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Standard Test Method for Evaluating Asphalt-Covered Concrete Bridge Decks Using Ground Penetrating Radar[1]

This standard is issued under the fixed designation D 6087; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

~~1.1This test method covers several radar evaluation procedures that can be used to evaluate the condition of concrete bridge decks overlaid with asphaltic concrete wearing surfaces. Specifically, this test method predicts the presence or absence of concrete or rebar deterioration at or above the level of the top layer of reinforcing bar.~~

~~1.2Deterioration in concrete bridge decks is manifested by the corrosion of embedded reinforcement or the decomposition of concrete, or both. The most serious form of deterioration is that which is caused by corrosion of embedded reinforcement. Corrosion is initiated by deicing salts, used for snow and ice control in the winter months, penetrating the concrete. In arid climates, the corrosion can be initiated by chloride ions contained in the mix ingredients.~~

1.1 This test method covers several ground penetrating radar (GPR) evaluation procedures that can be used to evaluate the condition of concrete bridge decks overlaid with asphaltic concrete wearing surfaces. These procedures can also be used for bridge decks overlaid with portland cement concrete and for bridge decks without an overlay. Specifically, this test method predicts the presence or absence of concrete or rebar deterioration at or above the level of the top layer of reinforcing bar.

1.2 Deterioration in concrete bridge decks is manifested by the corrosion of embedded reinforcement or the decomposition of concrete, or both. The most serious form of deterioration is that which is caused by corrosion of embedded reinforcement. Corrosion may be initiated by deicing salts, used for snow and ice control in the winter months, penetrating the concrete. In arid climates, the corrosion can be initiated by chloride ions contained in the mix ingredients. Deterioration may also be initiated by the intrusion of water and aggravated by subsequent freeze/thaw cycles causing damage to the concrete and subsequent debonding of the reinforcing steel with the surrounding compromised concrete.

1.2.1 As the reinforcing steel corrodes, it expands and creates a crack or subsurface fracture plane in the concrete at or just above the level of the reinforcement. The fracture plane, or delamination, may be localized or may extend over a substantial area, especially if the concrete cover to the reinforcement is small. It is not uncommon for more than one delamination to occur on different planes between the concrete surface and the reinforcing steel. Delaminations are not visible on the concrete surface. However, if repairs are not made, the delaminations progress to open spalls and, with continued corrosion, eventually affect the structural integrity of the deck.

1.2.2 The portion of concrete contaminated with excessive chlorides is generally structurally deficient compared with non-contaminated concrete. Additionally, the chloride-contaminated concrete provides a pathway for the chloride ions to initiate corrosion of the reinforcing steel. It is therefore of particular interest in bridge deck condition investigations to locate not only the areas of active reinforcement corrosion, but also areas of chloride-contaminated and otherwise deteriorated concrete.

1.3 This test method may not be suitable for evaluating bridges with delaminations that are localized over the diameter of the reinforcement, or for those bridges that have cathodic protection (coke breeze as cathode) installed on the bridge or for which a conductive aggregate has been used in the asphalt (that is, blast furnace slag). This is because metals are perfect reflectors of electromagnetic waves, since the wave impedances for metals are zero.

~~1.4The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses are for information only.~~

~~1.5~~

1.4 A precision and bias statement has not been developed at this time. Therefore, this standard should not be used for acceptance or rejection of a material for purchasing purposes.

1.5 The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility*

[1] This test method is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.32 on Bridges and Structures.

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of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Specific precautionary statements are given in Section 5.

~~1.6A precision and bias statement has not been developed at this time. Therefore, this standard should not be used for acceptance or rejection of a material for purchasing purposes.~~ .

2. Summary of Test Method

2.1 The data collection equipment consists of a short-pulse ~~ground penetrating radar~~ GPR device, data acquisition device, recording device, and data processing and interpretation equipment. The user makes repeated passes with the data collection equipment in a direction parallel or perpendicular to the centerline across ~~an asphalt-covered~~a bridge deck at specified locations. Bridge deck condition is quantified based on the data obtained.

3. Significance and Use

3.1 This test method provides information on the condition of concrete bridge decks overlaid with asphaltic concrete without necessitating removal of the overlay, or other destructive procedures.

3.2 This test method also provides information on the condition of bridge decks without overlays and with portland cement concrete overlays.

3.3 A systematic approach to bridge deck rehabilitation requires considerable data on the condition of the decks. In the past, data has been collected using the traditional methods of visual inspection supplemented by physical testing and coring. Such methods have proven to be tedious, expensive, and of limited accuracy. Consequently, ~~radar~~GPR provides a mechanism to rapidly survey bridges in an efficient, non-destructive manner.

3.~~3~~4 Information on the condition of asphalt-covered concrete bridge decks is needed to estimate bridge deck condition for maintenance and rehabilitation, to provide cost-effective information necessary for rehabilitation contracts.

~~3.4Ground penetrating radar~~3.5 GPR is currently the only non-destructive method that can evaluate bridge deck condition on bridge decks containing an asphalt overlay.

4. Apparatus

4.1 *~~Radar~~GPR System*—There are two categories of ~~radar~~GPR systems, depending on the type of antenna utilized for data collection.

4.1.1 ~~Radar control units capable of driving air-launched horn antennas with center frequencies 1 GHz and greater. The control units must operate at a transmit rate sufficient to collect 20 scans/m (6 scans/ft). The equipment may consist of an air-coupled, short-pulse monostatic or bistatic antenna(s) with sufficient center frequency to provide the accurate measurement of a 5 cm (2 in.) thick asphalt pavement.~~ GPR systems using air-launched horn antennas with center frequencies 1 GHz and greater. The equipment may consist of an air-coupled, short-pulse monostatic or bistatic antenna(s) with sufficient center frequency to provide the accurate measurement of a 5 cm (2 in.) thick asphalt pavement.

4.1.2 ~~Radar control units capable of driving ground-coupled antennas with central frequencies greater than 1 GHz. The control units must operate at a transmit rate sufficient to collect 80 scans/m (24 scans/ft).~~ GPR systems using ground-coupled antennas with central frequencies greater than 1 GHz.

4.2 *Data Acquisition System*—A data acquisition system, consisting of equipment for gathering ~~radar~~GPR data at the minimum data rates specified in 4.1.1 and 4.1.2. The system shall be capable of accurately acquiring ~~radar~~GPR data with a minimum of 60-dB dynamic range.

4.3 *Distance Measurement System* —A distance measurement system consisting of a fifth-wheel or appropriate distance measurement instrument (DMI) with accuracy of ±100 mm/km (±6.5 in./mile) and a resolution of 25 mm (1 in.).

~~4.4*Test Vehicle*— A vehicle with all equipment necessary to perform the test and proper warning and safety devices installed.~~

NOTE 1—Fig. 1 shows a functional block diagram for multiple ~~radars~~GPRs and support equipment.

5. Hazards

~~5.1During operation of the radar system, observe the manufacturer's safety directions at all times. When conducting inspections, ensure that appropriate traffic protection is utilized in accordance with accepted standards.~~

5.1 During operation of the GPR system, observe the manufacturer's safety directions at all times. When conducting inspections, ensure that appropriate traffic protection is utilized in accordance with accepted standards.

5.2 Electromagnetic emissions from the GPR apparatus, if the system is improperly operated, could potentially interfere with commercial communications, especially if the antenna is not properly oriented toward the ground. Ensure that all such emissions from the system comply with Part 15 of the Federal Communications Commission (FCC) Regulations.

6. Procedure

6.1 *Conditions for Testing*:

6.1.1 If soil, aggregate, or other particulate debris is present on the bridge deck surface, clean the bridge deck.

6.1.2 Test the bridge deck in a surface dry condition.

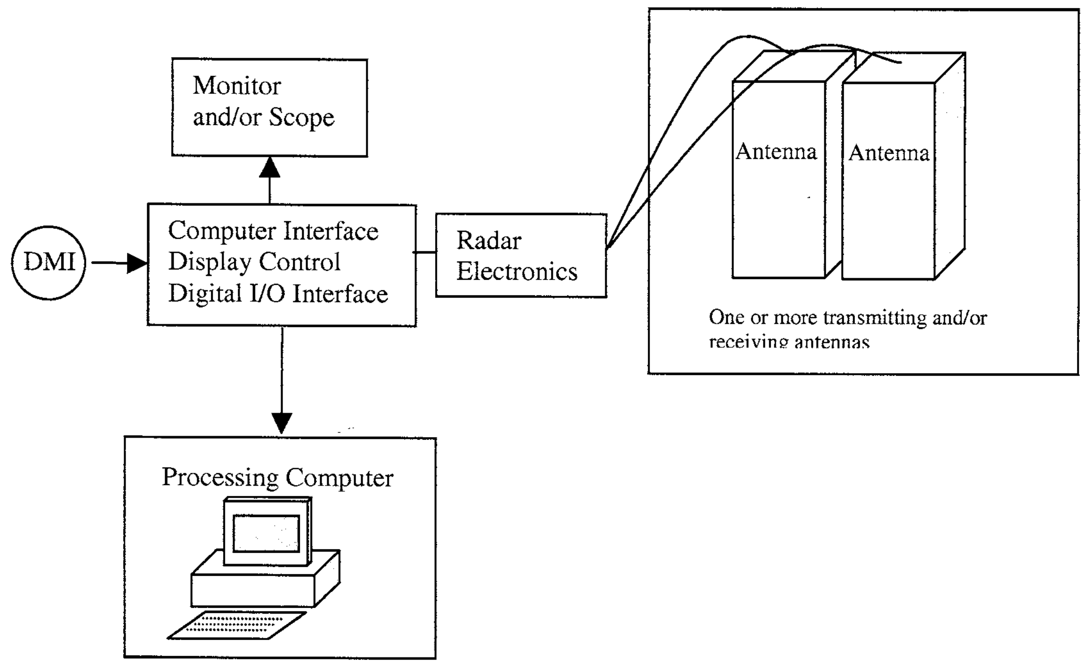

FIG. 1 Block Diagram of GP~~Radar~~ and Support Equipment

6.2 *System Performance Compliance* ~~—Conduct a test on the radar equipment to ensure proper performance, at least once per year, or after periods of prolonged storage, or in accordance with manufacturer's recommendations. For air-launched antennas, this test shall consist of the following:~~ —The system should be calibrated and performance verified in accordance with the manufacturer's recommendations and specifications. The following information is included for reference only and describes typical calibration procedures for different types of systems. Compliance with the following procedures is not required and the manufacturer's calibration procedure takes preference. For air-launched antennas, this test shall consist of the following:

6.2.1 *Signal-to-Noise Ratio*:

6.2.1.1 *Signal-to-Noise Ratio Test* —Position the antenna at its far field distance approximately equal to maximum dimension of antenna aperture above a square metal plate with a width of 4× antenna aperture, minimum. Turn on the ~~radar~~GPR unit and allow to operate for a 20-min warm-up period or the time recommended by the manufacturer. After warming up the unit, record 100 waveforms. Then evaluate the recorded waveform for signal-to-noise ratio. The signal-to-noise ratio is described by the following equation:

$$\frac{\text{Signal Level } (A_{mp})}{\text{Noise Level } (A_n)} > 20 \ (26.0 \ dB) \tag{1}$$

6.2.1.2 This will be performed on each of the 100 waveforms and the average signal-to-noise value of the 100 waveforms will be taken as the "signal-to-noise of the system." Noise voltage (A_n) is defined as the maximum amplitude occurring between metal plate reflection and region up to 50 % of the time window after the metal plate reflection, normally used with the antenna (that is, 1.0 GHz/20 ns: 10 ns.). The signal level (A_{mp}) is defined as the amplitude of the echo from the metal plate.

6.2.1.3 The signal-to-noise ratio test results for the GPR unit should be greater than or equal to 20 (+26.0 dB).

6.2.2 *Signal Stability*:

6.2.2.1 *Signal Stability Test*—Use the same test configuration as described in the signal-to-noise ratio test. Record 100 traces at the maximum data acquisition rate. Evaluate the signal stability using the following equation:

$$\frac{A_{max} - A_{min}}{A_{avg}} < 0.01 \ (1 \ \%) \tag{2}$$

where:

A_{max} = the maximum amplitude of the metal plate reflection for all 100 traces,
A_{min} = the minimum amplitude of the metal plate reflection for all 100 traces, and
A_{avg} = the average trace amplitude of all 100 traces.

6.2.2.2 The signal stability test results for the GPR system should be less than or equal to 1 %.

6.2.3 *Linearity in the Time Axis and Time Window Accuracy*:

6.2.3.1 *Variations in Time Calibration Factor*—Use the same test configuration as described in the signal-to-noise ratio test, except that the metal plate can be replaced by any reflecting object. Collect a single waveform and measure the distance from the antenna to the reflector. Perform this test at three different distances corresponding to approximately 15, 30, and 50 % of the time