AASHTO Provisional Standard

Standard Test Method For Evaluating Asphalt-Covered Concrete Bridge Decks Using Pulsed Radar

AASHTO Designation TP36
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This is Edition 1A of the provisional standard (PS) based on the technical substance provided by the Strategic Highway Resarch Program (SHRP) researchers. The PS was collated and formatted jointly by the AASHTO and SHRP staffs.

This PS is being referred to the AASHTO Subcommittee on Materials (SOM) for a review, ballot and approval. If the approval process produces changes, an amended version of the PS shall be published as the second edition.

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Standard Test Method for
Evaluating Asphalt-Covered
Concrete Bridge Decks Using Pulsed Radar

AASHTO Designation: TP36[1]

1. Scope

1.1 This test method covers a procedure for noninvasive evaluation of the condition of concrete bridge decks overlaid with asphaltic concrete wearing surfaces using ground-penetrating, pulsed radar.

1.2 Specifically, the method predicts the presence or absence of delaminations (fracture planes) associated with the top and bottom reinforcing steel mats.

1.3 This test method may not be suitable for evaluating pavement containing an abnormally shallow reinforcement cover. Abnormally shallow reinforcement cover can produce distortions that interfere with the detection of delaminations at the level of the top reinforcement mat, especially if the concrete deck is unusually dry.

1.4 The values stated in SI units are to be regarded as the standard.

1.5 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Summary of Test Method

2.1 A vehicle equipped with a system of ground penetration radar, data acquisition devises, and recording devices makes repeated passes parallel to centerline across an asphalt covered bridge deck at specified locations. Delamination of the deck concrete 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.

3.2 Information on the condition of asphalt covered concrete bridge decks is needed to estimate service life, to program rehabilitation and maintenance activities, and to estimate quantities for rehabilitation contracts.

4. Apparatus

4.1 Radar System - Air-coupled, short pulse radar(s) with 1.0 ns monocycle pulse 150 mm (6in.) free space resolution and 50 scan/second data rate, minimum.

4.2 Data Acquisition System - A data acquisition system, consisting of equipment for gathering radar data at the maximum data rate of the radar system(s), 50 kHz for one radar, 100 kHz for two radars, and 150 kHz for three radars. The system shall be capable of accurately acquiring radar data with a 60 dB dynamic range.

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1. This standard is based on SHRP Product 2015.

4.3 Distance Measurement System - A distance measurement system consisting of a marker wheel or equivalent with accuracy of ±80 mm (±3 in.) per kilometer.

4.4 Test Vehicle - a vehicle with all equipment necessary to perform the test and proper warning and safety devices installed.

> Note--Figure 1 shows a functional block diagram for one arrangement of the radar and support equipment. Realtime digital data acquisition and high-speed radar signal processing equipment and software have been designed around the **Penetradar Model PS-24** radar system to meet the needs of this test method. [1] Information regrading availability, use, or licensing, may be obtained from:
>
> **Penetradar Corporation, 2221 Niagara Falls Boulevard, P. O. Box 246, Niagara Falls, NY 14304, (716) 731-4369.**

5. Hazards

5.1 When operating a radar system, observe the manufacturer's safety directions at all times.

6. Procedure

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

6.2 Test the bridge deck in a surface dry condition.

6.3 Make radar inspection passes in a longitudinal direction parallel to the centerline of the bridge deck with the antenna mounted to maintain a distance of 225mm ±75mm (9in. ±3 in.) from the bridge deck surface.

6.4 Use a transverse distance (d_t) between radar inspection passes $\leq$ 1m (3ft.).

6.5 Use a longitudinal distance (d_l) between radar scans $\leq$ 150 mm (6 in.).

6.6 Conduct deck inspections when no visible moisture is present on the bridge deck surface and in areas where there is no accumulated soil, antiskid material, or other particulate debris.

6.7 Conduct tests for delamination at the top reinforcing steel as follows.

6.7.1 Measure and record the applied signal strength, $V_{i,}$ at the deck surface.

6.7.2 Measure and record the maximum signal strength of the deck bottom echo, $V_{bs.}$

6.7.3 If $V_{bs} \geq 0.0264\, V_i$ for a longitudinal radar inspection pass, proceed to section 6.7.6. (The number 0.0264 is a constant derived from research data).

6.7.4. If $V_{bs} < 0.0264\ V_i$ for a longitudinal radar inspection pass, repeat the test beginning with 7.1.

6.7.5 If $V_{bs} < 0.0264\ V_i$ after repeating the longitudinal radar inspection pass, the data is not reliable for determining removal quantities of bridge deck concrete. Withdraw this inspection pass data from further calculations and record the reason.

6.7.6 Measure and record the amplitude of the deck bottom echo, V_b, for each waveform.

6.8 Conduct tests for delamination at the bottom reinforcing steel as follows.

6.8.1 Measure and record the amplitude of the bottom reinforcing steel signal, V_{rb}.

6.9. Conduct tests for delamination existing simultaneously at both top and bottom reinforcing steel as follows.

6.9.1 Perform the measurements and recording specified in both section 7.7 and section 7.8.

7. Calculations

7.1 Determine delaminations at the top reinforcing steel as follows.

7.1.1 Consider the concrete delaminated if:

$$V_b \leq 0.385\ V_{bs}$$

where:

V_b = bottom echo amplitude, each scan

V_{bs} = bottom echo maximum signal, all scans

0.385 = a constant derived from research data

7.1.2 Calculate the percent delaminated at the top steel in each radar inspection pass using the following fomula.

$$X_{tn} = [(W_{dt} / W_{dt} + W_{st})][100]$$

where:

X_{tn} = percent delaminated in a radar inspection pass, n, at top steel

n = radar inspection pass identification number

W_{dt} = concrete delaminated at top steel, m

W_{st} = sound concrete at top steel, m

and:

$$W_{dt} = \sum (V_b \leq 0.385 V_{bs})(d_1)$$
$$W_{st} = \sum (V_b > 0.385 V_{bs})(d_1)$$

where:

d_l=longitudinal distance between radar scans, m

7.1.3 Calculate the estimated quantity of deck delaminated at top steel for each radar inspection pass using the following formula.

$$Q_t = (X_{tn})(L_n)(d_t)$$

where:

Q_t = m^2 of deck delaminated at top steel

L_n = length of radar inspection pass n, m

d_t = transverse distance between radar inspection passes, m

7.1.4 Calculate the total estimated quantity of deck delaminated at top steel using the following formula.

$$Q_{Tt} = \Sigma Q_t$$

where:

Q_{Tt} = total m^2 of deck delaminated at top steel for all radar inspection passes

7.2 Determine delaminations at bottom reinforcing steel as follows.

7.2.1 Calculate the mean value for the bottom reinforcing steel signal for each longitudinal radar pass using the following formula.

$$V_{avg} = \{(\Sigma V_{rb}) / [(L) / (d_l)]\}$$

where:

V_{avg} = mean value for bottom steel signal
V_{rb} = value for bottom steel signal, each scan

7.2.2 Consider the concrete delaminated if:

$$V_{rb} > 1.5V_{avg}$$

where:

1.5 = a constant derived from research data

7.2.3 Calculate the percent delaminated at bottom steel in each radar inspection pass using the following formula.

$$X_{bn} = [(W_{db})/(W_{db} + W_{sb})][100]$$

where:

X_{bn} = percent delaminated in a radar inspection pass, n, at bottom steel
n = radar inspection pass identification number
W_{db} = concrete delaminated at bottom steel, m
W_{sb} = sound concrete at bottom steel, m

and:

$$W_{db} = \sum(V_{rb} > 1.5V_{avg})(d_l)$$
$$W_{sb} = \sum(V_{rb} < 1.5V_{avg})(d_l)$$

where:

d_l = longitudinal distance between radar scans, m

7.2.4 Calculate the estimated quantity of deck delaminated at bottom steel for each radar inspection pass using the following formula.

$$Q_b = (X_{bn})(L_n)(d_t)$$

where:

Q_b = m^2 of deck delaminated at bottom steel

L_n = length of radar inspection pass n, m

d_t = transverse distance between radar inspection passes, m

7.2.5 Calculate the total estimated quantity of deck delaminated at bottom steel using the following formula.

$$Q_{Tb} = \Sigma Q_b$$

where:

Q_{Tb} = total m^2 of deck delaminated at bottom steel for all radar inspection passes

7.3 Determine delaminations existing simultaneously at both top and bottom reinforcing steel as follows.

7.3.1 Calculate the percent delaminated at both top and bottom steel in each radar inspection pass using the following formula.

$$X_{t \cap bn} = [(W_{dt \cap b})/(W_{dt \cap b} + W_{st \cap b})][100]$$

where:

$X_{t \cap bn}$ = percent delaminated in a radar inspection pass, n, at both top & bottom

n = radar inspection pass identification number

$W_{dt \cap b}$ = concrete delaminated at both top & bottom steel, m

$W_{st \cap b}$ = concrete not delaminated at both top and bottom steel, m

and:

$$W_{dt \cap b} = (\Sigma R_{dt \cap b})(d_l)$$

$$W_{st \cap b} = (\Sigma R_{Tforn} \Sigma R_{dt \cap b})(d_1)$$

where:

$R_{dt \cap b}$ radar scan indicating delamination at both top and bottom steel; i.e. a radar scan that satisfies the conditions

$$V_b \leq 0.385 V_{bs} \text{ and } V_{rb} > 1.5 V_{avg}$$

and:

$R_{T\ for\ n}$ = total radar scans for radar inspection pass, n, determined by the formula

$R_{Tfor\ n} = (L_n)/(d_l)$

7.3.2 Calculate the estimated quantity of deck delaminated at both top and bottom steel for each radar inspection pass, n, using the following formula.

$$Q_{t \cap b} = (X_{t \cap bn})\ (L_n)(d_t)$$

where:

$Q_{t \cap b}$ = m^2 of deck delaminated at both top and bottom steel

L_n = length of radar inspection pass n, m

d_t = transverse distance between radar inspection passes, m

7.3.3 Calculate the total estimated quantity of deck delaminated at both top and bottom steel using the following formula.

$$Q_{Tt \cap b} = \Sigma Q_{t \cap b}$$

where:

$Q_{Tt \cap b}$ = total m^2 of deck delaminated at both top and bottom steel for all radar inspection passes

8. Report

8.1 Report as a minimum, the following:

8.1.1 Bridge identification and location,

8.1.2 Date and weather conditions,

8.1.3 General deck status relative to moisture and debris,

8.1.4 Any unusual conditions or circumstances, and

8.1.5 Radar results, in the following forms:

8.1.5.1 Percent of bridge deck area delaminated for each radar pass, at top steel, at bottom steel, and at both top and bottom steel, in tabular form.

8.1.5.2 Bridge deck area, in m^2 delaminated for each radar pass, at top steel, at bottom steel, and at both top and bottom steel, in tabular form.

8.1.5.3 Total bridge deck area, in m^2, delaminated for the bridge deck, at top steel, at bottom steel, and at both top and bottom steel, in tabular form.

8.1.5.4 Plan view map of bridge deck, depicting radar inspection pass versus longitudinal distance and showing location and extent of detected delamination at top steel, bottom steel, and both top and bottom steel.

9. Precision and Bias

9.1 Precision - Insufficient data are available to determine the precision of this test method. However, for a sample of 10 bridge decks in New York, Virginia, and Vermont, an average error in radar prediction of ± 11.2 percent occurred with respect to top reinforcement delaminated area as determined from chain drag, core samples, and actual

repair quantities. No precision information is available for the bottom mat reinforcement.

9.2 Bias - The research necessary to determine the bias of this test method has not been performed.

10. Keywords

10.1 Asphalt-covered decks, bridge decks, delaminations, ground-penetrating radar, nondestructive testing, radar.