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16. Abstract

The artificial lighting system is a specially designed lighting device for the automated pavement distress measurement system (VCrack) developed in a previous TxDOT project. The basic function of this device is to provide intense, uniform, and linear illumination for the VCrack's line-scan camera and helps it grab high quality pavement images under any exterior lighting conditions. It consists of three major units: one 6-foot long central unit and two one-foot long wing units. Each unit utilizes three rows of red LED's, a cylindrical lens and two mirrors, forming a one-inch wide beam at a distance 16-inch. The energy consumption of the light bar is <250 watts, eliminating the need for a special generator. Along with a matching band pass filter, the lighting system enables the camera to avoid the variations of the ambient light, and to operate for nighttime surveys. It is eye-safe, durable, and easy to maintain.

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LINEAR LIGHTING SYSTEM FOR AUTOMATED PAVEMENT DISTRESS MEASUREMENT

Bugao Xu

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1. Introduction

An automated pavement distress rating system was developed under Texas Department of Transportation (TxDOT) Research Project 7-4975 in the past several years. The system now can scan 100 percent pavement surfaces, at any vehicle speed between 5 and 70 miles per hour, detect cracks at real time, and transmit the rating results to the central computer at a given distance interval (per station or per 0.1 mile). Currently, the system uses natural light for simplicity and energy conservation. Although the system can grab analyzable images under a wide range of lighting conditions (cloudy or sunny), natural light causes two problems for the system. One is that cracks detected under different lighting conditions are less consistent than those in similar conditions. The other problem is that the system has difficulty differentiating shadows of external objects (e.g., passing vehicles, trees, and wires) from sealed cracks or patches. Artificial lighting is the ultimate solution for eliminating all shadows in the image and for improving the data uniformity across different weather conditions.

The objective of this research is to develop a low power, linear light source that matches the need of the line scan camera used in the system. The light source should form a 0.25- to 1-inch-wide stripe covering the pavement width up to 12 feet at a height of 6 feet or under. The lighting intensity should give sufficient illumination for night scanning, and the energy consumption should not require a designated power supply. The system should be able to automatically turn the light source on or off based on the conditions of the natural light and shadows. The light source should be compact, light, and safe for operations.

2. Prototypes

Three different approaches of generating linear light source were implemented using halogen lamps, laser line projectors, and LED arrays. As a result, three prototypes of lighting devices were developed for performance tests.

2.1. Halogen Light with Specially-Designed Reflector

The researchers chose a 300-watt halogen lamp as a light source and designed an ellipsoidal, cylindrical reflector to focus the lights to form a 1.5-inch-wide beam at a working distance of 20 inches (Figure 2.1). Three units of such a device are needed to cover a 12-foot-wide pavement.

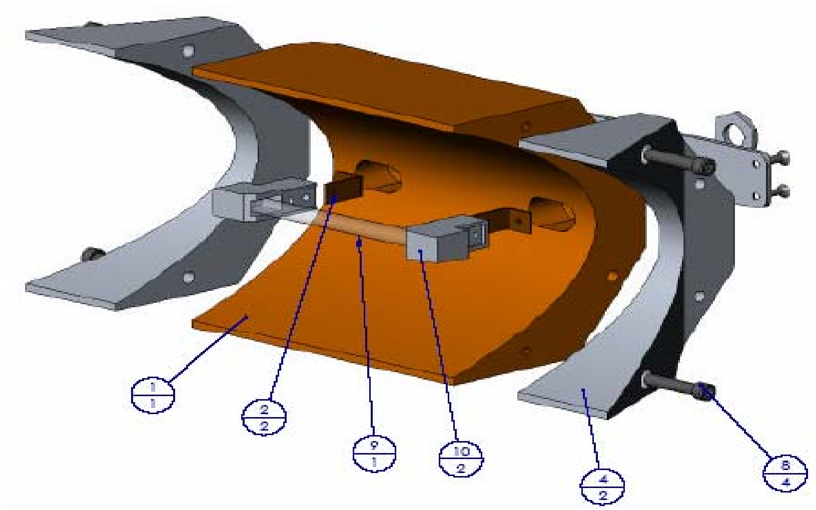

Figure 2.1 Halogen Light Device

2.2. High Power Laser Line Projector

The researchers chose a 2-watt laser line generator that can form a 0.25” wide beam and cover a 6-foot-wide pavement at a working distance of 6 feet (Figure 2.2). For full lane pavement inspection, two units were required.

Figure 2.2   Laser Line Projector

2.3.   High Intensity LED Array

An array of LED diodes was mounted behind a cylindrical lens to form an inch-wide beam (Figure 1.3). One unit consists of 40 LED diodes, which can cover 1.5 feet in distance at a working distance of 16 inches. Multiple units are aligned together to form a beam up to 10 feet.

Figure 2.3   LED Linear Lighting Unit

Both the halogen lighting device and the laser projector are compact in size and can project a long beam on the pavement. Two units of these devices can cover the scanned width of the pavement, but the halogen light consumes high energy (300 watts per unit), and the laser projector is not eye safe. Additionally, it is difficult to maintain the alignment of the laser line with the line scan camera. The LED device consumes 30 watts per unit. The total energy consumption for a pavement survey vehicle is less than 250 watts. The narrow bandwidth of the laser light also permits blockage of most visible light.

3. Field Tests

Figure 3.1 shows a TxDOT pavement survey vehicle used for a project level test. The vehicle houses the VCrack system, the LED lighting bar and other auxiliary devices, such as a distance measurement instrument (DMI) and a GPS unit, which provide the current travel distance and geographic location of the vehicle.

Figure 3.1 TxDOT Pavement Survey Vehicle

The tests were performed on FM 1625, FM 2001 and VC 2001, both in the daytime and nighttime, on April 27–29, 2005. The daytime weather was sunny. Figure 3.2 displays pavement images captured in the daytime and nighttime. There was no significant difference in these two images due to the uniform and stable illumination provided by the light bar to the camera. The VCrack system was able to generate highly consistent images even if the natural light changed from daytime to nighttime.

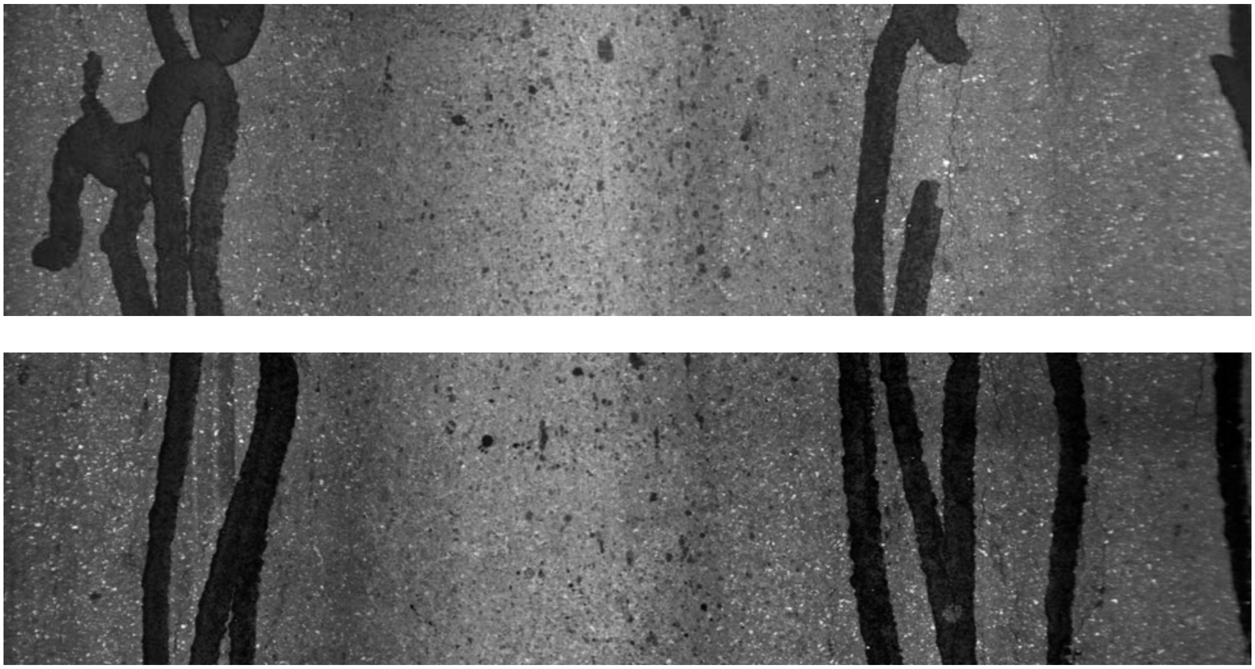

Figure 3.2 Daytime Image (top) and Nighttime Image (bottom)

The vehicle inspected the selected pavements in three lighting conditions: light-bar-off in daytime (K1), light-bar-on in daytime (K2), and light-bar-on in nighttime (K3). Under each lighting condition, the pavements were inspected three times (a, b, and c). Figure 3.3 presents the alligator cracking data of FM 1625. It is clear that only when the light bar was on (K2 and K3), the cracking data were repeatable and reproducible. The correlation coefficients of the six light-bar-on runs are all above 0.98. Because tree shadows distorted alligator cracks in the pavement images, the VCrack could not output repeatable and accurate measurements when the light bar was off (K1).

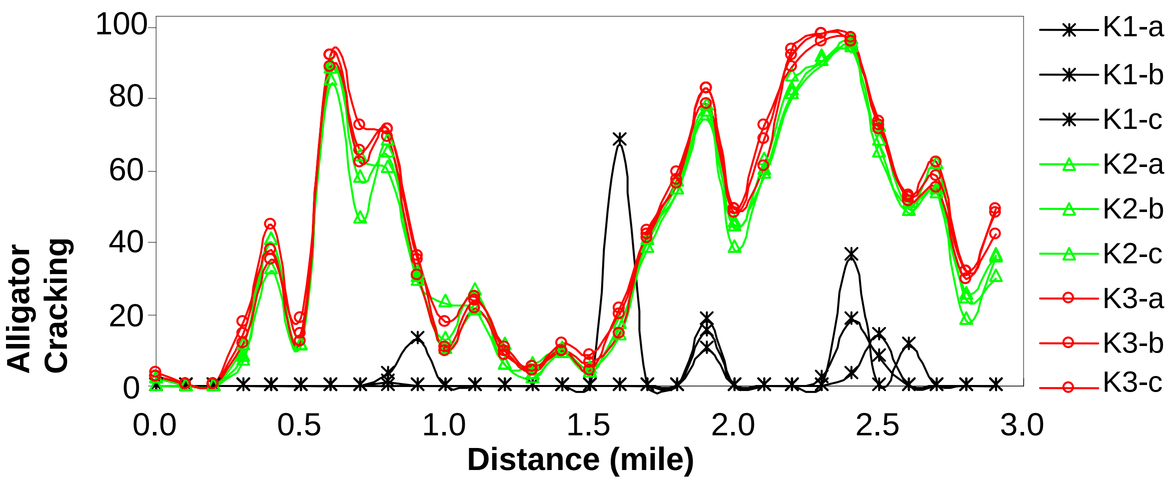

Figure 3.3 Comparisons of the Cracking Data Collected under Different Lighting Conditions

4. Summary

The light bar provides a consistent lighting condition to the camera so that the VCrack system can:

- Minimize the effects of change in cloudiness, vehicle driving direction, survey time, etc.
- Eliminate shadows of vehicles and roadside objects.
- Detect alligator cracks on dark pavements more reliably.
- Enable the vehicle to maintain more constant speeds.
- Reduce adjustments of camera scanning rates needed to accommodate changes in pavement condition.
- Perform the survey in nighttime.

Ultimately, the light bar greatly improves the repeatability and accuracy of the measurement data. Figure 3.3 shows the alligator cracking data of an FM pavement in six repeated surveys conducted from morning to midnight. A project level test proved that the use of the light bar can increase the correlations of the cracking data of multiple runs from under 0.8 to above 0.9. The light bar enables TxDOT to collect time-independent and weather-invariant cracking data.