Standard Practice for

Application of Ground Penetrating Radar (GPR) to Highways

AASHTO Designation: R 37-04 (2018)

Technical Subcommittee: 5a, Pavement Measurement

Release: Group 1 (April)

AASHTO

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1. SCOPE

1.1. This standard practice provides guidance to the highway engineer in the application of noncontact ground penetrating radar (GPR) to transportation facilities. It is intended to instruct the engineer regarding the specific uses of noncontact radar for pavement layer thickness surveys, quality control of new pavement construction, evaluation of granular base material, identification of zones of asphalt stripping, and assessment of bridge decks. GPR has numerous applications for the transportation industry, but at this time requires extensive training in its use and interpretation of the data output, as well as experience in local pavement conditions.

2. REFERENCED DOCUMENTS

2.1. *ASTM Standard*:

- D4748, Standard Test Method for Determining the Thickness of Bound Pavement Layers Using Short-Pulse Radar

2.2. *Federal Highway Administration Standard*:

- FHWA/TX-92/1233-1, Implementation of the Texas Ground Penetrating Radar System, Texas Transportation Institute with the Federal Highway Administration, 1992

3. SUMMARY OF METHOD

3.1. *Principles of GPR*—GPR utilizes radio waves as an energy source. They are transmitted into the pavement and reflected at layer interfaces. Radio waves have free space wavelengths on the electromagnetic spectrum ranging from 0.001 m to 10 m. GPR operates in the range of 0.1 m to 10 m, which is the low end of the radio wavelength spectrum. As with all electromagnetic waves, radio waves travel through a vacuum at the speed of light. When the radar waves pass through a medium other than a vacuum, the velocity of propagation becomes a function of the dielectric constant of the medium. A dielectric is defined as an insulator between two electrical conductors; the dielectric constant for any material measures its effectiveness when used as the dielectric of a capacitor. For example, air has a dielectric constant of one. If air in a capacitor is replaced by mica, the resulting capacitance is six times greater, so mica has a dielectric constant of six. Some representative dielectric constant values for earth materials are given in Table 1.

Table 1—Dielectric Constants for Construction Materials (Reference 9.9)

Material	Relative Dielectric Constant ($\in_r$)
Air	1
Water (fresh)	81
Water (salt)	80
Sand (dry)	3–5
Sand (wet)	20–30
Silts	5–30
Clays	5–40
Granite	4–6
Limestone	4–8
Portland cement concrete (cured)	6–11
Bituminous concrete	3–6

3.2. The velocity of a radar wave through a given medium varies in inverse proportion to the square root of the material's relative dielectric constant $\in_r$. For example, if a material with a dielectric constant value of 4 has a radar wave passing through it, the wave travels half as fast as it does through air ($\in_r = 1$) and twice as fast as it would through a material having an $\in_r$ value of 16. In general, radio waves propagate through dielectric materials, but are reflected from conductive materials. When there is a boundary between two materials having different dielectric properties, some of the radar energy will be reflected, and a portion will pass through the boundary. The time required for a radar pulse to travel from the source to an interface and back is the two-way travel time, and is dependent on the depth of the interface and the dielectric constant of the material overlying the interface. Converting two-way travel time to information about the depth to the interface can be done by means of the following formula:

$$d = v \times t/2 \tag{1}$$

where:

d = depth,

v = velocity, and

t = two-way time.

3.3. The velocity of the radar wave is primarily dependent on the dielectric constant of the medium, and can be calculated with the following equation:

$$v = c/\sqrt{\in_r} \tag{2}$$

where:

c = speed of light.

As can be seen from the data in Table 1, the moisture content has a large influence on the dielectric constant, and therefore affects the two-way travel time, so that the greater the amount of water saturation, the lower the radar wave velocity.

3.4. There is another electrical property upon which GPR depends, and that is conductivity. Attenuation of the radar waves (which causes the waves to decrease in amplitude and energy) is caused by higher conductivity of a medium and results in less depth of penetration. Attenuation is related to the frequency spectrum emitted by the radar—the higher the frequency, the greater the attenuation of the signal. For most pavement materials in dry condition, attenuation of the wave is not a serious problem. However, with some materials, particularly new concrete (within at least 180 days of placement), signal attenuation can have a significant impact on the amount of energy reflected from the pavement structure.