CONCRETE, HARDENED:
MODULUS OF ELASTICITY IN COMPRESSION

1. SCOPE AND FIELD OF APPLICATION

This NORDTEST method is intended for the determination of the modulus of elasticity of test specimens made of hardened concrete with normally existing rock-type aggregate.

Two modulus of elasticity may be determined, one of which, with the identification $E_o$ agrees with the CEB-FIPs definition of modulus of elasticity and represents the value that is obtained during the first loading.

The second modulus of elasticity, with the identification $E'_c$, agrees with ISO 6784 and represents the value which is obtained after at least three periods of loading and off-loading. With regard to deviations from the ISO 6784, see Comments.

The method does not state the number of test specimens or the age of the specimens at the time of testing.

2. REFERENCES

NT BUILD 191 CONCRETE, FRESH: SAMPLING
NT BUILD 200 CONCRETE, HARDENED: DIMENSIONS OF TEST SPECIMENS
3. SAMPLING

See NT BUILD 191 and 201 or NT BUILD 202.

The test specimens shall fulfill the demands on shape, measures and flatness for cylinders with \( d = h/2 \) acc. to NT BUILD 200.

The diameter of the test specimens shall be at least four times larger than the nominal maximum particle size in the concrete.

Cast test specimens shall be stored in an upright position until the concrete has hardened.

4. METHOD OF TEST

4.1 Principle

The modulus of elasticity is determined by defining the relation between load and deformation.

4.2 Apparatus

Tensile testing: machine of class 1 acc. to NT MECH 001 and NT BUILD 203.

Moulds for the manufacture of test specimens acc. to NT BUILD 200 or Equipment for core drilling of test specimens acc. to NT BUILD 202.
Deformation meter (e.g., extensometer or strain gauge) for the determination of changes in length of the specimen under load, with a gauge length l, so that \( 3d_{\text{max}} \leq l \leq h-d \), where the identification marks are shown in Fig. 1. The length gauge shall be centrically attached to the test specimen. Measurement shall be made on at least two opposing sides of the test specimen. The accuracy of the measurements shall be within \( \pm 25 \times 10^{-6} \).

![Diagram](image)

Fig. 1. The markings of the test specimens and the gauge length l. \( d_{\text{max}} \) is the maximum nominal particle size in the aggregate.

4.3 Preparation of Test Samples

The test specimens shall be stored in water acc. to NT BUILD 201 or 202.

The test specimens shall be removed from the water not earlier than 30 minutes prior to the test and should be dried so that there is no free water on the load-bearing surfaces.

4.4 Procedure

4.4.1 Compressive strength

The compressive strength shall be determined acc. to NT BUILD 203 on three cylindrical test specimens with the same measures, from the same concrete batch and cured as the test specimens, whose modulus of elasticity shall be determined. The mean value of the compressive strength is expressed as \( f_{\text{cm}} \).
If one has no access to test specimens for the determination of the compressive strength, the value of $f_{cm}$ must be estimated. This should be stated in the test report.

4.4.2 Modulus of elasticity

For each test specimen the following test procedure should be followed:

The platens of the compressive test machine should be dried off. The dimensions of the test specimen are determined by measuring acc. to NT BUILD 200. The weight is defined and the density is calculated.

The test specimen with the deformation meter are placed centrically in the compressive testing machine with an accuracy within $\pm 1$ mm. The test specimen is then loaded with the basic stress of $\sigma_0 = 0.5$ MPa and a reading is taken on the deformation meter, see Fig. 2.

The stress is then continuously increased at the rate of $0.8 \pm 0.2$ MPa/s until the stress of $\sigma_1 = 0.45 f_{cm}$ is reached.

This is maintained for 60 seconds whereafter the deformation meter is again read during the following 30 seconds. The strain $\varepsilon_{01}$ from the stress $\sigma_0$ to $\sigma_1$ is calculated. If the results deviate from the mean value with more than 20 per cent, the test specimens should be centered again and the process should be repeated.

When the centering is sufficiently accurate, the test specimen is off-loaded at the same rate as during the load until the basic stress $\sigma_{01}$ equals 0.5 MPa. The deformation meter is read after 60 seconds.

The test specimen is re-loaded until $\sigma_2 = f_{cm}/3$ is reached, and is then off-loaded at the same rate as was used earlier until the basic stress of $\sigma_0$ is reached while $\sigma_2$ and $\sigma_0$ are kept constant during 60 seconds, see Fig. 2.
The dislocation of at least two loads and off-loads.

Fig. 2. Stress and strain diagram showing the used markings.

The process is repeated once. The deformation meter is now read when the stress is \( \sigma_2 \) and \( \sigma_{02} \) after a pause of 60 seconds for each respective load. The strain \( \varepsilon_{02} \) resulting from the stress \( \sigma_2 \) to \( \sigma_{02} \) are calculated.

The test specimen is then made subject to the ultimate compression acc. to NT BUILD 203, and the compressive strength \( f_c \) is calculated. If \( f_c \) deviates with more than 20% from \( f_{cm} \) this should be stated in the test report.

The modulus of elasticity \( E \) is calculated according to the formula:

\[
E_0 = \frac{(\sigma_1 - \sigma_{01})}{\varepsilon_{01}}
\]

The \( E_c \) is calculated according to formula:

\[
E_c = \frac{(\sigma_2 - \sigma_{02})}{\varepsilon_{02}}
\]

4.5 **Expression of Results**

The modulus of elasticity is expressed in GPa (GN/m²) and is rounded off to the nearest 0.5 GPa.
4.6 Test Report

If a test report is submitted, it should contain at least the following information:

- a) Name and address of the testing laboratory
- b) Date and identification symbols of the report
- c) Test method (number and title)
- d) Any deviation from the test method
- e) Name and address of the person or institution who ordered the test
- f) Name and address of the person performing the test
- g) Name and address of the manufacturer of the concrete
- h) The identification symbols of the concrete. The composition, age and temperature of the concrete should also be noted
- i) Date when the test was performed and when the sample was received
- j) Test results
- k) Any other information of importance for the evaluation of the test results
- l) Evaluation of the test results, if this is required in the request for the test

Comments

The method may also be used on other test specimens than the ones stated in paragraph 3.

The method deviates from ISO 6784 with regard to the editing and the following points:

**Point 3** ISO permits cylinders and prisms with $2 \leq L/d \leq 4$ and states that core drilled test specimens may not always fulfill this demand and the demand on the diameter.

**Point 3** ISO permits that test specimens may be cast and stored in a horizontal position.

**Point 4.4.2** ISO does not define $E_o$. 
Point 4.4.2  ISO permits the highest stress to be $f_{cm}/4 - f_{cm}/2$.

Point 4.5  ISO expressed the results in MPa (MN/m$^2$) and rounds off the value to the nearest 100 MPa when $E_c = 10000$

The deviations from ISO 6784 are based on the regard for the definition of the modulus of elasticity in CEB and FIP as well as in the NBK.