BS 1881 : Part 209 : 1990

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British Standard

Testing concrete

Part 209. Recommendations for the measurement of dynamic modulus of elasticity

Essais des bétons
Partie 206. Recommandations relatives au mesurage du module dynamique d'élasticité

Prüfung von Beton
Teil 206. Empfehlungen für die Messung des dynamischen Elastizitätsmoduls

Contents

Recommendations

1 Scope

This Part of BS 1881 gives recommendations for the determination of dynamic modulus of elasticity of plain concrete in the laboratory using resonance of vibration in the longitudinal mode.

NOTE. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this Part of BS 1881 the definitions given in BS 3683 : Part 4 and BS 6100 : Part 6 apply, together with the following.

2.1 resonance. Condition in which the frequency of a vibration applied to a body is equal to one of the natural frequencies of vibration of that body.

NOTE. This concurrence of frequencies maximizes the amplitude of vibration in the body.

2.2 longitudinal mode of vibration. Mode in which compression waves travel through a prismatic specimen in the direction parallel to its length.

NOTE 1. The waves are partially reflected by the end faces of the specimen and thus travel to and fro within it.

NOTE 2. Other modes exist such as transverse and torsional.

2.3 fundamental frequency. Lowest resonant frequency at which a body will vibrate in a particular mode.

2.4 dynamic modulus of elasticity of concrete (E_D). Ratio of the stress to that part of the strain corresponding to elastic deformation only.

NOTE. The modulus obtained refers to the initial tangent to the non-linear stress/strain relationship for concrete, which does not obey Hooke's Law. It is normally appreciably larger than the statically measured value obtained by the method described in BS 1881 : Part 121.

3 Applications

Measurement of dynamic modulus is most commonly used for comparative testing of concretes in the laboratory and for assessing degradation in durability tests, e.g. in freezing and thawing tests.

4 Principle

An elastic or partially elastic body will vibrate if struck a blow. Each body possesses many modes of vibration and in geometrical bodies well defined modes may be identified. This method is concerned only with identifying the fundamental longitudinal mode of vibration in concrete prisms.

The frequency at which this vibration occurs depends largely on the dynamic modulus of elasticity, density, and length of the specimen.

5 Summary of the test method

A variable frequency oscillator imparts an alternating force to the specimen and the response is sensed by an accelerometer or vibration pick-up. The amplitude of vibrations is monitored by an indicator and when a resonant frequency is reached, the indicator shows the amplitude to be at a well defined maximum.

If this resonant frequency is the fundamental frequency it is related to the modulus of elasticity of the concrete through the equation in clause **8**.

6 Apparatus

6.1 *Variable frequency oscillator*, providing a variable narrow-band sinusoidal output from 500 Hz to 20 kHz with power adjustable from zero to at least 2 W.
The frequency of the oscillator output should be indicated within an accuracy of ± 0.5 %.

The output of a good quality oscillator tuned to a given frequency should not contain more than 2 % of its amplitude in the second and third harmonics of the frequency and should have a stability within ± 5 % of the operating voltage.

6.2 *Exciter*, of which the part in contact with the specimen should have a mass of not more than 0.2 % of the mass of the specimen.

6.3 *Pick-up*, of which any part in contact with the specimen should have a mass of not more than 0.2 % of the mass of the specimen. The vibration pick-up should have no resonances at frequencies below 20 kHz.

6.4 *Amplitude indicator*, consisting of a voltmeter or cathode ray oscilloscope incorporating appropriate amplification facilities.

6.5 *Support*, consisting of a pair of horizontal steel bars between which the specimen can be clamped. The width of the contact area of the clamping bars should not exceed one twentieth of the length of the specimen. The bars can be positioned by threaded vertical rods attached to a rigid baseboard which also carries the exciter and pick-up mounting posts as shown in figure 1. The baseboard stands on soft elastomeric pads on a rigid workbench to reduce the effects of extraneous vibrations transmitted through the laboratory floor.

Alternatively, the specimen may lie on a block of foam rubber provided that the exciter and pick-up centrelines are normal to the specimen's end faces.

6.6 *Balance*, of appropriate capacity to weigh the specimen to the accuracy required by **7.2**.

6.7 *Vernier calliper*, complying with BS 887, capable of measuring the lateral dimensions of the specimen to the accuracy required by **7.2**.

7 Methods of testing laboratory made specimens

7.1 Preparation

The laboratory made specimens should be prisms of circular or square section with a length not less than three nor more than five times the maximum transverse dimension. Specimens should preferably be beams made in accordance with BS 1881 : Part 109 and then cured in accordance with BS 1881 : Part 111.

7.2 Preliminary measurements

Immediately before testing, the length and density of each specimen should be obtained from the following procedures.

(a) *Length.* Calculate the mean length, L, (in mm) from at least four symmetrically placed measurements read to an accuracy of ± 1 mm.

(b) *Density.* Weigh the specimen in air and record its mass, M_A, (in kg) to an accuracy of ± 0.25 %.

Determine the volume, V, (in m^3) of the specimen either from its dimensions or by water displacement as follows.

(1) *Dimensions.* For a beam, calculate the mean width, a, and depth, b, (in mm) from at least six measurements of each dimension spaced equally along its length read to an accuracy of ± 0.25 mm. Then

$$V = Lba \times 10^{-9}$$

For a cylindrical specimen, calculate the mean diameter, d, (in mm) from at least six measurements spaced equally along its length read to an accuracy of ± 0.25 mm. Then

$$V = \frac{L \pi d^2}{4} \times 10^{-9}$$

(2) *Water displacement.* Weigh the specimen in water and record its apparent loss in mass, M_L, (in kg) to an accuracy of ± 0.25 %. Then

$$V = M_L / \rho_w$$

where

ρ_w is the density of water which may be taken as 1 kg/m^3 at ambient temperature.

Method 2 should not be used for unsaturated specimens.

Calculate the density, ρ, (in kg/m^3) of the specimen from the equation

$$\rho = M_A / V.$$

7.3 Measurement of resonant frequency

Specimens should be tested in a condition appropriate to the purpose of the investigation.

Where specimens have been stored in water they should be tested immediately on removal from the water, whilst they are still saturated. Surface water and grit should be wiped off the specimen.

The specimen should be clamped or balanced at its centre on the fixed support.

Contact should be made between the vibrating part of the exciter and the centre of one end face of the specimen by means of a weak adhesive or by gentle spring loading. Contact should be made between a piezo-electric vibration pick-up and the opposite end of the specimen in a similar way, as indicated in figure 1. Alternatively, an electromagnetic non-contacting pick-up can be used in accordance with the manufacturer's recommendations. Ensure that the axes of the transducers are in the centre of and normal to the end faces of the specimen.

The exciter should be driven by the variable frequency oscillator and the oscillations received from the pick-up should be fed to the amplitude indicator to show the changes in amplitude received.

The frequency of excitation should be varied until a resonance is obtained and the frequency noted. Resonance will be recognized when the amplitude indicator shows a peak response. As the frequency is further varied, the indicator may show the existence of several resonant frequencies, some of these relating to modes of vibration other than longitudinal.

The identification of the fundamental frequency in the longitudinal mode requires care. Generally the required frequency produces the greatest response on the indicator for given settings of the output and gain controls. As a check, with the specimen set up as shown in figure 1, resonance should also be obtainable at a frequency three times that of the fundamental frequency.

If difficulties are still encountered, an approximate value for the dynamic modulus of elasticity of the concrete may be obtained from a pulse transit time measurement (see BS 1881 : Part 203). This value may then be substituted into the equation in clause 8 to yield an approximate value for the desired resonant frequency. The search for the exact frequency may then be confined to a narrow range about the value so calculated.

Instrument manufacturer's literature sometimes provides very useful instructions for identifying the fundamental frequency. Once identified, this value should be recorded.

8 Calculations

The dynamic modulus of elasticity of concrete, E_D, (in GN/m^2) for each specimen should be calculated to the nearest 0.5 GN/m^2 from the formula

$$E_D = 4n^2 L^2 \rho 10^{-15}$$

where

L is the length of the specimen (in mm);

n is the fundamental frequency in the longitudinal mode of vibration of the specimen (in Hz);

ρ is the density of the specimen (in kg/m^3).

NOTE. This formula applies to all uniform specimens of constant cross section.

9 Report

9.1 General

The report should affirm that the dynamic modulus of elasticity of concrete was determined in accordance with the recommendations given in BS 1881 : Part 209 : 1990.

9.2 Information to be included in the test report

9.2.1 *Obligatory information.* The following information should be included in the test report:

(a) date of test;

(b) description and nominal size of the specimen with any identifying mark;

(c) age of the specimen when tested;

(d) conditions in which the specimen had been stored between manufacture and testing;

(e) the calculated dynamic modulus of elasticity of the concrete.

9.2.2 *Additional information.* When requested, the following information should also be included in the test report:

(a) the fundamental frequency;

(b) the measured dimensions of the specimen;

(c) the density of the specimen at the time of testing.

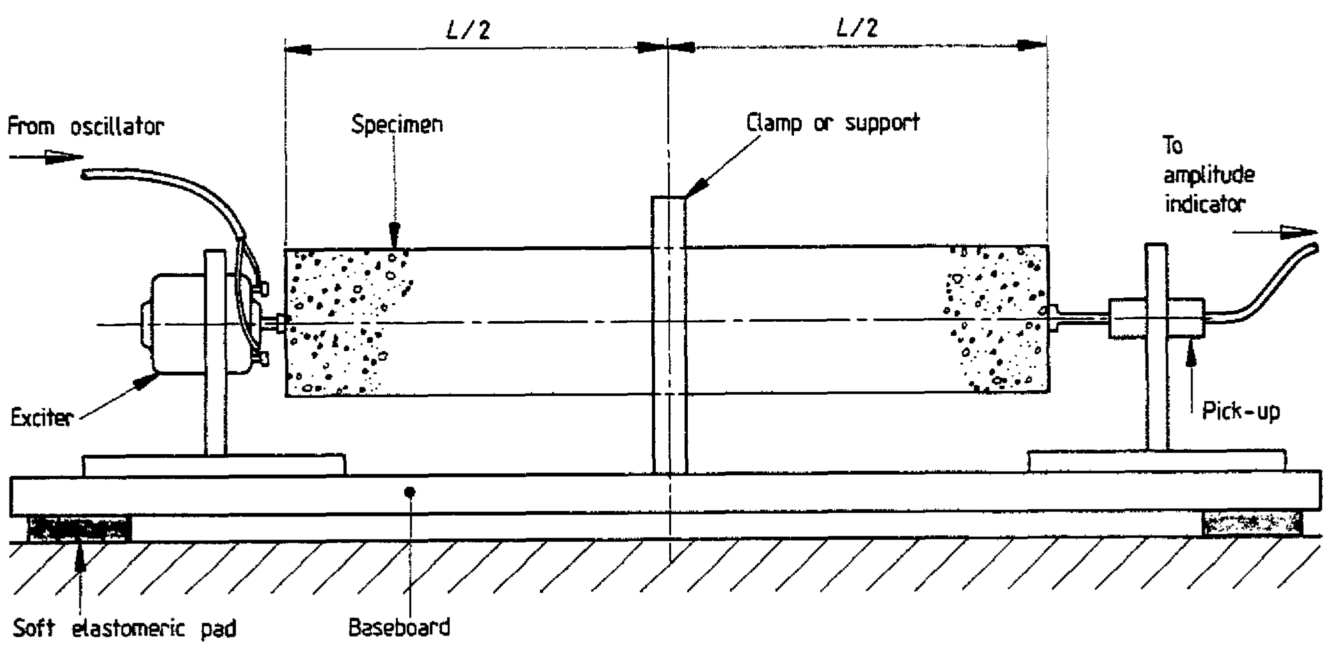

Figure 1. Test configuration for determination of dynamic modulus of elasticity

Publications referred to

BS 887 Specification for precision vernier callipers

BS 1881 Testing concrete
Part 109 Method for making test beams from fresh concrete
Part 111 Method of normal curing of test specimens (20 °C method)
Part 121 Method for determination of static modulus of elasticity in compression
*Part 201 Guide to the use of non-destructive methods of test for hardened concrete
Part 203 Recommendations for measurement of velocity of ultrasonic pulses in concrete

BS 3683 Glossary of terms used in non-destructive testing
Part 4 Ultrasonic flaw detection

BS 6100 Glossary of building and civil engineering terms
Part 6 Concrete and plaster

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*Referred to in the foreword only.

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Committees responsible for this British Standard

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