OLSON ENGINEERING, INC.

Experts in Nondestructive Evaluation

IE Method

N D E

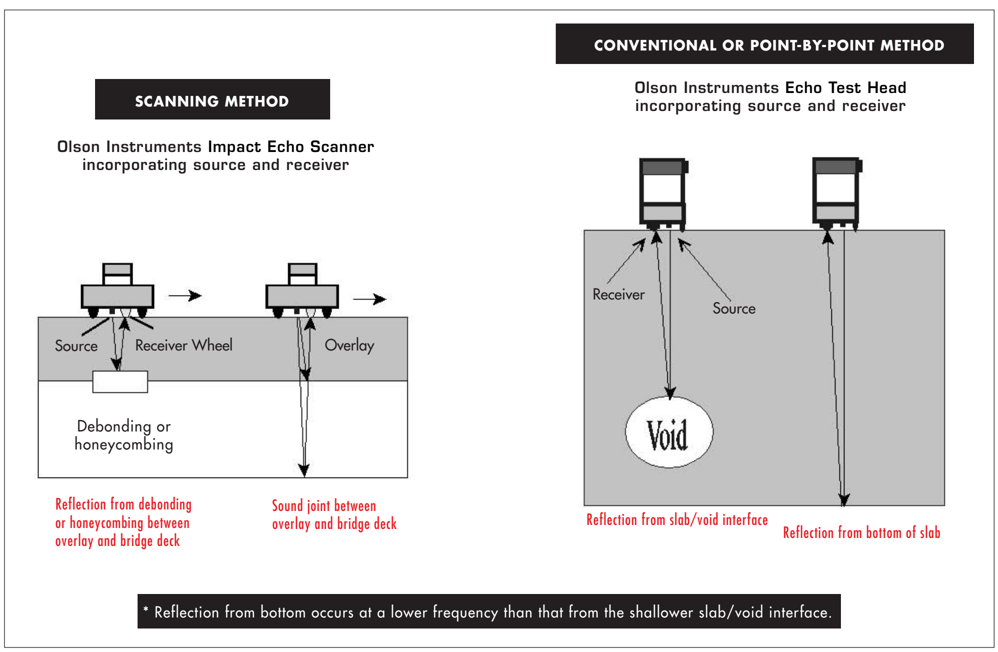
Impact Echo Scanning

Application

Impact Echo (IE) investigations are performed to assess the condition of slabs, beams, columns, walls, pavements, runways, tunnels, and dams. Voids, honeycomb, cracks, delaminations and other damage in concrete, wood, stone, and masonry materials can be found utilizing the IE method. IE investigations are also performed to predict the strength of early age concrete if the member thickness is known and to measure the thickness of structural members. An advantage of the IE method over the Ultrasonic Pulse Velocity (UPV) method is that only one side of the structure needs to be accessible for testing. In addition, the IE method will provide information on the depth of a flaw or defect, in addition to mapping its lateral location and extent.

For large area investigations such as slabs, bridge decks, beams, pipes, etc. where shallow voids or delaminations are of primary concern, Olson Instruments manufacturers an IE Scanner, which can record data at 1 to 2 inch increments for an entire scan path. IE Scanning is used in locating post-tensioning (PT) cables used in reinforcing various structures and determining duct grout condition. The scanning technology allows tracing of the PT cables through slabs and beams. The scanning device application of the IE method was developed by Olson Instruments and is a patented technology.

For simple investigations on slabs, pipes, or walls where the overall thickness is the primary concern, Olson Instruments manufactures a hand-held Concrete Thickness Gauge (CTG) based on the Impact Echo principle, which quickly and easily provides the thickness of an unknown concrete member. Variations of the CTG include an underwater IE device for point-by-point investigations and also customized application such as robotic applications.



Standards

This method is performed in accordance with ASTM C1383-98a.

■ **See end of document for full references.**

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FIELD INVESTIGATION

ACCESS

Only one surface needs to be accessible for receiver placement and hammer or solenoid impact. For IE investigations, relatively smooth, clean surfaces are needed. Water can be applied to the surface to improve coupling of the receiver. The figures on the previous page show the field setups for scanning IE investigations and conventional IE investigations. The IE scanning technology uses the Olson Instruments developed Scanner that contains two sources for generating acoustic energy with different primary frequency content and a receiver wheel made up of multiple sensors. Olson Instruments also developed the CTG which contains a source and receiver for simple operation.

COLLECTION OF DATA

In conventional IE investigations, the hammer or impactor is used to generate compressional waves which reflect back from the bottom of the tested member or from a discontinuity. The response of the system is measured by the receiver placed next to the impact point. The receiver output and sometimes the hammer input, depending on the equipment used, are recorded with an Olson Instruments Freedom Data PC equipped with an Impact Echo System (IE-1, IE-W, IE-2, and IE-T). However, Olson Engineering typically uses the CTG1-TF handheld unit in collecting conventional data due to the portability and flexibility of a handheld system.

IE scanning measurements are possible with Olson Instruments Scanner which contains two sources capable of generating acoustic energy with differing frequency content and a receiver wheel with multiple sensors. The scanner is pushed across one of the accessible surfaces of the structural element and measurements are taken every 1-2 inches. A calibrated distance wheel allows the impactor to hit the surface with precise timing and accurate positioning. The data are then automatically processed for identification of thickness echo peaks. The identified peaks are processed to calculate thicknesses and the thicknesses are plotted out on a graph of thickness versus location.

Conventional IE measurements are possible with either the Freedom Data PC equipped with an Impact Echo System or a Concrete Thickness Gauge (CTG). The conventional method is a point-by-point application often for quality assurance purposes. The data are processed for thickness echo peaks and the peaks are processed in the handheld unit or can be downloaded to a laptop for complete processing if necessary. An exportable table is generated for data collected using a CTG that indicates filename, depth, and thickness mode of investigation.

DATA REDUCTION

PROCESSING TECHNIQUES

The IE time traces are transformed to the frequency domain via FFT for calculations of the transfer and coherence functions, and the auto power spectrum of the receiver. Spectrum data are used to determine the depth of reflectors according to the following equation: $D = VP / (2 \times f1)$ where D is the reflector depth, f1 is the highest amplitude frequency peak identified in the response, and VP is the compressional wave velocity. Olson Engineering uses a proprietary, internally developed software package for IE processing and analysis. This software handles data collected using the Impact Echo Systems or the CTG1-TF. Often in QA/QC investigations of concrete placement either in slabs or beams, the field data must be immediately analyzed to ensure proper data collection design and parameters. The IE software permits on-site, preliminary analysis to ensure quality data have been collected. The software includes a variety of digital filters, and typically, a Butterworth high-pass filter is applied to the data in order to clarify echo peaks corresponding to void/debond peaks or slab bottom peaks.

Data Reduction

Interpretation of Data

The highest amplitude frequency peak is the main indicator of a reflector depth (thickness echo). The presence of additional echo peaks can also be significant, indicating the presence of possible defects or other interfaces in the concrete. Shape effects due to beam boundaries, or from an elevated slab positioned directly on a beam can influence thickness measurements. When void/debond areas exist, the thickness echo peak is often shifted to a lower frequency. This causes the slab to appear thicker as a result of a later arrival time around the void/debond area.

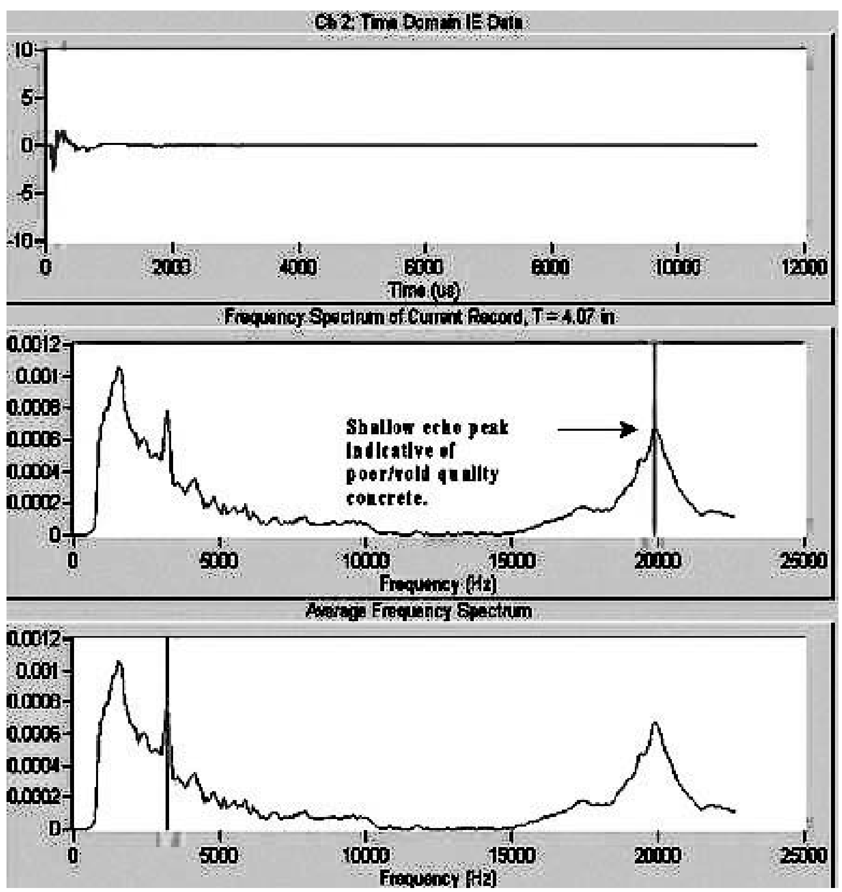
Effectiveness

The Impact Echo method requires access to only one side of the structural member being investigated. There are two modes of investigation: thin and thick. These two modes allow for a wide range of thicknesses to be measured utilizing one instrument. For thin members of 4 to 24 inches thick, a solenoid impactor is used to generate high frequency energy. For thick members of 24 to 48 inches thick, a small hammer is used to generate low frequency energy. Impact Echo investigations can determine member thickness within a 5% accuracy. The IE Scanning method is currently used for investigating shallow void/debond or honeycombing often found between an overlay on a bridge deck or surrounding dense rebar mats. The scanning method is not capable of determining bottom echo thicknesses beyond 24 inches.

Example Results

IE - Shallow Void/Debond

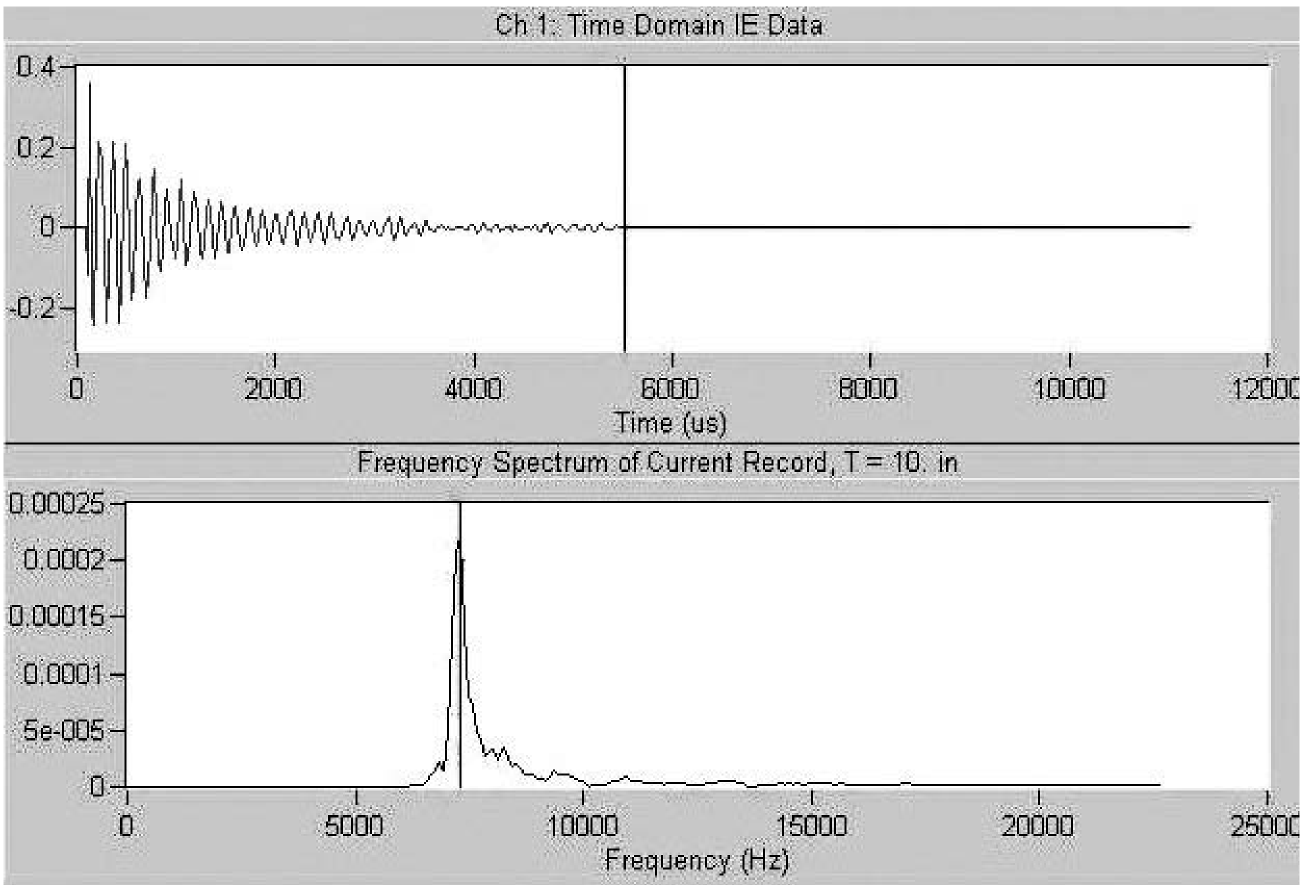
Figure to the right shows an example of a shallow void/debond beneath a rebar mat. The data were collected utilizing the conventional point-by-point method. A 6 x 6 inch grid was established on the elevated slab. The slab was placed directly on top of a beam, as is evident from the two peaks in the spectrum plots. The first peak is at a frequency indicative of the thickness of the slab. The second peak is an echo from the side of the underlying beam.



EXAMPLE RESULTS *cont.*

IE - CONCRETE LOCATION

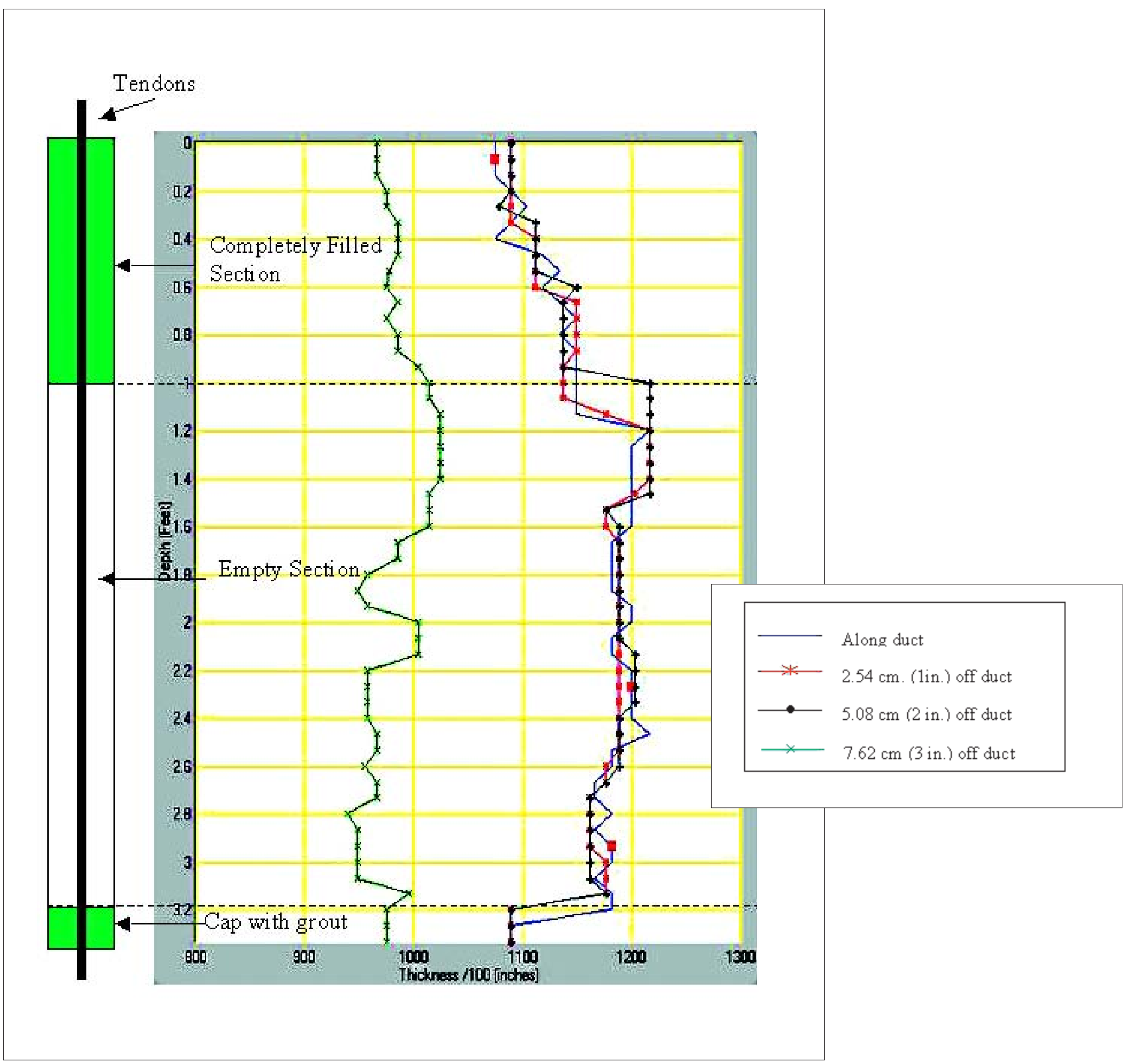
Performing the IE method at a sound concrete location gives results similar to the figure below. A single, sharp, clear peak representing a known thickness is indicative of sound concrete. The beam investigated was 10 inches wide and the bottom echo results in a peak at 10 inches.



EXAMPLE RESULTS *cont.*

IE - VOIDS IN POST TENSIONED DUCTS

An application of IE Scanning is locating voids in post-tensioned ducts. The figure below shows the results of scanning a concrete wall with PT ducts installed for research. IE scanning was performed on and off the centerline of the ducts. The first scan was performed along the centerline of the 7.5 cm (3 inch) diameter steel duct. The second, third, and fourth scans were performed 2.5, 5, and 7.5 cm (1, 2 and 3 inches) off the centerline of the steel duct. The thickness results from all four scans are presented in the figure below. Review of the figure shows that the first three scans yielded almost identical thickness results. The last scan (7.5 cm or 3 inches off the duct) yielded the nominal thickness of the concrete wall. This shows no effect from offset scanning as long as the offset was within 0.635 cm (0.25 inches) of the edge of the duct (5.5 cm or 2 inches offset from the centerline or less).



REFERENCES

Standards and Governmental Reports

- C1383-98a, "Standard Test Method for Measuring the P-Wave Speed and the Thickness of Concrete Plates Using the Impact-Echo Method," Book of Standards Volume 04.02, ASTM International.

OLSON ENGINEERING PUBLICATIONS

- "Impact-Echo Scanning for Internal Grout Evaluation in Post-Tensioned Ducts," *Yajai Tinkey, Larry D. Olson, P.E., and L. C. Muszynski,* Publication in the Proceedings of Seventh CAMNET/ACI International Concrete Conference on Recent Advance in Concrete Technology, to be published May of 2004.
- "Impact-Echo Scanning of Concrete Slabs and Pipes," *Dennis Sack and Larry D. Olson,P.E.,* Advances in Concrete Technology, The 2nd CANMET/ACI Intl. Symposium, Las Vegas, NV, pp. 683-692, 1995.
- "Impact-Echo Scanning for Internal Grout Evaluation in Post-Tensioned Ducts," *L. C. Muszynski,* Publication in the Proceedings of Seventh CAM NET/ACI International Concrete Conference on Recent Advance in Concrete Technology, to be published May of 2004.
- "Impact-Echo Scanning of Concrete Slabs and Pipes," *Dennis Sack and Larry D. Olson,P.E.,* Advances in Concrete Technology, The 2nd CANMET/ACI Intl. Symposium, Las Vegas, NV, pp. 683-692, 1995.

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