Kitchen Sink Approach for the Geophysical Evaluation of 150 Year-Old Sandstone Block Bridge Abutments, Stratford, Connecticut

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Abstract

Heavier and longer trains present new challenges in the assessment of existing 150 year-old railroad, sandstone block, bridge abutments for their re-use in new bridge designs. Specifically, lack of access to, and extreme geologic conditions beneath, these bridges limit the use of traditional geotechnical and geophysical evaluation techniques to determine abutment thickness and geometry, foundation depth, and bedrock depth. GPR and Ultra-Sonic Techniques, such as Impact Echo (IE), Sonic Echo (SE), and Ultra-Seismic (US), were used in the structural evaluation of abutments, while low-frequency GPR, seismic refraction, gravity, and electrical resistivity were used to help determine bedrock topography.

A GSSI 400 MHz antenna was mounted on the vertical face of each abutment, and GPR lines were acquired at 5 foot intervals, from just below the existing utilities to grade. GPR scans were generally of good quality, enabling us to differentiate between the first row of blocks and the back of the abutment. Because of the non-uniqueness of reflections, either from the back of each row and/or the sides of individual blocks, or from the fill-cut behind it, the interpreted total abutment thickness could occasionally be challenging. IE, using a NDE 360 instrument with a ball-pein hammer source and a 1000 Hz solenoid to record the reflection, typically only determined the thickness of the first row of blocks. SE, using a 3 lbs Dytrans hammer as its source, was used at several locations at the top of each abutment. The reflected arrivals were recorded using a 100 Hz geophone and 1,000 Hz accelerometer placed near the source. Typically, SE works well for depth determination of concrete structures, such as foundation walls, footings, and piers. While the large blocks were in structural contact with one another, allowing the transmission of acoustic energy, we observed some intermediary reflections between the rows of blocks, making the identification of the foundation bottom reflection less certain. Use of the US testing method at the same locations, however, often confirmed our SE interpretation.

Extreme bedrock depth and sandy till in most areas, limited the effectiveness of the low frequency GPR. Where bedrock is shallow, differentiating between competent and weathered bedrock and/or till was difficult. Likewise, excessive bedrock depths and lack of an explosive source rendered seismic refraction ineffectual at all but one location. Electrical resistivity was also not effective due to urbanization and proximity of soundings to utilities. A gravity survey was conducted using a Lacoste and Romberg D meter, which uses the earth's total gravitational field as its source. Raw meter readings were obtained at over 300 stations over the course of 8 field days, the locations of which were surveyed using a sub-cm GPS. After removing diurnal fluctuations, and applying free-air, Bouguer, and Terrain Corrections, the "residual gravity" or Complete Bouguer Anomaly (CBA) was determined. Based on known bedrock "calibration points" from borings and determined CBA values, a 3D tomographic inversion model was done using GeoTomo's Tomo+ program, to determine the bedrock surface. While not perfect, we find good correlation with known bedrock depths, and generally good correlation with GPR and seismic refraction in shallow bedrock areas.