SUBSURFACE VIEWS

QUARTERLY NEWSLETTER
PUBLISHED SINCE 1993

April 2021 - Vol. 31, No. 65

In this issue

Using GPR to estimate wall thickness of bridge structures

The Saratoga Creek Bridge along State Route 9 **(Figure 1)** was constructed in 1902 and enables the safe and stable connectivity between the City of Saratoga the community of Felton in California. The bridge has a two-span, earth-filled, concrete arch, with rubble masonry spandrel[1] walls. Previous surveys found no evidence of reinforcing steel bars at the bridge abutments[2] or at the pier[3]. These structural deficiencies, coupled with mortar joint deterioration, makes the bridge susceptible to damage during a seismic event, particularly considering its proximity to the San Andreas fault system, located approximately half a mile away.

Figure 1: State Route 9 Saratoga Creek Bridge Project Location.

Due to these issues, the bridge needs to be replaced or extensively renovated. The chosen way forward is to have a "hybrid" bridge design, where a new steel girder bridge will be built within the body of the existing bridge with the existing masonry walls and stone arches serving as a façade concealing the new support columns. The design retains the look and feel of the existing stone bridge (which has strong local support) while also ensuring the structure will survive a seismic event and is the fastest method to complete construction.

To assist in the hybrid bridge design, the Geophysics and Geology Branch (GGB) of Caltrans (California Department of Transportation) was tasked to identify the construction details for the concrete arch and rubble masonry spandrel walls of the bridge structure in January 2020. The bridge structure had been successfully surveyed with a GPR in 2010 so GPR was chosen for this non-destructive evaluation project.

The goals were to find the thickness of the concrete arch at the crown and base, the thickness of masonry rubble spandrel and the depth of the concrete pier.

continued on page 2

Survey & Results
For the wall survey, unidirectional profiles, starting from the top, were acquired vertically with pulseEKKO® PRO 500 MHz center-frequency transducers, mounted on a custom frame with access from the bridge deck **(Figure 2, top)**. To access the more difficult to reach parts of the arches and walls, a snooper truck was used **(Figure 2, bottom)**. Multiple lines were also collected on the base and crown of the concrete arch of the bridge.

Figure 2: GPR line data collection using a pulseEKKO® PRO 500 on the bridge abutment (top) and Conquest® 100 on the concrete arch at Pier 2 (bottom).

Figure 3 shows all the GPR lines collected along the spandrel (non-reinforced concrete arches of the bridge), center column of Pier 2 and Abutment 3.

As GPR work was limited to two days for this survey, all data were collected and saved in different projects on the GPR system and processed in EKKO_Project™ GPR software to obtain estimated thickness measurements. To get an accurate GPR wave velocity estimate, a core hole was drilled at the base of the concrete arch at Abutment 3 **(Figure 3, bottom)** to measure the bridge wall thickness. The GPR wave velocity was calculated by correlating the wall thickness from the core to the time of the GPR reflection from the back of the wall. This velocity was assumed to be representative of the rest of the concrete wall.

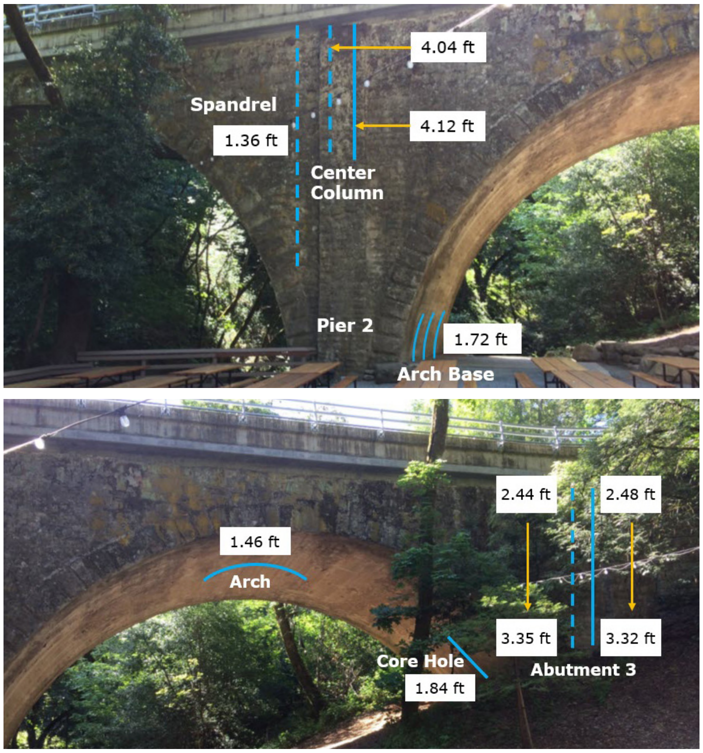


Figure 3: GPR line data collected on the Saratoga Bridge at labeled locations with estimated wall thicknesses. Solid lines represent data collected on the north wall and dotted line is data collected on the south wall. Thickness measurements down Abutment 3 indicated the wall thickness increased towards the base.

Interpreting and finding the wall thickness from the GPR data was simple, given that concrete is uniform in composition compared to the packed earth between the bridge walls. The GPR cross-sections show the transition from uniform to scattered radar reflections that was interpreted as the transition from concrete to rubble fill **(Figure 4)**.

Apart from successfully measuring the wall thickness of the concrete arch at the base and crown from the GPR data, they were also able to confirm the existence of batter, a receding slope of a wall at Abutment 3, as the estimated wall thickness appeared to increase towards the base of the wall

continued on page 3

(Figure 4, right). The results at Pier 2 provided more insights, with the GPR data indicating a relatively constant thickness at the center column **(Figure 4, left)**, implying the absence of wall batter. It also highlighted the significantly thinner walls when compared to Abutment 3 **(Figure 3, bottom)**.

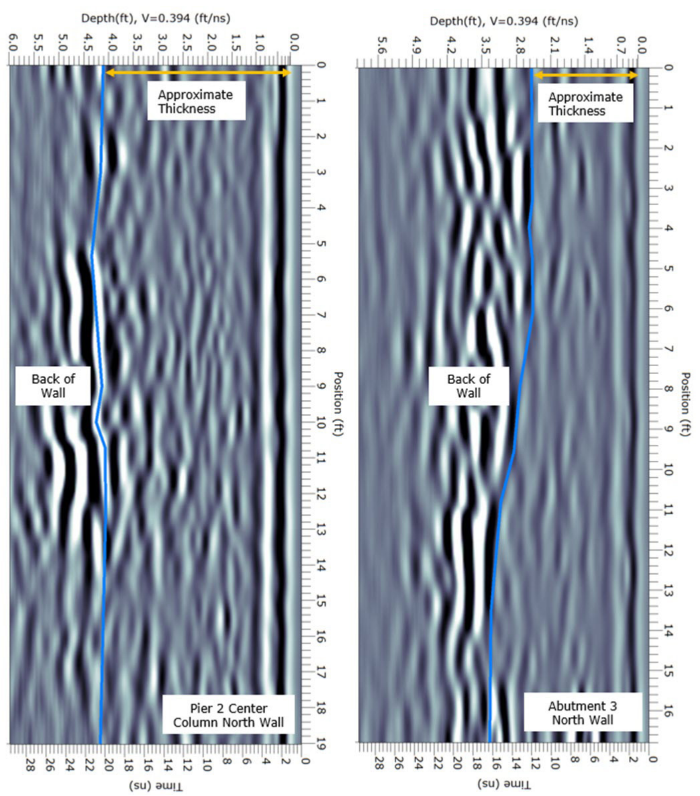


Figure 4: GPR cross-sectional data showing the approximate mean column thickness (4.12 ft) observed on the North Wall Center Column above Pier 2 (Left) and varying wall thickness at Abutment 3 confirming the existing of batter (Right).

Conclusions

GGB received positive feedback from the bridge design team that the GPR interpretations provided valuable details to draft their final design for preserving the existing bridge. The hybrid "bridge within a bridge" design was accepted, and construction is planned to start in September 2022.

Data courtesy of Bill Owen from Caltrans.

Footnotes:

[1] A spandrel is the triangular space between a side of the outer curve of an arch, a wall, and the ceiling or framework.

[2] A bridge abutment is the part of the bridge foundation that rests on the ground at either end of the bridge.

[3] A pier is the main support column for the span of the bridge deck that crosses between abutments.

Forensic Use of Ground Penetrating Radar: Casework

Due to the popularity of TV shows such as CSI, Law and Order, Forensic Files, and others, the term "forensic science" has become somewhat of a household phrase. As a result, most people have a general understanding of what forensic science is – often used interchangeably with crime scene investigation – but in reality, "forensic science" is more in depth than it may appear on the surface. More correctly defined as "the forensic sciences", this phrase refers to the application of any field of science to legal proceedings, particularly those relating to criminal matters. Common fields of study include forensic anthropologists that study bones, forensic pathologists that study diseases and the human body, forensic entomologists that study insects, and forensic chemists that perform toxicology and drug analyses, but there are myriad additional subspecialties within the forensic sciences. One particularly unique subspeciality is that of forensic taphonomy. Not as familiar with this phrase as the others previously mentioned? Don't worry! That is to be expected since forensic taphonomy isn't as popular of a science as some. In fact, forensic taphonomy is not its own field of science, but rather, a subfield of forensic anthropology that focuses on the study of human decomposition – often in the context of burial sites – and the relationship between the process of decomposition and the environment.

The basic premise of forensic taphonomy is that the process of decomposition itself will affect the surrounding environment in which a body is decomposing and conversely, the environment will affect the process of decomposition. The relationship between the two can yield important information about the circumstances at, around, and after the death event which can be critical for a medicolegal death investigation. This is especially important if a body has been buried because investigators will rely on environmental clues to help locate the grave. In cases such as these, ground penetrating radar is an immense asset to a death investigation as it can help locate a clandestine gravesite **(Figure 1).**

Figure 1: FINDAR® GPR system for forensic investigations.

continued on page 4

In the same way that certain presumptive tests can be used to quickly determine if a reddish-brown substance is actually blood before conducting more in-depth analyses of it, ground penetrating radar can be used as a sort of presumptive test for a suspected gravesite before undertaking a full-scale excavation.

Often, in the context of a medicolegal death investigation, investigators are operating based on tips that may be vague or unreliable. An informant may provide information such as "I think the body is buried somewhere out in the field behind the high school." While this certainly provides a good starting point for a search, it is not practical to dig up an entire field in search of a body that an informant only "thinks" might be there. This is where ground penetrating radar becomes vital. A well-trained GPR operator can conduct a search of the area in question and identify more specific areas of interest based on the results of the scan **(Figure 2).**

Figure 2: GPR forensic data collection with a FINDAR® system.

Unlike what is typically shown in the television-depicted use of GPR, an investigator will not be able to tell exactly what is buried beneath the surface; GPR doesn't work as an underground X-ray machine. However, it can provide information on anomalies beneath the surface that are likely to be of forensic significance such as a body, a weapon, or other items of evidence **(Figure 3)**.

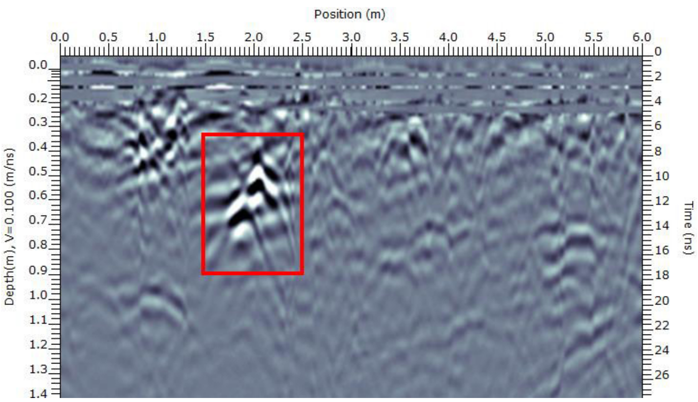


Figure 3: GPR cross-sectional data showing an anomaly and disturbed soil that may be a clandestine grave.

Based on the information provided by the GPR, investigators can then dig test pits in these areas of interest to determine what is actually beneath the surface and whether or not a full-scale excavation is necessary **(Figure 4)**.

Figure 4: Excavation of a possible clandestine grave site based on GPR survey results.

The use of GPR in this way can save a tremendous amount of time and resources by allowing investigators to target their searches to the areas that are most likely to yield promising results.

In future articles, I will discuss the application of GPR to unique fields within forensics, such as education and research.

Story courtesy of PhD. Lerah Sutton, PhD
Director - Forensic Medicine Educational Program
Assistant Director - Maples Center for Forensic Medicine
University of Florida College of Medicine

TIPS: How high can my GPR be off the ground?

GPR users invariably ask, “How close to the ground must the GPR be?”. The simplest answer is that the best GPR data is obtained when the antennas are in contact with the ground. This allows the antennas to “couple” to the ground and ensure the maximum amount of energy transmits into the subsurface. The more an antenna is elevated above the ground surface, the more the GPR energy reflects from that ground interface, and the less GPR energy transmits into the ground, greatly reducing the penetration depth. This not only reduces the amplitude of the response of smaller targets, but also decreases spatial resolution. But how high is too high? This will depend on the center frequency of your antenna. Higher center frequency antennas, which are physically shorter in length, need to be closer to the surface, whereas longer, lower center frequency antennas can tolerate more of an air gap. Theoretically, GPR antennas should be kept within 1/10 of the center frequency wavelength (in air) from the surface but our strong recommendation is to keep them even less than that. The table below lists some commonly used antennas and the recommended maximum allowable height:

Center Frequency	Wavelength in air	Wavelength/10 height	Recommended maximum antenna height
100 MHz	300 cm	30 cm	10 cm
250 MHz	120 cm	12 cm	3 cm
500 MHz	60 cm	6 cm	1.5 cm
1000 MHz	30 cm	3 cm	<1 cm

To illustrate this point, **Figure 1** shows NOGGIN® 250 MHz GPR cross-sections along the same line; one with antennas placed on the surface and the others with the antennas raised to heights of 7.5, 15, 22.5 and 30 cm, respectively. As GPR antennas are raised higher above the surface, the amplitude of target responses, the depth of penetration and the lateral resolution all decrease. This is particularly clear where hyperbolic-type responses are present in the GPR record.

The above guidelines are a maximum. Wherever possible, keep the antennas as low to the ground as practically possible; being in contact with the ground is the best. People hate the sound of their GPR system scraping on the ground, but all antennas sold by Sensors & Software are designed to be ground-coupled (i.e., in contact with the surface); antennas with center frequencies 50 MHz and higher have very resistant, high density polyethylene skid plates to protect the antennas from the abrasive ground surface.

There are times when certain applications lend themselves to antennas being placed a little higher off the ground surface. In these cases, refer to the operator’s manual for recommended deployment and setup.

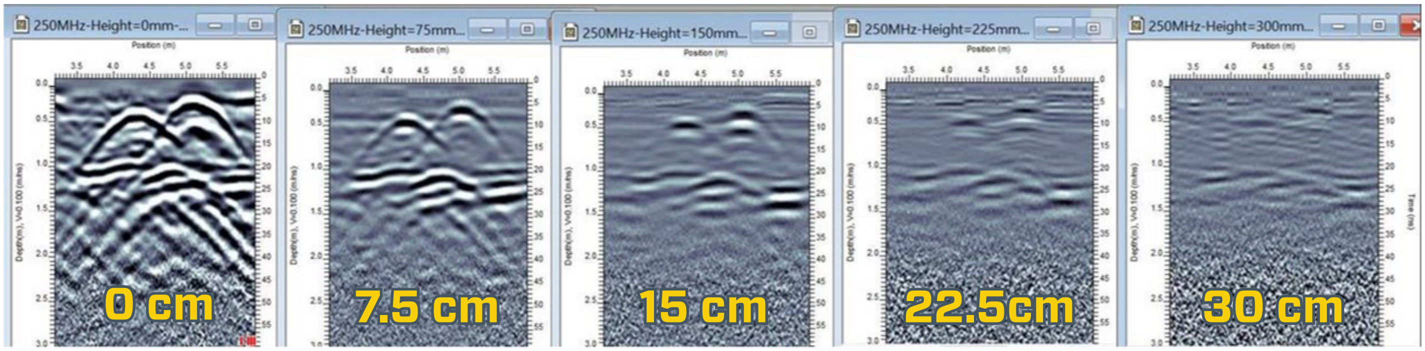
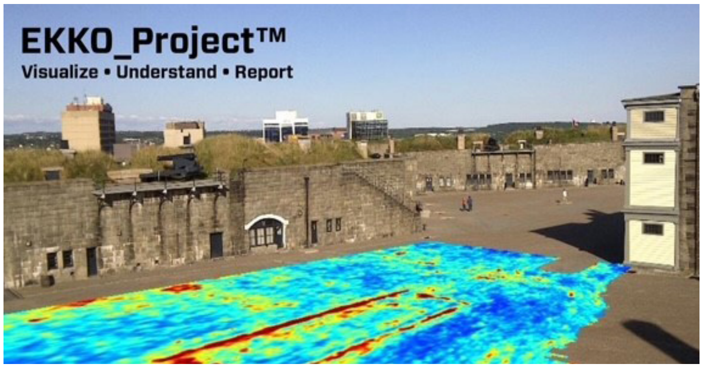


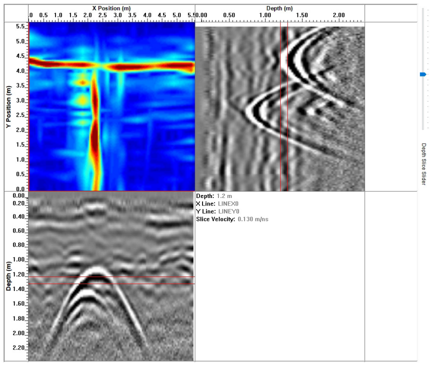
Figure 1: Noggin® 250 collected along the same line in contact with the ground surface (far Left) and raised above the ground at heights of 7.5, 15, 22.5 and 30 cm (far Right).

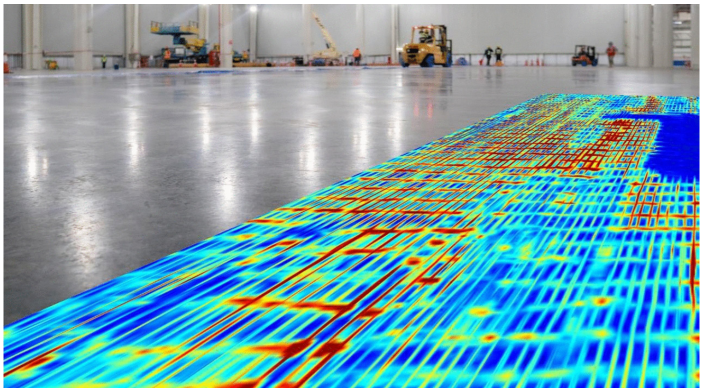
EKKO_Project Version 6 is now shipping!

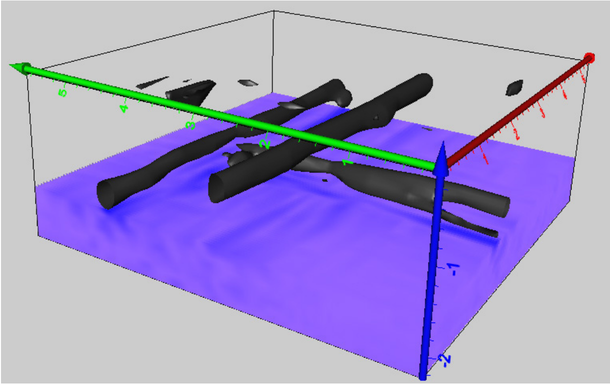
EKKO_Project™ GPR Processing Software, a comprehensive software solution for GPR data management, analysis, and reporting.

EKKO_Project™ makes powerful GPR data analysis simple, and **Version 6** delivers many new features that make visualizing your GPR data even easier.









For more information about the software, pricing and the upgrade path to V6, please contact our sales representatives.

Upcoming Courses

EKKO_Project V6 Webinar

- Apr 28, 2021 11:00 AM Eastern Time (US and Canada), 3:00 PM Universal Time, UTC - Online
- Apr 29, 2021 08:00 PM Eastern Time (US and Canada), 12:00 AM Universal Time, UTC - Online

On-Demand Training

Pre-recorded webinars and EKKO_Project tutorial webinars are at: www.sensoft.ca/georadar/webinars

Interactive courses are available via our online learning platform: www.SensoftU.com

Sensors & Software Inc.

1040 Stacey Court
Mississauga, ON
Canada L4W 2X8

+1 905 624 8909
+1 800 267 6013
www.sensoft.ca

subsurface imaging solutions