

**Standard Test Method for Determining
the Fundamental Transverse Frequency and
Quality Factor of Concrete Prism Specimens**

AASHTO Designation: TP18-94^{1,2} (Reapproved 1996)

1. Scope

1.1 This test method describes procedures for determining the fundamental transverse frequency and quality factor of concrete prism specimens for the purpose of non-destructively evaluating the condition of the concrete. The measurements of fundamental frequencies are also used to compute dynamic Young's modulus of elasticity.

1.2 *This procedure may involve hazardous materials, operations, and equipment. This procedure does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this procedure to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 AASHTO Standards

- R9 Acceptance Sampling Plans for Highway Construction
- T23 Making and Curing Concrete Test Specimens in the Field
- T24 Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
- T126 Making and Curing Concrete Test Specimens in the Laboratory
- T161 Resistance of Concrete to Rapid Freezing and Thawing

2.2 ASTM Standards

- C215 Fundamental Transverse, Longitudinal, and Torsional Frequencies of Concrete Specimens
- C670 Preparing Precision and Bias Statements for Test Methods for Construction Materials
- D3665 Random Sampling of Construction Materials
- E105 Probability Sampling of Materials
- E122 Choice of Sample Size to Estimate the

Average Quality of a Lot or Process

E141 Acceptance of Evidence Based on the Results of Probability Sampling

3. Terminology

3.1 Description of Terms Specific to this Standard

3.1.1 Quality Factor (Q) - the normalized width of the frequency response curve - the inverse of the measure of internal damping

3.1.2 Fundamental Transverse Frequency (ω_r) - the frequency at which a specimen vibrates in the transverse mode with the greatest amplitude for a given amount of input excitation. This frequency is sometimes termed the frequency at which a specimen resonates.

4. Summary of Method

4.1 The fundamental transverse frequency and the quality factor of a concrete prism are determined by analyzing the vibration frequency response spectrum produced when the prism is lightly struck.

4.2 The specimen is supported in such a way as to minimize interference with vibration of the specimen.

4.3 The measured time response of the beam vibrations is converted into a frequency response by a Fast Fourier Transform (FFT). The fundamental transverse frequency and quality factor are then determined by fitting a standard frequency response curve to the measured frequency data.

5. Significance and Use

5.1 This test method is intended primarily for determining the amount of deterioration produced by accelerated durability tests such as T161. The

¹ This standard is based on SHRP Product 2019.

² Approved in October 1994, this provisional standard was first published in March 1995. Reconfirmed in January 2001.

deterioration can be quantified either by evaluating changes in the dynamic modulus of elasticity, or by evaluating changes in the quality factor of the concrete.

5.2 Deterioration from accelerated durability tests results in a decrease in elastic modulus of concrete specimens. This decrease is measured as a decrease in fundamental transverse frequency.

5.3 Prior to the accumulation of sufficient deterioration to produce a measurable decrease in fundamental transverse frequency, a decrease in quality factor occurs. This decrease in quality factor is thought to be an indication of micro-cracking in the concrete specimen. Though the microcracking may not be of sufficient magnitude to produce a change in the fundamental transverse frequency, it does change the amount of internal damping of the vibrations in the specimen.

6. Interferences

6.1 Improper tensioning of the wires supporting the specimen during testing will affect the test results.

6.2 Insecure attachment of the accelerometer to the test specimen surface will affect the test results.

6.3 Improper positioning of the impact point on the test specimen surface will affect the test results.

6.4 Failure to completely damp test specimen vibrations before application of each test impact will affect the test results.

6.5 Supporting the test specimen at locations other than the nodal points of the specimen will affect the test results.

6.6 Using test specimens with shapes and/or dimensions other than those indicated will affect the test results.

7. Apparatus

7.1 Fourier Analyzer - The Fourier analyzer used shall meet the following requirements when coupled with the data analysis and control component:

7.1.1 The Fourier analyzer shall be capable of FFT analysis of vibrational input data to convert time-domain measurements to frequency-domain

response.

7.1.2 The Fourier analyzer shall be capable of averaging multiple frequency response measurements from a single specimen prior to determination of fundamental frequency and quality factor.

7.1.3 The Fourier analyzer shall be equipped with a minimum of two input channels.

7.1.4 The Fourier analyzer shall be capable of using the signal from one channel to normalize the signal from a second channel, thus allowing multiple readings to be averaged even though the vibration responses may have been produced by different impact magnitudes.

7.1.5 The Fourier analyzer shall be capable of using a minimal input level in one channel to trigger recording of data in all channels.

7.1.6 The Fourier analyzer shall be equipped with controls for lower and upper limits of the frequency range that may be set independently.

Note 1 - The lower limit of the frequency range is set above the frequency of the rigid body motion of the specimen on the support. For the support described under Section 7.4.1 and a normal-weight concrete specimen of dimensions 100 by 75 by 400 mm (4 by 3 by 16 in), a lower limit of 100 Hz. is appropriate. The upper limit of the frequency range should be set 500 Hz or greater above the expected fundamental transverse frequency of the specimens to be measured. This upper limit should not be made too high as the precision of many Fourier analyzers is dependent upon the frequency range being analyzed. An upper limit of 3000 Hz is appropriate for a normal-weight concrete specimen of dimensions 100 by 75 by 400 mm (4 by 3 by 16 in).

7.1.7 The Fourier analyzer shall be capable of recording the time history of the vibrations with an exponential weighting or "window".

Note 2 - An exponential weighting of 0.1 provides the best reproducibility for both damaged and un-damaged concrete prisms. (The time response of a vibrating prism is the summation of decaying sinusoids. Included in the measurement is an essentially constant

amount of noise. Thus, the signal-to-noise ratio decreases with measurement time. By treating the time-domain measurement to a decreasing exponential weighting, the readings with the best signal-to-noise ratio are weighted greater in the FFT analysis.) This procedure assists in obtaining the reproducibility of the quality factor results given in Section 13.1.1.

7.1.8 The Fourier analyzer shall be capable of storing at least 1024 points for FFT analysis with a maximum frequency capability 8 kHz or greater.

Note 3 - A sampling size of 1024 points was found to give the most reproducible fundamental frequency and quality factor results on both damaged and un-damaged prisms. While increasing the sampling size from 512 to 1024 points decreased the variability, a higher sampling size (2048 rather than 1024 points) increased variability. This is probably due to the longer measurement time required for the larger number of points and the decreasing signal-to-noise ratio with increasing sampling times.

7.1.9 The Fourier analyzer shall be capable of restricting the voltage range of any of the inputs that are used for analysis.

7.1.10 The Fourier analyzer shall be equipped with audible and/or visual feedback mechanisms to the operator indicating when an impact of proper magnitude has been delivered.

Note 4 - A sensitivity of 0.1 to 1.0 AC volts for the excitation channel and 0 to 5.0 AC volts for the vibration response channel are appropriate for the hammer and accelerometer described in Sections 7.2 and 7.3, below.

7.1.11 The Fourier analyzer shall be capable of producing a visual display of the frequency response spectrum through the data recording and analysis component described in section 7.5.

7.2 Impact Hammer - A modally tuned impact hammer component capable of producing vibrations in the test specimen by impact and meeting the following requirements:

7.2.1 The impact hammer shall be capable of producing a flat frequency response over the entire frequency range being sampled. A modally tuned impact hammer with a mass of 140 g and a frequency response of 0 to 8 kHz produces the appropriate impact.

7.2.2 The impact hammer shall be equipped with a hammer impact tip of sufficient hardness and appropriate shape to neither be damaged by the specimen nor cause damage to the specimen when an impact of proper magnitude is produced. A spherical tip is not mandatory.

7.2.3 The impact hammer shall be equipped with an electronic load cell and appropriate power supply capable of producing an output voltage proportional to the magnitude of the impact with the specimen. The sensitivity of the load cell shall be 12.5 ± 2.5 mV/N or better.

7.3 Accelerometer and Power Supply - The accelerometer shall have a flat base, a mass 3 g or less, an operating frequency range of at least 10 to 10000 Hz, and a fundamental frequency at least twice the highest expected fundamental frequency of any of the specimens to be measured. The accelerometer power supply shall provide an output through the accelerometer-power supply combination of at least 50 mV/g.

Note 5 - Amplification of the accelerometer output may be necessary to achieve the proper output level.

7.4 Specimen Support - The specimen support shall be fabricated from 2 parallel 0.62 mm diameter piano wires that permit the specimen to vibrate freely, and minimize the amount of vibration energy absorbed from the specimen.

7.4.1 The parallel support wires shall be arranged to support the specimen a distance of 22.4 percent of the specimen length from each end of the specimen. This is approximately the location of the nodal points of the specimen, and vibration magnitude will be minimal at these points.

7.4.2 The parallel support wires shall be positioned at least 25 mm above any horizontal table surface to facilitate placing the specimens on the wires.

7.4.3 The length of the specimen support wires shall be at least 3 times the width of the specimen when the specimen is placed on the support wires.