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Bitumenske zmesi - Preskusne metode za vroče asfaltne zmesi - 24. del: Odpornost proti utrujanju

Bituminous mixtures - Test methods for hot mix asphalt - Part 24: Resistance to fatigue

Asphalt - Prüfverfahren für Heißasphalt - Teil 24: Beständigkeit gegen Ermüdung

Mélanges bitumineux - Méthodes d'essai pour mélange hydrocarboné à chaud - Partie 24: Résistance à la fatigue

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Mélanges bitumineux - Méthodes d'essai pour mélange hydrocarboné à chaud - Partie 24: Résistance à la fatigue

Asphalt - Prüfverfahren für Heißasphalt - Teil 24: Beständigkeit gegen Ermüdung

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Foreword

This document (EN 12697-24:2012) 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of an identical text or by endorsement, at the latest by November 2012, and conflicting national standards shall be withdrawn at the latest by November 2012.

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.

This document supersedes EN 12697-24:2004+A1:2007.

The main changes with respect to the previous edition are as follows:

— clarification in the scope that tests using different failure criteria are not comparable;

— definition of conventional criteria of fatigue for constant force deleted, leaving just constant displacement;

— definitions of the average and standard deviation of the fatigue life of a series of specimens for the two-point and four-point bending tests on prismatic specimens removed;

— symbols for the frequency of the sinusoidal load applications and angular speed revised;

— requirements on age and drying of specimens added in the main text and removed from the individual annexes;

— limits on interpolation defined;

— alternative criterion given in a note;

— requirement for checking (rather than calibration of) the test equipment added in the main text and removed from the individual annexes;

— requirement added for the test report to include information on the chosen test method, the used testing equipment, results of the last check on calibration of the testing equipment and the age of the specimen at the time of testing;

— the tolerance for the displacement of the trapezoidal specimen widened;

— measurements on the three-point bending test on prismatic specimens started after fewer cycles;

— note added on rotating the specimen in four-point bending test on prismatic specimens;

— the optional requirement for choosing frequency spectrum of initial complex (stiffness) moduli removed from the four-point bending test on prismatic specimens;

— the principle, equipment, procedure and calculations of the indirect tensile test on cylindrical specimens revised.

This document is one of a series of standards for bituminous mixtures which includes the following:

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: Binder recovery: Rotary evaporator*

EN 12697-4, *Bituminous mixtures — Test methods for hot mix asphalt — Part 4: Binder 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: Compactibility*

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: Partial 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 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 coarse 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*

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

EN 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 the United Kingdom.

1) In preparation.

1 Scope

This European Standard specifies the methods for characterising the fatigue of bituminous mixtures using 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:

a) to rank bituminous mixtures on the basis of resistance to fatigue;

b) as a guide to relative performance in the pavement;

c) to obtain data for estimating the structural behaviour of the road; and

d) to judge test data according to specifications for bituminous mixtures.

Because this European 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 device used. For the choice of specific test conditions, the requirements of the product standards for bituminous mixtures need to be respected. The applicability of this document is described in the product standards for bituminous mixtures.

Results obtained from different test methods or using different failure criteria are not assured to be comparable.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 12697-8, *Bituminous mixtures — Test methods for hot mix asphalt — Part 8: Determination of void characteristics of bituminous specimens*

EN 12697-26:2011, *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 12697-29, *Bituminous mixtures — Test methods for hot mix asphalt — Part 29: Determination of the dimensions of a bituminous specimen*

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

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

3 Terms, definitions, symbols and abbreviations

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

3.1 General

3.1.1
fatigue
reduction of strength of a material under repeated loading when compared to the strength under a single load

3.1.2
conventional criteria of failure
number of load applications, $N_{f/50}$, when the complex stiffness modulus $S_{mix,0}$ has decreased to half its initial value

3.1.3
initial complex stiffness modulus
complex stiffness modulus, $S_{mix,0}$, after 100 load applications

3.1.4
fatigue life of a specimen
number of cycles $N_{i,j,k}$ corresponding to the conventional failure criterion at the set of test conditions k (temperature, frequency and loading mode)

Note 1 to entry: A loading mode could be constant deflection level, or constant force level, and or any other constant loading condition.

3.2 Two-point bending test on trapezoidal specimens

3.2.1
constant relative to maximum strain
constant that enables the head displacement z of the trapezoidal specimen of dimensions [B, b, e, h], to which a bending strain level ε is applied, to be converted into maximum strain

Note 1 to entry: The following formulae express K_ε and its relationship with the parameters mentioned above:

$$K_\varepsilon \times z = \varepsilon \quad (1)$$

$$K_\varepsilon = \frac{B^2 \times (B-b)^2}{4b \times h^2 \times \left[(b-B)\times(3B-b) + 2B^2 \times \ln\left(B/b\right)\right]} \quad (2)$$

3.2.2 Symbols

Where a strain of 1 microstrain (µstrain) is equal to 10^{-6} by convention, the symbols are as follows:

i is the index of the specimen for an element test (varies from 1 to n);

h_i is the height, in metres (m);

B_i is the large base, in metres (m);

b_i is the small base, in metres (m);

e_i is the thickness, in metres (m);

v_i is the void content of the specimen i by geometric method, in percent (%);

$K_{\varepsilon i}$ is the constant, relative to the maximum strain, in inverse metres (m^{-1});

z_i is the amplitude of displacement imposed at the head of specimen i, in metres (m);

ε_i is the maximum relative strain of specimen i corresponding with the displacement imposed at the head;

N_i is the conventional fatigue life of specimen i;

a is the ordinate of the fatigue line according to the formula $\log(N) = a + (1/b)\log(\varepsilon)$;

r_2 is the linear correlation coefficient ($\log(N_i)$, $\log(\varepsilon_i)$);

$1/b$ is the slope of the fatigue line;

$\log(\varepsilon)$ is the average value of $\log(\varepsilon_i)$;

$S_{\log(\varepsilon)}$ is the standard deviation of $\log(\varepsilon_i)$;

$S_{\log(N)}$ is the standard deviation of $\log(N_i)$;

ε_6 is the strain corresponding to 10^6 cycles;

s_N is the estimation of the residual standard deviation of the decimal logarithms of fatigue lives;

$\Delta\varepsilon_6$ is the quality index of the test;

n is the number of specimens.

3.3 Two-point bending test on prismatic shaped specimens

3.3.1
constants for consideration of the geometry of specimen

constants that enable the strength of the head P_{ij} of the specimen i of dimensions b_i ,e_i and $h_{i,}$ to which a bending strength is applied, to be converted to a maximum tension

Note 1 to entry: The following formulae express $K_{\varepsilon\, i}$ and its relationship with the parameters mentioned above:

$$K_{\sigma i} \times P_{ij} = \sigma_{jmax} \tag{3}$$

where

$K_{\sigma i}$ is the constant for consideration of the geometry of specimen at constant strength;

P_{ij} is the amplitude of the strength, with which the head is applied, in Newtons (N);

ε_{jmax} is the maximum relative strain of the specimen corresponding with the displacement imposed at the head;

σ_{jmax} is the greatest relative tension of the specimen, corresponding to the strength, with which the head is applied.

$$K_{\sigma i} = \frac{6\, h_i}{b_i^2 \times e_i} \tag{4}$$

where

$K_{\sigma i}$ is the constant for consideration of the geometry of specimen at constant strength (factor in accordance with EN 12697-26);

b_i is the base, in millimetres (mm);

h_i is the height, in millimetres (mm);

e_i is the width, in millimetres (mm).

3.3.2 Symbols

Where a strain of 1 microstrain (µstrain) is equal to 10^{-6} by convention, the symbols are as follows:

3.3.2.1 Sample *i*

h_I is the height, in millimetres (mm);

b_I is (A) small base or (B) base, in millimetres (mm);

e_I is the thickness, in millimetres (mm);

m_I is the mass, in grams (g);

v_i% is the vacuum, achieved by the geometric method as a proportion of atmospheric pressure, in percent (%);

$K\sigma_i$ is the constant for consideration of the geometry of specimen at constant strength, in inverse millimetres (mm^{-1}).

3.3.2.2 Strength at head and greatest tension at specimen *i* at level of tension $\varepsilon_{j\,max}$

P_{ij} is the amplitude of the strength with which the head is applied, in Newtons (N);

$\sigma_{j\,max}$ is the greatest relative tension of the specimen, corresponding to the strength, with which the head is applied.

3.3.2.3 Fatigue life of a specimen *i* at the level of tension $\sigma_{j\,max}$

N_{ij} is the fatigue life.

3.3.2.4 Fatigue life relative to sample *i* at the strain level ε_j

N_{ij} is the conventional fatigue life.

3.3.2.5 Fatigue line

p_σ is the slope of fatigue line $\ln(\sigma_{j\,max}) = f(\ln(N_{ij}))$;

$\hat{\sigma}_6$ is the tension corresponding to 10^6 cycles, in megapascals (MPa);

$s_{\sigma x/y}$ is the estimation of the residual standard deviation of the natural logarithms of fatigue lives;

$\Delta\hat{\sigma}_6$ is the confidence of $\hat{\sigma}_6$ for a probability of 95 %;

N is the number of element tests (number of specimens at the level of tension $\sigma_{j\ max}$ times the number of levels) where $N = n*l$;

s_N is the estimation of the standard deviation of ln(N_{ij}).

3.3.2.6 Fatigue life of a series of n specimens (A) at a strain level ε_{jmax} or (B) at the level of tension $\sigma_{j\ max}$

$N_{\varepsilon jmax}$ is the average number of cycles obtained at the level of tension $\sigma_{j\ max}$;

l is the number at the level of tension $\sigma_{j\ max}$;

n is the number of specimens at the level of tension $\sigma_{j\ max}$.

3.4 Three-point bending test on prismatic shaped specimens

3.4.1 Symbols

The symbols are as follows:

$2A_t$ is the amplitude of the approximate stress function, in megapascals (MPa);

$2A_t$ is the amplitude of the approximate strain function, in megapascals (MPa);

B is the measuring base of the extensometer, in millimetres (mm);

B_t is the phase angle of the approximate stress function, in radians (rad);

B_ε is the phase angle of the approximate strain function, in radians (rad);

D_c is the displacement at instant t, in microns (µm);

$2D_0$ is the total amplitude of displacement function, in microns (µm);

DDE is the density of dissipated energy, in megapascals (MPa) or megajoules per cubic metre (MJ/m^3);

$DE_{(total)}$ is the total density of dissipated energy throughout the whole test, in megajoules per cubic metre (MJ/m^3);

$DDE\ (x)$ is the density of dissipated energy at cycle x, in megajoules per cubic metre (MJ/m^3);

EXT is the instant extensometer signal, in millimetres (mm);

L is the distance between supports, in millimetres (mm);

MD is the dynamic modulus, in megapascals (MPa);

N is the number of cycles at the end of the test;

P is the instant load, in megapascals (MPa);

W is the total density of dissipated energy throughout the whole test, in megajoules per cubic metre (MJ/m^3);

b is the width of the specimen, in millimetres (mm);

e is the thickness of specimen, in millimetres (mm);

f is the wave frequency, in Hertz (Hz);

m is $(N - 200)/500$;

t is the time, in seconds (s);

ε is the instant strain or half-cyclic amplitude of strain function at cycle 200;

ε_a is the approximate strain function value;

ε_c is the cyclic amplitude of strain function;

ε_6 is the strain at 10^6 cycles;

σ is the instant stress, in megapascals (MPa);

σ_a is the approximate stress function value, in megapascals (MPa);

σ_c is the cyclic amplitude of stress function, in megapascals (MPa);

Φ is the phase difference angle, in degrees (°).

3.5 Four-point bending test on prismatic shaped specimens

3.5.1
(complex) stiffness modulus

ratio $S = S_{mix,n} \times e^{i\phi}$ of the calculated stress and strain during cycle n in the specimen

Note 1 to entry: The stiffness modulus defines the relationship between stress and strain for a linear viscoelastic material subjected to sinusoidal loading.

3.5.2
initial (complex) stiffness modulus
values for the initial modulus $S_{mix,0}$ in megapascals (MPa) of the complex modulus and for the initial phase lag ϕ_o in degrees of the complex modulus taken at the 100^{th} load application

3.5.3
fatigue life $N_{i,j,k}$
number of cycles for specimen i, corresponding with the chosen failure criteria j (e.g. conventional failure $j = f/50$) at the set of test conditions k (temperature, frequency and loading mode)

Note 1 to entry: A loading mode could be constant deflection level, or constant force level, and or any other constant loading condition

3.5.4
test condition k
set of conditions under which a specimen is tested

Note 1 to entry: This set contains the applied frequency f, the test temperature Θ and the loading mode (constant deflection, or constant force, and or constant dissipated energy per cycle.