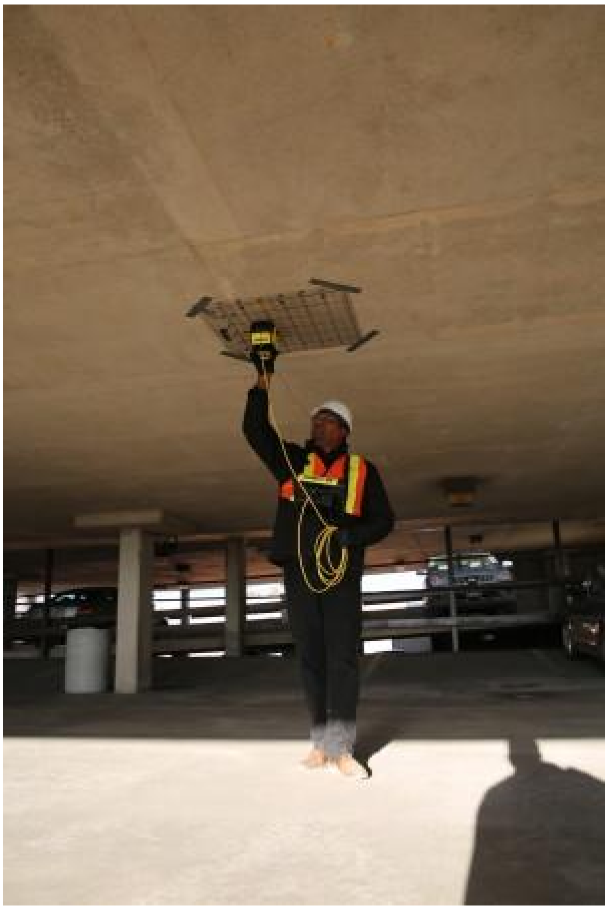
The Potential of GPR for Concrete Construction

Ground penetrating radars can be used to locate rebar, post-tension cables, and conduits prior to cutting or drilling into the concrete.

By Dan Bigman

Ground Penetrating Radar



The evolution of imaging technology and its applications to non-invasively map embedded items in concrete began with the goal of preserving structural integrity and increasing site safety. At the same time, using non-invasive imaging technology helps to reduce liability while managing project costs by minimizing the likelihood of structural disturbance during concrete cutting or drilling. Such disturbance can result in hundreds of thousands to millions of dollars for repairs. Imaging embedded reinforcement and conduit prior to work, however, can significantly reduce these risks.

An early technology used for this work was X-ray. This technique created 3D images of the embedded infrastructure, but needed a film to be placed on the reverse side of a scan, which was not always possible. Buildings would have to be evacuated due to safety concerns over radiation levels and this sometimes became a time-consuming process. In addition, data had to be processed off-site and could not be interpreted immediately. There were some benefits to this technique despite these issues, the main one being an accurate map of the locations of rebar and other reinforcement.

But more recently, the development of mobile high-frequency ground penetrating radar (GPR) antennae has solved some of the issues with x-ray imaging. GPR doesn't require film, data can be viewed immediately for marking embedded infrastructure, and there are no safety concerns regarding radiation. Antenna of different frequencies can also be used to identify targets at different depths. In addition to 3D imaging, GPR can also produce 2D and 1D data to help locate and mark out embedded infrastructure. 2D and 1D visualizations can be helpful when investigating congested sites.

How does GPR work?

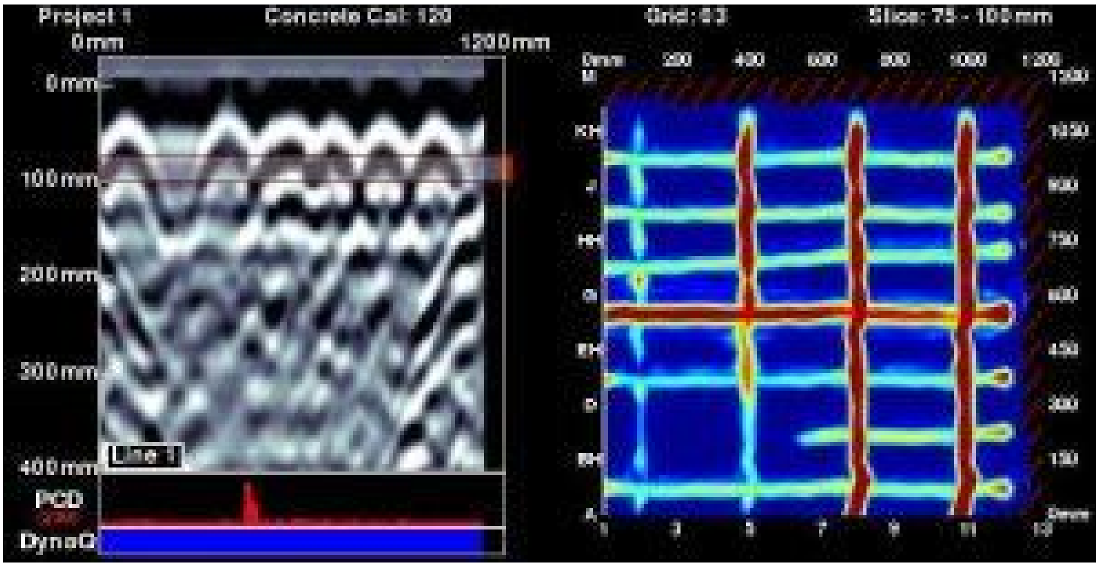
A GPR antenna produces an electromagnetic radio wave that travels through concrete (or any other material) until the wave encounters a discontinuity. Some of the wave's energy is reflected off of the discontinuity (such as rebar or the slab/soil interface) and travels back toward the antenna. Both the two-way travel time and the amplitude of the reflected signal are recorded. The two-way travel time can be converted into depth. The amplitude, which is the amount of energy that returns to the antenna, depends on how different the material the wave was traveling through is compared to the material that it reflected off of. The greater the difference between the two materials, the more energy that is reflected.

For example, steel and concrete have very different physical properties. When the wave reflects off of steel, most of the energy is reflected back to the antenna. On the other hand, concrete and PVC are more similar in the electromagnetic properties that affect GPR waves, so only a small amount of energy will be reflected back to the antenna. Understanding the differences in GPR responses can help the engineer or technician distinguish between different targets of interest.

In order to "scan" concrete with GPR, the instrument is placed flat on the surface. When the GPR is pushed along the concrete, still maintaining contact with the surface, it will produce a 2D profile of what is below the surface. If several 2D profiles are collected next to each other, then they can be turned into a series of "time-slices" or "depth maps" that show embedded targets at varying depths.

How can GPR be applied to concrete construction?

The most obvious application of GPR in concrete construction is to precisely locate rebar, post-tension cables, and conduits before cutting or drilling into the concrete. The accuracy of GPR imaging coupled with the ability of the GPR technician to mark these targets in real time creates an efficient process for contractors with a trail of accountability. A trained GPR technician can often distinguish between rebar, post-tension cables, and conduits based on the signal response recorded by the GPR which can be very useful information in preparation for a refurbishment or expansion.



Dan Bigman GPR produces a 2D profile of what is below the surface (left). When several 2D profiles are collected next to each other, then they can be resampled into a series of "time-slices" or "depth maps" that show embedded targets at varying depths (right).

Evaluating concrete slab thickness provides useful information for projects investigating slab on grade or pavements. A GPR wave will not only reflect off rebar and other embedded features, but will also reflect off the concrete-soil interface. This helps contractors evaluate structural capacity and measure deterioration in concrete. A single core can verify the slab thickness in one spot so GPR wave speeds can be calibrated with exactness and accurate thickness measurements can be produced for large areas.

Another benefit of GPR for concrete construction is its ability to evaluate corroded rebar. As corrosion proceeds it changes the physical properties of the reinforcing steel and causes the GPR wave to slow down as it moves through the affected portion of the concrete. The result is that it takes the GPR wave longer to reflect off rebar with substantial corrosion than to reflect off rebar embedded in unaffected concrete. An accurate repair estimate can be developed by contractors when the degree of corrosion is analyzed properly. A related issue is that preventative measures might be available if GPR is used to evaluate water saturation in a concrete structure. The greater the saturation, the more susceptible rebar is to corrosion.

Estimating rebar diameter is another useful application, especially for structural engineers who are calculating load-bearing capacity for expansions or refurbishments. The mathematical computation of rebar diameter can be complex and the results may vary in accuracy plus or minus 10% of actual rebar size, but the benefit of a quick estimate based on GPR results can help the engineer prepare initial plans. This is also a situation where large-scale non-invasive imaging can complement limited amounts of destructive verification. No plans should proceed without some verification, but the time requirements to verify rebar diameter through drilling can be minimized. If a few rebar can be verified to give a baseline, then many GPR scans can be quickly analyzed to estimate rebar diameter and compare the estimates to the verified samples. If they are in-line, then it can be assumed that those documented with GPR are the same or similar in size to those that were physically measured.

Finally, GPR allows contractors to identify cracks in concrete or voids below the slab surface. These can be difficult to identify and both present real safety concerns regarding the structural integrity of a building. However, the GPR signature of a void (such as delamination) or crack can be unique and an expert GPR practitioner with both theoretical background and experience can often identify these defects through an analysis of signal polarization. While a GPR wave slows down when it transitions from concrete to steel, it speeds up when it transitions from concrete to air. Recognizing these differences in behavior allows experts to distinguish the responses.

How to evaluate a GPR contractor

There is tremendous variation in the quality, background, and service between companies providing GPR and concrete scanning services. The applications discussed above get progressively more difficult as you move from basic locating and marking to rebar size estimation and void detection. As a contractor, you should make sure that the knowledge, experience, and cost of your GPR contractor fits the investigation being conducted. For basic locating, even a beginner can usually complete a successful project because the contrast between the steel and the concrete is so significant. But an expert with in-depth training and years of experience should be sought out for more complicated applications such as the detection of voids.

GPR is rapidly becoming standard in the concrete construction world. Knowing how this technology works and what problems it can solve will help contractors use the technology more effectively and hire the most appropriate GPR practitioners for any given situation. New applications of GPR continue to be discovered and using GPR for non-invasive concrete scanning will continue to grow. GPR's safety, cost, and accuracy benefits should encourage the use of this technology in all feasible situations.

About the Author

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Dan Bigman, PhD, is the founder of LearnGPR.com and trains engineers, locators, and construction professionals from around the world on ground penetrating radar. To learn more about training options, contact him at dbigman@bigmangeophysical.com.