



Impact-Echo Instruments, LLC
Ithaca, New York



Field Instruments for Nondestructive Evaluation of Concrete & Masonry

From the people who wrote the book on impact-echo (p. 7)



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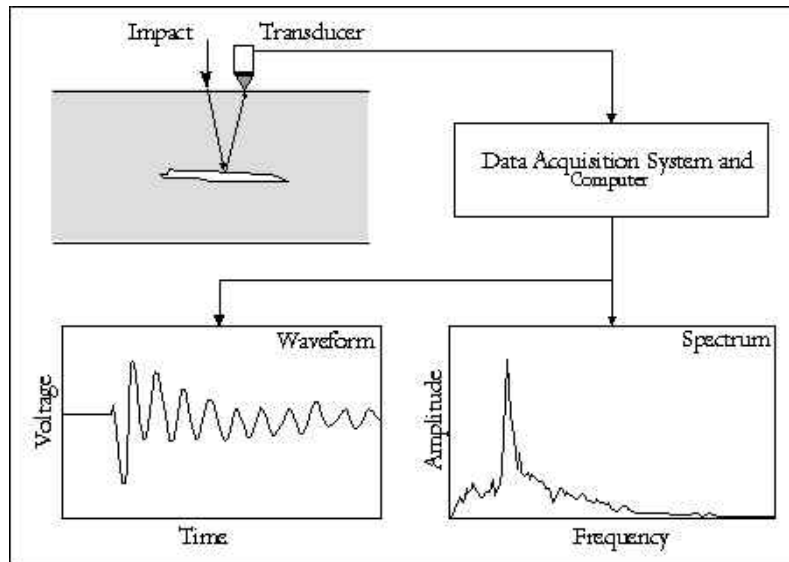
Visit our web site at www.impact-echo.com



The Impact-Echo Method

Impact-Echo is a method for nondestructive evaluation of concrete and masonry, based on the use of impact-generated stress (sound) waves that propagate through the structure and are reflected by internal flaws and external surfaces. Impact-Echo can be used to make accurate, nondestructive, ASTM approved measurements of thickness in concrete slabs and plates, (ASTM Standard C 1383 - 98a). It can also be used to determine the location and extent of flaws such as cracks, delaminations, voids, honeycombing and debonding in plain, reinforced and post-tensioned concrete structures. It can locate voids in the subgrade directly beneath slabs and pavements. It can be used to determine thickness or locate cracks, voids and other defects in masonry structures where the brick or block units are bonded together with mortar. Impact-echo is not adversely affected by the presence of steel reinforcing bars.

How Impact-Echo Works



Schematic diagram, illustrating how impact-echo works.

A short-duration mechanical impact, produced by tapping a small steel sphere against a concrete or masonry surface, produces low-frequency stress waves (up to about 80 kHz) that propagate into the structure and are reflected by flaws and/or external surfaces. The wavelengths of these stress waves are typically between 50mm and 2000mm -- longer than the scale of natural inhomogeneous regions in concrete (aggregate, air bubbles, micro-cracks, etc.). As a result they are only weakly attenuated, and propagate through concrete almost as though it were a homogeneous elastic medium. Multiple reflections of these waves within the structure excite local modes of vibration, and the resulting surface displacements are recorded by a transducer located adjacent to the impact. The piezoelectric crystal in the transducer produces a voltage proportional to displacement, and the resulting voltage-time signal (called a waveform) is digitized and transferred to the memory of a computer, where it is transformed mathematically into a spectrum of amplitude vs. frequency. Both the waveform and spectrum are plotted on the computer screen. The dominant frequencies, which appear as peaks in the spectrum, are associated with multiple reflections of stress waves within the structure, or with flexural vibrations in thin or delaminated layers.

The fundamental equation of impact-echo is $d = C/(2f)$, where d is the depth from which the stress waves are reflected (the depth of a flaw or the thickness of a solid structure), C is the wave speed, and f is the dominant frequency of the signal. The frequency f is obtained from the results of a test. To determine thickness or depth of a flaw, the wave speed C must be known. It can be measured by observing the travel time of a stress wave between two transducers held a fixed distance apart on the concrete surface (see next page) or by performing a test on a solid slab of known thickness and observing the dominant frequency. In the latter case the equation is rearranged to give $C = 2df$ (where d is the known thickness).

Test Instruments Available from Impact-Echo Instruments, LLC

Designed by the people who wrote the book on impact-echo (p. 7)



Impact-Echo Testing



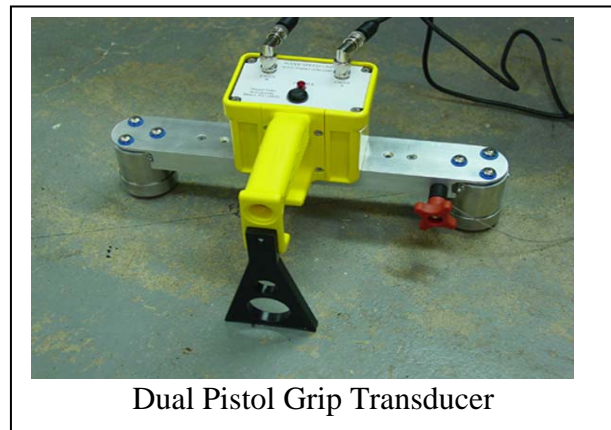
Wave Speed Measurement

Instrument Configurations

Two configurations of the instrument are shown above. The principal components are hand-held transducer units (the cylindrical devices on the left in each photo), a set of spherical impactors (hardened steel ball bearings on steel rods—in front of computer), a high-speed analog-to-digital data acquisition system (box at left of computer), a notebook computer, and a software system that guides and controls the tests and displays the results in graphical and numerical form. A single transducer is used for routine testing. Two transducers separated by a fixed distance are used for independent measurements of wave speed (photos at right above and right below). With a 7.5 lb. notebook computer, the system on the left weighs about 13 lbs. (5.9kg) and the system on the right weighs about 18 lb. (8.2 kg).



Single Pistol Grip Transducer



Dual Pistol Grip Transducer

Pistol Grip Transducers

The cylindrical transducers are especially useful for work in narrow and confined spaces. An alternative to the cylindrical transducers, called “pistol grip transducers”, is shown in the photos above. The single pistol grip model is well suited to use on flat surfaces. The dual pistol grip transducer on the right is used for wave speed measurements. The two sensing elements in the dual pistol grip transducer are separated by the same fixed distance (300mm) as in the two cylindrical transducers held by a spacer bar (right photo at the top of the page). The dual pistol grip transducer eliminates the need to strap two cylindrical transducers into a spacer bar for wave speed measurements. Pistol grip transducers have a “trigger” arming switch, positioned on the underside of the grip (not visible in these photos). Instruments are available with several combinations of cylindrical and/or pistol grip transducers.

Components



1. **Analog/Digital Data Acquisition System** (14-bit resolution, 2 MHz maximum sampling speed on each of two channels);
2. **Two Hand-Held Transducer Units** (cylindrical or pistol grip, or combination of the two);
3. **Impactors** (set of 10 hardened steel spheres on spring rods);
4. **Spacer bar with connecting handle** (for measurement of wave speed using two cylindrical transducers);
5. **Computer Software (CD - not shown in photo):**
Impact-E Operating Software;
Wave Animation Software (computer simulation of stress wave propagation and reflection);
6. **Two BNC Cables:** (for connecting transducer units to data acquisition system);
7. **Serial Port Cable** (to connect Data Acquisition System to serial port or USB port of computer);
8. **Output Adapter** (90v - 264v AC input, 12v DC output, to recharge batteries and provide power for Data Acquisition System);
9. **DC to AC Power Inverter** (10v - 15v DC input, 110v AC output, for use with item #8 to recharge batteries and provide power for the Data Acquisition System. Connects to cigarette lighter in car or truck);
10. **Printed Materials:**
Book: "Impact-Echo: Nondestructive Evaluation of Concrete and Masonry" by M. J. Sansalone and W. B. Streett, Bullbrier Press, Ithaca, NY, 1997, 339pp;
Impact-Echo Instrument Manual (instructions for use of impact-echo test system);
Impact-Echo User's Manual: (self-teaching course on impact-echo, for use with **Impact-E** software);
Packing List, "Read Me First", Warranty;
11. **Roll-On/Carry-On Case** (see next page).
12. **Notebook Computer** (see next page).

Power Requirements: Power is provided by internal batteries in the notebook computer and data acquisition system. *No external power source is required for operation in the field.* A fully charged notebook battery typically provides 2 – 3 hours of operating time, and extra batteries are available. The data acquisition system battery provides 6 – 8 hours of operating time when fully charged. Power supplies for recharging the batteries from a 110/220v AC source (or a 12v DC source such as a car or truck battery) are included.

Roll-On/Carry-On Case.

The heavy-duty, padded, roll-on, canvas case has a separately padded computer pocket, zippered accessory pockets, padded container for transducer units, zippered mesh pockets, telescoping handle, and in-line skate wheels. When fully packed its dimensions are approximately 18 x 14 x 10 inches (46 x 36 x 25 cm), and its total weight is about 30 pounds (13.6 kg).

Computer Recommendations for Impact-Echo Test Instruments

A Test System can be purchased from Impact-Echo Instruments with or without a computer. The **IMPACT-E** software program requires an IBM-compatible computer with a Windows 95 or later operating system, a serial port or USB port (available on virtually all computers) and English(U.S.) as an available option for both the "Regional Setting" and the "Keyboard Language" (these settings are found in the Control Panel of Windows operating systems). The minimum recommended capabilities for an IBM-compatible computer are as follows:

- 100 Mhz or faster processor
- 16 MB RAM
- 800 MB Hard Drive
- 10.3" TFT color screen
- 3.5" Floppy disk drive

Virtually all currently available IBM-compatible computers meet or exceed these requirements. Suitable notebook computers are available from many companies, including Acer, Compaq, Gateway, Dell, HP, IBM, Micron, Panasonic, Toshiba, Winbook, and others. The Panasonic "Toughbook" is a "ruggedized" computer that has a moisture- and dust-proof magnesium alloy case, shock mounted hard drive, spill-proof keyboard, sunlight readable screen, and other features well suited to outdoor use. (See the Panasonic web site listed below, or search for "Toughbook" on the Internet). Prices for notebook computers that meet or exceed the minimum requirements for use with an impact-echo test system start at about US\$1000. Ruggedized computers start at about \$2000. For current information, see the following web sites.

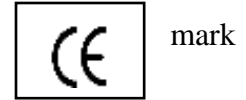
<http://www.acer.com/aac>
<http://www.compaq.com>
<http://www.gateway.com>
<http://www.dell.com>
<http://www.hp.com>

<http://www.pc.ibm.com/thinkpad>
<http://www.micronpc.com>
<http://www.panasonic.com/computer/notebook>
<http://www.toshiba.com>
<http://www.winbook.com>

See pages 10-11 for detailed information on instrument configurations and prices, with and without computers.

Technical Specifications for the Impact-Echo Test System:

The instrument was designed and tested for worldwide use. It carries the CE mark of conformity with European Union standards.



Dimensions and Weights: When fully packed the carrying case is approximately 18 x 14 x 10 inches in size (46 x 36 x 25 cm). Total weight, including notebook computer, manuals, case, cables, etc., is about 30 pounds (13.6 kg). The roll-on/carry-on case meets requirements for airline carry-on luggage. It contains a heavily padded inner compartment for storage and protection of a notebook computer.

Hand-Held Transducer Unit: Key components include piezoelectric crystal and on-board preamplifier.



Cylindrical (stainless steel)



Pistol Grip

Power Requirements: 9v battery (inside body of transducer).

Controls: Armed by depressing handle (cylindrical) or by trigger switch (pistol grip). Warning light for low battery.

Cable Connections: BNC connectors for connecting to data acquisition system.

Dimensions & Weights:

Cylindrical: Overall length is 11.3" (29 cm); main cylinder is 2" in diameter and 6.8" long (5 x 17 cm); handle is 1.5" in diameter and 4.5" long (3.8 x 11.4 cm). Weight is 2.2 pounds (1 kg).

Pistol Grip: Height 6.5" (16.5cm); Length 8" (20cm), Width 3" (7.6cm). Weight 1.5 pounds (0.7 kg).

Analog/Digital Data Acquisition System: Fourteen-bit analog/digital converter. Maximum sampling speed 2 MHz on each of two channels.



Power Requirements: Internal, rechargeable battery (5v DC) provides 5 - 8 hours of operating time on a full charge.

Software: Proprietary on-board software functions only with Impact-E operating software (next page).

Controls: On/off switch, indicator lights.

Cable Connections: Two BNC cable connectors for transducer units; one 9-pin serial port connector, coaxial connector for power supply.

Dimensions & Weight: 10.2 x 6.2 x 1.6 inches (26 x 16 x 4 cm) and 2.2 pounds (1.0 kg).

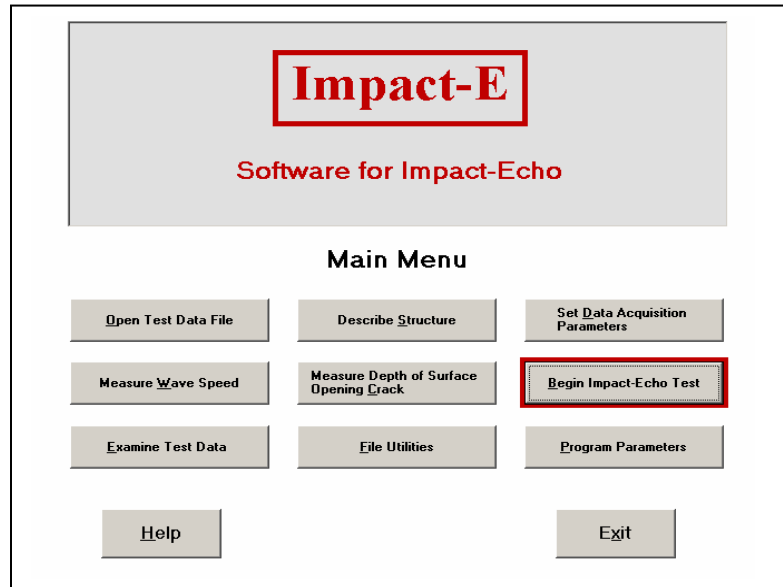
Warranty: All components, with the exception of the computer, are covered by a one-year parts and labor warranty from Impact-Echo Instruments, LLC. Warranties for computers are provided by the manufacturer.

Impact-E: Windows-Based Software For Impact-Echo

Impact-E is a Windows-based, interactive, user-friendly, software system for impact-echo testing and for examination and analysis of impact-echo test results. It is the product of two man-years of programming effort by the people who wrote the book on impact-echo (see p. 8). It incorporates the physics and mathematics on which the impact-echo method is based. **Impact-E** software can be installed on any computer and used for all purposes except testing, which requires a data acquisition system from Impact-Echo Instruments that is compatible with the software.

Key benefits of Impact-E software:

- **User friendly:** *Guides the user through the testing process.*
- **Interactive:** *The user is in control at every step.*
- **Well documented:** *Comprehensive instruction manual and a detailed on-line Help System.*
- **Comprehensive:** *Covers all known applications of impact-echo.*



The “Main Menu” screen of Impact-E software

Key Features:

Easy to use

- User interacts through clearly labeled command buttons and text boxes for data entry,
- Control exercised with mouse or keyboard, or combination of the two,
- Organization of screens guides the user through testing and data recall and analysis.
- Date and time of each test automatically recorded and stored with test results.

Fast

- Sets up for testing in two minutes.
- Test results appear on the computer screen within 2 seconds after impact is made.
- The time required to perform a test and store the results in a test file is 15 – 20 seconds.

Flexible

- Screens can be viewed in color or black and white (the latter is sometimes easier to read in outdoor light),
- Test results can be stored in data files on hard disk, floppy disk, or other drive, for later recall and analysis,
- Test records and summaries of test files can be printed or written to Excel spreadsheets.
- File utilities system facilitates printing, copying test records between files, writing information directly to Microsoft Excel spreadsheets, writing results to ASCII files for export, etc.

Software Protection

- Impact-E software is protected against unauthorized use by encrypted code that enables testing to be performed only with a compatible data acquisition system from Impact-Echo Instruments, LLC.

The Book

Impact-Echo: Nondestructive Evaluation of Concrete and Masonry

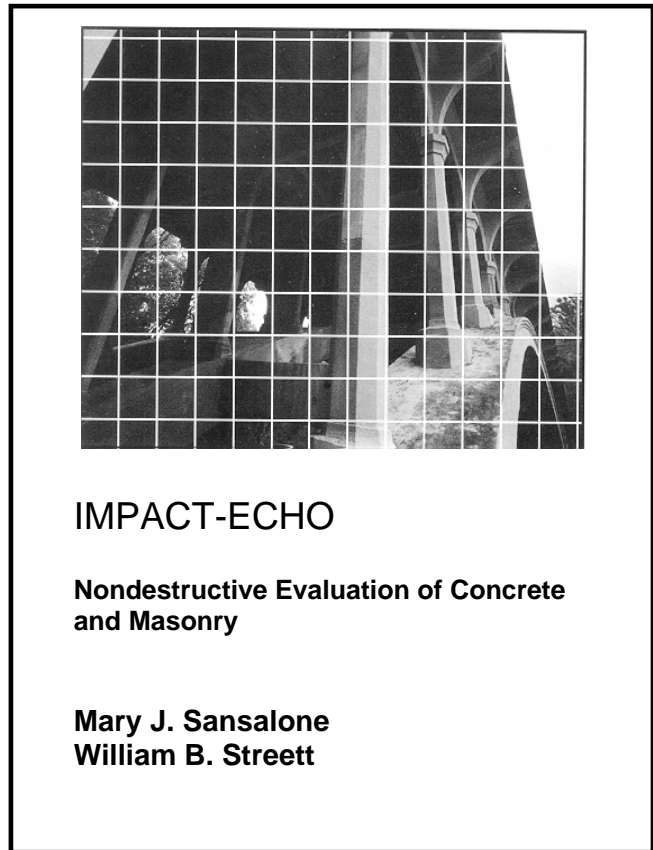
by **Mary J. Sansalone and William B. Streett**, Bullbrier Press (1997) 339 pp.

Chapter Titles:

1. Introduction
2. Development of the Method
3. Stress Waves
4. Waveforms
5. Frequency Analysis
6. Digital Signals
7. Wave Speed
8. Plate Thickness
9. Cracks and Voids in Plates
10. Shallow Delaminations
11. Unconsolidated Concrete
12. Surface-Opening Cracks
13. Plates in Contact With Soils
14. Plates Containing Two Layers
15. Bond Quality at Internal Interfaces
16. Plates With Asphalt Overlays
17. Steel Reinforcing Bars
18. Bonded Post-Tensioning Tendons
19. Hollow Cylinders
20. Mine Shaft and Tunnel Liners
21. Circular and Square Cross Sections
22. Rectangular Cross Sections
23. Masonry
24. Field Testing

This book draws together all available knowledge of the impact-echo method and presents it in a concise and logical format. Following a brief introduction and review of the development of the method, 5 chapters are devoted to physical and mathematical principles, followed by 17 chapters on applications and case studies. Photographs, drawings and results from tests on real structures are used throughout.

Order from:
Bullbrier Press
R.R. 1, Box 332
Jersey Shore, PA 17740 USA
 Phone or Fax: **570-769-7345**



Price: US\$35.00. Credit card orders accepted. Bullbrier ships promptly upon receipt of payment. Foreign orders must include payment in a form negotiable on a U.S. bank. The book can also be ordered from <http://www.amazon.com>.

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	First Copy	Additional	First Copy	Additional
U.S.	US\$2.50	\$.35	\$4.00	\$.50
Canada & Mexico	\$4.00	\$.60	\$7.50	\$.75
Elsewhere	\$6.00	\$.75	\$15.00	\$.90

Testimonials from engineers who have used our instruments worldwide.

"WDP has successfully utilized equipment from Impact-Echo Instruments, LLC to investigate a wide variety of civil infrastructure over the last 10 years ranging from bridges, parking structures and buildings to specialty structures such as tanks, storm-water retention boxes, flood control channels, and marine structures. Flaws such as delaminations, honeycombing, and voids in concrete, voids in grout of bonded post-tensioning tendons, and sub-grade voids under slabs have been successfully detected and confirmed using this technology. Impact-Echo has been used by WDP on over a hundred structures in the evaluation of thousands of individual concrete members. Over 100,000 signals have been recorded and analyzed over the last 10 years. Impact-Echo has become the leading investigative tool used by WDP personnel in the forensic evaluation of structural concrete. The successful application of this technology and its ability to accurately detect concrete flaws has resulted in the savings of tens of millions of dollars in repair and replacement costs for our clients."

[Randall W. Poston, Ph.D., P.E. / Principal / WDP & Associates, Inc., Austin, TX]

"We are using an instrument from Impact-Echo Instruments to locate voids beneath 80-90mm of a steel fibre concrete floor, forming the cap over cushion piles. We have located faulty pile heads, mapped the extent of voids and associated honeycombing, and after grouting checked for residual voids and concrete strength gain. No other available test method is appropriate. We also regularly use impact-echo in forensic studies of historic buildings, including recently St. Paul's Cathedral, London, The Federal Reserve Building in New York, and the U.S. Capitol Building, Washington."

[George Ballard / GBG Inc, New York, USA/ GB Geotechnics Ltd / Cambridge, England]

"The Federal Highway Research Institute of Germany (BAST) has used the equipment of Impact-Echo-Instruments for almost two years. The impact-echo-system was used successfully for thickness measurements, detection of delaminations and detection of voids and honeycombing. Furthermore the system was used for the investigation of prestressed concrete bridges to detect voids in the grouting of tendon ducts. For verification of the thickness of the inner tunnel lining of new road tunnels in Federal Roads, a procedure based on the use of impact-echo was prepared by BAST and implemented by the Federal Ministry of Transport, Building and Housing."

[Dr.-Ing. Juergen Krieger, Bundesanstalt fuer Strassenwesen (Federal Highway Research Institute), Germany]

"We have used the impact-echo method successfully in 13 projects since June 1999. These included:

1. detecting voids in tendon ducts in pre-stressed beams and slabs;
2. determination of retaining wall thickness;
3. detection of honeycombing in basement wall and marine spun piles (verified by cores);
4. determination of bonding between metal inserts and concrete in railway ties (verified by cores); and
5. determination of bonding condition between topping concrete and a pre-cast hollow-core slab."

[Zheng Yonghao / SETSCO Services Pte Ltd / Singapore]

"Based on our experiences with the technology, we strongly recommend the use of Impact-Echo as an effective tool to determine the likelihood of flaws within plate-type structures, including garage slabs, plaza deck slabs and foundation walls. It is particularly valuable when there is a concealed surface on the structure (e.g. the topside of a plaza deck slab)."

[Alan Cohen / Halsall Engineers – Consultants / Toronto, Canada]

"As an impact-echo researcher, I am very impressed by the products of Impact-Echo Instruments, with which I have done many impact-echo tests successfully, such as crack detection and thickness measurements. A test system integrating two handheld transducers, a 14-bit A/D converter and a user-friendly software makes the impact-echo field test system accurate and easy to use."

[Professor Yiching Lin, Ph.D. / National Chung Hsing University / Taiwan]