Designation: C1740 – 16

Standard Practice for
Evaluating the Condition of Concrete Plates Using the Impulse-Response Method[1]

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 and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this standard references 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.

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 *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 velocity transducer placed on the test element adjacent to the impact point to measure the response, and the use of signal processing to obtain the mobility spectrum of the test element.

3.2.1.1 *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 velocity transducer is used to measure the resulting motion of the test object (see top plots in Fig. 2). 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 velocity transducer are converted to the frequency domain and used to calculate the mobility spectrum, which is analyzed to obtain parameters representing the element's response to the impact. These parameters are used to identify anomalous regions within the tested element.

3.2.2 *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.

3.2.2.1 *Discussion*—For a plate-like structure, mobility is an indicator of the relative flexibility of the tested element, which is a function of plate thickness, concrete elastic modulus, support conditions, and presence of internal defects. A higher mobility indicates that the element is relatively more flexible at that test point (**1,2**).[3]

3.2.3 *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

3.2.3.1 *Discussion*—A high ratio of the peak mobility to the average mobility has been found to correlate with poor support

[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 service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

*A Summary of Changes section appears at the end of this standard

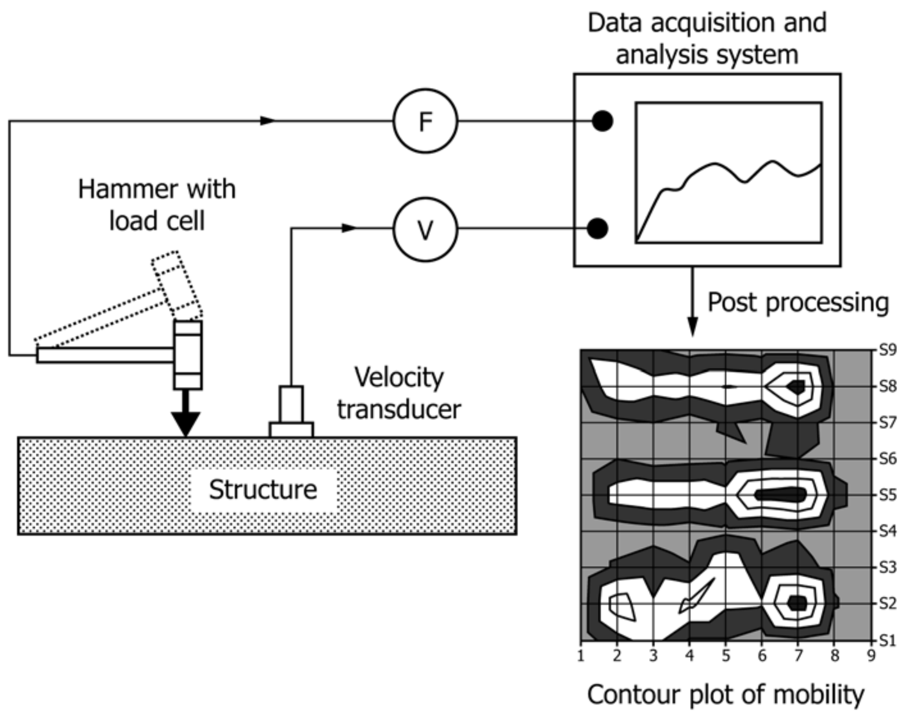

FIG. 1 Schematic of the Test Set-Up and Apparatus for Impulse-Response Test

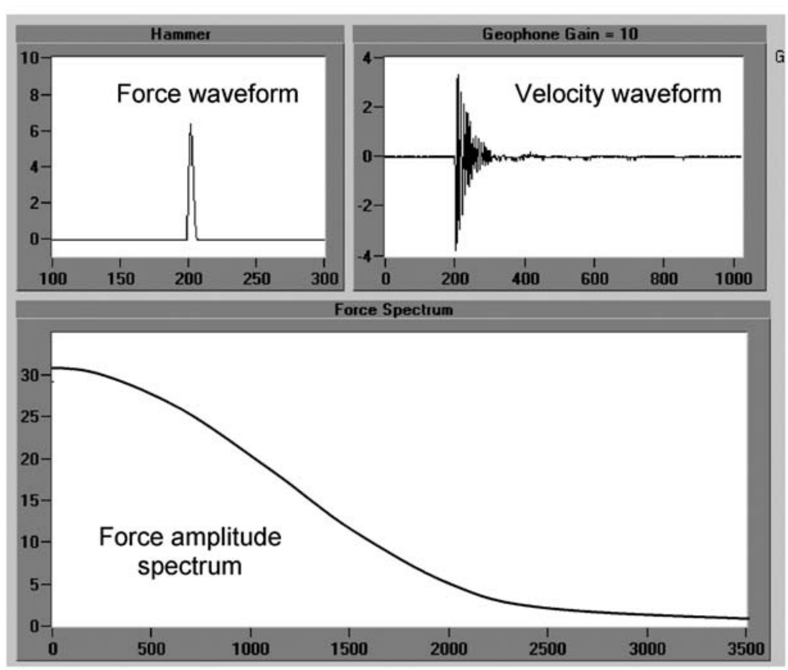

FIG. 2 Typical Force-Time Waveform and Amplitude Spectrum Plots for Hammer with a Hard Rubber Tip

conditions or voids that may exist beneath concrete slabs bearing on ground (**1**,**2**).

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

3.2.4.1 *Discussion*—This parameter is used to compare differences in overall mobility among test points in the tested element (**1**,**2**).

3.2.5 *slope, mobility, n*—the slope of the mobility spectrum obtained from the best-fit line to mobility values between 100 Hz and 800 Hz.

3.2.5.1 *Discussion*—A high mobility slope has been found to correlate with locations of poorly consolidated (or honeycombed) concrete in plate-like structures (**1,2**).

3.2.6 *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.

3.2.6.1 *Discussion*—The mobility spectrum, also referred to as the *transfer function*, is obtained by converting the recorded waveforms of the hammer impact force and velocity response into the frequency domain (**3,4**). The resulting spectra are used to compute the mobility spectrum as follows:

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

where:

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

The numerator is the cross power spectrum of the force and velocity and the denominator is the power spectrum of the force. Matrix multiplication by the complex conjugate of the force spectrum is required because the velocity and impact force spectra are matrices 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, that is, the force spectrum. Fig. 3 is an example of a mobility spectrum. The vertical axis represents response velocity amplitude per unit of force and the horizontal axis is frequency.

3.2.7 *stiffness, dynamic*—inverse of the initial slope of the mobility spectrum from 0 to 40 Hz, expressed in units of N/m (See Fig. 3).

3.2.7.1 *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 (**1,2**).

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 and generate transient stress waves in the concrete test element. These waves set up flexural and other vibrational modes of the element in the vicinity of the test point.

4.3 The impact point is within 100 ± 25 mm of the velocity transducer used to measure the response due to the hammer blow.

4.4 The force and velocity waveforms are recorded and subjected to digital signal processing to obtain the mobility spectrum at each test point. Key parameters are computed from the mobility spectra at the test points and displayed in the form of contour plots from which the likely locations of anomalous regions can be identified.

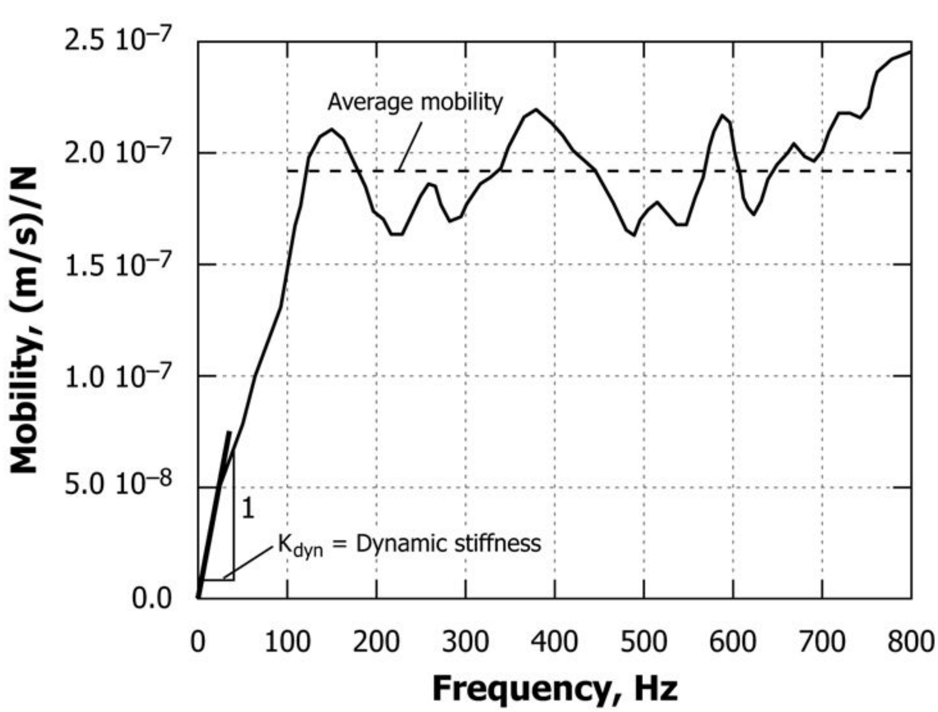

FIG. 3 Example of a Mobility Spectrum Obtained from an Impulse Response Test of a Plate-Like Concrete Element