corrected value is again used in the correction curve for the next lower deduct element to get another corrected value. This process is iterated until both values converge. However, such an iterative process was deemed too complicated and difficult to incorporate into the software already being implemented for VDOT's pavement management system. Therefore, VDOT searched for an alternative way to address this issue.

Like many other agencies, including the PAVER developers, VDOT recognizes shattered or divided slabs as the worst possible distress scenario on jointed concrete pavement and assigns the highest individual deduct to this distress. The underlying principle is, while most other distress conditions (or combination of distresses) can be addressed through rehabilitation, the only solution to shattered or divided slabs is complete slab replacement; the equivalent to new construction. Therefore, no combination of distresses on a single slab should result in a deduct greater than if the same slab is at a divided slab condition. However, directly aggregated single distress deduct values often exceed the divided slab scenario. In other words, the combined deduct exceeds the absolute worst-case scenario deduct, which is unrealistic. As an approach to correcting this excessive deduct condition VDOT engineers assume that the correct deduct should be the worst possible deduct, i.e., the deduct corresponding to the affected slabs being divided.

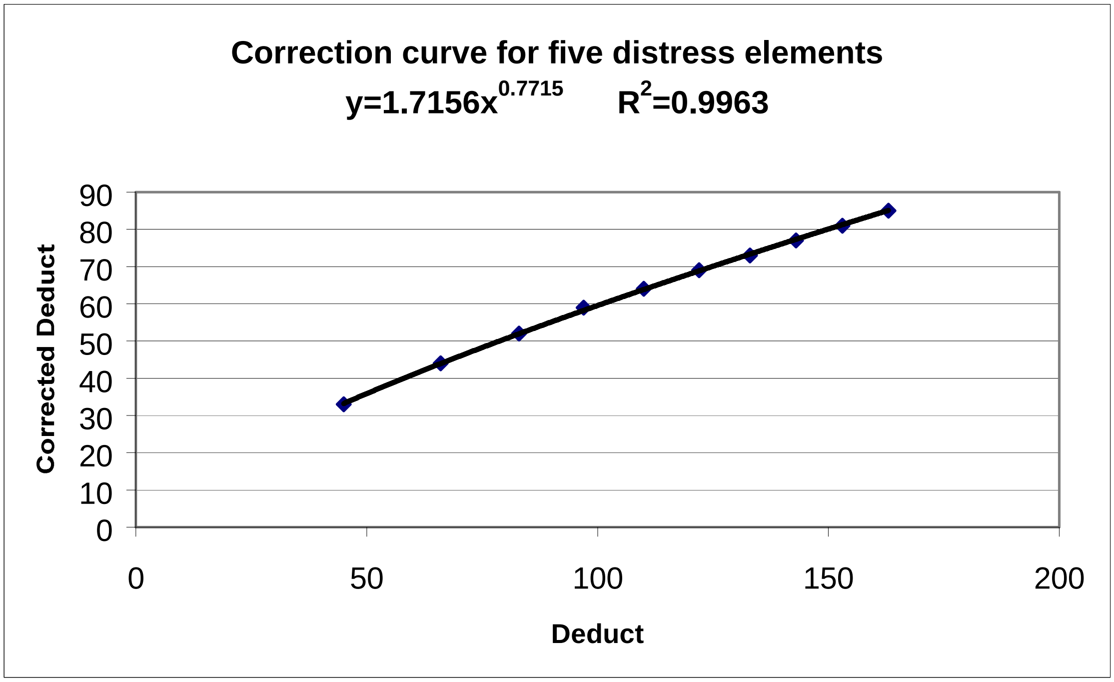
By changing the number of affected slabs and keeping the number of distresses unchanged, a tabulation of un-corrected and corrected deduct values can be obtained. These values can be used to generate the equation to correct the algebraically aggregated deduct for a given number of distress elements. However, because of the interaction of distresses a separate reduction formula is necessary for each different number of distress elements. The process of correction development is explained below for 5 distress elements.

A pavement section with 10 slabs is considered for this example. Assume that longitudinal cracking, transverse cracking, corner breaking, PCC patching, and joint spalling affect one slab. The highest severity of each distress type is considered so the combined deduct will exceed the worst-case deduct described above. The combined unadjusted deduct is 45 (Table 3). However, the deduct would have been only 33 if the same slab had been divided (divided slab column of Table 3). Therefore, the corrected deduct is 33, not 45 (corrected deduct column of Table 3). Now, if 2 slabs are affected by the above distresses, the combined deduct is 66 and if the same slabs are divided then the deduct will be 44. So, the corrected deduct in this case is 44. By increasing the number of affected slabs up to 10, eight other sets of un-corrected and corrected deducts are obtained and are shown in Table 3. These values are plotted as shown in Figure 7 and an equation corresponding to best-fit curve is obtained. A very high $R^2$ value was obtained for the equation. This equation will correct the combined deducts for various severity combinations of five distress elements.

Table 3: Un-corrected and corrected deduct for 5 distress elements

| No of affected Slabs | Combined deduct | Deduct for divided slab | Corrected Deduct |
|---|---|---|---|
| 1 | 45 | 33 | 33 |
| 2 | 66 | 44 | 44 |
| 3 | 83 | 52 | 52 |
| 4 | 97 | 59 | 59 |
| 5 | 110 | 64 | 64 |
| 6 | 122 | 69 | 69 |
| 7 | 133 | 73 | 73 |
| 8 | 143 | 77 | 77 |
| 9 | 153 | 81 | 81 |
| 10 | 163 | 85 | 85 |

Figure 7: Development of reduction curve for 5 distress elements




Similar equations were developed for other numbers of distress elements. VDOT recognizes the following types of distresses on jointed concrete: transverse cracking, longitudinal cracking, corner breaking, longitudinal/transverse joint spalling, PCC and AC patching (if both are present, only AC patching to be called) and shattered/divided slabs. So, at a maximum, six types of distresses (including shattered slab) can be present in a section. If all six distresses exist only the shattered slab is counted and the corresponding deduct assigned. Therefore, the correction curve for five distress elements should be used for both five and six distress elements. Also, it was found that when only two distress elements are present, the combined deducts, even with highest severity distresses, was less than the divided slab condition deduct and it is safely assumed that no reduction is necessary for two distress elements. The correction equations for three through six distresses along with the $R^2$ values are provided below and as reformatted for the VDOT index model in Appendix B .

$Y=1.7156X^{0.7715}$ $R^2=0.9963$ (for five/six distress elements)

$Y = 1.6932X^{0.7951}$ $R^2=0.9942$ (for four distress elements)

$Y = 1.5273X^{0.8549}$ $R^2=0.9916$ (for three distress elements)

Where,

Y=Corrected deduct, X=Combined/uncorrected deduct

## CRC PAVEMENTS

Unlike jointed pavements, the Virginia procedure for CRC pavements does not use a slab approach, i.e., the pavement is rated continuously as is the case with asphalt concrete pavements. This means that many engineering judgments had to be made on how to use the PAVER PCC deduct values for these pavements. Essentially, those judgments reflect limited staff experience with CRC pavements and attempts to make deduct values seem reasonable for various levels of distress. Clearly, such a subjective approach engenders the likelihood that many modifications will be necessary once deduct equations are applied to pavement conditions beyond the modest staff experience.

Efforts were still directed at retaining the shape of PAVER deduct curves while making adjustments to how the curves are applied. Unless otherwise noted, the extents of distress are based on area and expressed in terms of the percentage of the pavement section. There are two indices; (1) the concrete punchout rating (CPR), and (2) the concrete distress rating (CDR) and two additional rating team evaluations, pavement ride quality and whether or not pumping is present.

### The Concrete Punchout Rating (CPR)

The concrete punchout rating (CPR) is a CRCP condition index based on a rating of 100 being a "perfect" pavement and with deduct values assigned on the basis of four distresses. The distresses of concern are punchouts (PAVER[2] distress definitions apply except as otherwise noted), cluster cracking, , PCC patching and AC patching. As noted in Appendix A, cluster cracking is defined by VDOT to be the occurrence of transverse cracks in a pattern that forms a group of three or more transverse cracks with an average crack spacing of 2 feet or less. The CPR components were developed as follows:

*Punchouts of CRCP*

The PAVER deduct curves were evaluated and it was decided to use the shape of the medium severity curve for all punchout deducts. In addition, it appeared that approximately 1/10 of the jointed distress density based on percent defective slabs would be reasonable on an area basis, i.e., a deduct of 72 points based on 100% defective pseudo slabs was equated to 10% of the pavement area effected by punchouts.

The VDOT curve reflecting these values is given in Figure 8 and the deduct equation follows that figure.

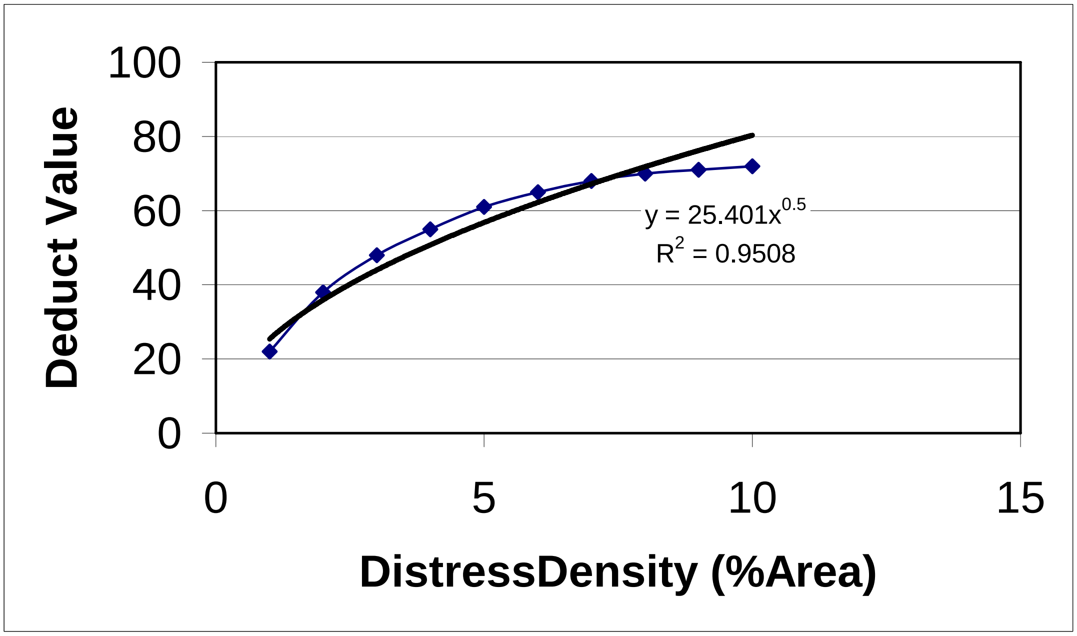



**Figure 8 – Punchouts of CRCP**

Deduct = 25*(%Pavement Area Punched)^0.5

*Cluster Cracking of CRCP*

Cluster cracking is a distress that has been defined by VDOT in order to deal with the undesirable condition of transverse cracks so closely spaced as to be detrimental to performance. As noted in Appendix A, cluster cracking is defined as a group of three or more transverse cracks with average spacing of 2 feet or less. Since the distress was not defined in PAVER the decision was made to apply the shapes of PAVER durability or "D" deduct curves. Since only low and medium severity cluster cracking is defined by VDOT only the low and medium severity curves were used. Further, it was reasoned that 1/5 of the percent defective slab densities would be applied on an area basis, i.e., a deduct of 42 points for 100% defective slabs was equated to a 42 point deduct for 20% effected pavement area.

The curves for the above conditions are given in Figure 9 and the combined deduct equation follows that figure.

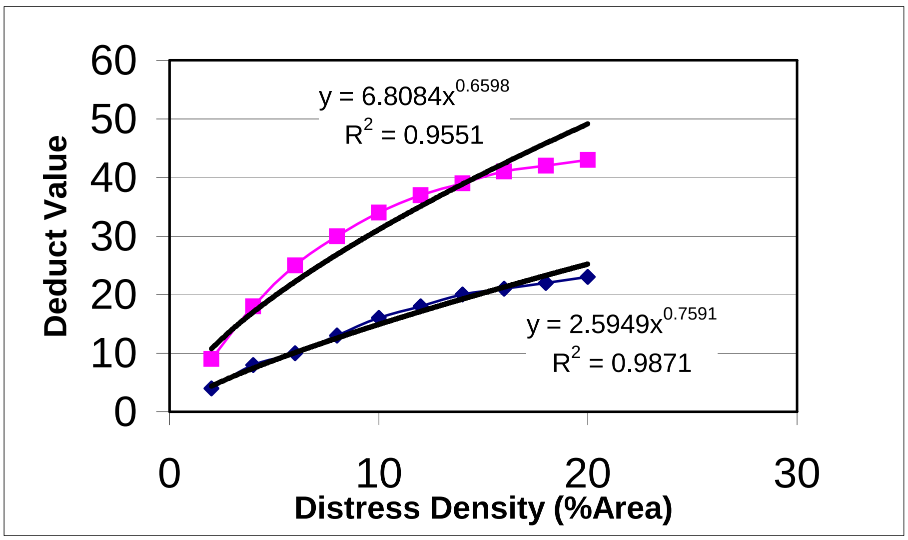



**Figure 9 – Cluster Cracking of CRCP**

Deduct = 2.6*(%Area_SEV1)^0.76 + 6.8*(%Area_SEV2)^0.66

*PCC Patching of CRCP*

The deduct curves defined earlier for PCC patching of jointed pavements were modified for use with CRCP pavements. The major change, brought about by trial and error, was to change the 0 to 100 "percent slabs" to 0 to 50 percent area. Again, it is recognized that adjustments likely will be required once trial evaluations are completed. The PCC patching deduct curves are given in Figure 12 and the combined best fit equation follows.

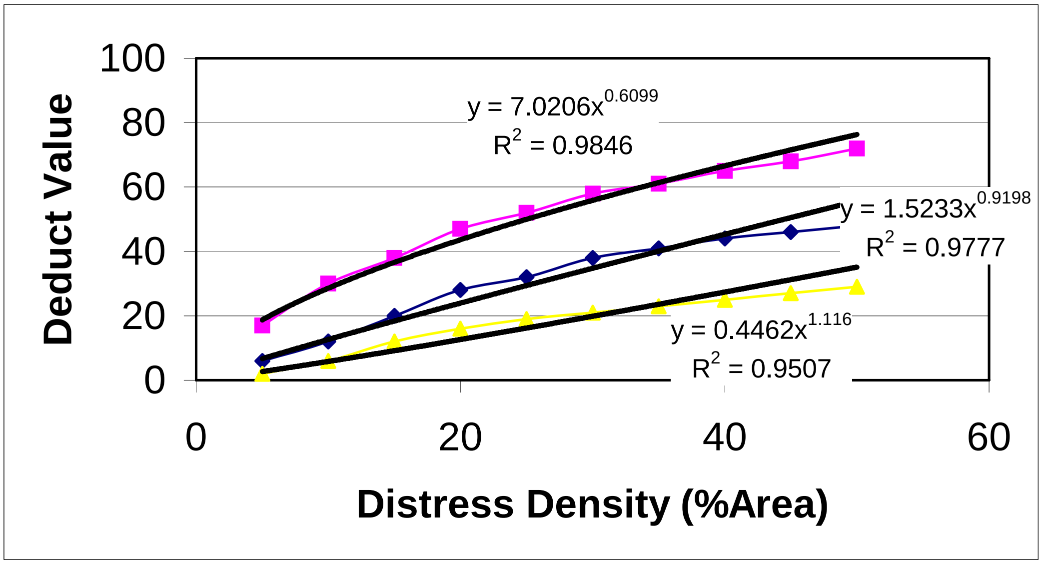



**Figure 12 – PCC Patching of CRCP**

*PCC Patching of CRCP:* Deduct = 0.45*(%Area_SEV1)^1.1 + 1.5*(%Area_SEV2)^0.92 + 7.0*(%Area_SEV3)^0.61

*Asphalt Concrete Patching Of CRCP*

The deduct curve defined earlier for asphalt concrete patching of jointed pavements was modified for use with CRCP pavements. The major change, brought about by trial and error, was to change the 0 to 100 "percent slabs" to 0 to 50 percent area. Further, only one severity level was needed to comply with Virginia rating procedures. Therefore, the curve for Severity 3 patching as modified was used. Again, it is recognized that adjustments likely will be required once trial evaluations are completed. The AC patching deduct curve is given in Figure 10 and the best fit equation follows.

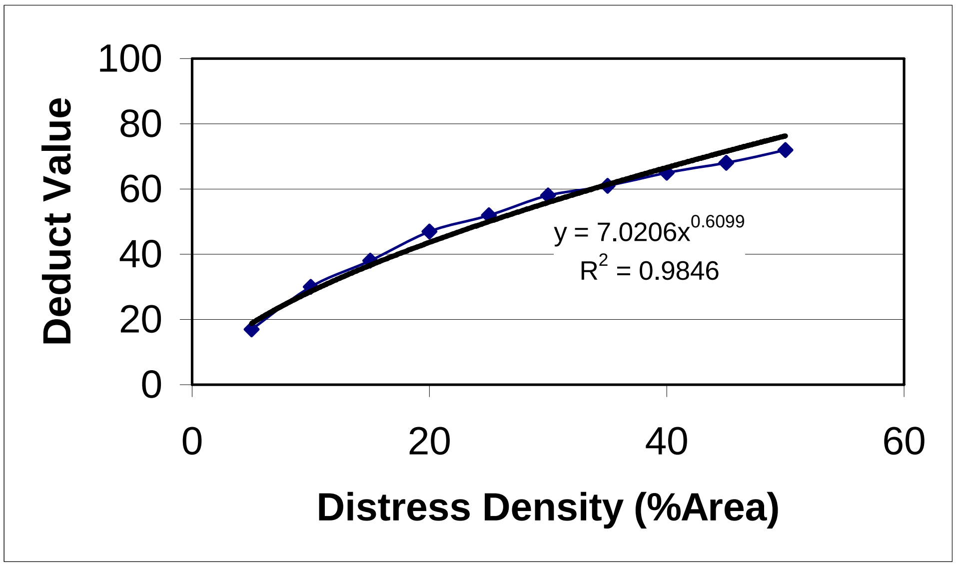



**Figure10– Asphalt Concrete Patching of CRCP**

*AC Patching of CRCP:* Deduct = 7.0*(AC Patch Density)^0.6

The AC patch density is defined as the area of AC patches expressed as a percentage of the area of the pavement section.

The Concrete Distress Rating (CDR)

The concrete distress rating (CDR) is a CRCP condition index based on a rating of 100 being a "perfect" pavement and with deduct values assigned on the basis of four distresses. The distresses of concern are transverse cracking (PAVER[(2)] distress definitions apply except as otherwise noted), longitudinal cracking, PCC patching, AC patching, and longitudinal joint spalling. The CDR components were developed as follows:

*Transverse Cracking of CRCP*

Transverse cracking of CRCP is a special case and, for that reason, the development of deduct equations are given special treatment in this report. Low severity transverse cracks (≤1/4" width) are by definition not a distress as they are a design characteristic of CRCP. Therefore, deductions for rating purposes are confined to what is defined as severity 2 (medium) and severity 3 (high) cracking. These severity levels are defined by Virginia as a crack greater than ¼" in width or any spalled crack, respectively (Table A2). Virginia further defines transverse cracking with a spacing of < 2 ft. as cluster cracking regardless of the severity level of cracking. For that reason, the transverse cracking of concern here is confined to medium and high severity cracking with an average spacing of greater than 2 ft.

The computations for determination of distress density are summarized in Table 4. Note that cracking density is defined as the linear feet of cracking expressed as a percentage of the area of the pavement section, i.e., (l/sf)*100. Note that this is the same as assigning each crack a one-ft. width. An example might be 10% cracking shown in Table 4 to be 53 cracks per 0.1 mi. section (average spacing of 10 ft.) or 53 x 12 = 636 sf for 12 ft. lanes. Since the 0.1 mi. section has 6336 sf of pavement area the cracking density is 10% of the pavement area.

The next step was to approximate the shape of the PAVER curves for medium and high severity linear cracking. However, those curves are based on the distress density being expressed in terms of percent slabs rather than area. It was evident that the deduct values transformed directly from percent slabs to percent area would not serve VDOT purposes such that those values were arbitrarily (based on engineering judgment) increased to the values given in Table 4 and plotted in Figure 11. Again, it is likely that major adjustments

**Table 4 – Transverse Cracking of CRCP**

| Cracks Per | | | | |
|---|---|---|---|---|
| 0.1 Mi. Section | 12' Wide Lane Crack | **TRANSVERSE CRACKING OF CRCP** | | |
| (spacing ft.) | Density (sf) | %Area | S2_Deduct | S3_Deduct |
| 5 (106) | 60 | 1 | 2 | 4 |
| 11(48) | 132 | 2 | 4 | 8 |
| 16(33) | 192 | 3 | 6 | 12 |
| 21(25) | 252 | 4 | 8 | 16 |
| 26(20) | 312 | 5 | 10 | 20 |
| 32(16.5) | 384 | 6 | 12 | 24 |
| 37(14.3) | 444 | 7 | 13 | 26 |
| 42(12.6) | 504 | 8 | 14 | 34 |
| 48(12) | 576 | 9 | 15 | 36 |
| 53(10) | 636 | 10 | 16 | 38 |
| 106(5) | 1272 | 20 | 30 | 58 |
| 158(3.3) | 1896 | 30 | 38 | 72 |
| 211(2.5) | 2532 | 40 | 46 | 82 |
| 264(2) | 3168 | 50 | 54 | 92 |

will be made once the deduct equations undergo full field trials. The “best fit” equation for the combined medium and high severity distresses is given after Figure 11.

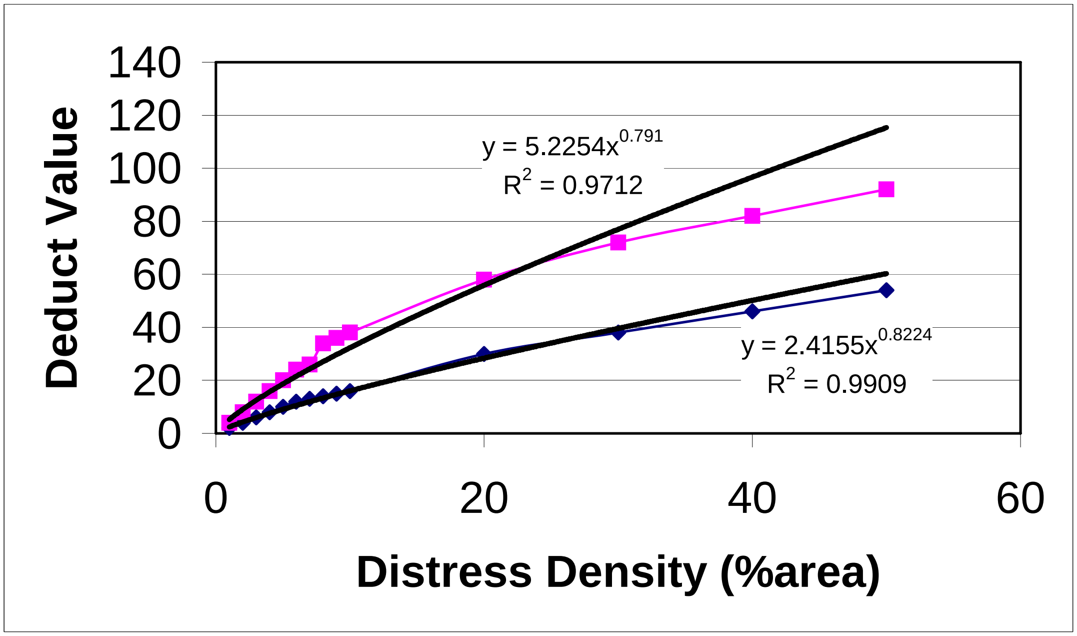



**Figure 11 – Transverse Cracking of CRCP**

*Transverse Cracking of CRCP:* Deduct = 2.4*(SEV2_Density)^0.82 + 5.2*(SEV3_Density)^0.79

Based on a cracking density defined as the linear feet of cracking expressed as a percentage of the area of the pavement section, i.e., (l/sf)*100. Note that this is the same as assigning each crack a one-ft. width. Note also that SEV1 transverse cracking is not a distress for CRCP

*PCC Patching of CRCP*

The deduct curves defined earlier for PCC patching of jointed pavements were modified for use with CRCP pavements. The major change, brought about by trial and error, was to change the 0 to 100 "percent slabs" to 0 to 50 percent area. Again, it is recognized that adjustments likely will be required once trial evaluations are completed. The PCC patching deduct curves are given in Figure 12 and the combined best fit equation follows.

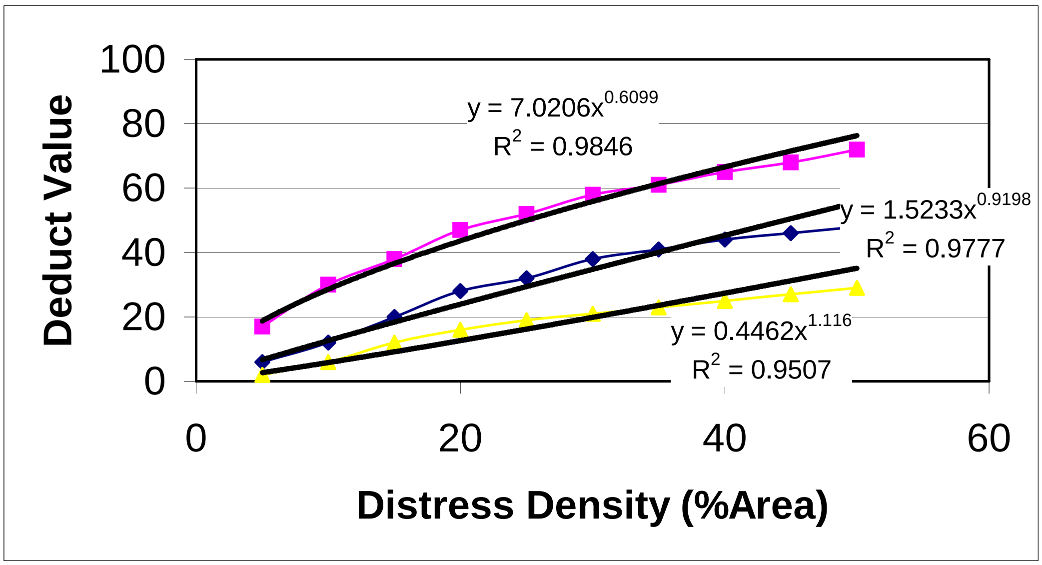



**Figure 12 – PCC Patching of CRCP**

*PCC Patching of CRCP:* Deduct = 0.45*(%Area_SEV1)^1.1 + 1.5*(%Area_SEV2)^0.92 + 7.0*(%Area_SEV3)^0.61

*Longitudinal Cracking of CRCP*

The rationale described above for transverse cracking of CRCP was applied to longitudinal cracking as well, i.e., the PAVER shapes were retained for the curves, but the distress density computations are specific to VDOT. In this all three severity levels of distress apply as longitudinal cracking is not a CRCP design characteristic. Longitudinal cracking deduct curves are given in Figure 13 and the combined equation follows.

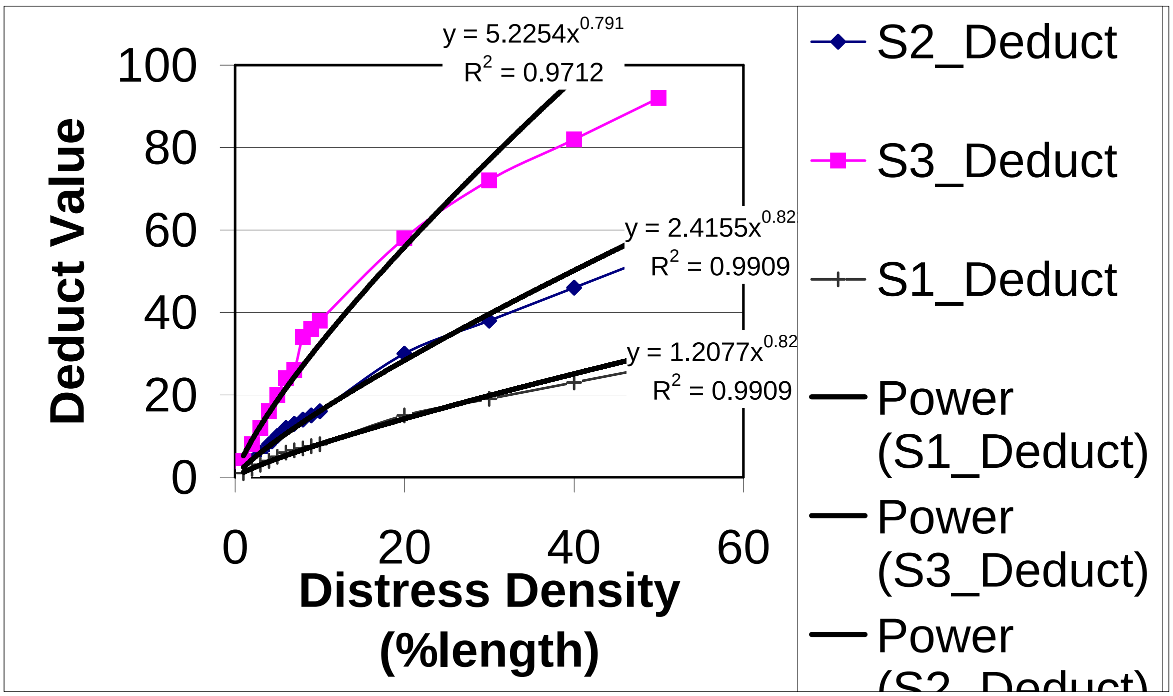



**Figure 13 – Longitudinal Cracking of CRCP**

*Longitudinal Cracking of CRCP:* Deduct = 1.2*(%Length_Sev1)^0.82 + 2.4*(%Length_SEV2)^0.82 + 5.2*(%Length_SEV3)^0.79

%Length (crack density) is defined as the length of longitudinal cracking in the section expressed as a percentage of the length of the section.

*Longitudinal Joint Spalling of CRCP*

The VDOT rating procedure provides for only one level of joint spalling severity (severity is difficult to discern from images). The engineering judgment was made to use the average of the medium and high severity PAVER deducts to shape the curve. Then, the distress density is expressed as %area rather than %slabs. The longitudinal joint spalling deduct curve is given in Figure 14 and the best fit equation follows.

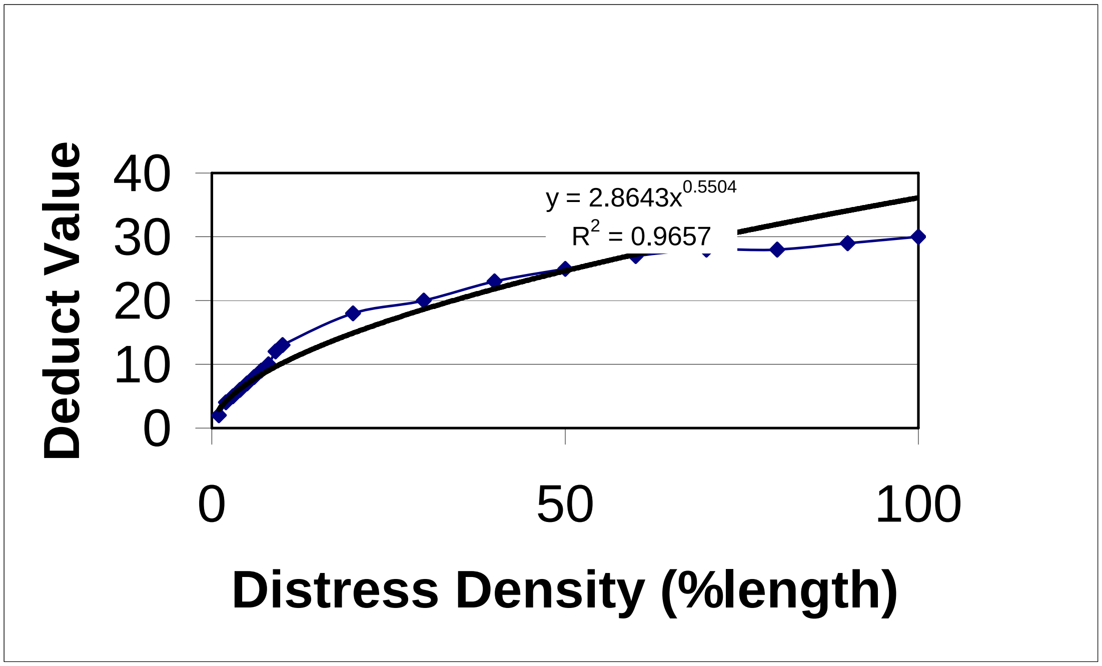



**Figure 14 – Longitudinal Joint Spalling of CRCP**

Deduct = 2.9*(%Length_SPALLED)^0.55

Spalling density is defined as the length of longitudinal joint spalling in the section expressed as a percentage of the length of the section.

# PILOT STUDY OF INDICE USE

A brief pilot study of PCC index data collection activities and of the use of the indices in characterizing pavement condition was conducted in 2001. This study is summarized below in the hope that the results will provide some direction for future efforts in evaluating PCC pavements in Virginia.

## DATA COLLECTION

In the absence of an ongoing automated data collection process as intended by the VDOT distress evaluation manual,[(4)] a manual data collection procedure was used. This procedure[(9)] included manual evaluation of key pavement distresses for both jointed and continuously reinforced concrete pavements. While termed a manual procedure, laptop computers were used to facilitate data collection and processing. A 10% sampling of each homogenous PCC section was employed to provide an estimate of pavement condition. It was anticipated that the aggregation of the resulting data would provide statewide and district-to-district comparative information.

The central office pavement management staff selected homogenous sections for all concrete pavements on the primary and interstate systems. The listings were provided by District, Residency, County, and Route location-reference. The listing, on electronic media, for each district was sent to the districts. After a district review and "cleanup" the lists were then returned to the central office for inclusion in the software to be used in the rating process. Distresses to be considered were those consistent with the earlier sections and appendices of the present report.

Homogeneous sections were evaluated by sampling at a 10% rate. This was accomplished by conducting a survey on a randomly selected 0.1mile from each mile in each homogeneous section.

The rating team was comprised of pavement management personnel from the Hampton Roads and Richmond Districts, and from the central office pavement management section. Operating procedures required that the representative from the district being rated would serve as navigator and driver for the team. The team reached consensus ratings for the distresses and other issues being addressed.

Subsequent to all production ratings, quality assurance (QA) teams made up of two people from the central office pavement management staff and one person from the district under consideration rated 30 sites from each district for comparison with the production teams' work.

## RESULTS

## JOINTED PAVEMENTS

Pilot study results for jointed PCC pavements (JPCP) are summarized in Table 5 for both Hampton Roads and Richmond districts. Note that the values given for each distress are in terms of average deduct points for the 30 QA sites for both production and QA teams. Deduct points are computed from the observed distresses using the deduct equations given in Appendix B. For example, in the Richmond district the production team found an average of 2.78 deduct points for longitudinal cracking while the QA team found an average of 4.62 points for the same pavements. Those differences and all other differences between the QA and production teams were found to be so significant that the procedure was judged to be non-reproducible and that major changes in the process would be required. Similarly, the SDR indices from these data were judged to be of little value due to the major differences between QA and production results.

Pavement management personnel evaluating the reasons for wide differences between production and QA teams noted that there were problems with both distress frequency and distress severity between teams. The problem seemed to be aggravated by the use of short evaluation sections, which too dramatically influences the percentage of slabs affected. Further, the effects of relatively minor differences in location between the production and QA teams are exaggerated on short sections. The conclusion was that more intensive training and the use of longer evaluation sections would alleviate many of the JPCP rating problems.

**Table 5 – Average Deduct Values and Indices**
**Pilot Study (JPCP Pavements)**

| | Hampton Roads | | Richmond | |
|---|---|---|---|---|
| | Prod. | QA | Prod. | QA |
| Long Cracking | 1.85 | 0.77 | 2.78 | 4.62 |
| Trans. Cracking | 3.69 | 8.33 | 3.58 | 11.91 |
| Corner Breaks | 0.9 | 6.64 | 3.14 | 10.45 |
| PCC Patching | 21.75 | 18.19 | 13.4 | 18.78 |
| AC Patching | 2.11 | 0.91 | 4.1 | 6.78 |
| Long. Jt. Spall. | 0.31 | 3.07 | 0 | 4.56 |
| Trans. Jt. Spalll. | 0.52 | 5.77 | 4.26 | 8.33 |
| Divided Slabs | 0 | 0 | 0 | 0 |
| SDR | 69 | 54 | 69 | 36 |

## CRC PAVEMENTS

Pilot study results for continuously reinforced concrete (CRC) pavements are summarized in Table 5 for both Hampton Roads and Richmond districts. Again the values given for each distress are in terms of average deduct points for the 30 QA sites for both production and QA teams and deduct points are computed from the observed distresses using the deduct equations given in Appendix B. Again the differences between the QA and production teams were found to be so significant that the procedure was judged to be non-reproducible while the CDR and CPR indices were judged unusable. As with JPC pavements major changes in the rating process were deemed necessary.

**Table 6 – Average Deduct Values and Indices**
**Pilot Study (CRC Pavements)**

| | **Hampton Roads** | | **Richmond** | |
|---|---|---|---|---|
| | **Prod.** | **QA** | **Prod** | **QA** |
| Long. Cracking | 0.05 | 0.21 | 0.17 | 0.37 |
| Avg. Trans. Crack Spacing | 5.6 | 9.6 | 5.7 | 7.8 |
| Avg. Trans. Crack Deduct | 7.15 | 11.04 | 22.35 | 18.15 |
| PCC Patching | 1.98 | 5.68 | 4.56 | 7.04 |
| Cluster Cracking | 4.49 | 5.61 | 0.61 | 12.5 |
| AC Patching | 0 | 0.13 | 1.11 | 1.3 |
| Long. Joint Spalls | 0.04 | 0 | 0 | 0 |
| Punchouts | 2.22 | 15.02 | 4.17 | 23.34 |
| CDR | 91 | 82 | 72 | 73 |
| CPR | 91 | 71 | 90 | 56 |

Again, differences between production and QA teams were clearly related to differences in both distress frequency and severity. However, in the case of CRC pavements it was also concluded that the rating process is too demanding to be conducted in the field such that the use of pavement images for rating purposes would be recommended.

# ACKNOWLEDGEMENTS

The contribution of VDOT district pavement managers and coordinators to this project is gratefully acknowledged. Special thanks go to Lynn Huseby, Glenn Gorman, Ken Hardy, and Tom Tate for initial field trials.

The work was begun and carried out for the first two years under the direction of then State Pavement Management Engineer Charles Larson and his assistants Trenton Clark and Naveed Sami. Later work has been under the direction of State Pavement Management Engineer Douglas Gilman and his assistants Tanveer Chowdhury, Affan Habib, and Michael Jennings. The latter gentlemen were instrumental in the sensitivity analysis of project results and in the review of draft reports and supporting documents while two served as co-authors of the report.

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# APPENDIX A - PORTLAND CEMENT CONCRETE PAVEMENT DISTRESSES

## Table A1 - Summary of Jointed Portland Cement Concrete Pavement Distress Evaluation

| <u>Distress Type</u> | | <u>Corner Breaks</u> | <u>Linear Cracking</u><br>• Transverse<br>• Longitudinal | <u>Divided Slabs</u> | <u>Joint Spalling</u><br>• Transverse<br>• Longitudinal | <u>Joint Seal Condition</u><br>• Transverse<br>• Longitudinal | <u>Blowups</u> | <u>PCC Patch Deterioration/ Asphalt Patching</u> |
|---|---|---|---|---|---|---|---|---|
| **Description** | | A Corner Break is defined by an angled crack intercepting one side and one end of a slab. | Cracks running roughly parallel or transverse to the centerline of the road. | A slab broken into 4 or more pieces by cracking.. | Breaking or chipping of slab edges along and within 1 foot of a joint. | Joints appearing unsealed or only partially sealed are considered to be unsealed. | Local upward movement at joints or cracks. May include shattering. | A portion > 1 sq. ft. of the slab has been removed and replaced. |
| **Severity Levels** | **1** | Crack is spalled no more than 1/2 the crack length and the corner break is in one piece. | • A well sealed indeterminate width crack, **<u>or</u>**<br>• A closed crack with no spalling. | N/A | N/A | N/A | N/A | No distress in patch or surrounding area. |
| | **2** | • Crack is spalled more than 1/2 the crack length, **<u>or</u>**<br>• The corner break is in two or more pieces. | • An open crack, **<u>or</u>**<br>• Any spalled crack | N/A | N/A | N/A | N/A | Severity 1 spalling or cracking in patch or surrounding area. |
| | **3** | N/A | N/A | N/A | N/A | N/A | N/A | Other severity 2 distress in patch or surrounding area.. |
| **How to Count** | | Count number of joints with adjacent corner breaks. | Count number of slabs with cracking greater than 1-ft. long. Count highest severity level present in slab. | Count the number of divided slabs in the section. | Trans. - No of slabs with joint spalling.<br>Long. – No. of slabs with joint spalling. | Trans. Joint Seal – No. of slabs with fully Sealed<br>Long. Joints – No. of Slabs with Fully Sealed Long.Joints. | Count the number of slabs with blowups in the section. | Count the number of slabs with PCC patching. Count the highest severity found. |
| **Other Features** | | If more than 1 severity, count highest severity present in slab. | Slabs broken into 4 or more pieces are defined as divided slabs. | **When a slab is divided no other distress is counted**. | Report as highest severity level present | | Crack blowup is 1 slab. Joint blowup is 2 slabs. | **Count the number of slabs with AC patches in the section.** |

**NOTE:** CLOSED CRACKS = Less than or equal to ¼ inch in width.
OPEN CRACKS = Greater than ¼ inch in width.

**Table A2 - Summary of Continuously Reinforced Concrete Pavement Distress Evaluation**

| Distress Type | | Transverse Cracks | Longitudinal Cracks | Punchouts and Spalled "Y" Cracks | Clustered Cracking | Longitudinal Joint Spalling/ SealCondition | PCC Patch Deterioration/ Asphalt Patches* |
|---|---|---|---|---|---|---|---|
| **Description** | | Cracks roughly transverse to the pavement centerline w/ avg spacing > 2'. | Cracks roughly parallel to the pavement centerline. **Must be greater than 1 foot in length.** | • Slab broken by 2 or more cracks **or**<br>• Spalled "Y" cracks. | A group of three or more transverse cracks with average spacing of 2 feet or less. | Breaking or chipping of slab edges along and within 1 ft. of a longitudinal joint. | A portion > 1 sq. ft. of the slab has been removed and replaced. |
| **Severity Levels** | **1** | A transverse crack <1/4" wide with no spalling. | A longitudinal crack with no spalling. | N/A | Spacing > 1 foot and < 2 feet. | N/A | No distress in patch or surround area. |
| | **2** | A transverse crack > ¼" wide with no spalling. | A longitudinal crack with spalling equal to or less than 1/4 of the crack length. | N/A | Spacing > 6 inches and < 1 foot. | N/A | Patch or surrounding area has some CRCP severity 1 distress. |
| | **3** | Any transverse crack with spalling. | A longitudinal crack with spalling greater than 1/4 of the crack length. | N/A | Spacing < 6 inches. | N/A | Patch or surrounding area has some CRCP severity 2 distress. |
| **How to Count** | | No. of ½ lane **and** No. of full lane cracks for each severity level. (software converted to linear feet). | Count the number **and** linear ft. of cracks for each severity level. | Count number of occurrences **and** Square Feet. | Count number of occurrences **and** Sq. Ft. by severity level. | Record the linear feet of joint spalling. | Count the Square Feet of patching by severity level. |
| **Other Features** | | Average transverse crack spacing needed (section length/total number of cracks) | | | Rate clustered cracking in addition to transverse cracking | Record linear feet of pavement/shoulder joint fully sealed. | *** Count the Number of asphalt patches in the section.** |

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# APPENDIX B – CONCRETE PAVEMENT INDEX MODEL

# CONCRETE PAVEMENT INDEX MODEL

(Revised 6/28/02)

After a year of experience with rating of PCC pavements it was found necessary to modify the deduct equations to provide "reasonableness" of results obtained. Changes were made to an earlier index model dated 7-1-01.

Concrete pavement indices and their inputs are described below separately for Jointed and CRCP pavements.

## JOINTED PCC PAVEMENTS

### SDR

The slab distress rating (SDR) components and equations, based on evaluating the percent slabs effected. In the equations "SEV1 refers to the %slabs with severity 1 distress, etc.

*Corner Breaks:* Deduct = 0.8*(SEV1_%Slabs)^0.8 + 2.8 *(SEV2_%Slabs)^0.6

Input – The number of slabs in the section with SEV1 and SEV2 corner breaks.

*Transverse Joint Spalls:* Deduct = 1.3*(%SLABS_SJ)^0.6

Input – The number of slabs in the section with transverse joint spalls.

*Long. Joint Spalls:* Deduct = 1.3*(%SLABS_SJ)^0.6

Input – The number of slabs in the section with longitudinal joint spalls.

*Transverse Cracking:* Deduct = 1*(SEV1_%Slabs)^0.7 + 2.9*(SEV2_%Slabs)^0.5

Input – The number of slabs in the section with SEV1 and SEV2 transverse cracks.

*Long. Cracking:* Deduct = 1*(SEV1_%Slabs)^0.7 + 2.9*(SEV2_%Slabs)^0.5

Input – The number of slabs in the section with SEV1 and SEV2 longitudinal cracks.

*Divided Slabs:* Deduct = 13.4*(%DIV_SLABS)^0.4

Input – The number of divided slabs in the section.

*PCC Patches:* Deduct = 0.18*(SEV1_%Slabs)^0.98 + 0.79*(SEV2_%Slabs)^0.92 + 4.4*(SEV3_%Slabs)^0.62

Input – The number of slabs in the section with SEV1, SEV2 and SEV3 PCC patches.

*AC Patches:* Deduct = 4.3*(%SLABS)^0.63

Input – The number of slabs in the section with asphalt concrete patches

*Joint Seal Condition:* No Deduct

Input - Transverse: Number of fully sealed joints in the section
Longitudinal: Number of slabs in the section with fully sealed joints.

The SDR equation is 100 – the sum of the individual deduct components
The SDR deduct programming should provide for a minimum value of zero.

Note: An adjustment has been built into the system such that a pavement with multiple distresses will rate no lower than a pavement with the same percentage of divided slabs, i.e., divided slabs are considered the worst situation and provide a "floor" for the SDR rating. The correction applies to the total deduct points for the section and takes the following forms:

When there are five or six distress elements:

Adj_Sum_Deducts = 1.72*(Sum_Deduct)^).77

When there are four distress elements:

Adj_Sum_Deducts = 1.69*(Sum_Deduct)^).80

When there are three distress elements:

Adj_Sum_Deducts = 1.53*(Sum_Deduct)^.85

After deduct adjustment the final SDR is:

SDR = 100 – Adj_Sum_Deducts

**CRC PAVEMENTS**

In the case of CRCP, the data are collected continuously (i.e., no slabs or pseudo-slabs) as with AC pavements. Unless otherwise noted, the extents of distress are based on area and expressed in terms of the percentage of the pavement section. There are two indices; (1) the concrete punchout rating (CPR), and (2) the concrete distress rating (CDR) and two additional rating team evaluations, pavement ride quality and whether or not pumping is present. Note that there is also an average transverse crack spacing computed.

**CPR**

The concrete punchout rating (CPR) has the following components and deduct equations:

*Punchouts:* Deduct = 25*(%Pavement Area Punched Out)^0.5

Includes spalled "Y" cracking as defined in the VDOT distress evaluation manual[4].

Input – The square feet of distressed pavement

*Cluster Cracking:*

Deduct = 2.6*(%Area_SEV1)^0.76 + 6.8*(%Area_SEV2)^0.66

See Table A2 definitions.

Input – Square feet at each severity level.

*AC Patching:* Deduct = 7.0*(AC Patch Density)^0.6

The AC patch density is defined as the area of AC patches expressed as a percentage of the area of the pavement section.

Input - The area of AC patches in the section.

The CPR equation is 100 - the sum of the individual deduct components.
The CPR deduct programming should provide for a minimum value of zero.

**CDR**

The continuous pavement Concrete Distress Rating (CDR) has the following components and deduct equations:

*Transverse Cracking:* Deduct =2.4 *(SEV2_Density)^0.82 + 5.2*(SEV3_Density)^0.79

Based on a cracking density defined as the linear feet of cracking expressed as a percentage of the area of the pavement section, i.e., (l/sf)*100. Note that this is the same as assigning each crack a one-ft. width. Note also that SEV1 transverse cracking is not a distress for CRCP.

Input – The number of ½ lane and full lane cracks for each severity level.

**SPECIAL COMPUTED VALUE: AVG. Crack Spacing = Section Length/Total No. of Transverse Cracks**

*PCC Patching:* Deduct = 0.45*(%Area_SEV1)^1.1 + 1.5*(%Area_SEV2)^0.92 + 7.0*(%Area_SEV3)^0.61

Input – Square feet of Severity 1, Severity 2 and Severity 3 patches in the section

*Long. Cracking:* Deduct = 1.2*(%Length_Sev1)^0.82 + 2.4*(%Length_SEV2)^0.82 + 5.2*(%Length_SEV3)^0.79

%Length (crack density) is defined as the length of longitudinal cracking in the section expressed as a percentage of the length of the section.

Input – The linear feet of each severity level of longitudinal cracking.

*Long. Joint Spalling:* Deduct = 2.9*(%Length_SPALLED)^0.55

Spalling density is defined as the length of longitudinal joint spalling in the section expressed as a percentage of the length of the section.

Input - The linear feet of longitudinal joint spalling in the section.

*Long. Joint Seal Condition:* No deduct.

Input – The linear feet of fully sealed longitudinal joint.

The CDR equation is 100 - individual deduct components.
The CDR deduct programming should provide for a minimum value of zero