

Evaluation of AASHTO Cracking Protocol: Quantifying Distress in Asphalt Pavement Surfaces

Jonathan L. Groeger
Vice President
Axiom Decision Systems, Inc.
6420 Dobbin Road, Suite E
Columbia, Maryland 21045
Telephone No: (410) 772-9900
Fax No: (410) 772-9988
E-mail address: jgroeger@axiomds.com

Mr. Peter Stephanos
Director
Office of Materials and Technology
Maryland State Highway Administration, Office of Materials and Technology
2323 West Joppa Road, Brooklandville, MD 21022
Telephone No: (410) 321-3110
Fax No: (410) 321-3099
E-mail address: pstephanos@sha.state.md.us

Mr. Paul Dorsey
Assistant Division Chief, Pavement Management
Office of Materials and Technology
Maryland State Highway Administration, Office of Materials and Technology
2323 West Joppa Road, Brooklandville, MD 21022
Telephone No: (410) 321-3133
Fax No: (410) 321-3099
E-mail address: pdorsey@sha.state.md.us

ABSTRACT

As part of a contract with the Federal Highway Administration (FHWA), the Maryland Department of Transportation, State Highway Administration, (MD SHA) evaluated AASHTO Protocol PP 44, "Quantifying Cracks in Asphalt Pavement Surface." The objective of this project was to determine the effectiveness of the protocol as a procedure to collect, process, and report performance data for network level pavement management needs. The AASHTO cracking protocol was evaluated in a systematic and rational approach for more than one year. The evaluation consisted of three primary activities including; (1) a pilot study to determine the feasibility of using the protocol, (2) a benchmark survey to ensure the results obtained were compatible with expert opinion, and (3) a production testing study in which a full evaluation was conducted for a subsection of the pavement network to determine the feasibility of using the procedure at the network level. Overall, we conclude that the protocol is suitable for use as a process to determine the network level crack condition for a state pavement network. In addition, we discuss ways in which the process adopted by MD SHA is not entirely compliant with the current AASHTO cracking protocol and will not be compliant for the foreseeable future due to hardware, software and policy issues. However, presently the MD SHA procedure is well within the spirit of the protocol. Lastly, we document a unique procedure developed for MD SHA to convert the AASHTO cracking matrix into an intuitive condition index.

INTRODUCTION

As part of a contract with the Federal Highway Administration (FHWA), the Maryland Department of Transportation, State Highway Administration, (MD SHA) evaluated AASHTO Protocol PP 44, “*Quantifying Cracks in Asphalt Pavement Surface (1)*.” The objective of this project was to determine the effectiveness of the protocol as a procedure to collect, process, and report performance data for network level pavement management needs. It should be emphasized that we were only evaluating if the protocol could accurately identify cracks to create a cracking condition category. We were not evaluating if the protocols accurately identified the type and severity of cracking directly. This document contains the results of this evaluation and contains several suggestions that may be considered for improvement of the procedure.

The evaluation consisted of three primary activities including; (1) a pilot study to determine the feasibility of using the protocol, (2) a benchmark survey to ensure the results obtained were compatible with expert opinion, and (3) a production testing study in which a full evaluation of the protocols was conducted for a subsection of the pavement network to determine the feasibility of using the procedure at the network level. Overall it was determined that the protocol, with a few exceptions, can be used as a suitable procedure to detect, rate and classify cracks at the network level for MD SHA purposes.

OVERVIEW OF PROTOCOL

The protocol reviewed in this evaluation is, “Standard Practice for Quantifying Cracks in Asphalt Pavement Surface,” which is also known as AASHTO Protocol PP44 (PP is used for provisional standards). This protocol has undergone an extensive development and improvement cycle over the last few years and has been adopted by AASHTO as a provisional standard.

The protocol specifically covers the procedures for quantifying cracking in asphalt pavement surfaces both in the wheel and non-wheelpath areas for network level cracking surveys typically used for Pavement Management purposes. It also allows categorization of the type of cracking by its location within the pavement section (wheel path/non wheel path, etc.) The protocol contains four primary sections as follows:

1. Scope
2. Cracking Definition and Estimation
3. Recording of Data
4. Quality Assurance

Each of these sections contains a number of key factors that dictate how the protocol is implemented. For this study, we extracted each of these parameters and investigated the relevance of each to the current network level crack data collection and evaluation business process used by MD SHA. A comparison of the protocol versus MD SHA’s current business process is summarized in Table 1.

MARYLAND APPROACH TO AUTOMATED CRACK DETECTION

MDSHA has developed a network level cracking evaluation process that is patterned, as much as possible, on the AASHTO protocols. A summary of this process is outlined in this section.

Data Collection

Every year, approximately ten thousand (10,000) lane-miles of digital video data are collected by the ARAN vehicle (a product of Roadware, Inc.) using State forces. No manual data collection is undertaken for network level surveys. The digital video data is collected at or near posted speed limits over approximately a six-month period. During this data collection, two downward looking digital cameras capture the road surface and store the images on electronic medium (removable hard drives). During processing or viewing, the data from the two cameras are spliced together longitudinally and transversely to form a continuous image of the pavement surface. This data is then transferred to the Pavement Management Division for subsequent quality assurance and processing.

Data Processing

The data processing task used by MD SHA consists of many steps. However, the bulk of the process revolves around the use of Wisecrux (WX). Wisecrux is a semi-automated crack detection tool that uses the digital images captured by the ARAN vehicle to detect and classify pavement cracking. WX can detect cracks that are as small as 4 mm. The automated crack detection process consists of five primary steps as follows:

TABLE 1 AASHTO protocol versus current MD SHA business process.

Location	Study Factor	MD SHA Compliance
1. Scope	Automated Survey – Use a vehicle traveling at near highway speeds and collect data on the entire length of roadway.	Compliant
	Manual Surveys – Observe distresses and record data at a minimum 10% sample of the lane surveyed. Rating continuous film or tape in an office setting is considered a manual survey.	N/A ¹
2. Cracking Definition	Survey a 2.500 m strip in the outside lane	Compliant ²
	For undivided highways survey one direction.	Compliant ³
	For divided highways, survey the outside lane in both directions.	Compliant
	Sealed cracks will not be quantified by manual surveys. Automated survey equipment will not quantify any discontinuity greater than 25 mm.	Compliant
	Wheel path cracking is determined in both inside and outside wheel path as shown in Figure 1 of PP44.	Compliant
	Non-wheel path cracking is determined in the area between the wheel path as shown in Figure 1 of PP44.	Semi-compliant ⁴
	Additional non-wheel path cracking will be defined by the agency.	Compliant
	Severity level 1 cracks classified as < 3 mm.	Non-compliant ⁵
	Severity level 2 cracks have dimensions μ 3mm and <6 mm.	Semi-compliant ⁶
	Severity level 3 cracks have dimensions μ 6mm.	Compliant
Quantify intensity of each cracking level as the total length of cracking per unit area (m/m ²) for each defined survey strip.	Compliant	
3. Recording of Data	The length of the data collection section is determined by the agency and shall be between 0.10 km and 1.0 km.	Compliant
	The entire length of the data collection section shall be surveyed (100% sample).	Compliant
	The data summary interval shall be 0.1 km.	Non-compliant ⁷
	Minimum data recorded requirements	Compliant
4. Quality Assurance	Qualification and Training	Compliant
	Equipment	Compliant
	Validation Sections	Non-compliant ⁸
	Additional Checks	Non-compliant ⁸

¹ Manual surveys not used to conduct network level cracking surveys.

² MDSHA exceeds this requirement; a 3.2 m strip is surveyed.

³ MD SHA exceeds this requirement; both directions of undivided highways are surveyed.

⁴ WX cannot establish the 0.125 mm zones between the wheelpath and the area between wheelpaths (see figure 1).

⁵ Current MSD SHA software cannot determine cracks less than approximately 4 mm.

⁶ See note 5.

⁷ Data summarized at 0.1 of a mile.

⁸ Will be developed in 2002.

Step 1: Preliminary Review. This step consists of performing a cursory visual examination of the forward and downward (pavement) images to identify areas that should not be processed (bridges, concrete, etc.).

Step 2: Crack Detection. The WX software is used to detect cracks. This is currently performed at approximately 8 to 12 mph.

Step 3: Quality Control/Quality Assurance. The detection process is reviewed to ensure that crack detection was performed successfully and completely.

Step 4: Classification/Rating. The WX software is used to classify (longitudinal/transverse) and rate (low, medium, high) the detected cracks according to the AASHTO cracking protocol. This is currently performed at approximately 800 mph.

Step 5: Post-processing. The resultant data is converted into a 0 to 100 rating, assigned a condition level, and formatted for entry in the PMS.

Record keeping is another important part of the process. As data is received and backed-up, a database is updated to reflect the data that has been collected. This database is used to track progress against the Pavement Management System section inventory list. As data are processed and uploaded to the PMS, a separate database tracks the progress to-date and records how much work remains. A computer program called “Automated Distress Analysis Tool,” (ADAT) developed by MD SHA performs this task along with many other data management and quality control tasks described herein.

PROTOCOL EVALUATION

MD SHA took a phased approach to evaluating the AASHTO protocols. Concurrent with this effort, MD SHA was evaluating various options with which to collect and process network level cracking data. Therefore, our work plan reflects both of these endeavors. The process that was followed can be broken down into three phases:

1. Pilot Study Evaluation
2. Benchmark Survey
3. Production Testing

Each of these phases and their results are described in more detail in the following sections.

Phase 1. Pilot Study Evaluation

The pilot study was undertaken to determine the feasibility of using WX as the software to perform the automated crack detection methodology and as a first test of the use of the AASHTO protocols. The data from this study was output in a raw cracking format, AASHTO format, and also in a PAVER Pavement Condition Index (PCI) format (2). MDSHA currently uses PCI on its project level crack surveys and thus this technology was compared with the AASHTO data reporting format.

The goals of this phase were two-fold. The first was to gain an understanding and proficiency in using the WX software and the second was to gain additional insight and experience using the AASHTO protocols. In addition, it was hoped that a comparison could be made between manual surveys and the automated analysis. For this study, a pool of projects that were scheduled for rehabilitation in FY2002 was selected. These projects were selected because they would theoretically have manual condition surveys performed in the near future (as a part of the rehabilitation design), and thus, an added comparison between automated and manual distress surveys could be performed.

In order to create a manageable and diverse data set, a site selection template was devised. The factors used to develop this “sampling template” were:

1. Pavement Type (factors = flexible, composite)
2. Traffic (low, high)
3. Representative Condition (very good, good/fair, mediocre, poor)
4. Environmental Region (mountain, piedmont, coastal)

This generated a sampling template consisting of 24 cells. Using this template, the FY2002 rehabilitation (also termed Fund 77) projects were placed in their appropriate sampling template cell. Finally, a candidate section was selected for each possible cell. Additional projects, outside the FY2002 candidate pool, were selected to fill empty cells. Table 2 illustrates the final distribution of projects that were evaluated.

TABLE 2 Distribution of projects selected for evaluation.

	Pavement Type	Flexible				Composite			
	Traffic	Low		High		Low		High	
	Rep. Condition	VG, Good	Fair Med. Poor	VG, Good	Fair Med. Poor	VG, Good	Fair Med. Poor	VG, Good	Fair Med. Poor
Environmental Region	MOUNTAIN	1	1	1	1	1	1	1	1
	Piedmont	1	1	1	1	1	2	1	3
	Coastal	1	1	1	2	1	1	1	1

Using data from the 1999 data collection season, all of the projects were evaluated using the network level cracking business process developed under a separate effort and outlined previously. Data were output in AASHTO and PCI format and a comparison was conducted.

Through the conduct of this study, it became quite clear that there were some fundamental technical problems that needed to be overcome. These problems had nothing to do with the AASHTO protocols per se, but rather with the data collection procedures and hardware on the data collection van. In spite of these problems, MD SHA staff were successful in completing the study and accomplishing the two primary goals. Pavement Management staff became proficient in the use of the crack detection software and network level crack detection business process, and gained an understanding of the format and use of the AASHTO cracking protocols. Due to the technical difficulties mentioned previously, the comparison between manual and automated surveys could not be carried out. Some of the lessons learned concerning the AASHTO protocols during this evaluation are as follows:

Sealed cracks are difficult for WX to handle. Either the program ignores the sealed portion entirely or it detects a crack around the periphery of the sealed portion, thus, in effect double counting the crack length. MD SHA worked with the manufacturer to try and remedy this issue; however the problem will remain for the foreseeable future.

WX does not have the capability to establish a zone between the wheelpath and the centerline as shown in Figure 1 (.125 m interval between the wheelpath and the between wheelpath zone).

Cracks less than 4 mm (1 pixel width) are very difficult to detect with WX. Therefore, very little low severity cracking will be detected using the AASHTO protocol criteria.

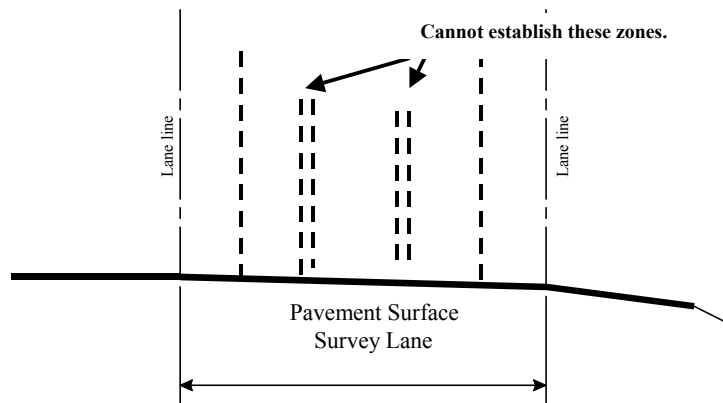


FIGURE 1 AASHTO definition of "Pavement Zones"

In spite of the obstacles encountered, MD SHA was very optimistic that the technical difficulties could be overcome and that the AASHTO protocols had shown promise as a method to report network level cracking information.

Phase 2. Benchmark Survey

After review of the results of the pilot study, a plan was developed to demonstrate that the ARAN vehicle could be used to generate accurate cracking data if all systems were working correctly. Thus, a cracking survey was performed on selected projects using the manufacturer's vehicle. The data were processed in-house and independently using the manufacturer's staff. In addition, an expert panel was convened to conduct a windshield survey to benchmark and verify the results. The goals of this study were as follows:

Benchmark the performance of WX and validate its potential to produce quality network level cracking data.

Verify that Maryland's process was viable based upon a comparison of results between manufacturer (experts) and MD data processing.

Verify AASHTO cracking protocol and PCI data processing scheme. Determine whether to use AASHTO or PCI as network level cracking indicator.

Verify cracking condition in the field versus results from WX.

Process

To conduct this study, 29 projects were selected. Because the manufacturer was conducting the data collection using their own equipment, these projects were geographically located in the central portion of the State in order to facilitate data collection in an efficient and cost-effective manner. The projects selected for this study are shown in Table 3 and represented approximately 220 miles. Data for these projects was collected in September 2000.

TABLE 3 Benchmark survey selected projects.

County	Route	Direction	Pavement Type ⁹	Begin MP	End MP
Baltimore	MD 45	N	F	3.13	8.85
Baltimore	MD 145	E	C	0	5.53
Baltimore	MD 146	N	F	9.24	11.64
Harford	MD 146	N	C	0	3.46
Harford	MD 152	S	F	17.34	8.05
Harford	US 1	N	F	2.67	6.13
Harford	MD 543	S	F	10.42	3.67
Harford	MD 136	N	F/C	2.39	16.41
Harford	MD 646	S	F	3.31	0.01
Harford	MD 543	N	F	15.92	19.06
Harford	MD 624	N	F	0	3.02
Harford	MD 136	S	C	21.64	19.15
Harford	MD 165	S	F/C	18.98	0
Harford	MD 165	N	F/C	0.0	18.98
Harford	MD 136	N	C	19.15	21.63
Harford	MD 624	S	F	3.02	1.29
Harford	MD 646	N	F	0	3.29
Harford	MD 136	S	F/C	16.41	2.60
Harford	MD 543	N	F	3.67	10.42
Harford	US 1	S	F	6.13	2.67
Harford	MD 152	N	F	8.05	17.35
Harford	MD 146	S	C	3.46	0

⁹ F = flexible, C = composite, F/C = combination

Baltimore	MD 146	S	F	11.64	9.24
Baltimore	MD 145	W	C	5.53	0
Baltimore	MD 45	S	F	8.85	3.12
Baltimore	MD 140	N	F	9.93	12.45
Carroll	MD 140	N	F/C	0	24.95
Carroll	MD 140	S	F/C	24.95	0
Baltimore	MD 140	S	F	12.45	9.86

The resulting data was collected and processed by MD SHA staff and by the manufacturer's staff independently. The results of this process were then compared to determine if the cracking data was consistent. After this analysis, a sub-section of eleven projects (approximately 11 miles) were selected for a field visit to verify the results. The projects selected for this phase are shown in Table 4.

TABLE 4 Selected projects - field verification.

County	Route	Direction	Pavement Type	Begin MP	End MP
Baltimore	MD 145	East	C	0.71	1.17
Baltimore	MD 145	East	C	2	3
Harford	MD 152	South	F	15.1	13.99
Harford	US 1	North	F	2.67	4.11
Harford	MD 165	South	C	13.61	11.8
Harford	MD 136	South	F	16.41	15.58
Harford	MD 136	South	F	15.07	14.44
Harford	MD 136	South	F	12.71	12
Carroll	MD 140	North	C	1.69	2.91
Carroll	MD 140	North	F	12.37	13.48
Carroll	MD 140	North	F	15.07	16.03

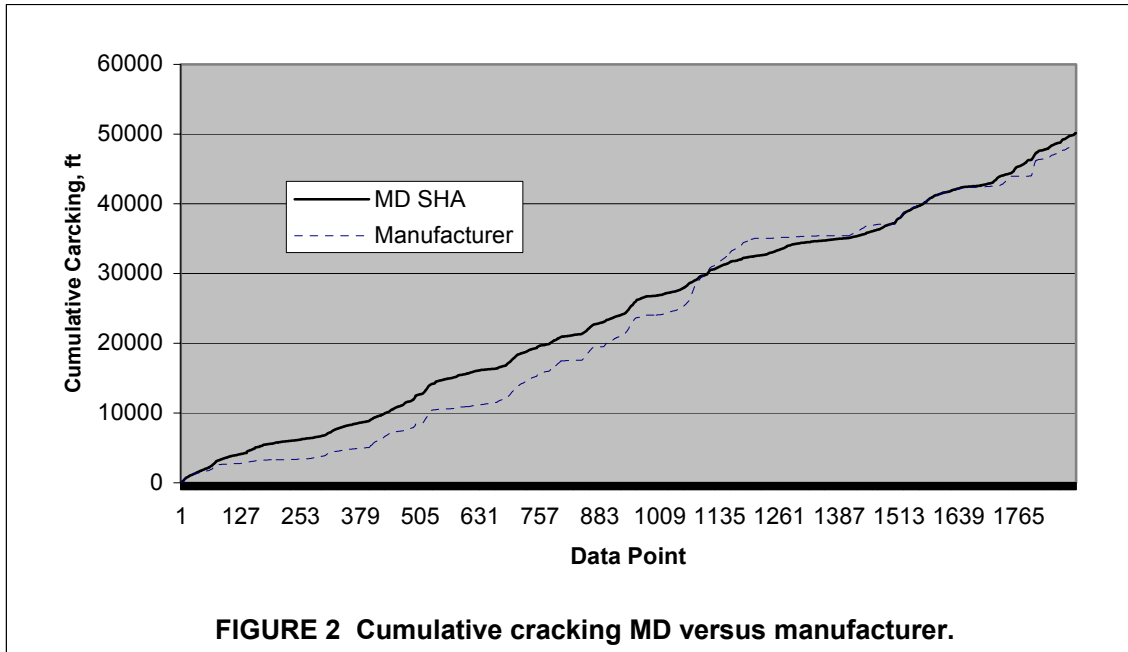
To facilitate this study, three individuals with extensive experience in pavement distress ratings were selected to perform the windshield surveys. The eleven sites were surveyed from the shoulder driving at approximately 5 miles-per-hour. Each section was divided into 1/10-mile increments and a rating was assigned by each team member for each segment. Each rater assigned a condition of Very Good, Good, Fair, Mediocre, or Poor. These ratings were then aggregated into a "consensus" rating.

Using the AASHTO cracking protocol methodology, crack condition levels were assigned to the data using an algorithm developed by MD SHA. The definition of the crack condition levels was identical to the field survey ratings (e.g. Very Good, Good, Fair, Mediocre, or Poor). In addition, the data was aggregated into the various pavement zones (within wheelpath, outside of wheelpath). The cracks found within the wheelpath were classified as fatigue cracks. Thus, two ratings were developed, one that just considered all cracking as longitudinal and transverse, and one ranking that used fatigue cracking along with longitudinal and transverse cracking.

MDSHA Versus Manufacturer Comparison

The data generated by MD SHA staff was compared with that generated by the manufacturer. For this comparison, only the total length of cracking was used as the use of additional criteria may have biased the comparison. From this analysis, it was determined that the Maryland process and the Roadware processes yielded similar results on a network basis. For the purposes of this paper, a detailed discussion of the results of this study is not warranted. In summary, Figure 2 illustrates cumulative cracking determined by each party. As can be seen by this figure, the total

cumulative cracking detected by each system is, for all intents and purposes, identical. This gave MD SHA confidence that the business process developed for network level cracking is feasible.



Automated Versus Field Survey Comparison

A comparison was made between the field and office ratings. This comparison was conducted for flexible pavements and composite pavements separately and summarized. The data were analyzed using field data as “truth.” Thereby, the office derived data was compared using a deviation methodology. Each result was compared to the field and its deviation was calculated. In this analysis, if the field data showed that the pavement was in “Good” condition and the office data determined that the pavement was in “Poor” condition, a deviation of three (3) was recorded. Likewise, if both methods indicated “Very Good,” a deviation of zero (0) was recorded, and so on. This comparison was conducted for all data collected and was summarized for Composite and Flexible pavement separately. Also, the method using longitudinal and transverse cracking was compared to the method that utilized fatigue cracking and long/trans cracking. Based upon this limited analysis, we could not reach a definitive conclusion on use of fatigue cracking in our methodology. The data set used contained very minimal cracking in the wheelpath and thus the jury is still out in this regard. This issue will be revisited when additional data are available. For the time being, Maryland will only use longitudinal and transverse cracking without regard for whether the cracking could be classified as fatigue. This greatly simplifies the crack rating process and is in line with the AASHTO cracking protocol. The results of this analysis are shown in table 5.

TABLE 5 Results of automated versus field comparison.

Type of Pavement	Long/Trans			Long/Trans/Fatigue		
	Within 1 Deviation	Within 2 Deviations	Within 3 Deviations	Within 1 Deviation	Within 2 Deviations	Within 3 Deviations
Composite	90%	98%	100%	81%	98%	100%
Flexible	98%	98%	100%	94%	98%	100%
Combined	94%	98%	100%	88%	98%	100%

The results for the scenario in which longitudinal and transverse cracking (no fatigue) were very encouraging, as it showed that 94% of the data was within one deviation from “truth.” Therefore, if the automated cracking procedure yielded a Very Good rating, the field data didn’t suggest that the pavement was indeed in Mediocre or Poor

condition. On the other hand, the classification scheme that included fatigue had only 88% within one deviation. These results influenced our decision to use only longitudinal and transverse cracking in the rating scheme.

Lessons Learned

These results gave the team a sense that the AASHTO cracking protocols could effectively be used to determine the network level crack condition of the network. However, it also became apparent that the AASHTO protocol needs to be extended in order to provide a cracking condition number or rating methodology for the network. At this point, only longitudinal and transverse cracking are considered when developing a condition rating. \

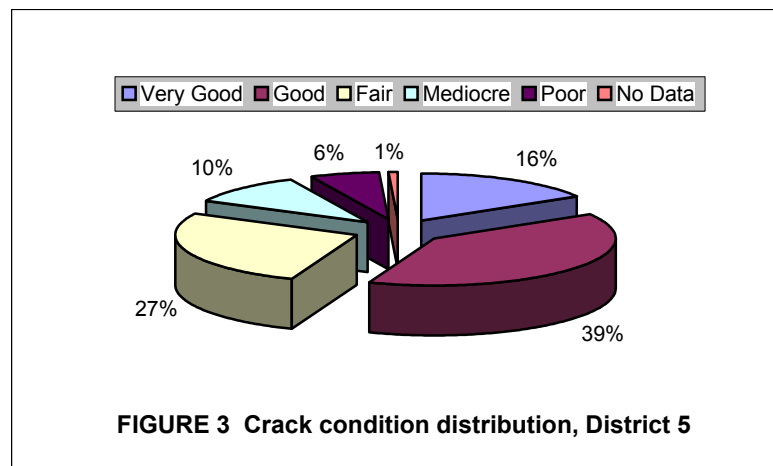
The current AASHTO protocol data summary specifications do not lend themselves easily to quantifying the condition of the pavement. The values produced are neither easy to understand nor intuitive. For this study, the AASHTO protocol outputs were converted into a numerical index and breakpoints used to establish a condition rating of Very Good, Good, Fair, Mediocre, or Poor.

We also learned that the PCI crack width definitions could NOT be used as a network level cracking indicator for automated distress surveys. The use of PCI is not warranted as this method does not provide enough “data dispersion,” since (due to the way the PCI method is structured) only one distress is effectively used (low severity longitudinal/transverse cracking). Therefore, PCI in its native state was not considered for further use at the network level.

Phase 3. Production Testing

As a final test of MD SHA automated crack detection procedures and a dry run of the implementation of these procedures for the 2001 data collection season, MD SHA staff performed a complete crack survey for one district. District five (5), consisting of four counties (Calvert, Charles, Saint Mary’s, and Anne Arundel) was used as the test case for this process. All of the data collected in 2000 was analyzed using the MD SHA business process and the AASHTO cracking protocol. The purpose of this study was to verify that a large amount of data could be processed in a timely fashion and yield accurate cracking data. The results were subsequently submitted to district personnel for their review and verification.

The results of this effort convinced MD SHA that the process put in place could effectively be used in a production environment. A summary of the results is presented in Figure 3. This figure shows a balanced condition distribution that seems reasonable based upon historical records and expert opinion within the State of Maryland. This study further validated the AASHTO protocols as the procedure of choice for performing network wide crack condition ratings. Further, these procedures have been put into place and are being used for the 2001 data collection season with successful results.



USEFULNESS OF PROTOCOL

The AASHTO cracking protocol was evaluated in a systematic and rational approach for more than one year. As a result of this evaluation several things were learned and a few suggestions for refinement are suggested. Overall, it is the MD SHA’s position that the protocol is suitable for use as a process to determine the network level crack condition for a state pavement network. The process adopted by MD SHA is not entirely compliant with the current AASHTO cracking protocol and will not be compliant for the foreseeable future due to hardware, software and policy

issues (see table 1). MD SHA will be working with the manufacturer of its equipment in an attempt to bridge the gaps that exist. However, presently the MD SHA procedure is well within the spirit of the protocol.

In the end, MD SHA does not use “pavement zones” in its pavement condition evaluation. For network level cracking, we have decided to only use the total amount of cracking within the section to derive the condition index. However, the pavement zone in which the cracking is found is stored in the database in case future analysis reveals the need for such data.

FACTORS FOR FURTHER EVALUATION

The technical committee developing the protocol should consider the following issues.

1. Wheelpath definitions. The current “buffer zone” between the wheelpaths and “area between wheelpaths” is probably not necessary and may be combined with the “area between wheelpaths.”
2. Crack width specifications. The current Maryland equipment cannot detect cracks smaller than 4 mm. Therefore, Maryland will have very little low severity cracking data. While this is seen as a manufacturer problem, the point needs to be made that not all equipment can currently meet this exacting specification without large increases in the resolution of digital/video images.
3. For MD SHA purposes, the location of the crack is not relevant; however we do store the crack location for potential future use.
4. Reflective cracking may need to be dealt with in a different way. We found that generally the condition of a composite pavement was not accurately reflected due to the nature of reflective cracks. The cracks may be small in length but they are quite damaging to the pavement structure as a whole. This is not accurately reflected in the current methodology used by Maryland. It is realized that the AASHTO protocol does not define reflective cracking we thought it bore mentioning for some consideration.
5. Development of condition indicator. The current output of the protocol is quite complex and is difficult to grasp as a condition state. As currently specified and shown in Table 6, a minimum 3 by 3 matrix is developed. In use by Maryland, a 3 by 6 matrix is developed. A process was developed by MD SHA to convert this matrix into a condition indicator of Very Good, Good, Fair, Mediocre, or Poor. This process is described below.

TABLE 6 Matrix developed using AASHTO protocol.

Severity Level	Outside WP	Inside WP	Between WP	Edge Crack Left	Edge Crack Right	Transverse
1 (Low)	Minimum AASHTO Matrix					
2 (Medium)						
3 (High)						

In order to convert the results of the AASHTO protocol to a condition indicator, MD SHA experimented with several different algorithms. In the end, the algorithm selected is derived by combining the AASHTO protocol with methods used in the development of the PCI (2) procedure. In this procedure, the cracking derived from the AASHTO procedure is summarized into total crack length for a given section consisting of severity levels of low, medium, and high (as determined by the AASHTO protocol). A deduct value is then determined using the density of cracking for each condition level and these values are adjusted and subtracted from 100 to determine the numerical rating. The numerical rating is then transformed into a condition rating. The deduct values and the condition indicator breakpoints are currently being refined by MD SHA but the overall process seems to work very well and yields an indicator that is reasonable and intuitive. With further study and refinement, a similar process may be adopted by the AASHTO protocol as an option for reporting pavement cracking data.

SUMMARY AND CONCLUSIONS

As part of a contract with the Federal Highway Administration (FHWA), the Maryland Department of Transportation, State Highway Administration, (MD SHA) evaluated AASHTO Protocol PP 44, “*Quantifying Cracks in Asphalt Surface Pavements*.” The objective of this project was to determine the effectiveness of the protocol as a procedure to collect, process, and report performance data for network pavement management needs.

The evaluation consisted of three primary activities including; (1) a pilot study to determine the feasibility of using the protocol, (2) a benchmark survey to ensure the results obtained were compatible with expert opinion, and (3) a production testing study in which a full evaluation of the protocols was conducted for a subsection of the pavement

network to determine the feasibility of using the procedure at the network level. **Overall it was determined that the protocol, with a few exceptions, can be used as a suitable procedure to detect, rate and classify cracks at the network level for MD SHA purposes.**

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