# Impact-Echo Scanning Evaluation of Grout/Void Conditions Inside Bridge Post-Tensioning Ducts for Tendon Corrosion Mitigation

**By Yajai Tinkey and Larry D. Olson**

Post-tensioned (PT) systems have been widely used for bridge transportation systems since the late 1950s. If a good quality control plan is not implemented, however, there is a strong possibility that during construction the ducts may not be fully grouted. This results in voids in some areas and the associated lack of cover for PT tendons that increase their risk of corrosion. Thus, over the long-term, water can enter the tendon ducts in the void areas, resulting in corrosion of the tendon.

The collapse of the Brickton Meadows Footbridge in Hampshire, UK, in 1967 is the first serious case of corrosion of tendons leading to a major catastrophe.[1] In 1985, the collapse of the Ynys-y-Gwas Bridge, a precast segmental PT bridge in Wales, was attributed to the corrosion of the internal prestressing tendons at mortar joints between segments.[1,2] Corrosion-related failures of PT tendons have been found in several major segmental bridges such as the Niles Channel Bridge near Key West, FL, in 1999 and Midway Bridge near Destin, FL, in 2000.[3] In addition to actual failures, corrosion damage was found in many PT bridge ducts in bridges still in use in Florida and on the East Coast.[4] Impact-Echo (IE) scanning research and consulting results for grout/void in PT ducts are discussed in the following.

## Research Objectives

The authors recently completed a National Cooperative Highway Research Program Innovations Deserving Exploratory Analysis (NCHRP IDEA) research project to develop reliable nondestructive near-continuous scanning methods using an impact-echo scanner (IES) (Fig. 1) for condition assessment of the internal grout conditions inside bridge ducts. The IE method (ASTM C 1338) identifies resonant frequency shifts of thickness echoes that result in increased apparent thicknesses due to the presence of void in a duct versus a grouted duct. Different sizes of ducts were included in this study as well as varying sizes of void defects. In addition, detailed sensitivity studies of nondestructive grout defect

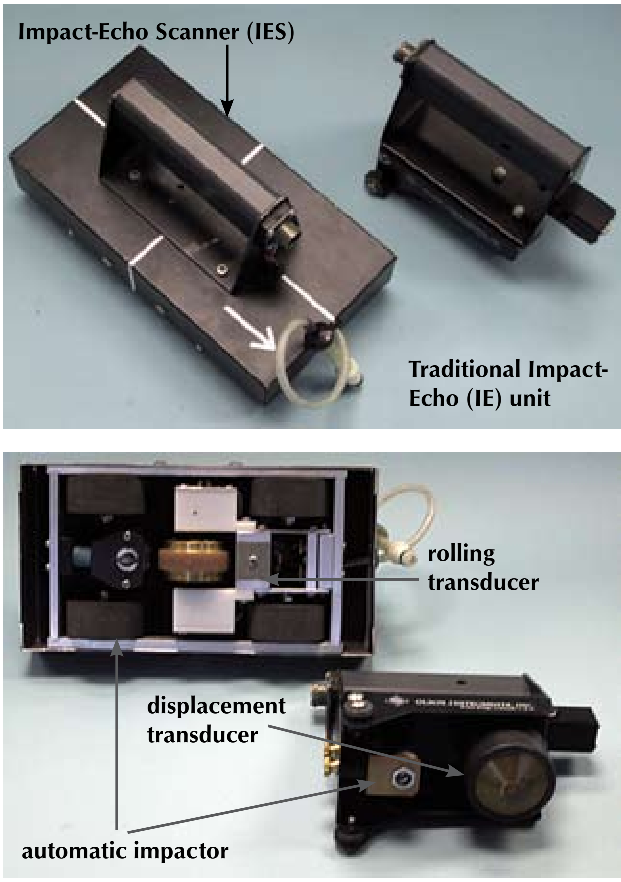


*Fig. 1: Impact-echo scanning unit and traditional point-by-point impact-echo unit*

*Fig. 2: U-shaped bridge girder (west end) and insertion of Styrofoam™ void prior to duct grouting*

detection with IE scanning of eight 4 in. (102 mm) diameter ducts with constructed defects were the main research focus.

## NCHRP Research Specimens and Test Results

The primary specimen used in this study was a full-scale, U-shaped bridge girder (Fig. 2). The length of the girder was 100 ft (30 m). However, only the first 20 ft (6 m) were included in this study. There were four empty 4 in. (102 mm) diameter steel ducts inside each wall of the girder (a total of eight ducts). Several pieces of Styrofoam™ were inserted inside the ducts and positioned on the roofs of the ducts to simulate real-world grout defect. The size of the foam used ranged from as small as 16% duct perimeter/6% depth lost to 84% perimeter/94% depth lost with some full void. A comparison of grouted versus voided duct IE frequency displacement spectrum results from IE scanning tests is shown in Fig. 3.

The use of 3D surface plotting of the IE thickness echo results was helpful with interpretation and visualization of grout defects. A grout defect as small as 20% perimeter lost or 11% depth lost in a 4-in. (102 mm) duct was detected by the IE tests with the interpretation using 3D surface plotting as shown in Fig. 4 (plan view) and Fig. 5 (skewed 3D view of Fig. 4). The 3D visualization with a color scale of the thickness change from normal (fully grouted duct) to thicker (partial to full void) proved to be an important tool for imaging sound grout versus partial to full void conditions for both the BAM and U-shaped girder test specimens. The 3D color scales proved to indicate very good precision at indicating the size of the internal voids as reflected by increasing thickness echo depths with increasing void size as reported herein. Such visualization of IE scanning results allows for much greater sensitivity and economical, near-continuous testing of real-world bridge ducts.

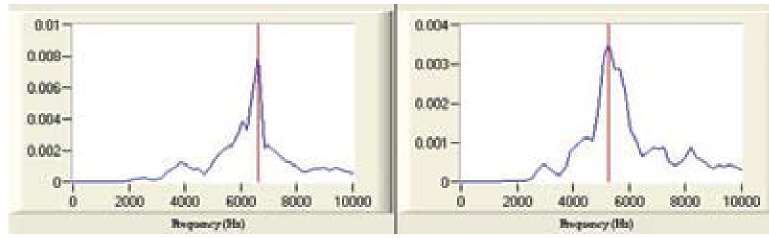


*Fig. 3: Comparison of IE scanning frequency displacement spectrum results from well-grouted duct on left (thickness echo frequency/depth of 6445 Hz/11.17 in.) and a voided duct on the right (thickness echo frequency/depth of 5274 Hz/13.65 in.)*

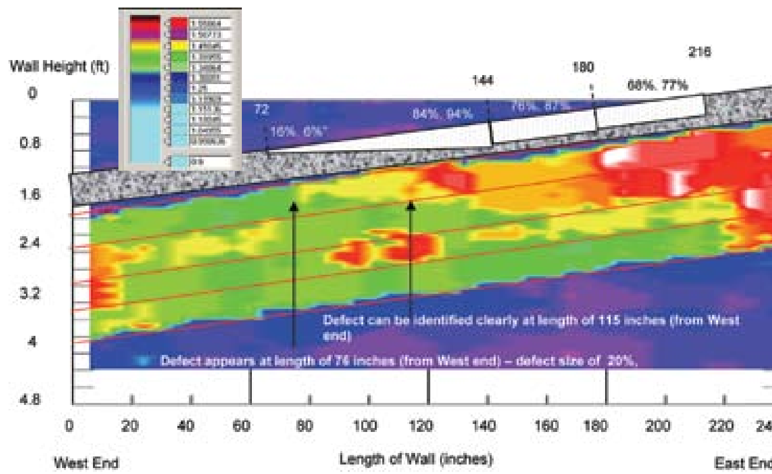


*Fig. 4: Plan view comparison of IE scanning results from top duct (south wall) and the defect design*

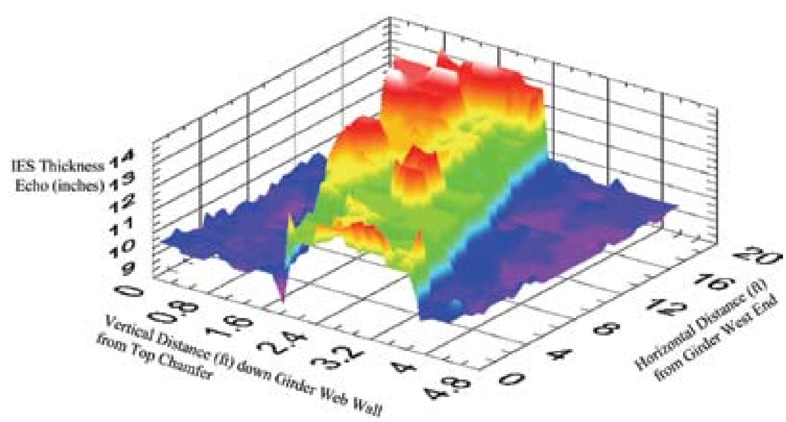


*Fig. 5: Skewed 3D view of Fig. 4 IE scanning results from south duct wall at 3 days of age—red to white areas show the most severe void conditions and thickest echoes*

## Case History

The results obtained from the research project have been applied to seven bridges on consulting projects by the authors. This section presents an example case history using the IES to locate anomalies inside PT bridge ducts inside the Orwell Bridge in the UK (Fig. 6). The testing was conducted typically from inside each bridge from one side of each of the web walls with the IE scanning system. The tests were typically performed

*Fig. 6: George Orwell Bridge over the Orwell River near Ipswich, England, UK*

in vertical lines located approximately every 6.5 ft (2 m) along a web wall and each vertical scan generally started from the bottom inside chamfer and ran to the top inside chamfer of the tested web walls for approximately 72 tests over 6 ft (1.8 m) of wall.

The results from the tests are presented in a thickness tomogram fashion for each web wall for each tested span. An example test result from one of the spans is presented in Fig. 7. Reviews of Fig. 7 show discontinuities or voids located at 65 ft (20 m) from Pier 2 and from the bottom of the wall (location where the scan started) to a height of 2 ft (0.6 m). The IE records indicated cracks/voids at depths of 4.5 to 6 in. (12 to 15 cm) from the test surface. In addition, the plot in Fig. 7 also indicated a thicker area (presented in black color) representing voids inside the duct(s) located at 138 ft (42 m) from Pier 2 and from heights of 2.9 to 3.8 ft (0.9 to 1.15 m). The color map in Fig. 7 shows normalized thicknesses (the IE thickness divided by the nominal thickness at the tested line) by color from 0.1 to 1.3.

The results from the NCHRP IDEA research using the portable rolling IES system show good agreement with the actual defect design. In the IE testing by the authors to date, the clearest indication of the presence of grouting defects is the apparent increase in the thickness due to a reduction in the IE resonant frequency as a result of the decrease in stiffness associated with a defect. No direct reflection from the ducts with grouting defects was observed in these experiments. This is because of a larger wavelength generated by the impactor inside the IES. In this study, with the help of 3D visualization, the IE scanning was able to identify voids as small as 9% depth lost or 20% circumferential diameter lost of a 4 in. (102 mm) diameter steel duct. The IES system has also been used on bridge and balcony decks and prestressed concrete cylinder pipes for delamination detection. IES has also been conducted on concrete pavements and slabs for thickness/honeycomb/void integrity evaluations where extensive testing and imaging of internal concrete conditions was needed for design and execution of repairs.

## References


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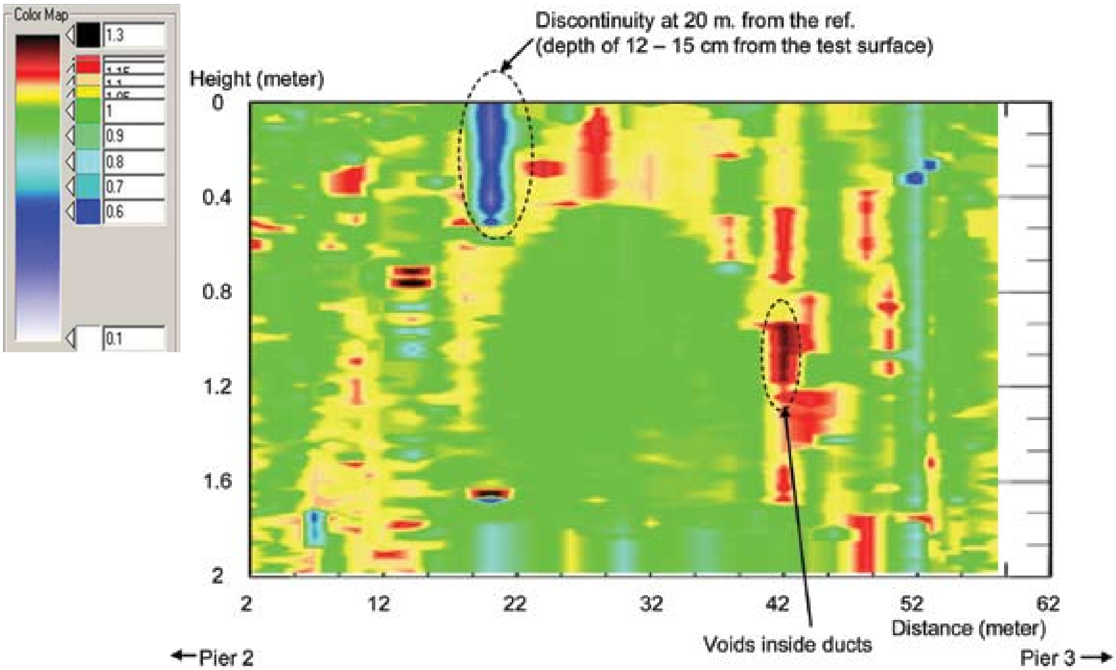


*Fig. 7: 3D normalized thickness tomogram of Span 2 of North Box (general condition)*

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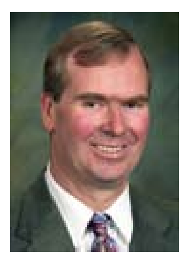

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