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Testing of concrete —

Part 10: Determination of static modulus of elasticity in compression

Essais du béton —

Partie 10: Détermination du module d'élasticité statique en compression

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 1920-10 was prepared by Technical Committee ISO/TC 71, *Concrete, reinforced concrete and pre-stressed concrete*, Subcommittee SC 1, *Test methods for concrete*.

This first edition cancels and replaces ISO 6784:1982 which has been technically revised.

ISO 1920 consists of the following parts, under the general title *Testing of concrete*:

— *Part 1: Sampling of fresh concrete*

— *Part 2: Properties of fresh concrete*

— *Part 3: Making and curing test specimens*

— *Part 4: Strength of hardened concrete*

— *Part 5: Properties of hardened concrete other than strength*

— *Part 6: Sampling, preparing and testing of concrete cores*

— *Part 7: Non-destructive tests of hardened concrete*

— *Part 8: Determination of drying shrinkage of concrete for samples prepared in the field or in the laboratory*

— *Part 9: Determination of creep of concrete cylinders in compression*

— *Part 10: Determination of static modulus of elasticity in compression*

Testing of concrete —

Part 10:
Determination of static modulus of elasticity in compression

1 Scope

This part of ISO 1920 specifies a test method for the determination of the static modulus of elasticity in compression of hardened concrete, on test specimens which are cast or taken from a structure.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1920-3, *Testing of concrete — Part 3: Making and curing test specimens*

ISO 1920-4, *Testing of concrete — Part 4: Strength of hardened concrete*

ISO 1920-5, *Testing of concrete — Part 5: Properties of hardened concrete other than strength*

ISO 1920-6, *Testing of concrete — Part 6: Sampling, preparing and testing of concrete cores*

EN 12390-4, *Testing hardened concrete — Part 4: Compressive strength — Specification for testing machines*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
static modulus of elasticity in compression of hardened concrete
property of concrete, that corresponds to the tangent of the stress-strain curve

NOTE 1 For design purposes the modulus of elasticity is considered equivalent to the chord modulus of deformation, when the test specimen is loaded between 0,5 MPa and $F_c/3$, as described in this part of ISO 1920.

NOTE 2 The modulus of elasticity can be considered as a modulus of deformation when the material is evaluated in the elastic range.

3.2
gauge length
each part of the test specimen, over which the strain or change in length is determined

4 Principle

A basic stress of 0,5 N/mm^2 (MPa) is applied to a test specimen and then the stress is gradually increased until it is equal to one-third of the 2:1 cylinder strength of the concrete. The strains at the different loadings are recorded.

The modulus of elasticity is calculated by dividing the difference between the basic stress and the upper stress by the difference between the corresponding strains.

5 Apparatus

5.1 Testing machine

The test shall be carried out using a compression-testing machine conforming to EN 12390-4 or to a national standard valid in the place of testing. The test machine shall be in calibration at the time of test. The calibration shall be carried out at least once a year. The compression testing machine shall be capable of applying the specified load at the specified rate and maintaining it at the required level.

5.2 Strain measuring apparatus

Instruments for measuring the changes in length (for example mirror or dial gauge extensometers, resistance strain gauges, inductance gauges, vibrating wire-strain gauges) shall have a gauge length of not less than two-thirds of the diameter of the test specimen (2/3 d) and shall not exceed its diameter size (d). It shall be attached in such a way that the gauge points are equidistant from the two ends of the specimen and at a distance not less than one-quarter of the length of the test specimen (L/4) from its ends.

Measurements shall normally be taken on not less than two opposite sides of the specimen. With specimens cast in a horizontal position, the gauge lengths should be arranged on the vertical sides as cast.

The measuring apparatus shall have an accuracy of $\pm\ 5 \times 10^{-6}$.

Measuring gauge having a length of not less than 100 mm may have an accuracy of $\pm 10 \times 10^{-6}$.

6 Test specimens

6.1 General

a) Cast specimens

When using the reference method, a minimum of five moulded specimens shall be made. Three of these shall be used to determine the mean compressive strength and two to determine the modulus of elasticity.

b) Specimens taken from a structure

When using the alternative method, three specimens shall be used to determine both the modulus of elasticity and the compressive strength. If taking specimens could pose a risk of damaging the structure, the number of specimens may be reduced to two. For specimens taken from a structure, the compressive strength may be estimated from other information.

6.2 Shape and dimensions of test specimens

Three test specimens shall be cylinders having the length to diameter ratio $L/d = 2$. These specimens shall be used to determine the compressive strength of the concrete. The other two specimens, used to measure the

modulus of elasticity, shall comply to the following requirements, except where provisions valid in the place of use state otherwise.

a) The minimum dimension of moulded specimens shall be 100 mm and at least four times the nominal maximum size of the aggregate in the concrete, whichever is the larger value.

b) The minimum dimension of drilled or cut-outs of structure specimens shall be 100 mm and at least three times the nominal maximum size of the aggregate in the concrete, whichever is the larger value.

c) The length to diameter ratio of the test specimens shall be between $L/d = 2$ to 4 and 2 is recommended.

Moulded test specimens should preferably be cylinders 150 mm in diameter and 300 mm in height. Alternatively, other test specimens may be used, provided that the length to diameter ratio, L/d, is not less than 2 nor more than 4, where L is the length and d the diameter, or, for a square cross-section, d is the width of one face of the specimen.

6.3 Preparation of test specimens

Moulded test specimens shall be prepared and cured in accordance with ISO 1920-3. The specimens shall be adjusted for testing if necessary in accordance with ISO 1920-4. Test specimens taken from a structure shall be prepared in accordance with ISO 1920-6.

If other curing procedures are used, for example in the case of drilled or cut specimens, this shall be clearly stated in the test report.

If adhesives are used for the fixing points they should be rapid setting and set hard. The specimen shall be removed from water for as short a time as possible to allow the surface to be dried for the application of adhesive. Specimens shall not be less than 7 d old when removed for this purpose. Specimens shall be re-immersed in water for a minimum of 12 h before testing.

7 Procedure

7.1 Determination of density

Determine the density of each test specimen in accordance with ISO 1920-5, if required.

7.2 Determination of compressive strength

For the reference method, determine the compressive strength of the concrete on three specimens made by the same concrete mixture and cured under the same conditions as the specimens to be used for the determination of the static modulus of elasticity. These three specimens shall be cylinders having the length to diameter ratio $L/d = 2$. Determine the compressive strength by the method specified in ISO 1920-4.

If the alternative method described in 7.3.2 is used, testing of separate compressive strength specimens is not required.

The mean value of the compressive strength, f_c, is used to determine the stress applied in the determination of static modulus of elasticity.

If, exceptionally, the specimens as described above are not available, the compressive strength may be estimated and the basis of the estimate reported. For specimens taken from structures, the compressive strength may be estimated from the information available or by using the alternative method described in 7.3.2.

7.3 Determination of static modulus of elasticity

7.3.1 Reference method

Place the test specimen centrally in the machine, with the measuring instruments or fixing points attached axially. Apply the basic stress of 0,5 N/mm^2 (MPa), (σ_b), maintain for 60 s, then measure and record the strain gauge readings taken at each measurement line.

Steadily increase the stress at a constant rate within the range 0,20 N/(mm^2·s) to 0,60 N/(mm^2·s) until the stress equals one-third of the 2:1 cylinder strength of the concrete ($\sigma_a = F_c/3$).

Maintain the stress for 60 s, then measure and record the strain readings taken during the succeeding 30 s at each measurement line. If the individual strains are not within a range of $\pm$ 20 % of their mean value at σ_a, recentre the test specimen and repeat the test. If it is not possible to reduce the differences to within this range, do not proceed with the test.

When the centring is sufficiently accurate reduce the load, at the same rate as during loading, to the level of the basic stress. Carry out at least two additional preloading cycles, using the same loading and unloading rate, and maintaining the stress (σ_a and σ_b) constant for a period of 60 s. After completion of the last preloading cycle and a waiting period of 60 s under the stress $\sigma_b = 0{,}5$ N/mm^2 (MPa), at the various measurement lines record the strain reading, ε_b, taken during the succeeding 30 s.

Reload the specimen to stress σ_a, maintain it for 60 s, at the specified rate, and at the various measurement lines measure and record the strain reading ε_a, taken within 30 s.

When all elasticity measurements have been completed, increase the load on the test specimen, at the specified rate, until failure of the specimen occurs. If the compressive strength of the specimen differs from F_c by more than 20 %, this shall be noted in the test report and it shall be reported that the result may not be reliable.

7.3.2 Alternative method

Where the strain and stress on the test specimen are continuously measured during the loading cycle, the loading may be continued to the point of obtaining the compressive strength without stopping the loading at the upper stress level. In this case, the compressive strength shall be the test value of that test specimen. The upper stress point for determining the modulus, i.e. the point of one-third of the stress corresponding to the compressive strength, may be determined from the test results. If this alternative procedure is followed, it shall be stated in the test report. An informative measuring procedure is detailed in Annex A.

Report if the individual strains are not within a range of $\pm$ 20 % of their mean value at σ_a.

7.4 Calculation and expression of results

Calculate the mean strain ε_a and ε_b respectively.

When the strain and stress are continuously measured, ε_a shall be determined by interpolation.

The static modulus of elasticity in compression, E_c [in N/mm^2 (MPa)], is given in Equation (1).

$$E_c = \frac{\Delta_\sigma}{\Delta_\varepsilon} = \frac{\sigma_a - \sigma_b}{\varepsilon_a - \varepsilon_b} \quad (1)$$

where

σ_a is the upper loading stress, in N/mm^2 (MPa)

($\sigma_a = f_c/3$);

σ_b is the basic stress, i.e. 0,5 in N/mm^2 (MPa);

ε_a is the mean strain under the upper loading stress;

ε_b is the mean strain under the basic stress.

Express the result in GPa, to the nearest three significant digits. Report both the individual determinations of the modulus of elasticity for each specimen and the average value.

8 Test report

8.1 Information to be provided by the producer of the test specimens for inclusion in the test report

8.1.1 Essential information

The following information shall be provided by the producer of the test specimens for inclusion in the test report:

a) the date of production of the concrete;

b) the time and place of making specimens;

c) the identification of each specimen;

d) the conditions of curing and storage;

e) the required age of the specimens at the time of testing, or the date of testing if the age is not known.

8.1.2 Optional information

If requested the following information shall be provided by the producer of the test specimens for inclusion in the test report:

a) a building project;

b) a part or component of the building;

c) any admixtures used;

d) a specified compressive strength.

8.2 Information to be provided by the test laboratory for inclusion in the test report

The following information shall be provided by the test laboratory for inclusion in the test report:

a) the condition of the specimens when received, and any surface treatment;

b) the type and dimensions of the specimens;

c) the date of receipt of the specimens;

d) the conditions of curing and storage;

e) the date of the test;

f) the age of the specimen at the time of testing;

g) the density (as received or saturated and the method of determining volume), if required;

h) the type and the number of measuring instruments and the gauge length;

i) the mean compressive strength of the specimens or, if estimated, the basis of the estimate;

j) the compressive strength of the specimen used for the determination of the static modulus of elasticity;

k) the upper loading stress (σ_a) and basic stress (σ_b);

l) the mean strain under the upper loading stress (ε_a) and the mean strain under the basic stress(ε_b);

m) the static modulus of elasticity for each specimen and the average value;

n) the appearance of the concrete and type of fracture, if unusual;

o) any deviation from the standard method;

p) a certificate that the test has been carried out in accordance with this part of ISO 1920, except as noted in 8.2 o).

Annex A
(informative)

Automatic measuring method with monotonic loading for static modulus of elasticity

A.1 Apparatus

The electronic data reading system such as a data logger is recommended for the automatic measuring method.

A.2 Measuring procedure

Place the test specimen centrally in the machine. Apply the basic stress, then measure and record the strain gauge readings taken at each measurement line. Steadily increase the stress at a constant rate within the range (0,6 to 0,4) N/(mm^2·s). Measure and record the strain gauge readings at least 10 times with almost equal stress intervals while increasing load up to 0,5 of the failure load.

If the individual strains are not within a range of approximately ± 30 % of their mean value at upper stress level, recentre the test specimen and repeat the test. If it is not possible to reduce the differences to within this range, do not proceed with the test.

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