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Comparative evaluation of nondestructive devices for measuring pavement thickness in the field

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Abstract

Estimating pavement surface thicknesses without requiring large footprint equipment or pavement repairs is critical for the structural evaluation of airfield pavement. A research team from the U.S. Army Engineer Research and Development Center conducted an evaluation of eleven nondestructive technologies, including eight ground penetrating radar (GPR) devices and three wave propagation technologies, on twenty-one hot-mix asphalt concrete (AC) and nineteen portland cement concrete (PCC) test locations with varying pavement thicknesses. The different technologies were used to estimate pavement thickness over predetermined test points. For each pavement structure, a core was extracted from one of the test points to provide calibration data of each testing device for data refinement. The accuracy of each technology was quantified by calculating the absolute difference between the actual core measurement and the estimated thickness measurement. The results from the devices tested led to the conclusion that separate devices are required on AC and PCC for optimal performance. The ultrasonic tomography and impact echo devices worked best on PCC surfaces, and the 1 GHz horn antenna GPR devices performed best on AC surfaces. The side-by-side testing demonstrated the capabilities of the technologies on varying pavement structures without discrepancies that would likely occur when comparing one set of results to those from a different study.

Keywords: Pavements; Nondestructive tests; Thickness; GPR; Impact echo; Ultrasonic tomography

1. Introduction

The U.S. Army Engineer Research and Development Center (ERDC) evaluated nondestructive testing devices that estimated the top pavement layer thickness, which is a critical component of the data needed to accurately assess the structural capacity of the pavement. Coring is often used to measure thicknesses; however, it is destructive and requires bulky equipment, a water source, and atching materials. Estimating pavement thickness by nondestructive means saves labor, materials, and time, which results in significant monetary and resource savings.

The ERDC research team evaluated eleven nondestructive devices, including eight that employed ground penetrating radar (GPR) technology and three that employed wave propagation technology. These technologies are described but not identified by manufacturer name to prevent unintentional endorsement. The devices were evaluated on twenty-one hot-mix asphalt concrete (AC) pavement test points and nineteen portland cement concrete (PCC) test points. Table 1 provides test point information, including the pavement layer composition, thickness, and age.

Vendors and researchers provided initial thickness estimates of the test points based on the results of testing with their respective devices. A core for each type of pavement

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Table 1
Constructed/reported thicknesses of test points.

Test	Site	Age of pavement[a]	Layer 1 (measured from cores)	Layer 2 (construction data)[b]	Layer 3 (construction data)
1	Poor House	<4 months	7.7 cm AC	15.2 cm limestone	25.4 cm clay gravel
2	Poor House	<4 months	8.1 cm AC	15.2 cm limestone	25.4 cm clay gravel
3	Poor House	<4 months	7.5 cm AC	15.2 cm limestone	25.4 cm clay gravel
4	Poor House	<4 months	12.3 cm AC	29.7 cm PCC[b]	15.2 cm gravel
5	Poor House	<4 months	11.5 cm AC	31.0 cm PCC[b]	15.2 cm gravel
6	Poor House	<4 months	13.0 cm AC	30.0 cm PCC[b]	15.2 cm gravel
7	Poor House	<4 months	16.7 cm AC	15.2 cm limestone	15.2 cm gravel
8	Poor House	<4 months	16.3 cm AC	15.2 cm limestone	15.2 cm gravel
9	Poor House	<4 months	14.6 cm AC	15.2 cm limestone	15.2 cm gravel
10[cal]	Poor House	<4 months	6.6 cm AC	15.2 cm limestone	15.2 cm gravel
21	Forest Service Road	23 years	11.4 cm AC	N/A	N/A
22	Forest Service Road	23 years	12.2 cm AC	N/A	N/A
23	Forest Service Road	23 years	11.3 cm AC	10.2 cm limestone	N/A
24	Forest Service Road	23 years	11.4 cm AC	10.2 cm limestone	N/A
25	Forest Service Road	23 years	22.2 cm AC	20.3 cm limestone	N/A
26[cal]	Forest Service Road	23 years	23.5 cm AC	20.3 cm limestone	N/A
27	Forest Service Road	23 years	21.0 cm AC	15.2 cm limestone	N/A
28	Forest Service Road	23 years	24.1 cm AC	15.2 cm limestone	N/A
29	Forest Service Road	23 years	31.6 cm AC	10.2 cm limestone	N/A
30	Forest Service Road	23 years	23.4 cm AC	10.2 cm limestone	N/A
31[cal]	Forest Service Road	23 years	13.4 cm AC	Unknown	N/A
11	Poor House	<4 months	21.4 cm PCC	15.2 cm limestone	N/A
12	Poor House	<4 months	63.4 cm PCC	15.2 cm limestone	N/A
13	Poor House	<4 months	63.3 cm PCC	15.2 cm limestone	N/A
14	Poor House	<4 months	62.5 cm PCC	15.2 cm limestone	N/A
15	Poor House	<4 months	37.9 cm PCC	15.2 cm limestone	N/A
16	Poor House	<4 months	38.0 cm PCC	15.2 cm limestone	N/A
17	Poor House	<4 months	39.4 cm PCC	15.2 cm limestone	N/A
18	Poor House	<4 months	19.2 cm PCC	15.2 cm limestone	N/A
19	Poor House	<4 months	20.3 cm PCC	15.2 cm limestone	N/A
20	Poor House	<4 months	21.2 cm PCC	15.2 cm limestone	N/A
32	Forest Service Road	6 months	19.9 cm PCC	76.2 cm flowable fill	N/A
33	Forest Service Road	6 months	12.1 cm PCC	76.2 cm flowable fill	N/A
34[cal]	Forest Service Road	6 months	22.3 cm PCC	76.2 cm flowable fill	N/A
35	Forest Service Road	6 months	32.3 cm PCC	30.5 cm compacted gravel	N/A
36	Forest Service Road	6 months	19.7 cm PCC	30.5 cm compacted gravel	N/A
37	Hangar 4	9 months	26.7 cm PCC	33.0 cm limestone	N/A
38	Hangar 4	9 months	26.4 cm PCC	33.0 cm limestone	N/A
39	Hangar 4	9 months	28.5 cm PCC	33.0 cm limestone	N/A
40[cal]	Hangar 4	9 months	22.6 cm PCC	45.7 cm limestone	N/A

[cal] Calibration test point.
[a] Approximate age of pavement during testing. Newly constructed PCC pavement was not tested until 28 days after placement.
[b] Measured from cores. Layers 2 and 3 thickness data were estimated from construction documents, except where indicated.

was then extracted to provide calibration points. Final thicknesses of the top pavement layers were determined based on post-calibration calculations. Devices were evaluated in terms of thickness measurement accuracy and implementation difficulty.

2. Materials and methods

2.1. Ground penetrating radar (GPR) technology

GPR technology has been used to locate pavement layer interfaces, buried utilities, voids, and items such as rebar. Air-coupled systems are mounted off the ground to facilitate rapid data collection and can operate effectively at highway speeds. Ground-coupled systems are placed on the ground and require either moving the device along the pavement by hand or by cart.

To determine the pavement thickness with GPR devices using pulsed systems (air-coupled or ground-coupled), a short electromagnetic pulse is transmitted into the pavement. When the electromagnetic wave encounters an interface with a dielectric discontinuity, the electromagnetic wave is partially reflected back to the receiving antenna. The relationships between the layer thicknesses, dielectric constants, and the reflection amplitudes have been described by Scullion et al. [1]. A limitation of the ground-coupled antenna method is that dielectric constants cannot be estimated from the collected data and must be assumed or calculated using cores. Air-coupled systems provide estimated dielectric values based on data collected.