The Importance of Knowing Velocity When Scanning Concrete with GPR

By Troy DeSouza

Every day, GPR is used to scan concrete prior to cutting or coring. In some cases, the users will set the velocity of the GPR signal as part of their routine scanning process. This article explains when and why it is necessary to determine the velocity of the GPR signal as part of your concrete scanning workflow.

First off, velocity is not how fast you scan with the GPR! (Though some might argue that one's speed of collection might be quickened on a Friday afternoon in the summer). Velocity, or sometimes referred to as dielectric constant, is the speed that the GPR wave travels in a material. Dielectric constant and velocity are related via the equation:

$$Velocity = \frac{c}{\sqrt{\varepsilon}}$$

where c is the speed of light
ε is the dielectric constant

GPR does not measure depth directly; it measures the travel time for the signal to travel from the GPR system to an object in the subsurface, such as a rebar, reflect from that object and return to the GPR system (Figure 1).

Figure 1: GPR measures the travel time for the transmitted wave, to and from an object in the concrete.

Since GPR measures travel time, depth determinations are obtained by multiplying the travel time by the velocity, as per the equation:

$$Depth = \frac{Velocity \times time}{2}$$

But what does all this mean for you? Equations aside, there are two main instances when the GPR operator must know the GPR velocity of the concrete.

LINE SCAN IMAGES

In most cases, the concrete cutter is not concerned with depth, just the location of the embedment so they can avoid it when cutting. However, there are times when slab thickness or cover depth to objects needs to be known. In these situations, having an accurate depth is critical. Remember that GPR inherently measures time, but a depth scale is calculated and displayed based on a velocity value. The three main methods to measure velocity are:

- Automatic velocity determination – many modern GPR systems use this to make it easier for the operator. Simply collect data containing some hyperbolas and press a button; the software will analyze the hyperbolas on the screen and automatically determine the velocity
- Curve fitting – fit a curve to a hyperbolic response
- Using a target at known depth

The curve fitting method is shown below, where the shape of a computer-generated hyperbola is adjusted to coincide with an actual hyperbolic response from the concrete.

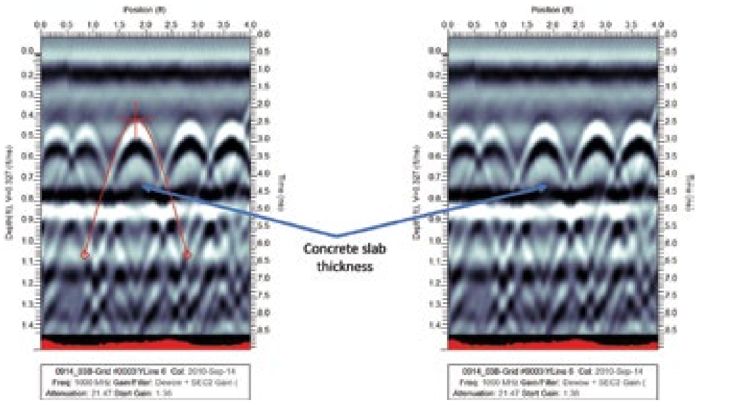

Figure 2: A correctly fit hyperbola (left) yields an accurate slab thickness of 9".

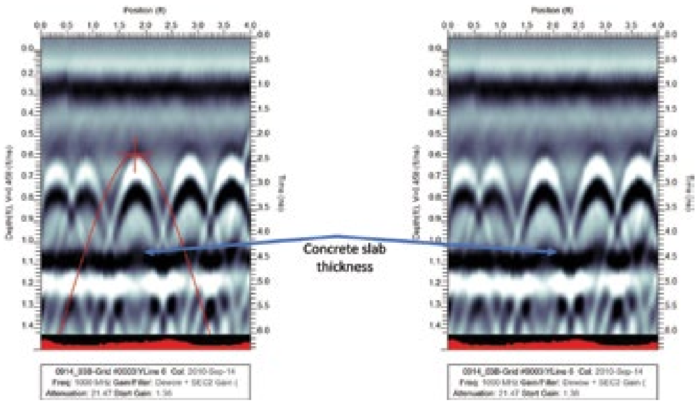

Figure 3: An incorrectly fit hyperbola (left) yields an overestimate of depth at just over 12"

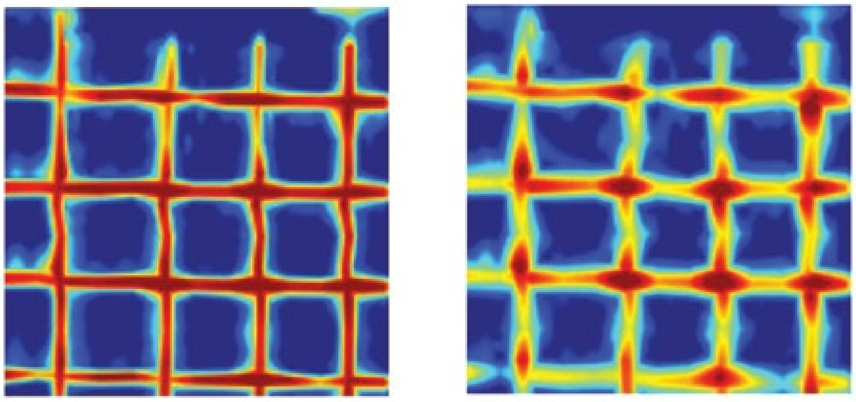

Figure 4: The depth slice image on left was processed using the correct velocity of 0.110 m/ns, whereas the image on the right used an incorrect velocity of 0.140 m/ns.

The width of the hyperbola is directly related to the GPR wave velocity. An example of a correct curve fitting is shown in Figure 2, while an incorrect one is shown in Figure 3.

Whichever method is used, it is important that objects used to calibrate for velocity are crossed perpendicularly. This results in the narrowest (or “tightest”) hyperbola, which yields the correct velocity. Crossing an object at an oblique angle results in a wider hyperbola, which will give a higher velocity and a correspondingly (false) higher depth reading.

Setting velocity does not change the GPR data, only the depth axis. If the velocity is incorrect, the target depth will be incorrect. However, the location marked on the ground is unaffected. In other words, you can pinpoint the position of an embedment, such as a rebar, but the depth to the rebar indicated by the GPR is not accurate with an incorrect velocity value.

DEPTH SLICE IMAGES

Some users may opt to collect a grid of data to help unravel a complex area. Once the grid is collected, the data is processed to create depth slice images. One of these processes is called migration. The purpose of migration is to focus the GPR signal back to the top of the hyperbola prior to creating depth slices. The key parameter for a successful migration is – you guessed it – an accurate velocity.

The correct velocity yields the tightest, most focused result on the depth slice images (Figure 4, left). Clearer depth slices not only enable you to visualize the data, but also make for a better report to the customer.

Some people ask, why can’t we just use the same velocity for all concrete? The reason is that the velocity will vary between concrete pours as it is a function of the water content, aggregate type, air entrainment and any admixtures. So anytime you are on a different pour and need to know depth or are collecting a grid, you should determine the GPR velocity for that location.

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