Designation: C215 – 14

Standard Test Method for Fundamental Transverse, Longitudinal, and Torsional Resonant Frequencies of Concrete Specimens[1]

This standard is issued under the fixed designation C215; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This test method covers measurement of the fundamental transverse, longitudinal, and torsional resonant frequencies of concrete prisms and cylinders for the purpose of calculating dynamic Young's modulus of elasticity, the dynamic modulus of rigidity (sometimes designated as "the modulus of elasticity in shear"), and dynamic Poisson's ratio.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C125 Terminology Relating to Concrete and Concrete Aggregates

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C469/C469M Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

E1316 Terminology for Nondestructive Examinations

3. Terminology

3.1 *Definitions*—Refer to Terminology C125 and the section related to ultrasonic examination in Terminology E1316 for definitions of terms used in this test method.

4. Summary of Test Method

4.1 The fundamental resonant frequencies are determined using one of two alternative procedures: (*1*) the forced resonance method or (*2*) the impact resonance method. Regardless of which testing procedure is selected, the same procedure is to be used for all specimens of an associated series.

4.2 In the forced resonance method, a supported specimen is forced to vibrate by an electro-mechanical driving unit. The specimen response is monitored by a lightweight pickup unit on the specimen. The driving frequency is varied until the measured specimen response reaches a maximum amplitude. The value of the frequency causing maximum response is the resonant frequency of the specimen. The fundamental frequencies for the three different modes of vibration are obtained by proper location of the driver and the pickup unit.

4.3 In the impact resonance method, a supported specimen is struck with a small impactor and the specimen response is measured by a lightweight accelerometer on the specimen. The output of the accelerometer is recorded. The fundamental frequency of vibration is determined by using digital signal processing methods or counting zero crossings in the recorded waveform. The fundamental frequencies for the three different modes of vibration are obtained by proper location of the impact point and the accelerometer.

5. Significance and Use

5.1 This test method is intended primarily for detecting changes in the dynamic modulus of elasticity of laboratory or field test specimens that are undergoing exposure to weathering or other types of potentially deteriorating influences. The test method may also be used to monitor the development of dynamic elastic modulus with increasing maturity of test specimens.

5.2 The value of the dynamic modulus of elasticity obtained by this test method will, in general, be greater than the static

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregatesand 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.

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

modulus of elasticity obtained by using Test Method C469/C469M. The difference depends, in part, on the strength level of the concrete.

5.3 The conditions of manufacture, the moisture content, and other characteristics of the test specimens (see section on Test Specimens) influence the results obtained.

5.4 Different computed values for the dynamic modulus of elasticity may result from different modes of vibration and from specimens of different sizes and shapes of the same concrete. Therefore, it is not advisable to compare results from different modes of vibration or from specimens of different sizes or shapes.

6. Apparatus

6.1 *Forced Resonance Apparatus* (Fig. 1)*:*

6.1.1 *Driving Circuit*—The driving circuit shall consist of a variable frequency audio oscillator, an amplifier, and a driving unit. The oscillator shall be calibrated to read within ±2 % of the true frequency over the range of use (about 100 to 12 000 Hz). The combined oscillator and amplifier shall be capable of delivering sufficient power output to induce vibrations in the test specimen at frequencies other than the fundamental and shall be provided with a means for controlling the output. The driving unit for creating the vibration in the specimen shall be capable of handling the full power output of the oscillator and amplifier. The driving unit is used in contact with the test specimen or separated from the specimen by an air gap. The oscillator and amplifier shall be capable of producing a voltage that does not vary more than ±20 % over the frequency range and, in combination with the driving unit, shall be free from spurious resonances that will be indicated in the output.

NOTE 1—It is recommended that the calibration of the variable frequency audio oscillator be checked periodically against signals transmitted by the National Institute of Standards and Technology radio station WWV, or against suitable electronic equipment such as a frequency counter, the calibration of which has been checked previously and found to be adequate.

6.1.2 *Pickup Circuit*—The pickup circuit shall consist of a pickup unit, an amplifier, and an indicator. The pickup unit shall generate a voltage proportional to the displacement, velocity, or acceleration of the test specimen, and the vibrating parts shall be small in mass so as to not affect the vibrational frequency of the test specimen by more than 1%. The pickup unit shall be free from spurious resonances in the normal operating range of 100 to 12 000 Hz. Either a piezoelectric or magnetic pickup unit meeting these requirements is acceptable. The amplifier shall have a controllable output of sufficient magnitude to actuate the indicator. The indicator shall consist of a voltmeter or a milliammeter that shows the relative amplitude of the signal from the pickup unit. The driver signal and the pickup signal shall be connected to the horizontal and vertical sweeps, respectively, of a real-time graphic display such as an oscilloscope or a data acquisition system with monitor. The displayed pattern is used to confirm that the driver frequency at maximum signal amplitude is the resonant frequency of the specimen.

NOTE 2—For routine testing of specimens whose fundamental frequency may be anticipated to be within known limits, a meter-type indicator is satisfactory for determining the fundamental resonant frequency. It is, however, strongly recommended that the graphic display be used. The graphic display will confirm that the specimen is vibrating at its fundamental resonant frequency, and is necessary when testing specimens for which the fundamental frequency range is not known beforehand. See Note 6 for additional guidance on using the graphic display.

6.1.3 *Specimen Support*—The support shall permit the specimen to vibrate freely (Note 3). The locations of the nodal points for the different modes of vibration are described in Notes 6-8. The support system shall be dimensioned so that its resonant frequency falls outside the range of use (from 100 to 12 000 Hz).

NOTE 3—This may be accomplished by placing the specimen on soft rubber supports located near the nodal points or on a sponge rubber pad.

6.2 *Impact Resonance Apparatus* (Fig. 2)*:*

6.2.1 *Impactor*—The impactor shall be made of metal or rigid plastic and shall produce an impact duration that is sufficiently short to excite the highest resonant frequency to be measured. The manufacturer shall indicate the maximum resonant frequency that can be excited when the impactor strikes a concrete specimen with surfaces formed by a metal or plastic mold.

NOTE 4—A 19-mm diameter solid steel ball mounted on a thin rod to produce a hammer is capable of exciting resonant frequencies up to about 10 kHz when impacting a smooth concrete surface. A 110 g steel ball peen hammer may act similarly. Larger steel balls will reduce the maximum resonant frequencies that can be excited. As an approximate guide, the maximum frequency that can be excited by the impact is the inverse of the impact duration.

6.2.2 *Sensor*—The sensor shall be a piezoelectric accelerometer with a mass less than 30 g and having an operating

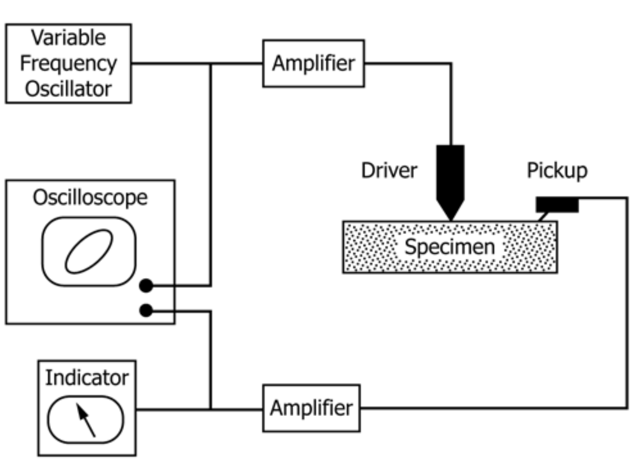

FIG. 1 Schematic of Apparatus for Forced Resonance Test

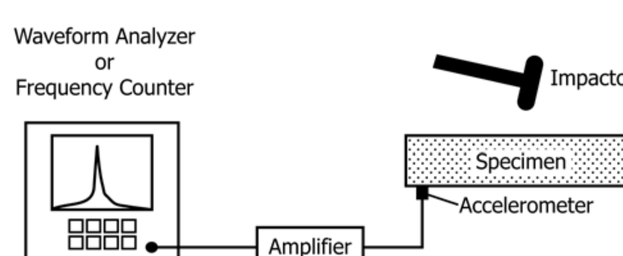

FIG. 2 Schematic of Apparatus for Impact Resonance Test

frequency range from 100 to 15 000 Hz. The resonant frequency of the accelerometer shall be at least two times the maximum operating frequency.

6.2.3 *Frequency Analyzer*—Determine the frequency of the specimen vibration by using either a digital waveform analyzer or a frequency counter to analyze the signal measured by the sensor. The waveform analyzer shall have a sampling rate of at least 2.5 times the maximum expected frequency to be measured and shall record at least 2048 points of the waveform. The frequency counter shall have an accuracy of ±1 % over the range of use.

NOTE 5—The maximum frequency that can be measured using a digital waveform analyzer and the fast Fourier transform method is one-half the sampling frequency; for example, a sampling frequency of 30 kHz will allow measuring resonant frequencies up to 15 kHz. A sampling frequency of 2.5 times the expected frequency is called for in case the actual frequency exceeds the expected maximum frequency to be measured. The frequency resolution in the amplitude spectrum is the sampling frequency divided by the number of points in the waveform.

6.2.4 *Specimen Support*—Support shall be provided as specified in 6.1.3 for the forced resonance method.

7. Test Specimens

7.1 *Preparation*—Make the cylindrical or prismatic test specimens in accordance with Practice C192/C192M, Practice C31/C31M, Test Method C42/C42M, or other specified procedures.

7.2 *Measurement of Mass and Dimensions*—Determine the mass and average length of the specimens within ±0.5 %. Determine the average cross-sectional dimensions within ±1 %.

7.3 *Limitations on Dimensional Ratio*—Specimens having either small or large ratios of length to maximum transverse direction are frequently difficult to excite in the fundamental transverse mode of vibration. Best results are obtained when this ratio is between 3 and 5. For application of the formulas in this test method, the ratio must be at least 2. For measurement of longitudinal resonant frequency, the specimen shall have a circular or square cross-section and the length shall be at least two times the diameter for a cylinder or at least two times the side dimension for a prism.

8. Determination of Resonant Frequencies—Forced Resonance Method

8.1 *Transverse Frequency:*

8.1.1 Support the specimen so that it is able to vibrate freely in the transverse mode (Note 6). Position the specimen and driver so that the driving force is perpendicular to the surface of the specimen. Locate the driver at the approximate middle of the specimen as shown in Fig. 3a. Place the pickup unit on the specimen so that the direction of pickup sensitivity coincides with the vibration direction. Position the pickup near one end of the specimen.

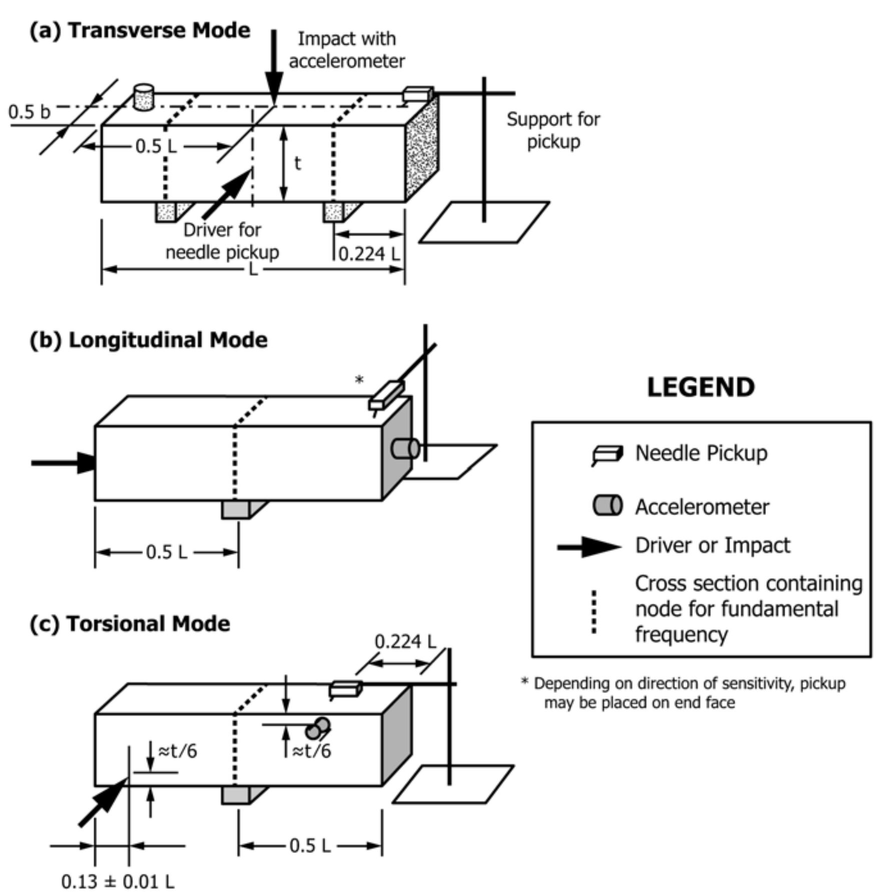

FIG. 3 Locations of Driver (or Impact) and Needle Pickup (or Accelerometer)

8.1.2 Force the test specimen to vibrate at varying frequencies. At the same time, observe the indication of the amplified output of the pickup. If an oscilloscope or other graphic display is used, connect the driver signal to the horizontal sweep of the display and connect the pickup signal to the vertical sweep. Record the fundamental transverse frequency of the specimen, which is the frequency at which the indicator shows the maximum reading and observation of the graphic display or the nodal points indicates fundamental transverse vibration (Note 6). Adjust the amplifiers in the driving and pickup circuits to provide a satisfactory indication. To avoid distortion, maintain the driving force as low as is feasible for good response at resonance.

NOTE 6—For fundamental transverse vibration, the nodal points are located 0.224 of the length of the specimen from each end (approximately the quarter points). Vibrations are a maximum at the ends, approximately three fifths of the maximum at the center, and zero at the nodal points; therefore, movement of the pickup along the length of the specimen will inform the operator whether the specimen is vibrating in its fundamental transverse mode. An oscilloscope or other graphic display may also be used to determine whether the specimen is vibrating in its fundamental transverse mode. If the pickup is located at the end of the specimen, which is vibrating in its fundamental transverse mode, the display will show an inclined elliptical pattern. If the pickup is placed at a node, the display shows a horizontal line. If the pickup is placed at the center of the specimen, the display will be an elliptical pattern but inclined in the opposite direction to when the pickup was placed at the end of the specimen. The display can also be used to verify that the driving frequency is the fundamental resonant frequency. Resonance can occur if the driving frequency is a fraction of the fundamental frequency. In this case, however, the displayed pattern will not be an ellipse.

8.2 *Longitudinal Frequency:*

8.2.1 Support the specimen so that it is able to vibrate freely in the longitudinal mode (Note 7). Position the specimen and driver so that the driving force is perpendicular to and approximately at the center of one end surface of the specimen. Place the pickup unit on the specimen so that the direction of pickup sensitivity coincides with the vibration direction, that is, the longitudinal axis of the specimen (see Fig. 3b).

8.2.2 Force the test specimen to vibrate at varying frequencies. At the same time, observe the indication of the amplified output of the pickup. Record the fundamental longitudinal frequency of the specimen, which is the frequency at which the indicator shows the maximum reading and observation of the graphic display or the nodal point indicates fundamental longitudinal vibration.

NOTE 7—For the fundamental longitudinal mode, there is one node and it is located at the center of the specimen. Vibrations are a maximum at the ends.

8.3 *Torsional Frequency:*

8.3.1 Support the specimen so that it is able to vibrate freely in the torsional mode (Note 8). Position the specimen and driver so that the driving force is perpendicular to the surface of the specimen. For prismatic specimens, locate the driving unit near the upper or lower edge of the specimen at a distance from the end that is 0.13 ± 0.01 of the length of the specimen and approximately ⅙ of the depth of the specimen from the edge (see Fig. 3c). For cylindrical specimens, locate the driving unit above or below the mid-line of the cylinder. Place the pickup unit on the surface of the specimen at a position on the opposite end that coincides with the node point for fundamental transverse vibration (see Fig. 3a). Position the pickup so that the direction of pickup sensitivity coincides with the vibration direction, that is, perpendicular to the longitudinal axis of the specimen.

8.3.2 Force the test specimen to vibrate at varying frequencies. At the same time, observe the indication of the amplified output of the pickup. Record the fundamental torsional frequency of the specimen, which is the frequency at which the indicator shows the maximum reading and observation of the graphical display or the nodal point indicates fundamental torsional vibration.

NOTE 8—For the fundamental torsional mode, there is one node at the center of the specimen. Vibrations are maximum at the ends. Locating the driving unit and pickup as shown in Fig. 3c minimizes interferences from transverse vibrations that can occur simultaneously with torsional vibration.

9. Determination of Resonant Frequencies—Impact Resonance Method

9.1 *Transverse Frequency:*

9.1.1 Support the specimen so that it is able to vibrate freely in the transverse mode (Note 6). Attach the accelerometer near the end of the specimen as shown in Fig. 3a.

NOTE 9—The accelerometer may be attached to the specimen using soft wax or other suitable materials, such as glue or grease. If the specimen is wet, an air jet may be used to surface dry the region where the accelerometer is to be attached. Alternatively, the accelerometer may be held in position with a rubber band, but a coupling material should still be used to ensure good contact with the specimen.

9.1.2 Prepare the waveform analyzer or frequency counter for recording data. Set the digital waveform analyzer to a sampling rate of at least 2.5 times the maximum expected frequency to be measured (Note 5) and a record length of at least 2048 points. Use the accelerometer signal to trigger data acquisition. Using the impactor, strike the specimen perpendicular to the surface and at the approximate middle of the specimen.

9.1.3 Record the resonant frequency indicated by the waveform analyzer (Note 10) or frequency counter. Repeat the test two more times, and record the average transverse resonant frequency. If a frequency measurement deviates from the average value by more than 10 %, disregard that measurement and repeat the test. If using a frequency counter based on zero crossings, delay the start of recording until approximately the first 10 cycles of transverse vibration have occurred (Note 11).

NOTE 10—When using a waveform analyzer, the resonant frequency is the frequency with the highest peak in the amplitude spectrum or the power spectrum obtained from the fast Fourier transform of the recorded accelerometer signal. The fundamental resonant frequency can be verified by impacting the specimen at one of the nodal points. The amplitude spectrum should show a small or no peak at the value of the fundamental frequency.

NOTE 11—Care should be exercised when using a test instrument based on the zero-crossing method to evaluate the resonant frequency of a specimen that is undergoing degradation, such as by cycles of freezing and thawing. As the specimen degrades, the damping value increases and the amplitude of vibration after impact decays more rapidly compared with an undamaged specimen. For accurate determination of frequency, the duration of the sampling time must be compatible with the decay time of the specimen. In addition, a lower number of cycles of delay prior to starting the sampling record may be acceptable.

9.2 *Longitudinal Frequency:*

9.2.1 Support the specimen so that it is able to vibrate freely in the longitudinal mode (Note 7). Attach the accelerometer (Note 9) at the approximate center of one end surface of the specimen as shown in Fig. 3b.

9.2.2 Prepare the waveform analyzer or frequency counter for recording data. Set the digital waveform analyzer to a sampling rate of at least 2.5 times the maximum expected frequency to be measured (Note 5) and a record length of at least 2048 points. Use the accelerometer signal to trigger data acquisition. Using the impactor, strike the specimen perpendicular to and at the approximate center of the end surface without the accelerometer.

9.2.3 Record the resonant frequency indicated by the waveform analyzer (Note 10) or frequency counter. Repeat the test two more times, and record the average longitudinal resonant frequency. If a frequency measurement deviates from the average value by more than 10 %, disregard that measurement and repeat the test. If using a frequency counter based on zero crossings, delay the start of recording until approximately the first 30 cycles of longitudinal vibration have occurred, and ensure a perpendicular impact with the surface (Note 11).

9.3 *Torsional Frequency:*

9.3.1 Support the specimen so that it is able to vibrate freely in the torsional mode (Note 8). For a prismatic specimen, attach the accelerometer near an edge of the specimen at a cross section that contains a node point for fundamental transverse vibration as shown in Fig. 3c. For a cylindrical specimen, mount the accelerometer so that its direction of sensitivity is tangential to a circular cross section that contains a node point for fundamental transverse vibration.

NOTE 12—One approach is to attach the accelerometer to a tab glued to the cylinder as shown in Fig. 4.

9.3.2 Prepare the waveform analyzer or frequency counter for recording data. Set the digital waveform analyzer to a sampling rate of at least 2.5 times the maximum expected frequency to be measured (Note 5) and a record length of at least 2048 points. Use the accelerometer signal to trigger data acquisition. For prismatic specimens, strike the specimen with the impactor at a point near the upper or lower edge of the specimen at a distance from the end that is 0.13 ± 0.01 of the length of the specimen and approximately ⅙ of the depth of the specimen from the edge (see Fig. 3c). For cylindrical specimens, strike the specimen tangentially to the surface at a similar distance from the end as shown in Fig. 4.

NOTE 13—Some practice may be required to learn the proper technique to excite the torsional mode of a cylinder. The idea is to strike the cylinder tangentially to the surface so that a twisting action is imparted to the end of the cylinder.

9.3.3 Record the resonant frequency indicated by the waveform analyzer (Note 10) or frequency counter. Repeat the test two more times, and record the average torsional resonant frequency. If a frequency measurement deviates from the average value by more than 10 %, disregard that measurement and repeat the test. If using a frequency counter based on zero crossings, delay the start of recording until approximately the first 10 cycles of torsional vibration have occurred (Note 11).

10. Calculation

10.1 Calculate dynamic Young's modulus of elasticity, *E*, in pascals from the fundamental transverse frequency, mass, and dimensions of the test specimen as follows:

$$\text{Dynamic } E = CMn^2 \tag{1}$$

where:

M = mass of specimen, kg,
n = fundamental transverse frequency, Hz,
C = $1.6067\ (L^3T/d^4)$, m^{-1} for a cylinder, or
= $0.9464\ (L^3T/bt^3)$, m^{-1} for a prism,
L = length of specimen, m,
d = diameter of cylinder, m,
t, b = dimensions of cross section of prism, m, t being in the direction in which it is driven, and
T = correction factor that depends on the ratio of the radius of gyration, K (the radius of gyration for a cylinder is $d/4$ and for a prism is $t/3.464$), to the length of the specimen, L, and on Poisson's ratio. Table 1 gives values of T for various values of K/L and Poisson's ratio.

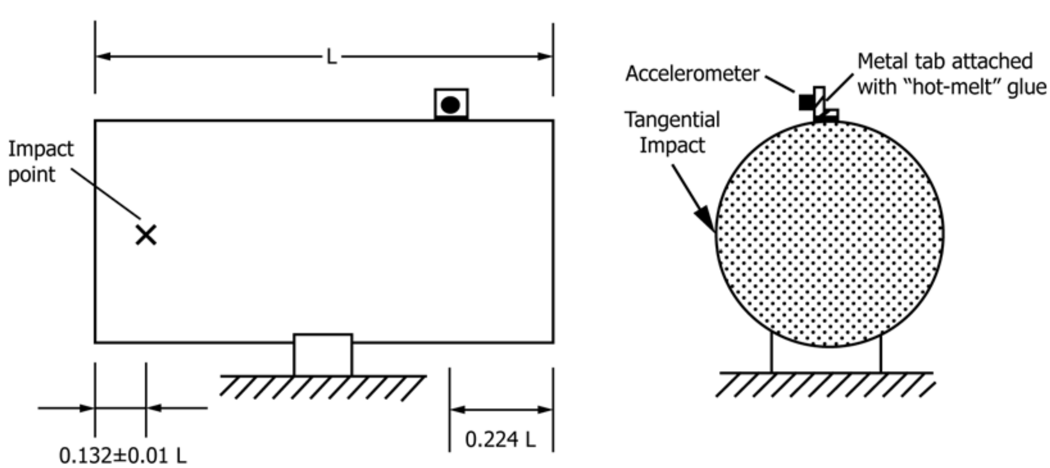

FIG. 4 Locations of Impact and Accelerometer for Torsional Mode of a Cylinder

TABLE 1 Values of Correction Factor, *T*

K/L	Value of T^A			
	μ = 0.17	μ = 0.20	μ = 0.23	μ = 0.26
0.00	1.00	1.00	1.00	1.00
0.01	1.01	1.01	1.01	1.01
0.02	1.03	1.03	1.03	1.03
0.03	1.07	1.07	1.07	1.07
0.04	1.13	1.13	1.13	1.14
0.05	1.20	1.20	1.21	1.21
0.06	1.28	1.28	1.29	1.29
0.07	1.38	1.38	1.39	1.39
0.08	1.48	1.49	1.49	1.50
0.09	1.60	1.61	1.61	1.62
0.10	1.73	1.74	1.75	1.76
0.12	2.03	2.04	2.05	2.07
0.14	2.36	2.38	2.39	2.41
0.16	2.73	2.75	2.77	2.80
0.18	3.14	3.17	3.19	3.22
0.20	3.58	3.61	3.65	3.69
0.25	4.78	4.84	4.89	4.96
0.30	6.07	6.15	6.24	6.34

[A]Values of *T* for Poisson's ratio of 0.17 are derived from Fig. 1 of the paper by Gerald Pickett, "Equations for Computing Elastic Constants from Flexural and Torsional Resonant Frequencies of Vibration of Prisms and Cylinders," *Proceedings*, ASTEA, Am. Soc. Testing Mats., Vol 45, 1945, pp. 846–863.

Poisson's ratio for water-saturated concrete may be higher than 0.17. The correction factor, *T'*, for other values of Poisson's ratio, μ, and given *K/L*, are calculated from the following relationship:

$$T' = T\left[\frac{1+(0.26\mu+3.22\mu^{2})K/L}{1+0.1328\,K/L}\right]$$

where *T* is the value for μ = 0.17 shown in the second column of Table 1 for the given *K/L*.

10.2 Calculate dynamic Young's modulus of elasticity, *E*, in pascals from the fundamental longitudinal frequency, mass, and dimensions of the test specimen as follows:

$$\text{Dynamic } E = DM(n')^2 \tag{2}$$

where:

n' = fundamental longitudinal frequency, Hz, and
D = 5.093 (L/d^2), m^{-1} for a cylinder, or
= 4 (L/bt), m^{-1} for a prism.

10.3 Calculate dynamic modulus of rigidity, *G*, in pascals from the fundamental torsional frequency, mass, and dimensions of the test specimen as follows:

$$\text{Dynamic } G = BM(n'')^2 \tag{3}$$

where:

n'' = fundamental torsional frequency, Hz,
B = $(4LR/A)$, m^{-1},
R = shape factor,
= 1 for a circular cylinder,
= 1.183 for a square cross-section prism,
= $(a/b + b/a)/[4a/b - 2.52(a/b)^2 + 0.21(a/b)^6]$ for a rectangular prism whose cross-sectional dimensions are a and b, m, with a less than b, and
A = cross-sectional area of test specimen, m^2.

10.4 Calculate the dynamic Poisson's ratio, the ratio of lateral to longitudinal strain for an isotropic solid, μ, as follows:

$$\mu = (E/2G) - 1 \tag{4}$$

NOTE 14—Values for Poisson's ratio for concrete normally vary between about 0.10 for dry specimens and 0.25 for saturated specimens. Higher values are expected for concrete tested at early ages.

11. Report

11.1 Report the following for each specimen:

11.1.1 Identification number,

11.1.2 Cross-sectional dimensions within 0.1 %,

11.1.3 Length within 0.5 %,

11.1.4 Mass within 0.5 %,

11.1.5 Description of any defects that were present, and

11.1.6 Mode of vibration and corresponding resonant frequency to the nearest 10 Hz.

11.2 If the dynamic Young's modulus of elasticity or dynamic modulus of rigidity are calculated, report to the nearest 0.5 GPa.

11.3 If the dynamic Poisson's ratio is calculated, report to the nearest 0.01.

12. Precision and Bias

12.1 The data used to develop the precision statements were obtained using an earlier inch-pound version of this test method.

12.2 *Precision of Forced Resonance Method*—The following precision statements are for fundamental transverse frequency only, determined on concrete prisms as originally cast. They do not necessarily apply to concrete prisms after they have been subjected to freezing-and-thawing tests. At the present time, data appropriate for determining precision of fundamental torsional and longitudinal frequencies are not available.

12.2.1 *Single-Operator Precision*—Criteria for judging the acceptability of measurements of fundamental transverse frequency obtained by a single operator in a single laboratory on concrete specimens made from the same materials and subjected to the same conditions are given in Table 2. These limits apply over the range of fundamental transverse frequency from 1400 to 3300 Hz. The different specimen sizes represented by the data include the following (the first dimension is the direction of vibration):

76 by 102 by 406 mm
102 by 76 by 406 mm
89 by 114 by 406 mm
76 by 76 by 286 mm
102 by 89 by 406 mm
76 by 76 by 413 mm

NOTE 15—The coefficients of variation for fundamental transverse frequency have been found to be relatively constant over the range of frequencies given for a range of specimen sizes and age or condition of the concrete, within limits.

TABLE 2 Test Results for Single Operator in a Single Laboratory

	Coefficient of Variation, %[A]	Acceptable Range of Two Results, % of Average[A]
Within-batch single specimen	1.0	2.8
Within-batch average of 3 specimens[B]	0.6	1.7
Between-batch, average of 3 specimens per batch	1.0	2.8

[A]These numbers represent, respectively, the 1s % and d2s % limits as described in Practice C670.
[B]Calculated as described in Practice C670.

12.2.2 *Multilaboratory Precision*—The multilaboratory coefficient of variation for averages of three specimens from a single batch of concrete has been found to be 3.9 % for fundamental transverse frequencies over the range from 1400 to 3300 Hz (Note 16). Therefore, two averages of three specimens from the same batch tested in different laboratories should not differ by more than 11.0 % of their common average (see Note 16).

NOTE 16—These numbers represent, respectively, the 1s % and d2s % limits as described in Practice C670.

12.3 *Precision of Impact Resonance Method*—The precision of this test method has yet to be determined. Experience, however, has shown that, when a frequency analyzer is used, replicate tests on the same specimen result in resonant frequency values that are within ± 1 digital step of each other (Note 17).

NOTE 17—The digital step in the amplitude spectrum equals the sampling frequency divided by number of points in the time domain waveform. For example, for a sampling frequency of 30 kHz (33.3-µs sample interval) and 2048 points in the waveform, the digital step is 30 000/2048 ≈ 15 Hz.

12.4 *Bias*—The bias of either the forced resonance method or the impact resonance method has not been determined because there are no reference samples available.

13. Keywords

13.1 dynamic modulus of rigidity; dynamic Poisson's ratio; dynamic Young's modulus of elasticity; forced resonance; fundamental resonant frequency; impact resonance; nondestructive testing

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C215 – 08, that may impact the use of this test method. (Approved December 15, 2014)

(1) Updated standards in Section 2.
(2) Revised 5.1, 5.2, 5.3, and 5.4.
(3) Revised 6.1.1, 6.1.2, 6.1.3, Note 1, and Note 2.
(4) Revised Note 4, 6.2.2, and 6.2.3.
(5) Added Note 5.
(6) Revised 7.3.
(7) Revised 8.1.1, 8.1.2, 8.2.2, 8.3.2, Note 6, Note 7, Note 8, and Fig. 3a.
(8) Revised 9.1.2, 9.1.3, 9.2.2, 9.2.3, 9.3.2, 9.3.3, and Note 17.
(9) Added Note 13.