

**A CRITICAL ASSESSMENT OF JOINTED PLAIN CONCRETE PAVEMENT (JPCP)
USING SENSING TECHNOLOGY - A CASE STUDY ON I-285**

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ABSTRACT

Most of the Jointed Plain Concrete Pavement (JPCP) in Georgia was laid in the 1970s. The in-service JPCPs have carried significant traffic (e.g., more than 2 times of designed ESALs) and now are in need of concrete pavement restoration (CPR), such as broken slab replacement, grinding, and joint reseal. Detailed distress information, including crack type, length, severity level, and condition of adjacent slabs, are essential for determining CPR need at the slab-level and estimating the quantity (e.g., length of slab replacement). However, current manual survey cannot provide such detailed information, especially on multi-lane roadways with high traffic volumes. In this paper, a method is proposed to effectively identify the slabs that need to be replaced and accurately estimate their lengths using geo-referenced joint and distress information, especially crack patterns that can be extracted from 3D pavement data. A case study was conducted on a 1-mile section on I-285, one of Atlanta's most heavily traveled roadways. This section was built in 1968 as 10-in un-doweled JPCP with 30-ft joint spacing. It has lasted 45 years and carried more than 4 million ESALs. Detailed distress data, including joint location, crack type, and length was extracted from 3D pavement data and used to determine the CPR (e.g. 6-ft to 30-ft slab replacement) at the slab-level. The case study, using the actual pavement distress data on an interstate highway, demonstrated the proposed method is promising for developing an accurate, cost-effective, and safe CPR program.

INTRODUCTION

Most of the Jointed Plain Concrete Pavement (JPCP) in Georgia was laid in the 1970s. While the JPCPs in service have performed well, they have passed their design life and designed Equivalent Single Axle Load (ESALs); they are now in need of concrete pavement restoration (CPR) or reconstruction, which requires large capital investment. Detailed distress data, including joint location, crack type, extent, and severity level, are essential for reliably and accurately determine the slab-level JPCP treatment need and cost (1).

While the treatment is determined and applied on a slab basis, DOTs typically conduct condition evaluations at the segment (e.g., 1 mile) or project level in support of the project selection (2, 3). For example, the Georgia Department of Transportation (GDOT) has conducted an annual pavement condition evaluation on its JPCP using visual inspection in the field to identify and measure the presence, types, and severity levels of distresses since 1976 (4). Faulting at every 8th joint is measured using the Georgia Fault Meter, and distresses (e.g., number of broken slabs and number of slabs with longitudinal crack) are recorded for each mile. This information is used to support the project selection. However, the lack of detailed data at slab level poses challenges for developing a slab-level JPCP treatment plan (5–7). Therefore, GDOT's engineers follow up with a field inspection to determine the slabs to be treated and estimate the quantity based on, primarily, an engineering judgment. Such a task is unsafe, subjective, time-consuming, and labor-intensive, especially on heavily trafficked roadways. Hence, there is a need for an alternative means for effectively, reliably, and accurately determining slab-level treatment needs at the slab level based on detailed pavement condition assessments.

Because current manual and visual methods of surveying pavement distresses are difficult or even dangerous, especially on high-speed and high-volume roadways, more recently, some agencies have begun to adapt advanced sensing technology to streamline and standardize

the process of pavement condition assessment (8–11). In this paper, a method was proposed to model distress on JPCP at different levels (e.g., crack level and slab level) based on a multi-scale Crack Fundamental Element (CFE) model introduced by Tsai et al. (12) to support the determination of slab-level treatment need. A case study was conducted using actual data collected on I-285 to demonstrate the use of the proposed method for accurately and reliably determine slab-level CPR need.

This paper is organized as follows: this section introduces the research need and the objective. A proposed method for effectively and reliably determining slab-level treatment using a multi-scale CFE model to represent crack topological properties at different scales (e.g., distress level and slab level) is then introduced. A case study using actual data collected on a one-mile section on I-285 in Atlanta, is presented to demonstrate the capability of the proposed method. Lastly, conclusions and recommendations are presented.

PROPOSED METHOD

A method was proposed to determine a proper slab-level JPCP treatment using detailed, high-resolution 3D pavement profile data. The proposed method uses high-resolution 3D pavement data for extracting detailed crack properties and adopts the multi-scale CFE model to represent real-world joint and distress characteristics at different scales (e.g., distress level and slab level), which are essential for determining a slab-level treatment. The proposed method consists of four primary steps, including data acquisition, data processing, a multi-scale topological slab representation, and distress level and slab level classification application.

Data Acquisition

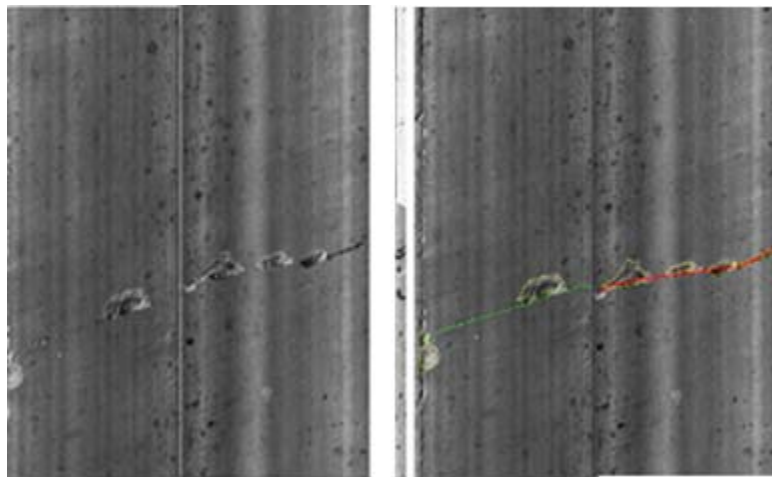
The first step is to collect high-resolution 3D pavement data on JPCP, which is necessary for measuring faulting, crack length, and severity. Georgia Tech's sensing vehicle (GTSV), as shown in Figure 1, equipped with a 3D line-laser-imaging system, GPS, cameras, and a high-resolution distance measurement instrument (DMI), was used to collect data on JPCP. With a line scan rate of 5,600 profiles per second, the system used on the sensing van can provide an interval of 5 mm (0.2-inch) in the longitudinal direction (travel direction) driving at up to 100 km/hr (62.5 mph) (13). On a 30ft slab on I-285, approximately 7.3 million 3D points can be collected; detailed distress information can be extracted from this set of data. The 3D pavement profile data can achieve a 0.5-mm resolution in the z-direction.



FIGURE 1 Georgia Tech's sensing van for collecting data.

Data Processing

The second step is to process the huge amount of raw sensing data to detect or extract the crack map with crack, joint, and spall. Current software collect data in similar manner, however data processing shows little promise when relying on outside software. The automatic detection of joints, cracks, and spalls in software result in high levels of error when comparing with semi-automatic processes. Therefore, an in-house program was developed to semi-automatically identify these objects using the high-resolution 3D pavement profile image. Figure 2(a) shows an example of the data acquired by 3D line laser imaging system, and results after a semi-automatic pavement distress identification data processing is performed, illustrated in Figure 2(b). As seen in Figure 2(b), the pavement cracks are identified by green and red lines and spalls by yellow polygons.



(a) 2D pavement surface

(b) Distress detection

FIGURE 2 An example of data collected by the 3D line laser imaging.

Multi-scale Topological Slab Representation using CFE Model

The third step is to adopt the multi-scale CFE model introduced by Tsai et al. (10, 12) to represent real-world crack and joint characteristics at different levels, including distress level and slab level, in support of a systematic slab-level treatment determination). In this study, three scales of crack properties (fundamental crack properties, aggregated crack properties, and CFE geometrical properties) were defined to intelligently and comprehensively mimic pavement engineers' evaluation of crack characteristics and patterns in real-world crack classification practice. A load cracking severity level classification application was developed to demonstrate the use of the multi-scale CFE model in support of crack type and severity level classification on asphalt pavement (10, 12). Figure 3 illustrates three levels of crack properties for the application.

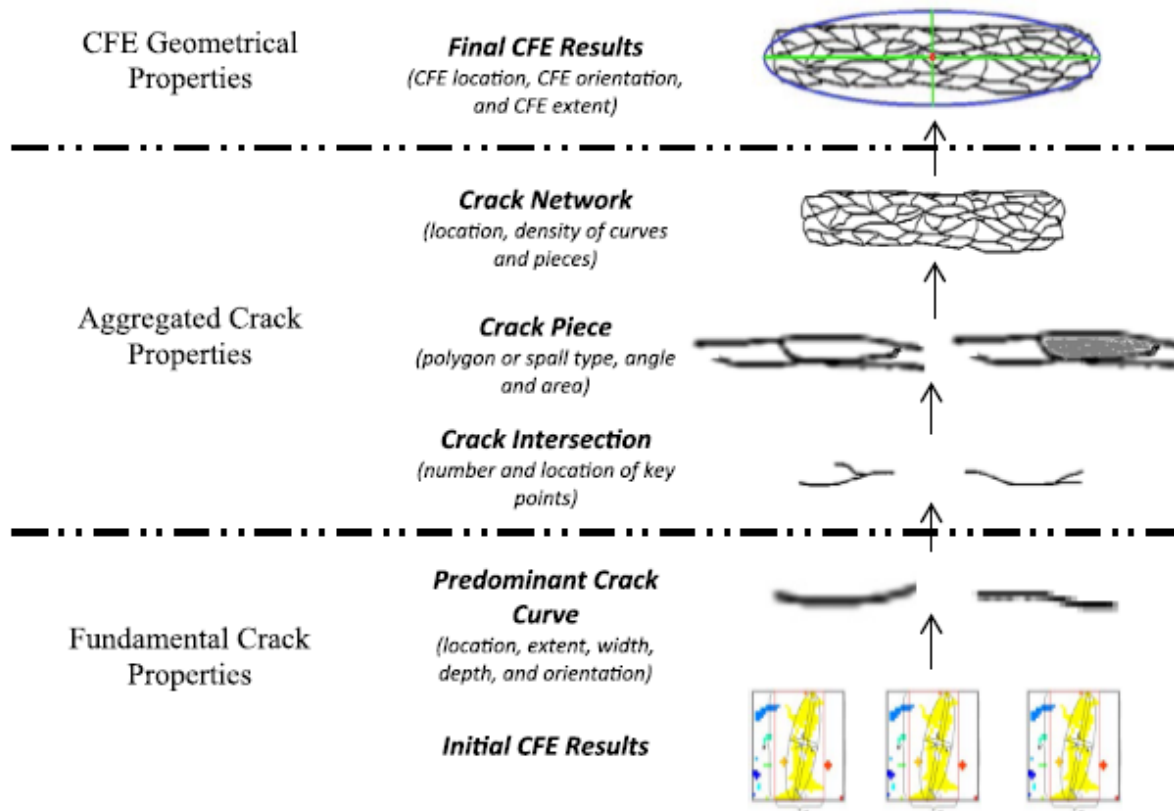


FIGURE 3 Multi-scale crack characteristics inside each CFE (10)

Distress & Slab Severity Level Classification Application

The fourth step in the proposed method is to apply defined rules and criteria to the multi-scale topological slab representation to determine distress/slab severity levels and slab treatment needs. This paper adopts GDOT's protocol and its engineers' inputs to formulate these rules for classification (11). Based on GDOT's protocols, faulting and crack width play an integral role in the severity level of distresses. GDOT's protocol for slab severity level considers spatial conditions of distresses as well as joint faulting. Distress classification incorporates fundamental and aggregated crack properties, while slab classification incorporates geometrical and aggregated properties.

CASE STUDY ON I-285

A case study was conducted using actual data collected on I-285 to demonstrate the proposed method can feasibly be used for determining slab-level JPCP treatment. This section of road was constructed in 1967 and opened to traffic in 1968. It was constructed with un-doweled, 10 inches of JPCP and a 30-ft joint spacing. The pavement design layers consisted of a 10" thick concrete layer, a 6" cement stabilized graded aggregate base, an 8" thick sub-base, followed by subgrade and bedrock shown in Figure 4. According to Georgia's State Traffic and Report Statistics (STARS), the average AADT between 1990 and 2010 is approximately 100,000 with a truck percentage of 12%.

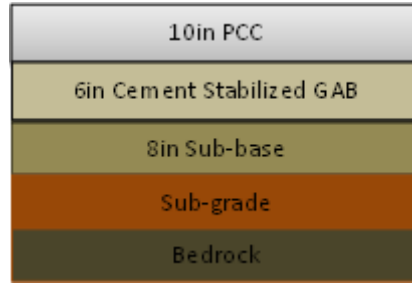


FIGURE 4 Pavement layer design on I-285.

Georgia Tech’s sensing vehicle was used to collect the data on a one-mile section, Milepost 12 and Milepost 13, at highway speed on Lane 3. Figure 5 shows the pavement condition at a specific location. Data collected and faulting measurements have been validated in a separate field test study. Applying the slab-level treatment model along the test section, automatic distress detection and multi-scaled CFE topology are summarized in a basic pavement condition assessment illustrated in Table 1.



FIGURE 5 Pavement condition on I-285.

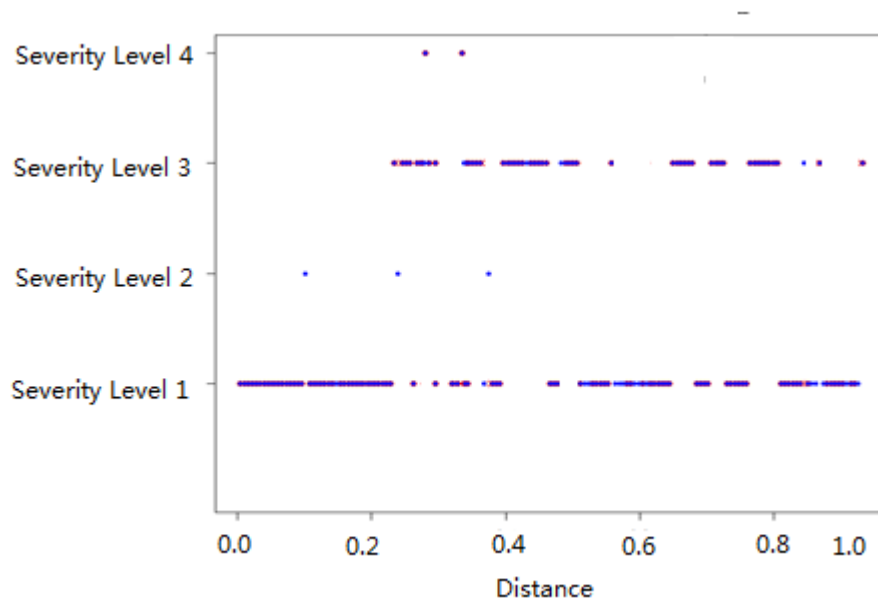
TABLE 1 Automatic Pavement Condition Assessment

Distresses	Measurement
Number of Slabs	171
Number of Longitudinal Cracks	79
Total Longitudinal Crack Length (ft.)	329.40
Number of Transverse Cracks	12
Total Transverse Crack Length (ft.)	62.21
Number of Corner Cracks	1
Average Faulting of Joints (in)	0.12

The distresses throughout the section can be further categorized at the slab-level. Applying the classification methodology for distresses and broken slabs, the severity levels of each slab can be determined, as shown in Table 2. It is determined that there are 69 slabs that require rehabilitation in which 2 slabs with severe distresses (e.g., require base replacement). The distribution of the severity level is shown in Figure 6. This geo-referenced joint and distress information can be used for identifying the location of CPR and estimating the quantity.

TABLE 2 Slab-Level Treatment Prioritization Model

Severity Level	Number of slabs
4	2
3	67
2	3
1	99

**FIGURE 6 Distribution of severity level.**

CONCLUSIONS AND RECOMMENDATIONS

State DOTs must accurately and reliably determine an effective slab-level JPCP treatment plan in response to budget constraints. This paper presents a method using 3D line laser imaging, GPS/GIS technologies, and crack fundamental elements to determine an effective slab-level JPCP treatment plan at highway speed, along with a case study using actual data on I-285.

The proposed method generates a pavement condition assessment to evaluate the type of treatment needed. Incorporating 3D line laser imaging and GPS/GIS technologies into the pavement condition assessment process has simplified but effectively identified distresses. Thus, a slab-level JPCP treatment planning can be developed. The method of slab-level classification shows that applying crack fundamental element model is used for supporting real world distress classification and standardized performance measurements (fundamental, aggregate, and geometrical distress properties).

The case study introduced the effectiveness of the proposed method, identifying 69 slabs that required slab replacement and 2 slabs that required preservation treatments. 89% slab-level treatments identified by the proposed method aligned with GDOT's treatment plan. Comparison of GDOT's treatment plan and the proposed method identify false positives and negatives that should be addressed to fine-tune the model. Results of the case study show that the proposed

method provides quantitative means with which state DOTs can effectively determine a slab-level treatment.

The slab-level treatment method is effective for identifying distresses and classifying slabs, however supplementary recommendations to improve the method are considered. Recommendations to improve the proposed method are to expand to a larger data set in different lanes, to incorporate spalled cracks and depth information to classify treatment methods, and to consider extracting existing JPCP repairs from sensing data. Future research, focus on distress deterioration rates, expansion on additional slab severity levels, spatial arrangements of slabs, prioritization and clustering, and cost optimization will be included in the analysis for determining a cost-effective slab-level JPCP treatment.

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