



Designation: C1740 – 24

Standard Practice for Evaluating the Condition of Concrete Plates Using the Impulse-Response Method¹

This standard is issued under the fixed designation C1740; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice provides the procedure for using the impulse-response method to evaluate rapidly the condition of concrete slabs, pavements, bridge decks, walls, or other plate-like structures.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this practice refers to notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:²

C125 Terminology Relating to Concrete and Concrete Aggregates

C1383 Test Method for Measuring the P-Wave Speed and the Thickness of Concrete Plates Using the Impact-Echo Method

D5882 Test Method for Low Strain Impact Integrity Testing of Deep Foundations

E1316 Terminology for Nondestructive Examinations

3. Terminology

3.1 Definitions:

3.1.1 Refer to Terminology **C125** for general terms related to concrete. Refer to Terminology **E1316** for terms related to nondestructive ultrasonic examination that are applicable to this practice.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *function, frequency response, n*—response amplitude per unit of applied force as a function of frequency obtained from an impulse-response test at a point on the test element.

3.2.1.1 *Discussion*—The response that is measured at the test point can be displacement, velocity, or acceleration. If velocity is measured, the frequency response function is known as a mobility spectrum.

3.2.2 *impulse-response method, n*—a nondestructive test method based on the use of mechanical impact to cause transient vibration of a concrete test element, the use of a broadband transducer placed on the test element adjacent to the impact point to measure the response, and the use of signal processing to obtain the frequency response function of the test element.

3.2.2.1 *Discussion*—**Fig. 1** shows the testing configuration for the impulse-response method. The hammer contains a load cell to measure the transient impact force and a transducer, such as a velocity transducer, is used to measure the resulting vibration of the test object (see top plots in **Fig. 2**). Tests are performed at grid points marked on the surface of the test object. In plate-like structures, the impact results predominantly in flexural vibration of the tested element, although other modes can be excited. Waveforms from the load cell and transducer are converted to the frequency domain and used to calculate the frequency response function. Each frequency

¹ This practice is under the jurisdiction of ASTM Committee **C09** on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee **C09.64** on Nondestructive and In-Place Testing.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at www.astm.org/contact. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

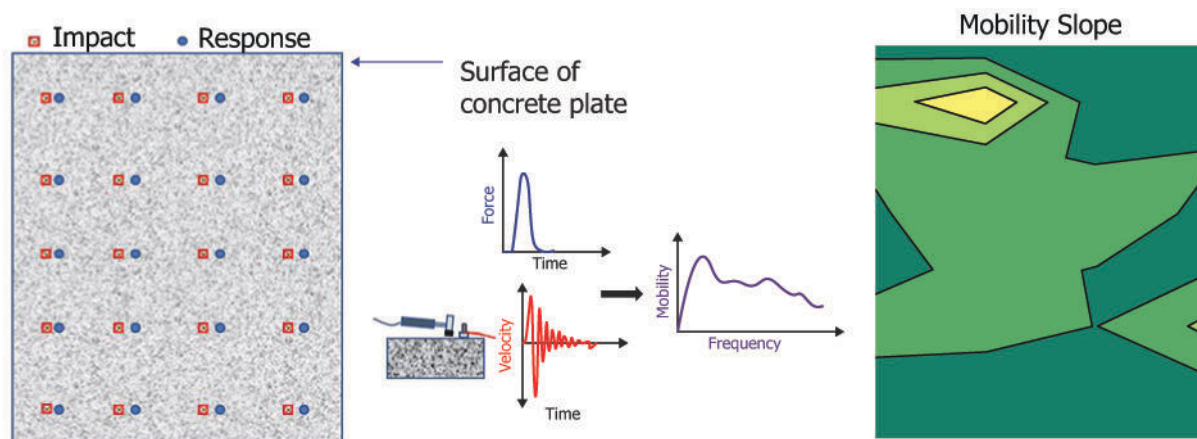


FIG. 1 Schematic of Impulse-Response Test Showing Grid Points, Acquired Data at Each Test Point, Frequency Response Function at a Test Point, and Contour Plot of a Selected Parameter

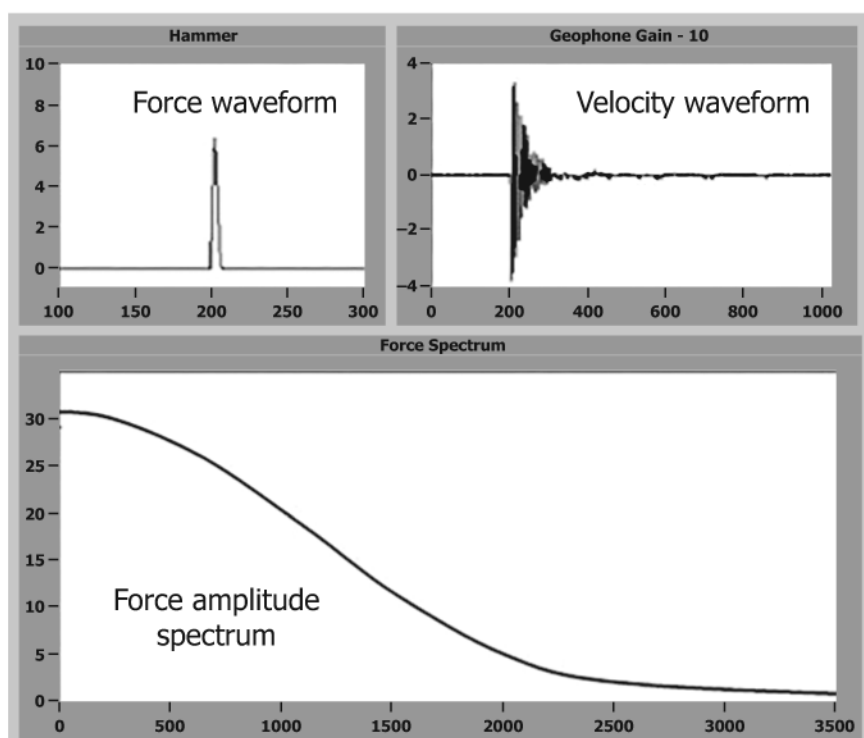


FIG. 2 Typical Force-Time Waveform and Amplitude Spectrum Plots for Hammer with a Hard Rubber Tip

response function is analyzed to obtain parameters characterizing the element's response to the impact. Contour plots of these parameters, or pattern recognition methods, (1)³ can be used to identify anomalous regions within the tested element.

3.2.3 *mobility, n* —ratio of the velocity amplitude at the test point to the force amplitude at a given frequency, expressed in units of (m/s)/N.

3.2.3.1 *Discussion*—For a plate-like structure, mobility is an indicator of the relative flexibility of the plate at the test point, which is a function of plate thickness, concrete elastic

modulus, support conditions, and presence of internal defects. A higher mobility indicates that the plate is relatively more flexible at that test point (2, 3).

3.2.4 *mobility ratio, peak-mean, n* —the ratio of the peak mobility value between 0 to 100 Hz to the average mobility between 100 to 800 Hz

3.2.4.1 *Discussion*—A high ratio of the peak mobility to the average mobility has been found to correlate with poor support conditions or voids that may exist beneath concrete slabs bearing on ground (2, 3).

3.2.5 *mobility, average, n* —average of the mobility values from the mobility spectrum between 100 and 800 Hz, expressed in units of (m/s)/N.

³ The boldface numbers in parentheses refer to a list of references at the end of this standard.

3.2.5.1 *Discussion*—This parameter is used to compare differences in overall mobility among test points in the tested element (2, 3).

3.2.6 *slope, mobility, n* —the slope of the mobility spectrum obtained from the fitting a straight line to mobility values between 100 Hz and 800 Hz.

3.2.6.1 *Discussion*—A high mobility slope has been found to correlate with locations of poorly consolidated (or honey-combed) concrete in plate-like structures (2, 3).

3.2.7 *spectrum, mobility, n* —the value of mobility as a function of frequency obtained from an impulse-response test at one point on the surface of the tested element; the name applied to the frequency response function if velocity is measured during an impulse-response.

3.2.7.1 *Discussion*—The mobility spectrum is obtained by converting the recorded waveforms of the hammer impact force and velocity response into the frequency domain (4, 5). The resulting spectra are used to compute the mobility spectrum as follows:

$$M(f) = \frac{V(f) \times F^*(f)}{F(f) \times F^*(f)} \quad (1)$$

where:

- $M(f)$ = mobility spectrum,
- $V(f)$ = velocity spectrum,
- $F(f)$ = impact force spectrum, and
- $F^*(f)$ = complex conjugate of force spectrum.

Matrix multiplication in the numerator and denominator by the complex conjugate of the force spectrum is required because the velocity and impact force spectra are vectors of complex numbers. By the rule for division of complex numbers, the numerator and denominator have to be multiplied by the complex conjugate of the denominator, which in this case is the force spectrum. The spectrum determined from Eq 1 is a vector of complex numbers, which can be

converted to amplitude and phase spectra. In practice the amplitude spectrum, as shown by the example in Fig. 3, is used in subsequent analyses. The vertical axis represents response velocity amplitude per unit of force and the horizontal axis is frequency.

3.2.8 *stiffness, dynamic*—inverse of the initial slope of the mobility spectrum from 20 Hz to 5 Hz, expressed in units of N/m (See Fig. 3).

3.2.8.1 *Discussion*—The initial slope of the mobility spectrum defines the dynamic compliance (or flexibility) at the test point. The inverse of the initial slope is the dynamic stiffness, which is an indicator of the relative quality of the concrete, of the relative thickness of the member, of the relative quality of the subgrade support for slabs-on-ground, and of the support conditions for suspended structural slabs and walls (2, 3).

4. Summary of Practice

4.1 A grid is laid out on the surface of the concrete element to be tested. Grid spacing normally ranges between 500 mm and 2000 mm and is selected on the basis of the size and shape of the element to be tested. A closer spacing is used for smaller elements and to locate smaller anomalous regions.

4.2 A hand-held hammer with a force measuring load cell is used to impact the concrete surface adjacent to a surface mounted transducer. The impact generates transient stress waves that propagate in the concrete test element. Reflections of these propagating stress waves create standing waves within the element in the vicinity of the test point. The transducer measures the vibrational response of the test element during the test.

4.3 The force and vibration waveforms are recorded and subjected to digital signal processing to obtain the mobility spectrum, or other frequency response function, at each test point. Parameters that characterize the shape features of the

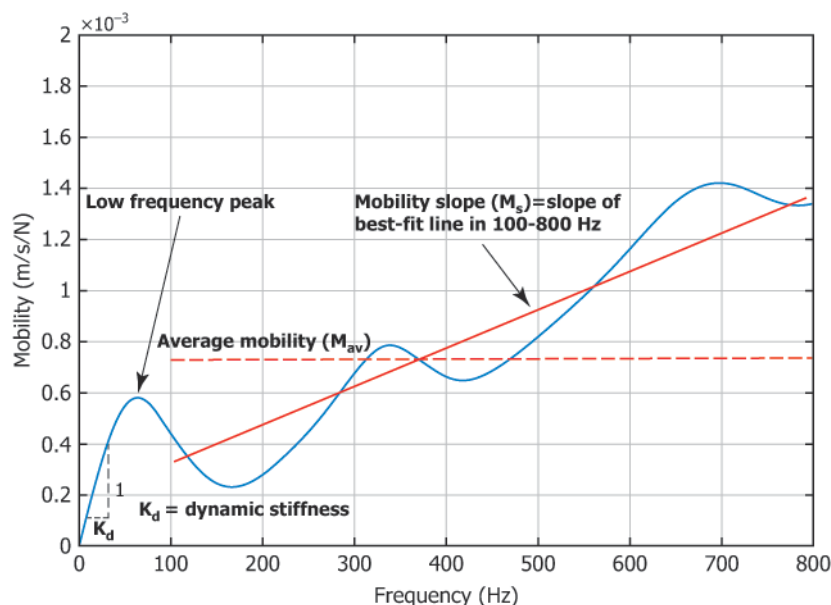


FIG. 3 Example of a Mobility Spectrum Obtained from an Impulse Response Test of a Plate-Like Concrete Element Showing Parameters Used to Characterize the Response (1)