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Bitumenske zmesi - Preskusne metode za vroče asfaltne zmesi - 26. del: Togost

Bituminous mixtures - Test methods for hot mix asphalt - Part 26: Stiffness

Asphalt - Prüfverfahren für Heißasphalt - Teil 26: Steifigkeit

Mélanges bitumineux - Méthodes d'essai pour mélange hydrocarboné à chaud - Partie 26: Module de rigidité

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Bituminous mixtures - Test methods for hot mix asphalt - Part 26: Stiffness

Mélanges bitumineux - Méthodes d'essai pour enrobés à chaud - Partie 26: Rigidité

Asphalt - Prüfverfahren für Heißasphalt - Teil 26: Steifigkeit

This European Standard was approved by CEN on 18 September 2011.

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COMITÉ EUROPÉEN DE NORMALISATION

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Foreword

This document (EN 12697-26:2012) has been prepared by Technical Committee CEN/TC 227 “Road materials”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2012, and conflicting national standards shall be withdrawn at the latest by September 2012.

This document will supersede EN 12697-26:2004.

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

The main changes deal with putting similar procedures in all the test in the general part of the standard. Also the correct wording is applied within all the test procedures.

This document is one of a series of standards as listed below:

EN 12697-1, *Bituminous mixtures — Test methods for hot mix asphalt — Part 1: Soluble binder content*

EN 12697-2, *Bituminous mixtures — Test methods for hot mix asphalt — Part 2: Determination of particle size distribution*

EN 12697-3, *Bituminous mixtures — Test methods for hot mix asphalt — Part 3: Bitumen recovery: Rotary evaporator*

EN 12697-4, *Bituminous mixtures — Test methods for hot mix asphalt — Part 4: Bitumen recovery: Fractionating column*

EN 12697-5, *Bituminous mixtures — Test methods for hot mix asphalt — Part 5: Determination of the maximum density*

EN 12697-6, *Bituminous mixtures — Test methods for hot mix asphalt — Part 6: Determination of bulk density of bituminous specimens*

EN 12697-7, *Bituminous mixtures — Test methods for hot mix asphalt — Part 7: Determination of bulk density of bituminous specimens by gamma rays*

EN 12697-8, *Bituminous mixtures — Test methods for hot mix asphalt — Part 8: Determination of void characteristics of bituminous specimens*

EN 12697-10, *Bituminous mixtures — Test methods for hot mix asphalt — Part 10: Compactability*

EN 12697-11, *Bituminous mixtures — Test methods for hot mix asphalt — Part 11: Determination of the affinity between aggregate and bitumen*

EN 12697-12, *Bituminous mixtures — Test methods for hot mix asphalt — Part 12: Determination of the water sensitivity of bituminous specimens*

EN 12697-13, *Bituminous mixtures — Test methods for hot mix asphalt — Part 13: Temperature measurement*

EN 12697-14, *Bituminous mixtures — Test methods for hot mix asphalt — Part 14: Water content*

EN 12697-15, *Bituminous mixtures — Test methods for hot mix asphalt — Part 15: Determination of the segregation sensitivity*

EN 12697-16, *Bituminous mixtures — Test methods for hot mix asphalt — Part 16: Abrasion by studded tyres*

EN 12697-17, *Bituminous mixtures — Test methods for hot mix asphalt — Part 17: Particle loss of porous asphalt specimen*

EN 12697-18, *Bituminous mixtures — Test methods for hot mix asphalt — Part 18: Binder drainage*

EN 12697-19, *Bituminous mixtures — Test methods for hot mix asphalt — Part 19: Permeability of specimen*

EN 12697-20, *Bituminous mixtures — Test methods for hot mix asphalt — Part 20: Indentation using cube or Marshall specimens*

EN 12697-21, *Bituminous mixtures — Test methods for hot mix asphalt — Part 21: Indentation using plate specimens*

EN 12697-22, *Bituminous mixtures — Test methods for hot mix asphalt — Part 22: Wheel tracking*

EN 12697-23, *Bituminous mixtures — Test methods for hot mix asphalt — Part 23: Determination of the indirect tensile strength of bituminous specimens*

EN 12697-24, *Bituminous mixtures — Test methods for hot mix asphalt — Part 24: Resistance to fatigue*

EN 12697-25, *Bituminous mixtures — Test methods for hot mix asphalt — Part 25: Cyclic compression test*

EN 12697-26, *Bituminous mixtures — Test methods for hot mix asphalt — Part 26: Stiffness*

EN 12697-27, *Bituminous mixtures — Test methods for hot mix asphalt — Part 27: Sampling*

EN 12697-28, *Bituminous mixtures — Test methods for hot mix asphalt — Part 28: Preparation of samples for determining binder content, water content and grading*

EN 12697-29, *Bituminous mixtures — Test methods for hot mix asphalt — Part 29: Determination of the dimensions of a bituminous specimen*

EN 12697-30, *Bituminous mixtures — Test methods for hot mix asphalt — Part 30: Specimen preparation by impact compactor*

EN 12697-31, *Bituminous mixtures — Test methods for hot mix asphalt — Part 31: Specimen preparation by gyratory compactor*

EN 12697-32, *Bituminous mixtures — Test methods for hot mix asphalt — Part 32: Laboratory compaction of bituminous mixtures by a vibratory compactor*

EN 12697-33, *Bituminous mixtures — Test methods for hot mix asphalt — Part 33: Specimen prepared by roller compactor*

EN 12697-34, *Bituminous mixtures — Test methods for hot mix asphalt — Part 34: Marshall test*

EN 12697-35, *Bituminous mixtures — Test methods for hot mix asphalt — Part 35: Laboratory mixing*

EN 12697-36, *Bituminous mixtures — Test methods for hot mix asphalt– Part 36: Determination of the thickness of a bituminous pavement*

EN 12697-37, *Bituminous mixtures — Test methods for hot mix asphalt — Part 37: Hot sand test for the adhesivity of binder on precoated chippings for HRA*

EN 12697-38, *Bituminous mixtures — Test methods for hot mix asphalt — Part 38: Common equipment and calibration*

EN 12697-39, *Bituminous mixtures — Test methods for hot mix asphalt — Part 39: Binder content by ignition*

EN 12697-40, *Bituminous mixtures — Test methods for hot mix asphalt — Part 40: In situ drainability*

EN 12697-41, *Bituminous mixtures — Test methods for hot mix asphalt — Part 41: Resistance to de-icing fluids*

EN 12697-42, *Bituminous mixtures — Test methods for hot mix asphalt — Part 42: Amount of foreign matters in reclaimed asphalt*

EN 12697-43, *Bituminous mixtures — Test methods for hot mix asphalt — Part 43: Resistance to fuel*

EN 12697-44, *Bituminous mixtures — Test methods for hot mix asphalt — Part 44; Crack propagation by semi-circular bending test*

prEN 12697-45, *Bituminous mixtures — Test methods for hot mix asphalt — Part 45: Saturation ageing tensile stiffness (SATS) conditioning test*

prEN 12697-46, *Bituminous mixtures — Test methods for hot mix asphalt — Part 46: Low temperature cracking and properties by uniaxial tension tests*

EN 12697-47, *Bituminous mixtures — Test methods for hot mix asphalt — Part 47: Determination of the ash content of natural asphalts*

prEN 12697-48, *Bituminous mixtures — Test methods for hot mix asphalt — Part 48: Inter-layer bond strength*[1)]

prEN 12697-49, *Bituminous mixtures — Test methods for hot mix asphalt — Part 49: Skid resistance of asphalt in the laboratory*[1)]

prEN 12697-50, *Bituminous mixtures — Test methods for hot mix asphalt — Part 50: Scuffing resistance of surface course*[1)]

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

1) In preparation

1 Scope

This European Standard specifies the methods for characterising the stiffness of bituminous mixtures by alternative tests, including bending tests and direct and indirect tensile tests. The tests are performed on compacted bituminous material under a sinusoidal loading or other controlled loading, using different types of specimens and supports.

The procedure is used to rank bituminous mixtures on the basis of stiffness, as a guide to relative performance in the pavement, to obtain data for estimating the structural behaviour in the road and to judge test data according to specifications for bituminous mixtures.

As this standard does not impose a particular type of testing device the precise choice of the test conditions depends on the possibilities and the working range of the used device.

For the choice of specific test conditions, the requirements of the product standards for bituminous mixtures should be respected.

The applicability of this document is described in the product standards for bituminous mixtures.

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.

EN 12697-6, *Bituminous mixtures — Test methods for hot mix asphalt — Part 6: Determination of bulk density of bituminous specimens*

EN 12697-27, *Bituminous mixtures — Test methods for hot mix asphalt — Part 27: Sampling*

EN 12697-29, *Bituminous mixtures — Test methods for hot mix asphalt — Part 29: Determination of the dimensions of a bituminous specimen*

EN 12967-31, *Bituminous mixtures — Test methods for hot mix asphalt — Part 31: Specimen preparation by gyratory compactor*

EN 12967-33, *Bituminous mixtures — Test methods for hot mix asphalt — Part 33: Specimen prepared by roller compactor*

3 Terms, definitions and symbols

3.1 Terms and definitions

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

3.1.1
stiffness

$$E = \frac{\sigma}{\varepsilon}$$

3.1.2
complex modulus
relationship between stress and strain for a linear visco-elastic material submitted to a sinusoidal load wave form at time, t, where applying a stress $\sigma \times \sin(\omega \times t)$ results in a strain $\varepsilon \times \sin(\omega \times (t - \Phi))$ that has a phase angle, Φ, with respect to the stress

NOTE 1 The amplitude of strain and the phase angle are functions of the frequency, f, and the test temperature, Θ.

NOTE 2 The stress strain ratio defines the complex modulus E^* as:

$$E^* = \left|E^*\right| \times (\cos(\Phi) + i \times \sin(\Phi)) \quad (1)$$

The complex modulus is characterised by a pair of two components. This pair can be expressed in two ways: the real component E_1 and the imaginary components E_2:

$$E_1 = \left|E^*\right| \times \cos(\Phi) \quad (2)$$

$$E_2 = \left|E^*\right| \times \sin(\Phi) \quad (3)$$

the absolute value of the complex modulus $\left|E^*\right|$ and the phase angle, Φ:

$$\left|E^*\right| = \sqrt{E_1^2 + E_2^2} \quad (4)$$

$$\Phi = \arctan\left(\frac{E_2}{E_1}\right) \quad (5)$$

NOTE 3 This second characterisation is more often used in practice. In linear elastic multi-layer calculations for instance the E^* modulus is generally used as input value for Young's modulus.

NOTE 4 For purely elastic materials, the phase angle is zero and then the complex modulus reduces to the Young's modulus. This happens when bituminous materials are at very low temperatures. Then the complex modulus reaches its highest possible value noted E_∞.

3.1.3
secant modulus
relationship between stress and strain at the loading time, t, for a material subjected to controlled strain rate loading:

$$E(t) = \frac{\sigma(t)}{\varepsilon(t)} \quad (6)$$

with stress, $\sigma(t)$, and strain, $\varepsilon(t)$, at time t

NOTE 1 The strain law is:

$$\varepsilon(t) = \alpha_i \times t^n \quad (7)$$

where α_i and n are constants.

NOTE 2 Several successive tests may be carried out on the same specimen for different values α_i. For linear visco-elastic materials, the secant modulus obtained for different values of α_i at the same temperature depends on the loading time, t, only.

3.2 Symbols

For the purposes of this document, the following symbols apply:

E the stiffness (modulus), in megapascals (MPa);

E^* the complex modulus, in megapascals (MPa);

E_1 the real component of the complex modulus, in megapascals (MPa);

E_2 the imaginary component of the complex modulus, in megapascals (MPa);

E_∞ the highest possible value of the complex modulus, in megapascals (MPa);

F the loading force, in newtons (N);

h the mean thickness of the specimen, in millimetres (mm);

H the height of a cylindrical specimen, in millimetres (mm);

k the load area factor;

l_0 the original length of the measurement area in millimetres (mm);

Δl the elongation of the measurement area in micrometers (µm);

L the span length between outer supports in bending tests, in millimetres (mm);

t the loading time, in seconds (s);

Θ the test temperature, in degrees celsius (°C);

z the displacement, in millimetres (mm);

f the test frequency in Hertz (Hz);

σ the applied stress, in megapascals (MPa);

ε the applied strain, in micrometer per meter or in microstrain (µm/m);

ω the angular speed, in radians per second (rad/s);

Φ the phase angle, in degrees (°);

γ the form factor which is a function of specimen size and form (1/mm or mm^{-1});

μ the mass factor which is a function of the mass of the specimen and the mass of the movable parts that influence the resultant force by their inertial effects (in g);

ν the Poisson's ratio;

$\varnothing$ the diameter of a cylindrical specimen, in millimetres (mm).

4 Principle

Suitable shaped samples are deformed in their linear range, under repeated loads or controlled strain rate loads. The amplitudes of the stress and strain are measured, together with the phase difference between stress and strain.

5 Sample preparation

5.1 Age of the specimens

Prior to the start of testing, the specimens shall be stored on a flat surface at a temperature of not more than 25 °C for between 14 days and 42 days from the time of their manufacture. In the case of samples requiring cutting and/or gluing, the cutting shall be performed no more than 8 days after compaction of the asphalt and the gluing shall be performed at least 2 weeks from cutting. The time of manufacture for these samples is the time when they are cut.

5.2 Drying of the specimen

After sawing and before gluing and/or testing, the specimens shall be dried to constant mass in air at a relative air humidity of less than 80 % at a temperature not more than 20 °C. A test specimen shall be considered to be dry after at least 8 h drying time and when two weighings performed minimum 4 h apart differ by less than 0,1 %.

5.3 Dimensions and bulk density of the specimens

The dimensions of the specimens shall be measured according to EN 12697-29.

The bulk density shall be determined in accordance with EN 12697-6 or EN 12697-7. The bulk density of each specimen shall not differ by more than 1 % from the average apparent density of the batch. Otherwise, the specimen shall be rejected.

5.4 Temperature of the specimen before testing

The test shall not be started until the specimen has reached the required test temperature.

NOTE The specimen temperature can monitored using a dummy specimen or the required temperature conditioning time can be evaluated in pre-tests. The needed conditioning time depends on the test equipment, specimen size and tested material.

5.5 Number of test specimens

For all the mentioned tests, the minimum amount of specimens that need to be tested to get one test result (=one stiffness modulus) is 4 specimens.

6 Checking of the testing equipment

The complete testing equipment shall be checked periodically with at least one reference specimen with a known stiffness modulus (modulus and phase lag). To check the test equipment for Annexes A, B, C, or D, the bending moment ($E.I$) of the specimen(s) shall be chosen to be equal to the bending moment of a normal asphalt test specimen (adopting a stiffness modulus for the asphalt in the range of 3 GPa to 14 GPa); for Annex E and Annex F an appropriate checking specimen with a known stiffness between 3 GPa and 14 GPa shall be used. The reference specimen shall be tested at not less than 6 frequencies and 2 deflection levels. The back-calculated stiffness moduli shall be within 2 % with respect to the known modulus and within 1,0° for the known phase lag. If, due to the electronic components or mechanical equipment, systematic deviations (or larger deviations) of:

— the stiffness modulus is observed, all electronic components and mechanical equipment shall be checked for proper working and no procedure for the back-calculation software is permitted;

— the phase angle is observed, a correction procedure for the back-calculation software is permitted.

NOTE The geometry of the reference specimen should be selected so that it will lead to a mass comparable with the mass of an asphalt specimen. The clamping of the reference specimen should be equal to the procedure for an asphalt specimen. A reference material with a phase lag unequal to zero is preferred but a material like aluminium (E around 70 GPa, phase lag is zero) is also acceptable.

7 Test methods

7.1 General

The following test methods can be adopted by use of the relative form and mass factor (see Clause 9). The testing procedures that shall be followed are described in Annexes A, B, C, D, E and F. If other test procedures are used to characterise stiffness properties of bituminous mixtures, the equivalence shall first by verified by comparison with one of these procedures and a statement on that equivalence shall be attached to test reports.

NOTE Inter-laboratory tests have shown that the following mentioned bending tests are in good agreement provided that the equipment is carefully calibrated and that some basic guidelines are strictly followed.

7.2 Tests with sinusoidal or pulse loading

7.2.1 Bending tests

The bending test options are:

— 2PB-TR: test applying two point bending to trapezoidal specimens, see Annex A;

— 2PB-PR: test applying two point bending to prismatic specimens, see Annex A;

— 3PB-PR: test applying three point bending to prismatic specimens, see Annex B;

— 4PB-PR: test applying four point bending to prismatic specimens, see Annex B.

7.2.2 Indirect tensile test

The indirect tensile test options are:

— IT-CY: test applying indirect tension to cylindrical specimens, see Annex C;

— CIT-CY: test applying cyclic indirect tension to cylindrical specimens, see Annex F.

7.2.3 Direct uniaxial tests

The direct uniaxial test options are:

— DTC-CY: test applying direct tension-compression to cylindrical specimens, see Annex D;

— DT-CY: test applying direct tension to cylindrical specimens, see Annex E;

— DT-PR: test applying direct tension to prismatic specimens, see Annex E.

7.2.4 Loading conditions

The amplitude and the frequency of the loading signal shall be controlled by a feedback control, which may be based either on the force or on the displacement.

NOTE The waveform should be harmonic. Any distortion is the sign of an abnormal set up or of a resonance phenomenon that can disturb the measurement.

7.2.5 Load amplitudes

The amplitude of the load shall be such that no damage can be generated during the time needed to perform the measurements.

NOTE 1 Experience with a number of test methods has shown that for most bituminous mixtures strains should be kept at a level lower than 50 microstrain (= 50×10^{-6} m/m) to prevent fatigue damage.

NOTE 2 It is known that, beyond certain levels of strain, non-linear behaviour (e.g. stress dependency) can be displayed by the material. In such a case, the proportionality between stress and strain is no longer valid and the concept of complex modulus defined above is no longer correct. This limit depends on the material but it also varies with temperature for a given material.

NOTE 3 Special attention should be given in the highest range of temperature. Therefore, it is recommended to perform linearity tests at the highest temperature to be undertaken within the testing programme. This test consists of measuring the complex modulus at a fixed frequency for an increasing range of strains (or stresses) and to determine the value of strain at which the modulus is no longer constant (starts to decrease).

NOTE 4 Attention should be paid to the danger of fatigue damage during testing by minimising the number of cycles or loading time at each applied stress level and/or minimising the number of stress levels. It is recommended to carry out also a reverse scheme of stress levels in order to see if any fatigue damage has occurred (see also NOTE 1).

NOTE 5 The admissible level of deformation is determined for the direct tensile test by a preliminary test at 10 °C, 50 microstrain and loading times 3 s and 300 s.

7.2.6 Loading frequencies

The range of frequencies is device dependent.

NOTE 1 Most equipment is able to cover a range between 0,1 Hz and 50 Hz. However, it is preferable to make it as wide as possible in order to allow a logarithmic presentation of the isotherms. A typical set of frequencies could be 0,1 Hz, 0,2 Hz, 0,5 Hz, 1 Hz, 2 Hz, 5 Hz, 10 Hz, 20 Hz, 50 Hz and again the starting frequency of 0,1 Hz. This last measurement is to check that the specimen has not been damaged during the loading with various frequencies. If the difference between stiffness of the specimen at the first and last measurements at identical frequency and at the same temperature is greater than 3 %, it can be concluded that the specimen is damaged and, therefore, cannot be used for further testing (e.g. at different temperatures).

NOTE 2 Care should be taken to avoid resonance phenomena especially at high frequencies.

NOTE 3 Care should be taken that the heat is not accumulated in the specimen in an extent that the temperature differs more than ±0,3 °C from the temperature of the climatic chamber. This problem is especially dominant at prolonged measurements and/or higher frequencies.

7.3 Controlled strain rate loading

7.3.1 Test method

Uniaxial direct tensile test on cylindrical or prismatic specimens (DT-CY and DT-PR see Annex E) can be adopted.

NOTE The procedure gives comparable test results to sinusoidal loading for loading time less than 1 s, if the moduli at the loading time, t, expressed in seconds, are compared to the complex modulus at a frequency:

$$f = \frac{1}{2\,\pi \times t} \tag{8}$$

expressed in Hertz (Hz).

7.3.2 Loading conditions

A controlled rate displacement shall be applied to a specimen in direct tension to provide a constant strain rate with $n = 1$ so that the strain law is:

$$\varepsilon(t) = \alpha_\mathrm{i} \times t \tag{9}$$

7.3.3 Strain amplitudes

7.3.3.1 Preliminary test

For direct tensile tests, at least one element test shall be performed in accordance with Annex E in order to determine the level of the stiffness of the mixture. The conditions shall be a temperature of 10 °C, strain amplitude of 50 microstrain, loading force $F > 200$ N and loading times 3 s and 300 s.

7.3.3.2 Strain amplitudes during the test

The maximum strain during the test shall be less than the values given in Table 1.

Table 1 — Strain expressed in microstrain to be applied during a controlled strain rate test in accordance with the stiffness determined by a preliminary test to 50 microstrain

Test temperature Θ °C	**Stiffness**, 10 °C, 3 s		**Stiffness**, 10 °C, 300 s	
	< 7,5 GPa	≥ 7,5 GPa	< 1 GPa	≥ 1 GPa
	Strain amplitude microstrain			
≤10	100	50	–	–
10 ≤ Θ < 20	–	–	200	100
20 ≤ Θ ≤ 40	–	–	300	200

7.3.3.3 Test loading times

A series of tests shall be performed on the same specimen with various loading times and with the same maximum strain given in Table 1. Four loading times shall be used for at least one test temperature, and at least two loading times for the other test temperatures.

8 Temperatures

The temperature of the climatic chamber, in the vicinity of the specimen, shall be equal to the specified temperature to ± 0,5 °C other than for the direct tension test for which the specific temperature conditions are given in Annex E. For each test temperature, the specimen shall be placed in the climatic chamber for at least 4 h before testing.