



BSI Standards Publication

Bituminous mixtures - Test methods

Part 24: Resistance to fatigue

National foreword

This British Standard is the UK implementation of EN 12697-24:2018. It supersedes BS EN 12697-24:2012, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/510/1, Asphalt products.

A list of organizations represented on this committee can be obtained on request to its secretary.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

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European foreword

This document (EN 12697-24:2018) 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of an identical text or by endorsement, at the latest by December 2018, and conflicting national standards shall be withdrawn at the latest by December 2018.

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

This document supersedes EN 12697-24:2012.

Compared with EN 12697-24:2012, the following changes have been made:

- the series title no longer makes the method exclusively for hot mix asphalt [Title];
- editing of several text sections in order to clarify the procedures [Ge];
- “load applications” amended to “load cycles” [Ge];
- Figure A.1 corrected: Key 3 pointing at the groove [A.1.2];
- completion of Figure E.3: Line 1 added to extensiometer in front view figure [E.2.5.3];
- introduction of new annex for cyclic indirect tensile test on cylindrical specimens (CIT-CY) [Annex F].

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, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This European Standard specifies the methods for characterizing 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.

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 12697-7, *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 12697-26, *Bituminous mixtures — Test methods — Part 26: Stiffness*

EN 12697-27, *Bituminous mixtures — Test methods — Part 27: Sampling*

EN 12697-29, *Bituminous mixtures — Test method 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 — Part 33: Specimen prepared by roller compactor*

3 Terms, definitions, symbols and abbreviations

For the purposes of this document, the following terms, 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 cycles, $N_f/50$, when the absolute value of the complex stiffness modulus S_{mix} (stiffness modulus) has decreased to half its initial value $S_{\text{mix},0}$

Note 1 to entry: In this standard not only the conventional criteria of failure, based on the reduction of stiffness, is presented. Also other failure criteria like the occurrence of macro cracks or the energy-based failure mechanism are used.

Note 2 to entry: Different test methods and different failure criteria might lead to results that are not comparable.

Note 3 to entry: In a displacement controlled fatigue test the reduction to half of the initial stiffness is a gradual process. In a force controlled test in most cases there will be a progressive collapse of the specimen.

3.1.3

initial complex stiffness modulus

complex stiffness modulus, $S_{\text{mix},0}$, after 100 load cycles

3.2 Two-point bending test on trapezoidal shaped specimens (2PB-TR)

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:

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

$$K_{\varepsilon j} = \frac{(B_i - b_i)^2}{8 \cdot b_i \cdot h_i^2 \left[\frac{(b_i - B_i) \cdot (3B_i - b_i)}{2 \cdot B_i^2} + \ln \frac{B_i}{b_i} \right]} \quad (2)$$

3.2.2 Symbols

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

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

h_i is the height, in millimetres (mm);

B_i is the large base, in millimetres (mm);

b_i is the small base, in millimetres (mm);

e_i is the thickness, in millimetres (mm);

- v_i is the void content of the specimen i by geometric method, in percent (%);
- $K_{\epsilon i}$ is the constant, relative to the maximum strain, in inverse millimetres (mm^{-1});
- z_i is the amplitude of displacement imposed at the head of specimen i , in millimetres (mm);
- 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 $\lg(N) = a + (1/b) \lg(\epsilon)$;
- r_2 is the linear correlation coefficient ($\lg(N_i), \lg(\epsilon_i)$);
- $1/b$ is the slope of the fatigue line;
- $\lg(\epsilon)$ is the average value of $\lg(\epsilon_i)$;
- $S_{\lg(\epsilon)}$ is the standard deviation of $\lg(\epsilon_i)$;
- $S_{\lg(N)}$ is the standard deviation of $\lg(N_i)$;
- 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;
- $\Delta\epsilon_6$ is the quality index of the test;
- n is the number of specimens.

3.3 Two-point bending test on prismatic shaped specimens (2PB-PR)

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 calculate the maximum tension

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

$$K_{\sigma i} \cdot P_{ij} = \sigma_{j\max} \quad (3)$$

where

- $K_{\sigma i}$ is the constant for consideration of the geometry of specimen at constant strength (mm^{-2});
- 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.

$$K_{\sigma i} = \frac{6 h_i}{b_i^2 \cdot e_i} \quad (4)$$

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 $\sigma_{j \max}$

- 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, in megapascal (MPa).

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

- $N\sigma_{ji}$ is the fatigue life in a force controlled test.

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

- $N\varepsilon_{ji}$ is the conventional fatigue life in a displacement controlled test.

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);
 $s_{\sigma \text{ x/y}}$ 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 %, in megapascal (MPa);
 N is the number of element tests (number of specimens at the level of tension $\sigma_{j \max}$ times the number of levels) where $N = n \cdot l$;
 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 $\varepsilon_{j\max}$ or (B) at the level of tension $\sigma_{j\max}$

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

$N_{\varepsilon j\max}$ is the average number of cycles obtained at the level of tension strain $\varepsilon_{j\max}$

3.4 Three-point bending test on prismatic shaped specimens (3PB-PR)

3.4.1 Symbols

The symbols are as follows:

$2A_t$	is the amplitude of the approximate stress function, in megapascals (MPa);
$2A_\varepsilon$	is the amplitude of the approximate strain function, in meter per meter (m/m);
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 micrometres (μm);
$2D_0$	is the total amplitude of displacement function, in micrometres (μm);
DDE	is the density of dissipated energy, in megapascals (MPa) or 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, in 10^{-6} ($\mu\text{m}/\text{m}$);
ε_a	is the approximate strain function value, in 10^{-6} ($\mu\text{m}/\text{m}$);
ε_c	is the cyclic amplitude of strain function, in 10^{-6} ($\mu\text{m}/\text{m}$);

ε_6	is the strain at 10^6 cycles, in 10^{-6} ($\mu\text{m}/\text{m}$);
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 ($^\circ$).

3.5 Four-point bending test on prismatic shaped specimens (4PB-PR)

3.5.1

(complex) stiffness modulus

ratio $S = S_{\text{mix},n} \times e^{i\phi}$ 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

Initial value $S_{\text{mix},0}$ in megapascals (MPa) of the (complex) stiffness modulus and for the the initial phase angle ϕ_0 in degrees ($^\circ$) of the complex modulus taken at the 100th load cycle

3.5.3

fatigue life $N_{i,j,k}$ of a specimen

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).

3.5.5

total length L_{tot}

total length of the prismatic specimen, in millimetres (mm)

3.5.6

effective length L

distance between the two outer clamps, in millimetres (mm)

3.5.7

width B

width of the prismatic specimen, in millimetres (mm)

3.5.8

height H

height of the prismatic specimen, in millimetres (mm)

3.5.9**mid-span length a**

distance between the two inner clamps, in millimetres (mm)

3.5.10**co-ordinate A**

distance between the left outer ($x = 0$) and left inner clamp ($x = A$), in millimetres (mm)

3.5.11**co-ordinate x**

distance between x and the left outer clamp ($0 \leq x \leq L/2$), in millimetres (mm)

3.5.12**co-ordinate x_s**

co-ordinate x where the deflection is measured ($A \leq x_s \leq L/2$), in millimetres (mm)

3.5.13**density ρ**

geometrical density of the specimen, in kilograms per cubic metre (kg/m^3):

$$\rho = \frac{M_{\text{beam}} \cdot 10^9}{(H \cdot L \cdot B)} \quad (5)$$

3.5.14**mass M_{beam}**

total mass of the prismatic beam, in kilograms (kg)

3.5.15**damping coefficient T**

coefficient needed for calculation of the system losses, in kilograms per second (kg/s)

Note 1 to entry: This coefficient can only be established by tuning the equipment with a reference beam of which the stiffness modulus and (material) phase angle are known. In good working equipment, the coefficient T can be neglected (adopting a zero value).

3.5.16**weighing function $R(x)$**

dimensionless function depending on the distance x to the left outer clamp, the co-ordinate A of the left inner clamp and the effective length L between the two outer clamps:

$$R(x) = \frac{12L^3}{A \cdot (3L \cdot x - 3x^2 - A^2)} \quad (6)$$

3.5.17**equivalent mass M_{eq}**

weighed mass in kilograms (kg) of the moving parts of beam (M_{beam}), sensor (M_{sensor}) and clamps (M_{clamp}) whose values depend on the place where the deflection $Z(x_s)$ is measured:

$$M_{\text{eq}} = \frac{R(x_s)}{\pi^4} \cdot M_{\text{beam}} + \frac{R(x_s)}{R(A)} \cdot M_{\text{clamp}} + M_{\text{sensor}} \quad (7)$$

3.5.18**equivalent coefficient for damping**

weighed coefficient for the damping in the system in kilograms per second (kg/s), the value of which depends on the place where the deflection $Z(x_s)$ is measured:

$$T_{\text{eq}} = \frac{R(x_s)}{R(A)} \cdot T \quad (8)$$

3.5.19**deflection $Z(x_s)$**

amplitude of the deflection of the beam during one cycle, measured on or between the two inner clamps at a distance x_s from the left outer clamp, in millimetres (mm)

Note 1 to entry: With a perfect sinusoidal signal is the peak-peak value twice the amplitude of the signal.

3.5.20**force F_0**

amplitude of the total force at the two inner clamps, in Newtons (N)

3.5.21**frequency f_0 [Hz] and circular frequency ω_0 [rad/s]**

frequency of the applied sinusoidal load:

$$\omega_0 = 2\pi \cdot f_0 \quad (9)$$

3.5.22**inertia function $I(x_s)$**

dimensionless function depending on the distance x_s used to account for mass inertia effects:

$$I(x_s) = M_{\text{eq}} \cdot \frac{Z(x_s)}{F_0} \cdot \omega_0^2 \cdot 10^{-3} \quad (10)$$

3.5.23**damping function $J(x_s)$**

dimensionless function depending on the distance x_s used to account for damping (non-viscous) effects in the system (system losses):

$$J(x_s) = T_{\text{eq}} \cdot \frac{Z(x_s)}{F_0} \cdot \omega_0 \cdot 10^{-3} \quad (11)$$

3.5.24**measured phase lag $\varphi^*(x_s)$**

measured phase lag in degrees (°) during one cycle between the applied sinusoidal load and the measured deflection $Z(x_s)$

3.5.25**system phase lag $\theta(x_s)$**

calculated phase lag in degrees (°) during one cycle representing the system losses:

$$\tan\left(\theta \cdot \frac{\pi}{180}\right) = \frac{T_{\text{eq}} \cdot \omega_0}{M_{\text{eq}} \cdot \omega_0^2} \quad (12)$$

3.5.26

phase lag ϕ

calculated phase lag in degrees (°) during one cycle between the occurring stress and strain in the specimen at the applied frequency:

$$\tan\left(\phi \cdot \frac{\pi}{180}\right) = \frac{\sin\left(\phi^*(x_s) \cdot \frac{\pi}{180}\right) - J(x_s)}{\cos\left(\phi^*(x_s) \cdot \frac{\pi}{180}\right) + I(x_s)} \quad (13)$$

3.5.27

the complex (stiffness) modulus or dynamic stiffness modulus S_{mix}

calculated modulus of the complex modulus for the specimen during one cycle, in megapascals (MPa):

$$S_{\text{mix}} = \frac{12F_0 \cdot L^3}{Z(x_s) \cdot R(x_s) \cdot B \cdot H^3} \cdot \sqrt{1 + 2[\cos(\phi^*(x_s)) \cdot I(x_s) - \sin(\phi^*(x_s)) \cdot J(x_s)] + [I^2(x_s) + J^2(x_s)]} \quad (14)$$

3.5.28

constant K relative to (maximum) strain

constant that enables the calculation of the maximum bending strain amplitude at the place where the deflection is measured, in inverse millimetres (mm⁻¹):

$$K(x_s) = \frac{H \cdot A}{4L^3} \cdot R(x_s) \quad (15)$$

3.5.29

strain amplitude $\varepsilon = \varepsilon(x_s)$

maximum strain amplitude during one cycle which occurs between the two inner clamps, in micrometres per metre (µm/m):

$$\varepsilon = K(x_s) \cdot Z(x_s) \cdot 10^6 \quad (16)$$

3.5.30

stress amplitude σ

maximum stress amplitude during one cycle which occurs between the two inner clamps, in megapascals (MPa):

$$\sigma = S_{\text{mix}} \cdot \varepsilon \cdot 10^{-6} \quad (17)$$

3.5.31

dissipated energy per cycle

dissipated viscous energy in the beam per unit volume ΔW_{dis} and per cycle, in kilojoules per cubic metre (kJ/m³) that, for sinusoidal strain and stress signals, is:

$$\Delta W_{\text{dis}} = 10^{-3} \cdot \pi \cdot \varepsilon \cdot \sigma \cdot \sin\left(\phi(x_s) \cdot \frac{\pi}{180}\right) \quad (18)$$

3.5.32**cumulated dissipated energy**

summation of the dissipated energies per cycle up to cycle n :

$$W_{\text{dis},n(m)} = \sum_{i=1}^n \Delta W_{\text{dis},i} \quad (19)$$

Note 1 to entry: If the measurements are taken at intervals $n(i)$, it is recommended to use the trapezium rule:

$$W_{\text{dis},n(m)} = n(1) \cdot \Delta W_{\text{dis},n(1)} + \sum_{i=1}^m \left[0,5 \cdot (n(i+1) - n(i)) \cdot (\Delta W_{\text{dis},n(i+1)} + \Delta W_{\text{dis},n(i)}) \right] \quad (20)$$

3.5.33**amplitude**

half the difference between the maximum and the minimum of a (sinusoidal) signal measured during one cycle

3.5.34**measuring error**

difference between the true value of a physical quantity and the value indicated by the measuring instrument, expressed as a proportion of the true value, in percent (%)

3.5.35**accuracy class**

permissible measuring error in the output signal of a transducer or sensor

3.5.36 Symbols

The symbols are as follows:

A_1	is the estimate of the slope, p ;
A_0	is the estimation of the level of loading, Q ;
B	is the width of the prismatic specimen, in millimetres (mm);
D	is the maximum nominal grain size of the mixture being tested, in millimetres (mm);
H	is the height of the prismatic specimen, in millimetres (mm);
L	is the effective length of the prismatic specimen, in millimetres (mm);
L_{tot}	is the total length of the prismatic specimen, in millimetres (mm);
M_{beam}	is the mass of the whole beam without the masses of the mounted clamps, in kilograms (kg);
M_{clamps}	is the masses of the two inner clamps, including the mass of the adhesive, and the mass of the load frame between the load cell and the jack, in kilograms (kg);
M_{sensor}	is the mass of the moving parts of the sensor, in kilograms (kg);
M_{eq}	is the equivalent mass, in kilograms (kg);
$N_{i,j,k}$	is the length of life for specimen number i , the chosen failure criteria j and the set of test conditions k in cycles;
$N_{f/50}$	is the number of load cycles at conventional failure when the modulus of the (complex) stiffness modulus has decreased to half its initial value;

Q	is the level of the loading mode test condition corresponding to 10^6 cycles for the fatigue life according to the chosen failure criteria, k ;
ΔQ	is the confidence interval relative to Q ;
S_{mix}	is the initial value of the calculated modulus, in megapascal (MPa);
$S_{x/y}$	is the estimation of the standard deviation of the residual dispersion of the natural logarithms of fatigue lives, $\sigma_{x/y}$;
T	is the coefficient for the system losses in the interpretation formulae for Young's modulus;
p	is the slope of the fatigue line;
r	is the correlation coefficient of the regression;
x	is the distance from end of sample, in millimetres (mm);
x_s	is the distance from the end of the specimen to where the sensor is placed, in millimetres (mm);
ε_i	is the initial strain amplitude measured at the 100 th load cycle, in 10^{-6} ($\mu\text{m}/\text{m}$);
f	is the test frequency in Hertz (Hz);
ω	the angular speed, in radians per seconds (rad/s);
θ	is the test temperature, in degrees Celsius ($^{\circ}\text{C}$).

3.6 Symbols for indirect tensile test on cylindrical shaped specimens (IT-CY)

The symbols are as follows:

F	is the measured amplitude of the force, in Newtons (N);
t	is the specimen thickness, in millimetres (mm);
Ω	is the specimen diameter, in millimetres (mm);
ΔH	is the total horizontal deformation between pulse 60 and 100, in millimetres (mm);
$\Delta H_{R,n}$	is the resilient horizontal deformation amplitude at pulse n , in millimetres (mm);
ν	is Poisson's ratio;
σ_0	is the tensile stress amplitude at the centre of the specimen, in megapascals (MPa);
ε_0	is the initial strain at the centre of the specimen, in micrometres per metre ($\mu\text{m}/\text{m}$);
$\varepsilon_{R,n}$	is the resilient strain amplitude at load cycle n during cyclic loading, in micrometres per metre ($\mu\text{m}/\text{m}$);
$S_{\text{mix},n}$	is the stiffness modulus at pulse n , in megapascals (MPa);
W_n	is the energy ratio;
n	is number of load cycles
$N_{f,w}$	is the number of load cycles using the resilient approach;
k_w, n_w	are material constants using the resilient approach.

3.7 Symbols for Cyclic Indirect tensile Test on cylindrical shaped specimen (CIT-CY)

F_m	is the medium vertical force, in kilonewtons (kN);
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F_l	is the lower vertical force, in kilonewtons (kN)
F_a	is the vertical force amplitude, in kilonewtons (kN);
f	is the load frequency, in hertz (Hz);
t	is the test time, in seconds (s);
σ	is the maximum horizontal tensile stress in the middle of the specimen, in megapascals (MPa);
Ω	is the specimen diameter, in millimetres (mm);
h	is the specimen thickness, in millimetres (mm);
u_m	is the mean horizontal displacement, in millimetres (mm);
u_a	is the horizontal displacement amplitude, in millimetres (mm);
u_d	is the horizontal displacement rate, representing the viscoplastic deflections, in millimetres per second (mm/s).
σ_a	is the amplitude of the horizontal tensile stress in the middle of the specimen, in megapascals (MPa);
ε_a	is maximum horizontal strain amplitude in the middle of the specimen, in meters/meters (m/m);
$\Delta\varepsilon$	is the maximum strain difference in the middle of the specimen, in millimetres/meter (mm/m);
ν	is the Poisson ratio, without dimension (-);
φ	is the phase angle between vertical force and horizontal displacement function, in degrees.
$S_{\text{mix},n}$	stiffness modulus as calculated for the load interval n , in megapascal (MPa).
n	load cycle number representing the recorded interval, (-)
$ER(n)$	energy ratio for load interval represented by load cycle number n , (-)
$N_{f,w}$	is the number of load cycles until fracture life according to energy criterion, (-);
$k_\varepsilon, n_\varepsilon$	are material constants of the fatigue function.

4 Sample preparation

4.1 Storage 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 20 °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 after cutting. The time of manufacture for these samples is the time when they are cut.

NOTE 1 The storage time influences the mechanical properties of the specimen.

NOTE 2 For test purposes other than for CE marking, different storage times can be applied.

4.2 Drying of the specimens

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 % and at a temperature not more than 20 °C. A test specimen shall

be considered to be dry when two weighings performed at a minimum of 4 h apart differ by less than 0,1 %.

NOTE If a specimen has been stored under cover in the dry for at least 14 days, it can be assumed to be dry.

4.3 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. For CE-marking purposes, the bulk density of each specimen shall not differ by more than 1 % from the average density of the batch. If it does differ outside this tolerance, the specimen shall be rejected. For other purposes, larger differences are allowed. However, this has an effect on the accuracy of the test results.

5 Failure

The conventional failure criterion for the type of test undertaken, as defined in 3.1.2, shall be used to determine the failure life of a material unless otherwise prescribed. In such cases, the criterion used shall be included in the test report.

6 Selection test conditions

For fatigue tests according to Annexes A to D, the test loads, deformations and frequencies shall be selected so that the ε_6 -value is calculated by interpolation and not by extrapolation. At least 20 % of the measurements shall be at either side of the calculated result.

For tests according to Annexes E and F, the procedure for finding suitable test conditions is described in the individual annexes.

7 Summary of the procedures

7.1 Two-point bending test on trapezoidal shaped specimens (2PB-TR)

This method characterizes the behaviour of bituminous mixtures under fatigue loading with controlled displacement by two-point bending using trapezoidal shaped specimens. The method can be used for bituminous mixtures with a maximum aggregate size of up to 20 mm on specimens prepared in a laboratory or obtained from road layers with a thickness of at least 40 mm. For mixtures with an upper size D between 20 mm and 40 mm, the test can be performed using the same principle but with adapted specimen sizes. For a given frequency of sinusoidal displacement, the method shall be carried out on several elements tested in a ventilated atmosphere at a controlled temperature.

7.2 Two-point bending test on prismatic shaped specimens (2PB-PR)

This method characterizes the behaviour of bituminous mixtures under fatigue loading by 2-point-bending using square-prismatic shaped specimens. The method can be used for bituminous mixtures with a maximum aggregate size of up to 20 mm and on specimens prepared in a laboratory or obtained from road layers with a thickness of at least 40 mm.

7.3 Three-point bending test on prismatic shaped specimens (3PB-PR)

This method characterizes the behaviour of bituminous mixes under fatigue loading, with controlled displacement by three-point bending using prismatic beam shaped specimens. The behaviour is characterized through the determination of the fatigue law in terms of strain (relation between strain and number of load cycles at failure) and the associated energy law. The method can be used for bituminous mixture specimens with a maximum aggregate size of 22 mm or for samples from road layers with a thickness of at least 50 mm. For a given frequency of sinusoidal displacement, the method shall be carried out on several elements tested at a controlled temperature.

7.4 Four-point bending test on prismatic shaped specimens (4PB-PR)

This method characterizes the behaviour of bituminous mixtures under fatigue loading in four-point bending test equipment in which the inner and outer clamps are symmetrically placed and slender rectangular shaped specimens (prismatic beams) are used. The prismatic beams shall be subjected to four-point periodic bending with free rotation and translation at all load and reaction points. The bending shall be realized by loading the two inner load points (inner clamps) in the vertical direction, perpendicular to the longitudinal axis of the beam. The vertical position of the end-bearings (outer clamps) shall be fixed. This load configuration shall create a constant moment, and hence a constant strain, between the two inner clamps. The applied load shall be sinusoidal. During the test, the load needed for the bending of the specimen, the deflection and the phase lag between these two signals shall be measured as a function of time. The fatigue characteristics of the material tested shall be determined from these measurements.

7.5 Indirect tensile test on cylindrical shaped specimens (IT-CY)

This method characterizes the behaviour of bituminous mixtures under repeated load fatigue testing with a constant load mode using an indirect tensile load. A cylindrical specimen manufactured in a laboratory or cored from a road layer can be used in this test. A cylinder-shaped test specimen shall be exposed to repeated compressive loads with a (ha)versine load signal with rest periods through the vertical diametrical plane. This loading develops a relatively uniform tensile stress perpendicular to the direction of the applied load and along the vertical diametrical plane, which causes the specimen to fail by splitting along the central part of the vertical diameter. The resulting horizontal deformation of the specimen shall be measured and an assumed Poisson's ratio used to calculate the tensile strain at the centre of the specimen.

An alternative failure criterion is that the fracture life can be determined as the total number of load cycles before fracture of the specimen occurs. Further alternative failure criteria can be based on energy ratio. The use of this criterion should be stated in the test report.

7.6 Cyclic Indirect tensile test on cylindrical shaped specimens (CIT-CY)

This method characterizes the behaviour of bituminous mixtures under cyclic load fatigue testing in a force-controlled loading mode using an indirect tensile load. A cylindrical specimen manufactured in a laboratory or cored from a road layer can be used in this test. A cylinder-shaped test specimen shall be exposed to vertical cyclic compressive load impulses without rest periods through the vertical diametrical plane. This loading develops a sinusoidal tensile stress perpendicular to the direction of the applied load and along the vertical diametrical plane, which causes the specimen to fail by splitting along the central part of the vertical diameter. The resulting horizontal deformation of the specimen shall be measured and an assumed Poisson's ratio used to calculate the tensile strain at the centre of the specimen. As alternative failure criterion, the number of load cycles until macro crack initiation shall be applied.

8 Checking of the testing equipment

The complete testing equipment shall be checked against at least one reference non-asphalt specimen with a known stiffness modulus (modulus and phase lag) to ensure that the results are within the precision of the test. To check the test equipment for Annex 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 Annexes E and 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 2 frequencies, 1 temperature 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 are observed, all electronic components and mechanical equipment shall be checked for proper working and no procedure for the back-calculation software is permitted; or
- the phase angle are observed, a correction procedure for the back-calculation software is permitted.

The geometry of the reference specimen should be selected so that it will lead to a weight comparable with the weight 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.

9 Test report

The test report shall include:

- a) information on the chosen test method, the used testing equipment and results of the last check on the testing equipment;
- b) identification of the mixture;
- c) date that the test was undertaken and the age of the specimen at the time of testing (in days);
- d) average air void content in the specimen, according to EN 12697-8;
- e) method of manufacture or sampling, if applicable;
- f) conditions of the fatigue testing (temperature, frequency, etc.);
- g) chosen failure criterion (if not the conventional failure criterion);
- h) number of cycles up to the point at which the fatigue criterion is reached for each specimen, stating the strain or stress level, mean value and standard deviation obtained for each strain or stress level;
- i) representation of the fatigue line;
- j) title of the relevant annex of this European Standard;
- k) other results required by the relevant annex;
- l) details not provided for in this European Standard;
- m) any incidents which may have an effect on the results.