BS ISO 10844:2014

BSI Standards Publication

Acoustics — Specification of test tracks for measuring noise emitted by road vehicles and their tyres

National foreword

This British Standard is the UK implementation of ISO 10844:2014. It supersedes BS ISO 10844:2011 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EH/1/2, Transport noise.

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

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ISBN 978 0 580 83641 1

ICS 17.140.30; 43.020

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 May 2014.

Amendments issued since publication

Date	Text affected

INTERNATIONAL STANDARD

ISO 10844

Third edition
2014-05-15

Acoustics — Specification of test tracks for measuring noise emitted by road vehicles and their tyres

Acoustique — Spécification des surfaces d'essai pour le mesurage du bruit émis par les véhicules routiers et leurs pneumatiques

Reference number
ISO 10844:2014(E)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*, in collaboration with ISO/TC 22, *Road vehicles*.

This third edition cancels and replaces the second edition (ISO 10844:2011), of which it constitutes a minor revision.

Introduction

In general, the road surface parameters affecting the noise emission of vehicles are the texture and sound absorption characteristics. In addition, the mechanical impedance and the skid resistance properties of the surface layer can also influence measured noise levels.

In order to minimize the variation in rolling sound emission and vehicle sound emission measurements made at different testing locations, it is therefore necessary to specify the relevant surface properties and recommend carefully the properties of the materials, design, and construction of the test surface.

The principal objective of this International Standard is to provide a revised specification of the surface which improves the reproducibility of measurement.

This International Standard is designed in a way that test tracks conforming to this International Standard are compatible with the first edition, but in addition the variability of properties is reduced.

It is important that the test provides a high degree of reproducibility between different test sites and that the surface design should not only minimize the inter-site variation of tyre or road noise, but should also ensure that the propagation of noise is unaffected by the surface used. This latter consideration precludes the use of road surfaces which have open textures and which have the property of absorbing noise from the power unit and other related sources.

In relation to the first edition, this International Standard includes, including more restrictive specifications of the surface and recommendations for the test track construction process and maintenance. The basic properties of the surface remain unchanged.

The users of this International Standard are encouraged to measure END_T and to communicate the data to the ISO/TC 43/SC 1 for analysis before the next periodical review.

Furthermore, this International Standard recommends a non-destructive test method for periodical checking of the surface characteristics.

This International Standard is quoted in several International Standards (e.g. the ISO 362 series, ISO 13325).

Acoustics — Specification of test tracks for measuring noise emitted by road vehicles and their tyres

1 Scope

This International Standard specifies the essential characteristics of a test surface intended to be used for measuring vehicle and tyre or road noise emissions.

The surface design given in this International Standard

— produces consistent levels of tyre or road sound emission under a wide range of operating conditions including those appropriate to vehicle sound testing,

— minimizes inter-site variation,

— provides minor absorption of the vehicle sound sources, and

— is consistent with road-building practice.

NOTE For the purposes of this International Standard, the terms noise and sound are used interchangeably.

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.

ISO 362-1, *Measurement of noise emitted by accelerating road vehicles — Engineering method — Part 1: M and N categories*

ISO 13472-2, *Acoustics — Measurement of sound absorption properties of road surfaces in situ — Part 2: Spot method for reflective surfaces*

ISO 13473-1, *Characterization of pavement texture by use of surface profiles — Part 1: Determination of mean profile depth*

ISO 13473-3, *Characterization of pavement texture by use of surface profiles — Part 3: Specification and classification of profilometers*

ISO/TS 13473-4, *Characterization of pavement texture by use of surface profiles — Part 4: Spectral analysis of surface profiles*

EN 13036-7, *Road and airfield surface characteristics — Test methods — Part 7: Irregularity measurement of pavement courses: the straightedge test*

3 Terms and definitions

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

3.1
sound absorption coefficient
α
fraction of the sound power incident on the test object that is absorbed within the test object for a plane wave at normal incidence

Note 1 to entry: Expressed as a percentage, it is called sound absorption.

3.2
surface profile

3.2.1
texture profile
two-dimensional sample of pavement texture generated if a sensor, such as the tip of a needle or a laser spot, continuously touches or shines on the pavement surface while it is moved along a line on the surface

Note 1 to entry: It is described by two coordinates: one along the surface plane, called "distance" (the abscissa), and the other in a direction normal to the surface plane, called "amplitude" (the ordinate).

3.2.2
irregularity
maximum distance of a surface from the measurement edge of the straightedge between two contact points of the straightedge when placed perpendicular to the surface

Note 1 to entry: Pavement characteristics at longer wavelengths than 0,5 m are considered to be above that of texture and are referred to here as irregularity.

Note 2 to entry: See Figure C.1.

3.2.2.1
longitudinal irregularity
irregularity in the longitudinal axis of the track

3.2.2.2
transversal irregularity
irregularity in the direction perpendicular to the axis of the track

3.2.3
straightedge
device used for measuring the deviation from a plane

3.2.4
megatexture
deviation of a pavement surface from a true planar surface with the characteristic dimensions along the surface of 50 mm to 500 mm, corresponding to texture wavelengths with one-third-octave bands including the range of 63 mm to 500 mm of centre wavelengths

Note 1 to entry: Peak-to-peak amplitudes normally vary in the range of 0,1 mm to 50 mm. This type of texture is the texture which has wavelengths in the same order of size as a tyre or road interface and is often created by potholes or "waviness". It is usually an unwanted characteristic resulting from defects in the surface. Surface roughness with longer wavelengths than megatexture is referred to as irregularity.

3.2.5
macrotexture
deviation of a pavement surface from a true planar surface with the characteristic dimensions along the surface of 0,5 mm to 50 mm, corresponding to texture wavelengths with one-third-octave bands including the range of 0,63 mm to 50 mm of centre wavelengths

Note 1 to entry: Peak-to-peak amplitudes can normally vary in the range of 0,1 mm to 20 mm. This type of texture is the texture which has wavelengths of the same order of size as tyre tread elements in the tyre or road interface. Surfaces are normally designed with a sufficient macrotexture to obtain suitable water drainage in the tyre or road interface. The macrotexture is obtained by suitable proportioning of the aggregate and mortar of the mix or by surface finishing techniques.

3.2.6
microtexture
deviation of a pavement surface from a true planar surface with the characteristic dimension along the surface below 0,5 mm, corresponding to texture wavelengths with one-third-octave bands with centre wavelengths less than or equal to 0,50 mm

3.3
gradient and cross fall
3.3.1
gradient
ratio of the height difference and the length measured along the longitudinal axis of the drive lane, expressed as a percentage

3.3.2
cross fall
height difference expressed as a percentage of the length measured along the transversal axis of the drive lane

3.4
propagation area
part of the test track on each side of the drive lane

Note 1 to entry: See Figure 1.

3.5
drive lane
part of the test track where the vehicle runs

3.6
stiffness
ratio of a normal force and resulting displacement

3.7
dense asphalt concrete
asphalt in which the aggregate particles are essentially continuously graded to form an interlocking structure

Note 1 to entry: [SOURCE: EN 13108–1]

3.8
mean profile depth
average value of the height difference between the profile and a horizontal line through the highest peak (the peak level) over a 100-mm long baseline

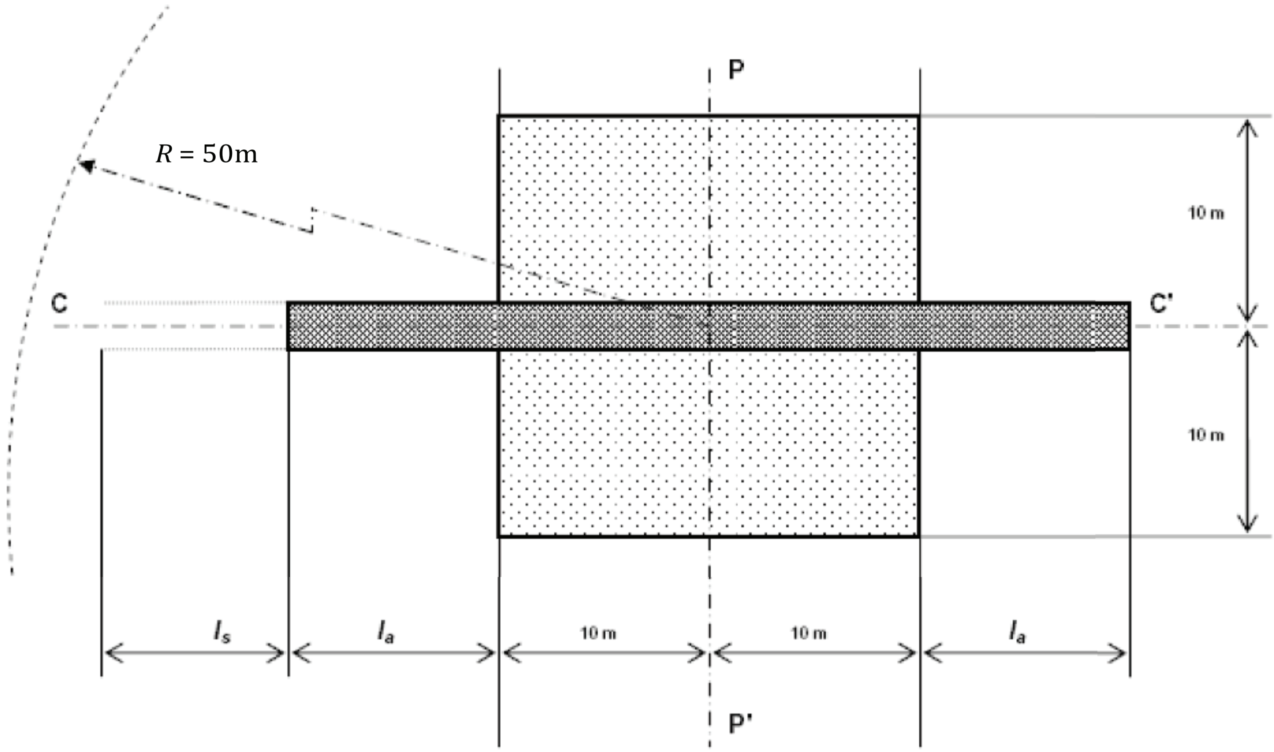
Note 1 to entry: [SOURCE: ISO 13473-1:1997, 3.5.4]

4 Requirements of the test track

4.1 Size and geometry

4.1.1 Size

The test track shall consist of two areas, a drive lane and a propagation area. The dimensions shall comply with Figure 1 and Table 1.



Key

l_s	construction run-up section
l_a	drive lane extension beyond propagation area
CC’	drive lane centre line
PP’	microphone line
light-grey area	propagation area
dark-grey area with dotted line	drive lane

Figure 1 — Size of the test track

A drive lane with a length of l_a and width of at least 3,0 m that is centred around line PP’. The value of l_a is defined in Table 1.

Table 1 — Minimum drive lane extension length

Length	For testing tyres, passenger cars, motorcycles, light duty vehicles, and trucks	For long vehicles with rear engine, having a distance of more than10 m between the reference point and the front axle (reference point as defined in ISO 362-1)
l_a	10 m	20 m[a]
[a] 20 m is necessary only for the exit side (BB’), as defined in ISO 362-1, of the test track according to the purpose of this requirement.		

For the stabilization of the laying process, a minimum length of l_s = 60 m is recommended on at least one side.

The propagation area shall extend at least 10 m from the centre of the drive lane and at least 10 m at both sides of the line PP’.

Within a radius of 50 m around the centre of the track, the space shall be free of large reflecting objects such as fences, rocks, bridges, or buildings.

NOTE Buildings outside the 50 m radius can have significant influence if their reflection focuses on the test track.

4.1.2 Geometry

Drive lane

The drive lane shall fulfil the following requirements:

— for acceptance of the test track only, transverse irregularities equal to or less than 0,003 m and longitudinal irregularities equal to or less than 0,002 m, measured with the straightedge according to EN 13036-7;

— for periodical checking of the test track only, transverse irregularities equal to or less than 0,005 m and longitudinal irregularities equal to or less than 0,005 m, measured with the straightedge according to EN 13036-7;

— for acceptance only, deviation from the horizontal plane in transverse direction of 1,0 % maximum (see Figure 2) and in a longitudinal direction of 0,5 % maximum.

It is recommended that the irregularities requirements be fulfilled starting from the microphone line to cover the drive lane plus 10 m from the end of the section l_a on both sides.

Propagation area

— The propagation area shall have irregularities equal to or less than 0,02 m, measured with the straightedge according to EN 13036-7.

— The propagation area can have one or both sides lower than the drive lane. Cross fall in transverse direction, measured using an appropriate instrument, shall be equal or less than 2,0 % (see Figure 2).

The slope should be designed in such a way that the draining of water is possible.

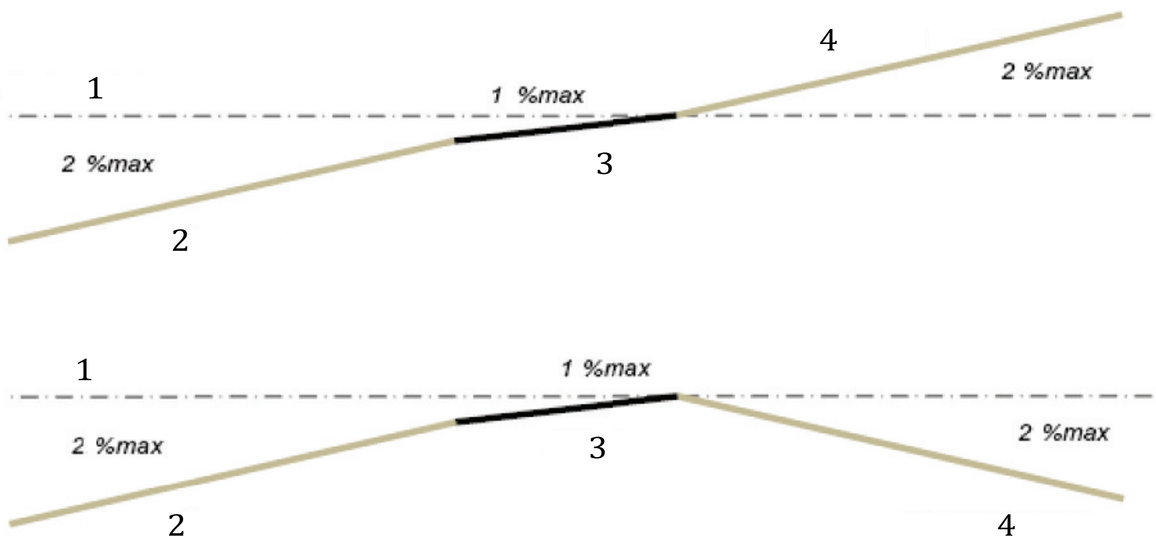
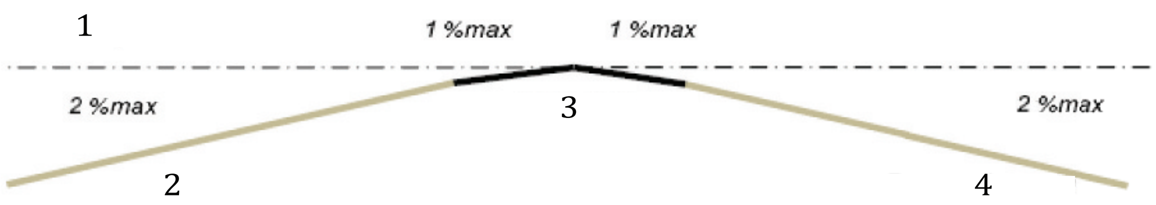


Figure 2 — (*continued*)

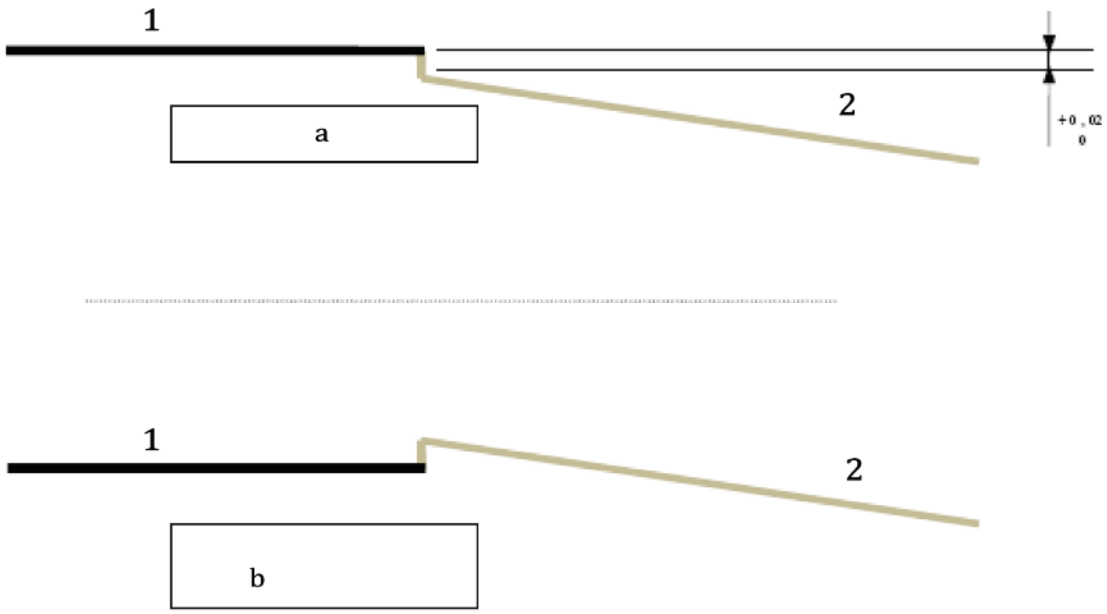


Key

1 horizontal plane
2 propagation area
3 drive lane
4 propagation area
1 % max allowed drive lane cross fall
2 % max allowed propagation area cross fall

Figure 2 — Propagation area slope in transverse direction

— Steps or discontinuities between the propagation area and the drive lane shall be $0^{+0,02}_{0}$ m (see Figure 3).



Key

1 drive lane
2 propagation area
a Allowed step ≤ 0,02 m.
b Not allowed step even if ≤ 0,02 m.

Figure 3 — Propagation area — Steps or discontinuities

4.2 Surface properties of the propagation area

The average of the values of the sound absorption in each one-third-octave band between 315 Hz and 1 600 Hz central frequency shall be less than or equal to 10 %. The sound absorption coefficient shall be measured according to 5.3.

Location and number of measurement points are given in 4.4.

4.3 Surface properties of the drive lane

The surface of the drive lane shall:

a) be dense asphalt concrete;

b) exhibit a sound absorption equal to or less than 8 % in any one-third-octave band between 315 Hz and 1 600 Hz when measured according to 5.3;

c) have a maximum chipping size of 8 mm (tolerance allowed between 6,3 mm to 10 mm);

d) have a thickness of the wearing course greater than or equal to 30 mm;

e) have a mean profile depth (MPD), measured according to ISO 13473-1, of 0,5 mm ± 0,2 mm;

f) have a target sieving curve for the aggregate, as described in Figure 4;

g) have no elastic material (rubber, polyurethane, etc.) applied on the top layer or sublayers except for the modification of bitumen that is less than 1 % of the mass of the total mix.

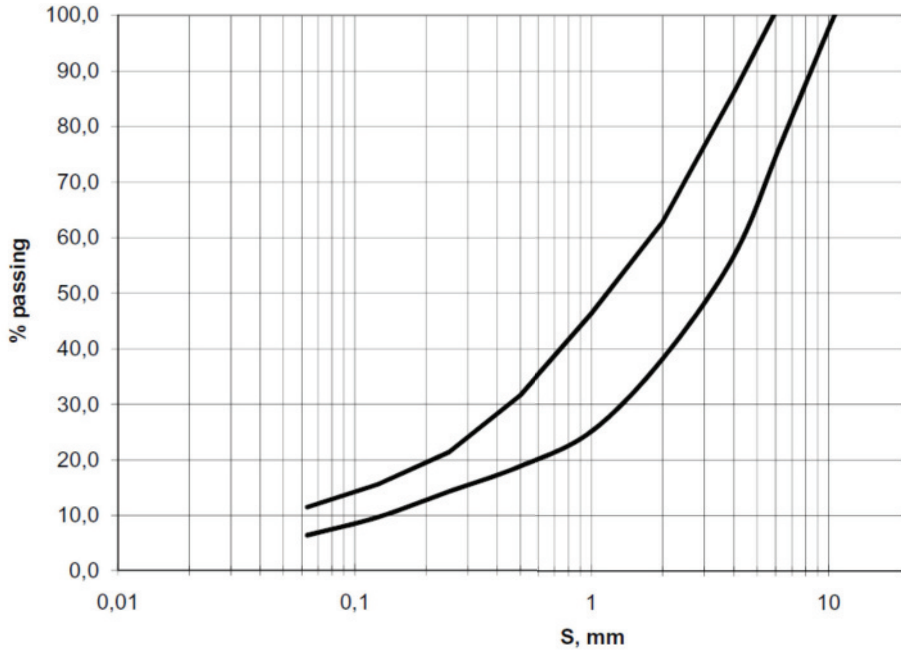


Figure 4 — Sieving curve area

NOTE Until more results for validation are available, END_T is not part of the normative part of this International Standard. Polymer-modified Bitumen (PmB) allows higher temperature operation and reduced surface wear.

4.4 Conformity tests

a) The surface properties for each requirement shall be determined at the following occasions:

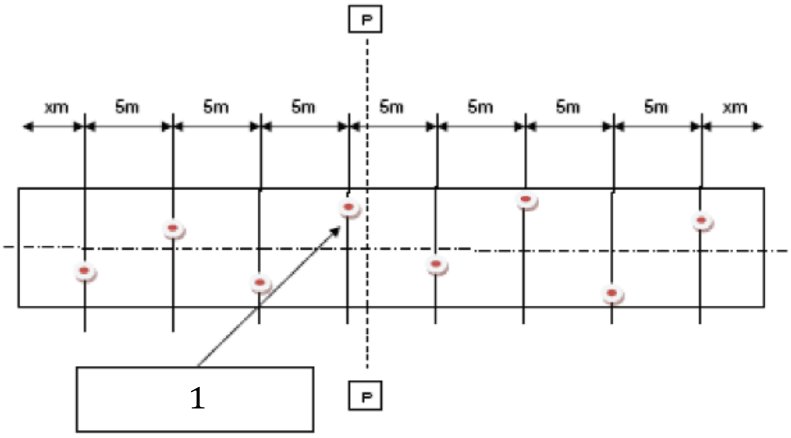
1) before the acceptance of the track (make reference to Table 2);

2) during the periodical checking of the track (make reference to Table 2).

b) All measurements shall be made along the total length of the drive lane in each wheel track according to the following scheme (see an example in Figure 5).

c) For sound absorption, texture, and geometrical compliance, the first point shall be chosen randomly on each side in the vicinity of the line PP' and the subsequent measurements shall be performed at 5 m intervals not on the same axis of the centre line to cover the whole track.

d) After the construction, take a total of four cores, preferably at 10 m intervals outside the wheel tracks on the driving lane run-up section, and measure the sieving curve from these samples.



Key

1 first point randomly chosen

Figure 5 — Measurement positions on test track, example for *l* = 40 m

For checking the surface properties of the propagation area, take at least two measurements randomly chosen on each side.

In addition, sound absorption of the propagation area shall be measured at both sides of the drive lane, between the microphone location and the centre of drive lane in the vicinity of the line PP'.

Table 2 — Periodicity for checking the requirements during acceptance and periodical checking

Requirements for the track		**For acceptance**		**For periodical checking**	
		Drive lane	**Propagation area**	**Drive lane**	**Propagation area**
Slope	Gradient	× (0,5 %)	N.A.	N.A.	N.A.
	Cross fall	× (1 %)	× (2 %)	N.A.	N.A.
Longitudinal irregularity		× (≤2 mm)	× (≤20 mm) randomly	× (≤5 mm) 2 years[a]	N.A.
Transverse irregularity		× (≤3 mm)		× (≤5 mm) 2 years[a]	N.A.

Table 2 *(continued)*

Requirements for the track	For acceptance		For periodical checking	
	Drive lane	Propagation area	Drive lane	Propagation area
Texture	× MPD 0,5 mm ± 0,2 mm	N.A.	× MPD 0,5 mm ± 0,2 mm 2 years[a]	N.A.
Absorption	× (8 % maximum)	× (10 % maximum)	× (8 % maximum) 4 years[a]	N.A.
Grading curve	×	N.A.	N.A.	N.A.
× to be checked N.A. not applicable [a] Periodicity.				

4.5 Homogeneity of surface properties

In order to ensure that the properties of the drive lane and the properties of the propagation area are homogeneous, the average of all positions and 80 % of the samples shall meet the requirements with respect to:

— acoustic absorption;

— surface texture;

— geometrical compliance.

4.6 Stability with time and maintenance

The test track is a test instrument and shall be protected from damage and be taken care of. The test track should be used only for noise measurements.

Loose debris or dust which could significantly reduce the texture depth shall be removed from the surface.

Sealing of cracks is acceptable as long as acoustical performances (according to 4.2 and 4.3) of the test track are not affected.

See Annex B for recommendations.

4.7 Break-in of the test track

The texture and absorption characteristics shall be checked not earlier than 4 weeks after the construction or 1 000 passes after the construction.

If the surface is exclusively used for testing heavy vehicles (M2 above 3,5 t, M3, N2, and N3), this break-in period is not necessary.

5 Measurement methods and data processing

5.1 Irregularity measurement methods

The irregularity of the drive lane shall be determined according to EN 13036-7 using a straightedge consisting of a beam of 3,0 m in length and a wedge with 1-mm steps on the oblique side.

5.2 Texture measurements methods

5.2.1 Profile measurement

The profile is measured according to ISO 13473-1 for MPD and ISO/TS 13473-4 for END_T. The measurement instrumentation shall meet the requirements of class DE defined in ISO 13473-3.

Additional details according to ISO 13473-1, MPD shall be measured in the wheel tracks of the driving lane and the following two options can be used.

— Continuous measurement: MPD is measured continuously over the entire driving lane. The measured profile shall be divided into eight sections, each 5 m long, for which MPD shall be evaluated separately as average over the section. A total of two measurement runs shall be made in each wheel track.

— Segmented measurement: MPD is measured at a minimum of four locations in each of the two wheel tracks (eight if the test track is used for two-wheeled vehicles). These locations shall be evenly distributed over the driving lane length. At each such location, a minimum length of 2,0 m of profiles shall be measured, each one at least 0,8 m long and positioned in a way which give statistically independent MPD values.

The MPD requirement in 4.3 shall be met at each of the eight locations or sections.

When calculating END_T, the wavelength spectrum from 100 mm to 5 mm one-third-octave band of the profile shall be obtained, according to the specifications of ISO/TS 13473-4. A tapered cosine window is preferred (make reference to ISO/TS 13473-4).

5.2.2 Texture profile data pre-processing

Removal of spike data is necessary. Spike data shall be removed prior to further processing of the data.

NOTE ISO/TS 13473-4 gives examples of the spike removal processes. Spikes are data artefacts that are not part of the texture under measurement.

5.3 Acoustic absorption measurement method

The acoustic absorption shall be measured in the frequency range from 280 Hz to 1 800 Hz with an *in situ* device meeting the specifications of ISO 13472-2. The results shall be expressed in the one-third-octave-band coefficients, according to the procedure described in ISO 13472-2.

6 Conformity report

The test report for each pavement test surface shall contain all the information required for the construction approval or periodical inspection, whichever is applicable.

Example:

a) General information

- — owner
- — contractor's name
- — date of the construction of the test track
- — location of the test track
- — certifying authority (if applicable)
- — certification status
- — main use of the test track (e.g. truck tyre coast by, testing, passenger car drive by)

— notable features (e.g. under track, heating)

b) Size and geometry

1) size

i) dimensions of the driving lane

— total length (m)

— width (m)

— l_a (m)

— l_s (m)

ii) dimensions of the propagation area

— length (m)

— width (m)

iii) free space

— radius (m)

— notable feature

2) geometry

i) drive lane

— transverse and longitudinal irregularities (m)

— deviation from the horizontal plane in transverse direction (%)

ii) propagation area

— irregularities (m)

— slope in transverse direction (%)

— steps or discontinuities (m)

c) Surface properties

1) material

i) drive lane

— sound absorption

— maximum chipping size

— thickness of wearing course

— texture

— sieving curve

— elastic material

ii) propagation area

— sound absorption

   2) homogeneity statement of surface properties

d) Proving the requirements

   — scheme of the measuring point

   — measuring material description

   — description of the measuring methods

e) Homogeneity of surface properties

7 Practices from different countries

Annex C gives information on current practices from different countries.

8 Summary of improvements on the 1994 edition

Annex D lists the improvements made compared to ISO 10844:1994.

Annex A
(informative)

Calculation of the Expected pass-by noise level difference from texture level variation of road surface (END_T)

A.1 General information — Principle

The END_T is a single-number rating that provides an estimation of the variation of the dB(A) global noise level due to texture changes with respect to a reference surface. The reference surface is characterized by a third-octave texture profile spectrum, $L_{\text{tx, ref, }\lambda}$, as a function of the texture wavelength, λ, and a third-octave noise spectrum, $L_{\text{m}i}$, as a function of the frequency, f.

The END_T is evaluated from the third-octave texture profile spectrum, $L_{\text{tx, }\lambda}$, of the track to be tested. It is composed of two terms intended to handle two tyre or road noise generation mechanisms: the texture-induced vibration and radiation of the tyre belt and the air-pumping phenomenon.

The first term, 10 lg (A/B), is evaluated from the texture level differences at wavelengths $\lambda = v/f$, where v is the rolling speed considered. For greater convenience, the texture levels at wavelengths v/f are evaluated by linear interpolation from the texture levels at standard λ values (see A.3). The second term, C, is evaluated from the texture level difference at λ = 5 mm.

A.2 Surface properties of the drive lane — Texture measured using END_T

The texture is measured using END_T method as defined in A.2. The reference texture profile is given in Table A.1. The value to achieve shall be ±1,5 dB.

NOTE A direct comparison of texture spectra is inadequate because of the fact that different spectral ranges affect the rolling noise level in different ways. The END_T procedure takes into account the effect of a wavelength band on the related acoustic frequency band and weights these effects on the basis of their contribution to the overall A-weighted sound pressure level.

Table A.1 — Reference texture profile spectrum

One-third-octave-band wavelength (in mm)	100	80	63	50	40	32	25	20	5
Level texture L_{tx} (in dB) with reference to1 µm	32,0	34,0	34,5	35,2	36,2	37,3	37,9	38,8	39,8

The profile is measured according to ISO 13473-2.

In order to calculate the END_T value for a given test track with measured one-third-octave-band spectrum levels, $L_{\text{tx, }\lambda}$, one can follow the procedure as outlined below. The levels $L_{\text{tx, }\lambda}$ have to be available for every one-third-octave band between 20 mm and 100 mm and for λ = 5 mm. These levels shall be measured according to ISO/TS 13473-4 and be expressed as levels re. 1 µm in decibels.

A.3 Calculation of the differences, $\Delta L_{\text{tx, }\lambda}$, between $L_{\text{tx, }\lambda}$ and the reference ISO 10844 Test track spectrum, $L_{\text{tx, ref, }\lambda}$

$$\Delta L_{\text{tx, }\lambda} = L_{\text{tx, }\lambda} - L_{\text{tx, ref, }\lambda} \quad \text{(A.1)}$$

Values for the $L_{\text{tx, ref, }\lambda}$ are given in Table A.2.

Table A.2 — One-third-octave-band levels for the relevant texture wavelengths, λ, and the corresponding acoustic frequencies, f, at 80 km/h

λ mm	$L_{tx, ref, \lambda}$ dB	f Hz
100	32,0	222
80	34,0	278
63	34,5	353
50	35,2	444
40	36,2	556
31,5	37,3	705
25	37,9	889
20	38,8	1 111

The third column of Table A.2 shows the corresponding (acoustic) frequency, f, for a speed of 80 km/h. By means of linear interpolation, one calculates the values $\Delta L_{tx,\, i}$ for the acoustic frequencies 250 Hz, 315 Hz, 400 Hz, 500 Hz, 630 Hz, 800 Hz, and 1 000 Hz. Subscript $i = 1$ corresponds to $f = 250$ Hz, $i = 2$ to $f = 315$ Hz, and so on.

A.4 Calculation of the term A as follows

$$A = \Sigma\ 10(L_{mi} + b_i\ \Delta L_{tx,\, i})/10 \text{ for } i = 1 \ldots 13 \tag{A.2}$$

where

L_{mi} are reference noise levels, as given in Table A.3;

b_i are fixed factors, as given in Table A.4.

A.5 Calculation of the term B as follows

$$B = \Sigma\ 10L_{mi}/10 \text{ for } i = 1 \ldots 13 \tag{A.3}$$

where L_{mi} are again given in Table A.3.

Table A.3 — Values for the reference noise levels

Index i	f (one-third octave) Hz	L_{mi} dB
1	250	51,9
2	315	52,1
3	400	55,1
4	500	59,7
5	630	61,6
6	800	64,9
7	1 000	64,6
8	1 250	62,8
9	1 600	62,2
10	2 000	61,3
11	2 500	59,9
12	3 150	56,6
13	4 000	54,2

Table A.4 — Factors b_i

Index i	f Hz	b_i
1	250	0,9
2	315	0,85
3	400	0,8
4	500	0,75
5	630	0,7
6	800	0,65
7	1 000	0,4
8	1 250	0
9	1 600	0
10	2 000	0
11	2 500	0
12	3 150	0
13	4 000	0

A.6 Calculation of the term C as follows

$$C = 0{,}25\ \Delta L_{\text{tx, 5 mm}} \tag{A.4}$$

where

$$\Delta L_{\text{tx, 5 mm}} = L_{\text{tx, 5 mm}} - L_{\text{tx, ref, 5 mm}} \tag{A.5}$$

With $L_{\text{tx, 5 mm}}$ as the measured texture level of the surface under consideration for the texture wavelength 5 mm and $L_{\text{tx, ref, 5 mm}}$ as the corresponding level of the reference surface, equalling 39,8 dB.

A.7 Calculation of END_T

$$END_T = 10\ \lg(A/B)\ \text{dB} - C \tag{A.6}$$

A.8 Worked example

Suppose one measured a one-third-octave-band spectrum on a new test track as given in Table A.5.

Table A.5 — Example of the measured one-third-octave-band spectrum

λ mm	$L_{tx,\lambda}$ dB
100	46
80	45
63	43
50	41
40	40
31,5	39
25	38
20	44
5	48

— Calculate the differences, $\Delta L_{tx,\lambda}$, between the $L_{tx,\lambda}$ and the reference ISO 10844 Test Track spectrum, $L_{tx,ref,\lambda}$.

The values $\Delta L_{tx,\lambda}$ are calculated and given in Table A.6.

Table A.6 — Calculated values for $\Delta L_{tx,\lambda}$

λ mm	$\Delta L_{tx,\lambda}$ dB	f Hz
100	14,0	222
80	11,0	278
63	8,5	353
50	5,8	444
40	3,8	556
31,5	1,7	705
25	0,1	889
20	5,2	1 111

The linearly interpolated $\Delta L_{tx,i}$ for the reference acoustic frequencies 250 Hz, 315 Hz, etc. are given in Table A.7.

— Calculate the term A

Using the values from Table A.7 for $\Delta L_{tx,i}$, the values for the b_i from Table A.4 and the values given in Table A.3 for the L_{mi}, Formula (A.2) can be evaluated as:

$$A = 2{,}26 \times 10^7 \tag{A.7}$$

Table A.7 — Interpolated values for $\Delta L_{tx,\,i}$

Index i	F Hz	$\Delta L_{tx,\,i}$ dB
1	250	12,5
2	315	9,7
3	400	7,2
4	500	4,8
5	630	2,8
6	800	0,9
7	1 000	2,7

— Calculate the term B

Using the values from Table A.3 for the L_{mi}, Formula (A.3) can be evaluated as:

$$B = 1{,}56 \times 10^7 \quad \text{(A.8)}$$

— Calculate the term C as follows:

$$C = 0{,}25 \times (L_{tx,\,5\,mm} - L_{tx,\,ref,\,5\,mm}) = 0{,}25 \times (48 - 39{,}8) = 2{,}1 \text{ dB} \quad \text{(A.9)}$$

where $L_{tx,\,5\,mm}$ = 48 dB was a measured value from the example (Table A.5) and $L_{tx,\,ref,\,5\,mm}$ = 39,8 dB was given.

— Calculate END_T

END_T can now be evaluated with Formula (A.6):

$$END_T = 10 \lg (A/B) \text{ dB} - C = 10 \lg (2{,}26 \times 10^7 / 1{,}56 \times 10^7) \text{ dB} - 2{,}1 \text{ dB} = -0{,}4 \text{ dB} \quad \text{(A.10)}$$

Hence, based on the texture data, the example of the surface is expected to be 0,4 dB less noisy than the reference test track.

Annex B
(informative)

Maintenance and stability of acoustic performance of test surface over time

B.1 General

This annex gives information on maintaining the test track and on stability with time of the test track.

B.2 Maintenance

In the process of cleaning, be careful not to use devices that can alter the texture such as rotating steel brushes, and high pressure water spray. The dust should be sucked off or brushed off.

Salt can alter the surface temporarily or even permanently in such a way as to increase noise and therefore, application of salt is prohibited.

B.3 Influence of age

The surface will achieve its required characteristics approximately 4 weeks after the construction, or after sufficient crossings are made in order to remove the bitumen cover from the mineral surface.

From practical experience, it is known that the tyre or road noise levels measured on the test surface increase slightly during the first 6 months to 12 months after the construction.

The influence of age on the noise from trucks is generally less than that from cars.

The surface wears out depending on the frequency of use mainly in the wheel tracks (ravelling and rutting) and as a consequence, the acoustic properties can be affected.

The stiffness of the base and subgrade can influence the durability of the track.

When the track surface is hot, additional damage can occur.

Avoid conducting acceleration tests when the surface temperature is over 50 °C, unless the track is specifically designed for operation above this temperature.

For use at higher surface temperatures, this edition of this International Standard allows the use of Polymer-modified Bitumen.

B.4 Repaving the test area

When necessary to repave the test track drive lane, it is unnecessary to repave more than the test strip of 3 m in width, where vehicles are driving, provided the test area outside the strip meets the requirements for sound absorption.

The whole width of the drive lane should always be renewed according to the width of the finisher or the milling machine. Additional longitudinal joints should be avoided.

Annex C
(informative)

Examples of test track construction practices

C.1 Aim of Annex C

The aim of this annex is to give information on current practices from different countries. It is not the aim to describe a standardized process to build a test track. It does not guarantee that applying one of these processes will automatically lead to the fulfilment of the specification at the first attempt. Any other construction practice can be applied as far as it satisfies the requirements of this International Standard.

— C.3 is an example from Germany.

— C.4 is an example from Japan.

— C.5 is an example from USA.

— C.6 is an example from The Netherlands.

C.2 General

The requirements in this International Standard are more severe than those for building common roads. The experience shows the necessity to have a good know-how of road-building practice and skill to be able to construct the test track according to the present standard requirements.

IMPORTANT — The base and the subbase shall ensure stability and evenness, according to best road construction practice.

IMPORTANT — In the practices illustrated by the following examples, coring is used because the first edition required void content or absorption. At the time of publication of this International Standard, void content is replaced by non-intrusive methods.

C.3 Example from Germany

C.3.1 Sublayers

a) New construction of a test track

In the case of a completely new road construction, base and subbase layers shall ensure good stability and evenness, according to best road construction practice. The unevenness of the base and binder layer should be less than 2 mm under a 3-m straightedge in any direction.

Dimensions in millimetres

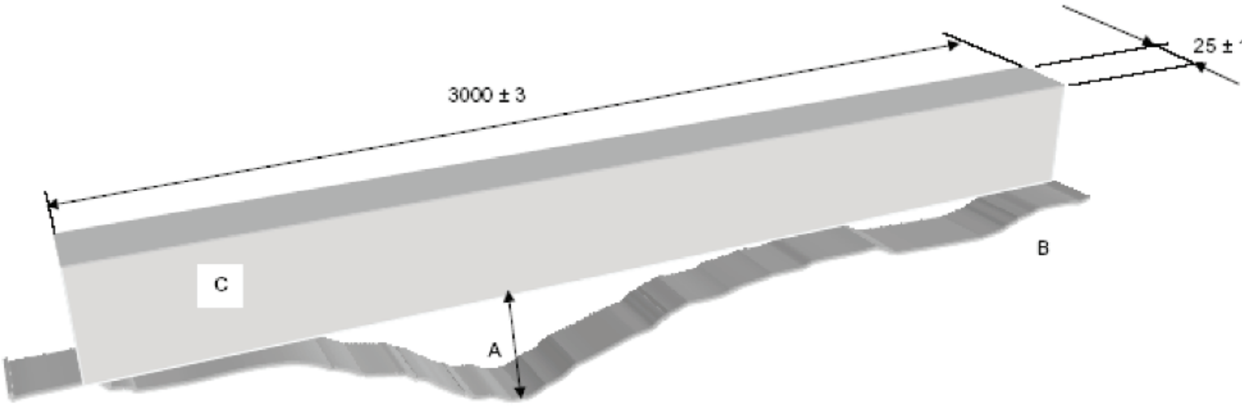


Figure C.1 — To check the unevenness using the straightedge method

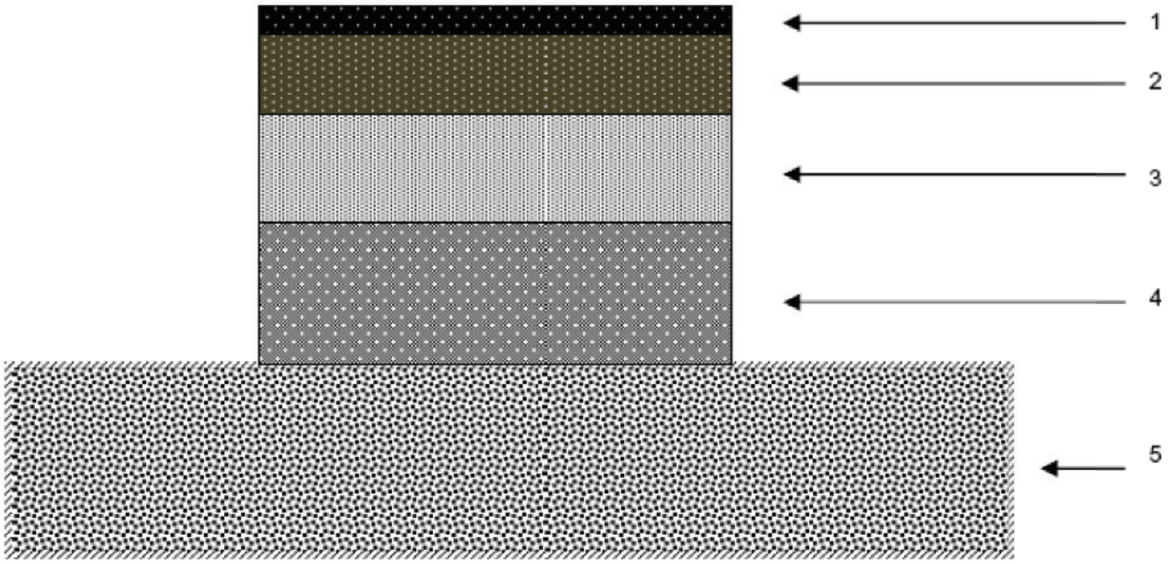
For checking the 2 mm requirement, the distance between the straightedge and the surface can be measured using a staggered gauge with steps of 0,1 mm as described in EN 13036–7. If laser profilometer is used, care shall be taken to obtain equivalent result, i.e. not considering very localized variation.

The recommended value of E_v2 (Young modulus) of the asphalt wearing and the top layer course for passenger cars track and for trucks track (see Figure A.2) is:

— for the subgrade[1)]: $E_v2 \geq 150$ MN/m^2;

— for the natural soil[1)]: 60 MN/m^2 $\leq E_v2 \leq 80$ MN/m^2.

1) To determine the modulus values of the subgrade and natural soil, the California Bearing Ratio method (ASTM D1883-99 or Reference [12] can be used.



Key

1 asphalt concrete top layer (wearing course) E_v2 XX

2 asphalt binder (second layer) E_v2 XX

3 asphalt subbase (first layer or tout venant)

4 subgrade (mix granulat base course)

5 natural soil or soil stabilized by lime E_v2 XX

Figure C.2 — Schematic of the layers — Recommended value for E_v2

NOTE Depending on the Young modulus of the natural soil (E_v2) asphalt subbase, subgrade is defined according to the local road practice considering its influence on the test surface characteristics, as defined in this International Standard.

To ensure that these characteristics are fulfilled, the evenness of the interface between the asphalt binder and subbase shall be less than 4 mm with a straightedge.

b) Renewal of the asphalt concrete top layer (wearing course)

When the asphalt concrete top layer (wearing course) has to be replaced by a new test surface, the milling of the old asphalt concrete top layer (wearing course) should only be done by means of a precise levelling cutter, guided by levelled wires on each side or similar laser or ultrasonic sensors (see Figure C.3). This is to ensure that possible unevenness of the old asphalt concrete top layer (wearing course) is not copied into the new top layer.

The minimum working width should be 2 m and the maximum distance between cut lines should not exceed 6 mm.

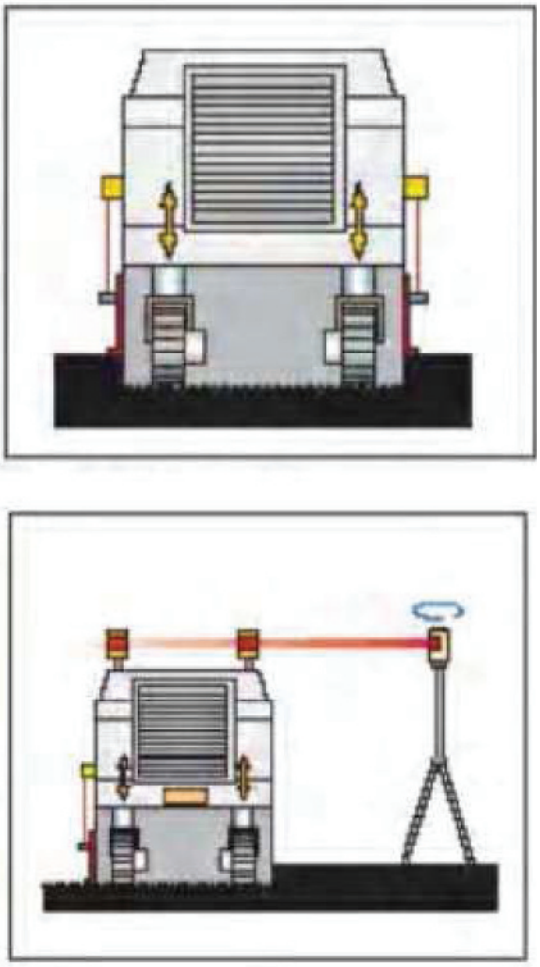


Figure C.3 — Renewal of the asphalt concrete top layer (wearing course)

Both longitudinal and transversal joints should be sealed with a cold joint based on Polymer-modified Bitumen (PmB), since it can be processed cold. Self-adhesive joint tapes are not suitable and shall be avoided. Firm adhesion between the new top layer and the milled plane shall be ensured by an adhesion promoter (see Figure C.4), for example, bitumen emulsion (200 g/m^2 to 300 g/m^2).

Figure C.4 — Finely milled surface ready for the application of new asphalt concrete top layer (wearing course)

C.3.2 Mix design of the asphalt concrete top layer (wearing course)

C.3.2.1 Ingredients

a) Mineral materials

Mineral materials of the highest quality are essential and shall comply with the highest requirements of the country.

Selection criteria are strength, abrasion resistance, polishing resistance, crushing resistance, frost resistance, as well as grain shape.

Magmatic rocks such as “basalt”, “gabbro”, “diabase”, “granite”, and “porphyry” (or similar) are generally recommended due to their high level of microtexture and their high shear resistance of compacted layers. Limestone is too soft and moraine has no enough microtexture so they are not suitable.

The Polished Stone Value (PSV) should be at least 50, according to EN 1097-8.

Grain shape is an important feature. It should approximate a cubic form, with a length/thickness ratio less than 3:1 (see EN 13043 and EN 933-5 - category $C_{100/0}$).

Chipping size D > 2 mm should be 100 % crushed rock and the chippings should be washed. The test surface shall be dense asphalt concrete and the maximum chipping size shall be 8 mm nominal (tolerances in the range of 6,3 mm to 10 mm, according to EN 13108-1).

The sand fraction (0,063 mm < D < 2 mm) should have a flow value of at least 30, according to EN 933-6.

Delivery conditions are important and should comply with EN 933-6 as well as EN 13043.

The filler according to B 11-121 is, by definition, a mineral powder with a chipping size D < 0,063 mm.

Limestone powder (calcium carbonate) or (slaked) spent lime (calcium hydroxide) are recommended due to their alkaline nature, which favours adhesion with bitumen.

Other grain sizes can be used depending on the local supply, but shall not exceed 0,09 mm.

The filler fraction fines of the crushed rock (≤0,09 mm) shall be totally removed and replaced by the limestone powder added filler with a maximum grain size of 0,09 mm.

b) Binder

The binder shall be bitumen. Depending on the climatic condition of the area, bitumen as binder can be a straight-penetration type bitumen or a modified bitumen.

c) Mix formulation

Grading curve is the most important parameter for noise and should be a requirement of the surface.

For the suitability tests, the crushed-rock granulate are washed, and sieved (ISO 565) into the following grain classes:

— ≤0,09 mm;

— 0,09/0,125;

— 0,125/0,25;

— 0,25/0,71;

— 0,71/2,0;

— 2,0/5,0;

— 5,0/8,0 mm.

Bitumen B 50/70 shall be used (employed as bitumen for road construction work) according to geographical situation. Bitumen 70/100 can be used for low temperature.

An example for the size grading of the mineral components of the mixture is given in Table C.1.

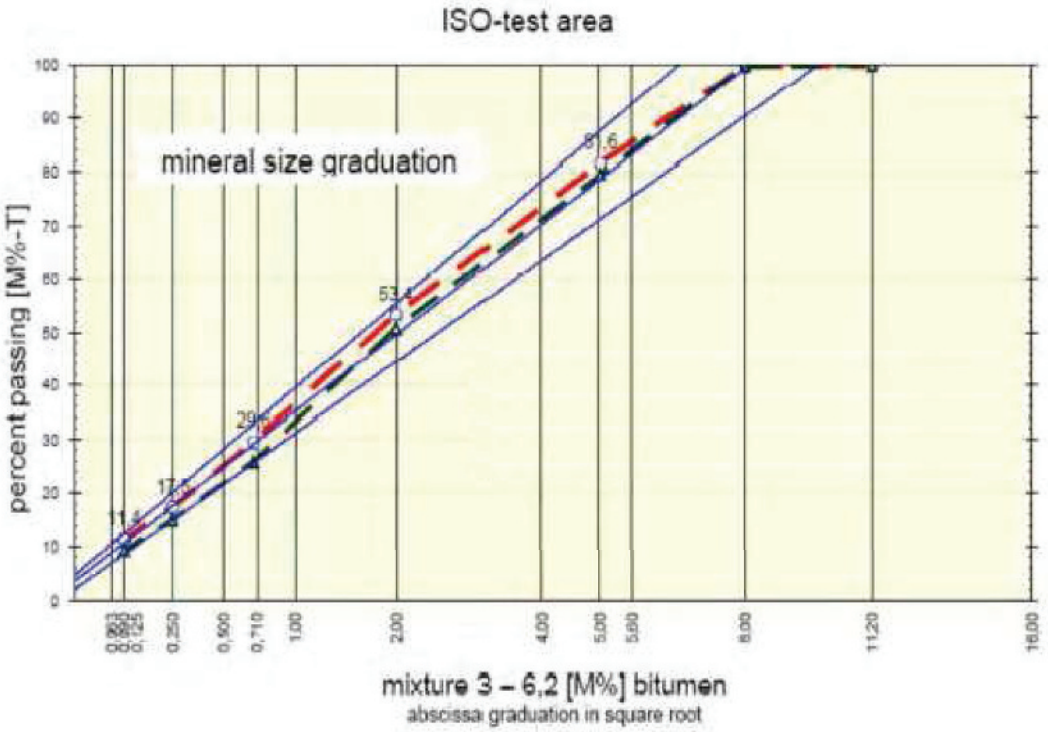
Table C.1 — Example of the size grading of the mineral components of the mixture

Fraction	< 0,009	0,009/ 0,25	0,25/ 0,71	0,71/ 2,0	2,0/ 5,0	5,0/ 8,0	8,0/ 11,2	11,2/ 16,0	16,0/ 22,4	22,4/ 31,5	Sum	Dosage	
												M %	Vol
1 – Gabbro 5/8	0,00	0,00	0,00	0,50	4,30	94,40	0,80	0,00	0,00	0,00	100,00	-	
2 – Gabbro 2/5	0,00	0,00	1,60	4,90	91,20	2,30	0,00	0,00	0,00	0,00	100,00	-	
3 – Diabas BS	15,70	15,90	29,60	36,50	2,30	0,00	0,00	0,00	0,00	0,00	100,00	-	
4 – Diabas 2/5	0,00	0,00	0,80	5,90	82,80	10,50	0,00	0,00	0,00	0,00	100,00	-	
5 – Diabas 5/8	0,00	0,00	0,00	0,80	3,50	94,30	1,40	0,00	0,00	0,00	100,00	-	
6 – Limestone filler	85,50	14,50	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	100,00	-	
3[a] – Diabas BS	8,60	16,44	32,44	40,00	2,52	0,00	0,00	0,00	0,00	0,00	100,00	-	
4 – Gritstone - BS	9,86	9,05	19,85	44,89	16,35	0,00	0,00	0,00	0,00	0,00	100,00	-	
4[a] – Gritstone - BS	4,86	9,55	20,95	47,38	17,26	0,00	0,00	0,00	0,00	0,00	100,00	-	
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		-	
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		-	
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		-	
(Σ)	124,52	65,44	105,24	180,87	220,23	201,50	2,20	0,00	0,00	0,00	900,00	-	-
1 – Gabbro 5/8	0,00	0,00	0,00	0,10	0,88	19,26	0,16	0,00	0,00	0,00	20,40	20,40	
2 – Gabbro 2/5	0,00	0,00	0,34	1,04	19,43	0,49	0,00	0,00	0,00	0,00	21,30	21,30	
3 – Diabas BS	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
4 – Diabas 2/5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
5 – Diabas 5/8	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
6 – limestone filler	7,18	1,22	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	8,40	8,40	
3[a] – Diabas BS	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
4 – Gritsone BS	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
4[a] – Gritstone BS	2,43	4,77	10,45	23,64	8,61	0,00	0,00	0,00	0,00	0,00	49,90	49,90	
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Size graduation	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Remaining [M %-T]	9,6	6,0	10,8	24,8	28,9	19,7	0,2	0,00	0,00	0,00	100,00	100,00	
Passing [M %-T]	9,6	15,6	26,4	51,2	60,1	99,8	100,00	100,00	100,00	100,00	100,00		

[a] Dedusted.

NOTE The upper part of the table is the original grain size distribution of the fractions. The bottom part is the calculation of the size graduation minerals as shown in the last row.

After compaction, during qualification tests, or after the mix design assembly, the grading curve shall fall inside the tolerances given in Figure C.5.



Key

after compaction by Marshall (2 × 75 N blows)

graduation before compaction

Figure C.5 — Mixture tolerance

The grading curve fits Formula (C.1):

$$P = 100\left(\frac{S}{S_{\max}}\right)^{0,5} \qquad \text{(C.1)}$$

where

P is the amount passing the sieve, expressed as a mass fraction (in per cent);

S is the square mesh sieve size, in millimetres, see ISO 565;

$S_{\max}$ = 8 mm for the mean curve;

$S_{\max}$ = 10 mm for the (lower) upper tolerance curve;

$S_{\max}$ = 6,3 mm for the (upper) lower tolerance curve.

The properties of the mixture are given in Table C.2.

Table C.2 — Properties of the mixture

	Target value		Tolerance
	Total mass fraction of mix	Mass fraction of the aggregate	
Mass of stones (S > 2 mm)	47,5 %	50,5 %	±2,5 %
Mass of sand (0,063 mm < S < 2 mm)	37,9 %	40,2 %	±2 %
Mass of filler (S < 0,063 mm)	8,8 %	9,3 %	±1 %
Mass of binder (bitumen)	5,6 % up to 6,8 %	Not applicable	
Void content (by volume)		3 % to 5 %	

C.3.2.2 Laboratory test to measure the sound absorption during the qualification test for the mix design

C.3.2.2.1 General

Figure C.6 — Example for compaction sample

The Marshall (method) test should be used before the mixture is applied (in full scale in order) to verify that the mixture can be processed properly and that the mixture, after compaction, will comply. It complies with the 6 % void requirement.

At least five Marshall samples should be made, each having a different mass of binder level (slightly differing from the value given) within the range given in Table C.2, e.g. 6,0 %, 6,2 %, 6,4 %, 6,6 %, and 6,8 %.

The filler/bitumen ratio should be the same for all mixtures in order to obtain a constant mortar viscosity for the five mixtures.

The Marshall samples should be made with standard two-sided compaction (of) (2 × 50 blows).

It should be taken into account that the process of compaction unavoidably leads to a partial (fragmentation) breakdown of the larger aggregates into the smaller ones (see Figure C.7 for an example).

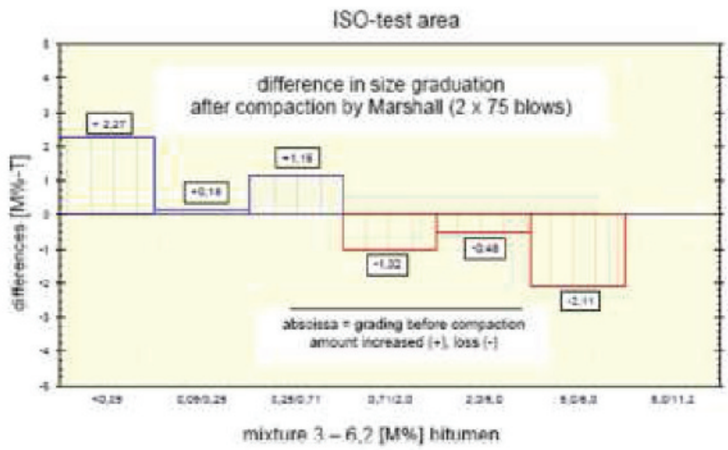


Figure C.7 — Illustration of the fragmentation of the larger aggregates into the smaller ones by Marshall compaction

Therefore, it is recommended to choose for the preparation of the Marshall samples, a sieving grading curve which lies for the larger aggregates above the medium curve, and for the smaller aggregates close to the lower tolerance curve (see Figure C.5).

The resulting grading curve after Marshall compaction (see Figure C.5) lies between the prescribed tolerances.

For each of the Marshall samples, the following parameters should be determined: the volume of the filler (V_F), the volume of the bitumen (V_B), the volume of stones and sand [i.e. mineral minus filler, indicated with (V_{M-F})], the air volume (V_A), and the following parameters should be calculated for each sample:

$\varepsilon_{M-F} = (V_F + V_B + V_A)/V_{M-F}$ = mineral without filler = graduation of ordinate

and

$\varepsilon_{B+F} = (V_F + V_B)/V_{M-F}$ = asphaltic mortar bitumen + filler = graduation of abscissa

The five couples (ε_{M-F}, ε_{B+F}) shall be displayed in a diagram, as shown in Figure C.8, and should show a curve which rises, reaches a top value, and decreases again.

The mixture corresponding to the point in the vertex area which is closest to a void volume of 4 % is most suitable for the construction of the test track in full scale.

C.3.2.2.2 Experimental approach

The following parameters were determined for the grain classes:

— the grain size distribution;

— the bulk density;

— the grain shape;

— the surface roughness.

The sequence of a mix design is presented as an example, which is valid for asphalt concrete 0/8 mm, according to this International Standard.

NOTE 1 M%T is the mass fraction (in per cent)of the aggregate without bitumen.

The composition of the aggregates is identified for the setting adjustment of the plant, e.g.:

— Gritstone excavated sand ≈ 50,0 M%T, ≈ 5 M%T intrinsic filler dust-free;

— Gabbro 2/5 mm ≈ 21,0 M%T, in the “as-received” condition;

— Gabbro 5/8 mm ≈ 20,6 M%T, in the “as-received” condition gabbro;

— Limestone powder ≈ 8,4 M%T, in the “as-received” condition;

— Aggregates Σ 100,0 M%T.

The calculation of the distribution curve and its representation follows.

Bitumen: In the stages: **(1)** 6,0; **(2)** 6,2; **(3)** 6,4; **(4)** 6,6; **(5)** 6,8 M%T.

Filler to bitumen ratio = 58,4/41,6 M%T = constant in order to obtain a constant viscosity of the mortar, see Note 2.

With this, the mortar viscosity is held constant for all mixture stages.

NOTE 2 Mix design of asphalt can be done according to road building standard or guidelines in each country. The main target is to fulfil the aggregate grading curve. Care should be taken to maintain viscosity constant. The amount of filler can be changed depending on its quality (diatomite versus slaked line) in order to maintain the viscosity constant. The ratio filler/bitumen should be constant for all steps of qualification test described in Figure A.8.

Table C.3 — Mix design of asphalt — Mixture: 1a

M%T	**Mineral type/ fraction**	**Eff. spec. density** g/cm^3	M %	**Volume 4:3** cm^3/100 g	**Mass of specimen** g
1	**2**	**3**	**4**	**5**[a]	**6**
2,26	Gritstone-Bs < 0,09	2,742	2,12	0,775	26,8
4,81	Gritstone-Bs 0,09/0,25	2,726	4,52	1,659	57,0
10,55	Gritstone-Bs 0,25/0,71	2,707	9,92	3,663	125,0
23,84	Gritstone-Bs 0,71/2,0	2,722	22,41	8,233	282,4
8,69	Gritstone-Bs 2,0/5,0	2,717	8,17	3,006	102,9
0,37	Gabbro 0,25/0,71	2,894	0,35	0,120	4,4
1,25	Gabbro 0,71/2	2,894	1,18	0,406	14,8
21,97	Gabbro 2/5	2,894	20,65	7,136	260,2
18,56	Gabbro 5/8	2,896	17,44	6,023	219,8
0,15	Gabbro 8/11,2	2,896	0,15	0,050	1,8
6,38	Limestone < 0,09	2,729	6,00	2,198	75,6
1,17	Limestone > 0,09	2,729	1,10	0,403	13,9
100,00	Bitumen	1,020	6,00	5,882	75,6
6,38					

Table C.3 *(continued)*

106,38	Asphaltic mixture		100,00	39,554[b]	1 260
a	Column 5 selected the change from M % to Vol.-%.				
b	The reciprocal of 39,554 × 100 = 2,528 g/cm³ = specific density of mixture.				

Eff. spec. density ρ_R		g/cm³	2,528
Bulk density ρ_A		g/cm³	2,380
Air voids $H_{bit.}$		Vol.-%	6,62
Compaction by Marshall 2 × 50 blows			
Volume of specimen	V_K	Vol.-%	100,00
Air voids $H_{bit.}$	V_L	Vol.-%	6,62
Solid matter by volume	V_{M+B+F}	Vol.-%	93,38
Volume of mineral - filler	V_{M-F}	Vol.-%	72,48
Volume of filler < 0,09	V_L	Vol.-%	7,02
Volume of bitumen	V_B	Vol.-%	13,89
Volume of air voids	V_L	Vol.-%	6,62
			100
$\varepsilon_{(M-F)}$ =	$\dfrac{V_F+V_B+V_L}{V_{M-F}}$	[1]	0,380
$\varepsilon_{(B+F)}$ =	$\dfrac{V_F+V_B}{V_{M-F}}$	[1]	0,288
proportion filler: bitumen F:B = const. M % 58,4 filler 41,6 bitumen			

The adaptation in the dosed filler is distributed in percent over the entire sieve curve.

Five Marshall samples of increasing mortar volume (1) – (5) are subjected to two different compactions,

— standard compaction: 2 × 50 (impacts) blows and

— increased compaction: 2 × 75 (blows),

to take into account the higher axle loads of heavy trucks on the test track, (to) and obtain the data about the stability and compaction properties.

An aggregate grading curve which can give the desired characteristics is shown in Figure C.5.

Table C.4 — Mix design of asphalt — Mixture: 3a

M%T	**Mineral type/ fraction**	**Eff. spec. density** g/cm³	M %	**Volume 4:3** cm³/100 g	**Mass of specimen** g
1	**2**	**3**	**4**	**5**[a]	**6**
2,26	Gritstone-Bs < 0,09	2,742	2,12	0,771	26,7
4,81	Gritstone-Bs 0,09/0,25	2,726	4,50	1,652	56,7

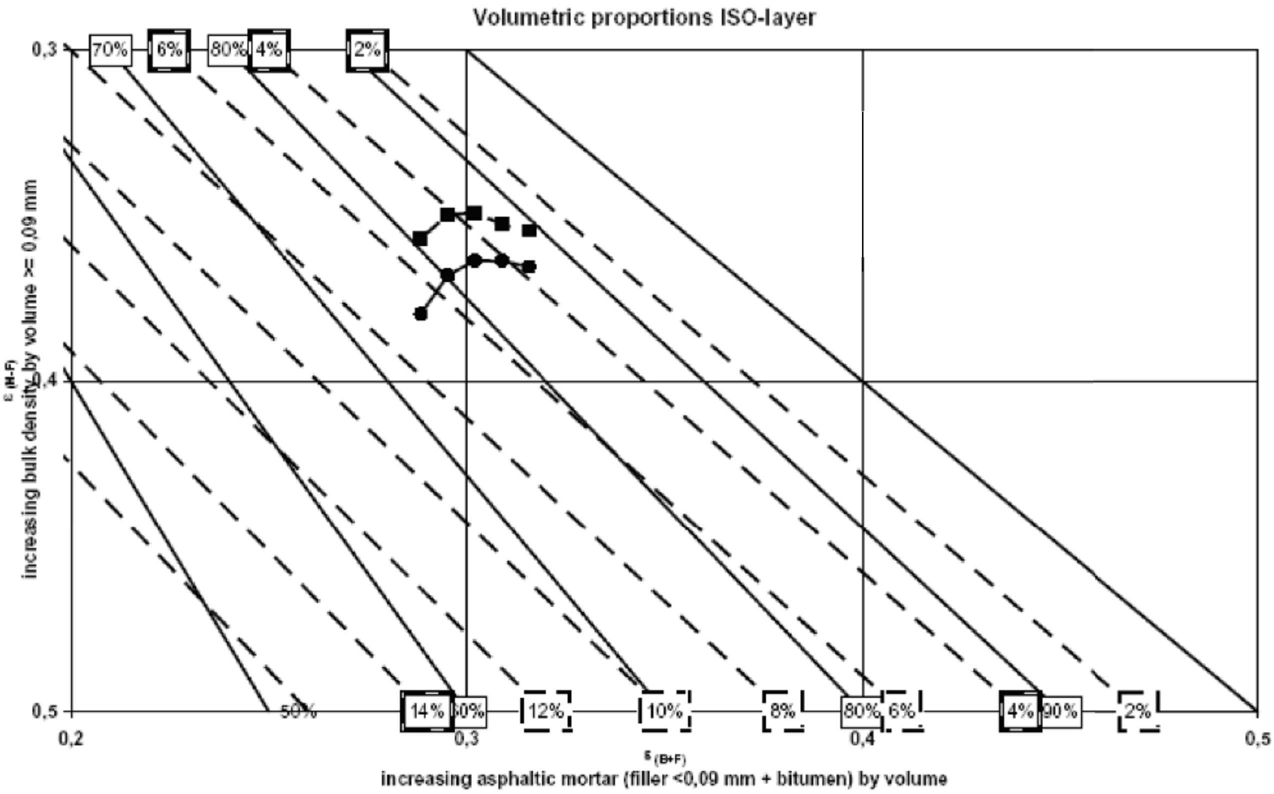
Table C.4 *(continued)*

10,55	Gritstone-Bs 0,25/0,71	2,707	9,87	3,648	124,4
23,84	Gritstone-Bs 0,71/2,0	2,722	22,31	8,198	281,2
8,69	Gritstone-Bs 2,0/5,0	2,717	8,13	2,994	102,5
0,37	Gabbro 0,25/0,71	2,894	0,35	0,120	4,4
1,25	Gabbro 0,71/2	2,894	1,17	0,405	14,8
21,97	Gabbro 2/5	2,894	20,56	7,106	259,1
18,56	Gabbro 5/8	2,896	17,37	5,997	218,8
0,15	Gabbro 8/11,2	2,896	0,14	0,050	1,8
6,38	Lime-stone < 0,09	2,729	5,97	2,188	75,2
1,17	Lime-stone > 0,09	2,729	1,10	0,401	13,8
100,00	Bitumen	1,020	6,40	6,275	80,6
6,84					
106,61	Asphaltic mix-ture		100,00	39,803[b]	1 260
a	Column 5 selected the change from M % to Vol.-%.				
b	The reciprocal of 39,803 × 100 = 2,512 g/cm^3 = specific density of mixture.				

Eff. spec. density ρ_R		g/cm^3	2,512
Bulk density ρ_A		g/cm^3	2,399
Air voids $H_{bit.}$		Vol.-%	4,51
Compaction by Marshall 2 × 50 blows			
Volume of specimen	V_K	Vol.-%	100,00
Air voids $H_{bit.}$	V_L	Vol.-%	4,51
Solid matter by volume	V_{M+B+F}	Vol.-%	95,49
Volume of mineral-filler	V_{M-F}	Vol.-%	73,34
Volume of filler < 0,09	V_L	Vol.-%	7,10
Volume of bitumen	V_B	Vol.-%	15,05
Volume of air voids	V_L	Vol.-%	4,51
			100
$\varepsilon_{(M-F)}$ =	$\dfrac{V_F+V_B+V_L}{V_{M-F}}$	[1]	0,364

Eff. spec. density ρ_R		g/cm³	2,512
$\varepsilon_{(B+F)}$ =	$\dfrac{V_F + V_B}{V_{M-F}}$	[1]	0,302
proportion filler: bitumen F:B = const. M % 58,4 filler 41,6 bitumen			

NOTE Figure C.8 shows a result of the aptitude test done with different asphalt mixtures by which the content of asphalt/mortar was changed. Two curves are shown which give different results due to difference in compaction energy. The optimum of the solid line curve is mixture 4; the optimum of the other curve is mixture 3.



Key

- Marshall compaction 2 × 50 blows
- Marshall compaction 2 × 75 blows
- percent of voids filled with mortar
- air voids in compacted mixture

Figure C.8 — The ε_{B+F}, ε_{M-F} curves

It is advisable to repeat this procedure of the Marshall test, with the Marshall samples that have identical compositions, but which are produced with a nonstandard two-sided compaction of 2 × 75 blows, in order to test the mixtures on their suitability to withstand tests with vehicles with high-axle loads.

The acoustic absorption shall be measured in the frequency range from 280 Hz to 1 800 Hz with an *in situ* device, meeting the specifications of ISO 13472-2. The results are to be expressed in the one-third-octave-band coefficients, according to the procedure described in ISO 13472-2.

C.3.2.3 Mix design requirements

The Mass % Part (M%P) is the fraction of mixture which is expressed with respect to the total mass of minerals only (chipping + sand + filler = 100 % of mass).

The Mass % (M %) is the fraction of the mixture which is expressed with respect to the total mass of minerals and bitumen (chipping + sand + filler+ bitumen = 100 % of mass of the mixture).

Allowable tolerance:

— bitumen ±0,1 % of its own mass (weight);

— filler ±1 % of its own mass (weight);

— sand ±1 % of its own mass (weight);

— chippings ±1 % of its own mass (weight).

Test runs are required to adjust the mixing plant requirements.

C.3.3 Construction of the top layer

C.3.3.1 Requirements concerning the construction machinery and their usage

a) Cutter(s): Only precise levelling cutters can be deployed, cutting line distance of 6 mm with precision control engineering as a prerequisite for the evenness and uniform thickness of the new layer. The old surface shall not be copied due to possible unevenness. As a rule, the working width is 2 m. The device is guided on the levelled wire. Area levelling of the existing test tracks is a prerequisite (top-layer height plan).

   Longitudinal and transversal seams should be sealed with a seam adhesive on Polymer modified Bitumen (PmB) basis that can be processed cold.

   Self-adhesive jointing tapes are not suitable.

b) Paver or Finisher(s): Finishers of defined configuration are suitable if these ensure a high-initial compaction alongside the geometric surface characteristics. Tracked finishers equipped with a high-compaction plank are preferable. The finisher shall be guided on a levelled wire on both sides. Other means of machine control that ensure high precision in the evenness of the laid area are also suitable. It is strived for a precompaction under the laying plank of $k \geq 90$ % Marshall.

   NOTE Marshall compaction is 50 blows on each face of the sample (make reference to ASTM D1559–89 or EN 12697–30).

c) Roller compaction: The compaction shall be started at approximately 140 °C to 150 °C. This is essential for the end degree of compaction $k \geq 98$ % Marshall. It is essential for the high degree of compaction that rolling compaction is conducted at the highest laid asphalt temperature condition according to the local practice.

   A degree of compaction of $k = 100$ % should be strived for. However, roller compaction should be reduced to the necessary minimum in order not to affect the surface texture. The steel rollers cannot reverse in the measuring field because this leaves measurable bumpiness. For the same reason, vibration compaction in the second passes is only admissible after static precompaction.

   Steel rollers of the same model arranged in pairs, which run over the laid area behind the finisher at the same distance and at the same forward speed, should be deployed. They shall completely cover the whole lane width.

   The roller width shall exceed half of the track width.

   Thus two steel rollers are required per lane.

With service mass (weight) of approximately 80 kN to 100 kN, only static compaction is made during the first pass. A further roller train is required for reasons of temperature; this runs over the laid surface at a defined distance to the first roller train. Damped vibration can also be applied for this purpose. The rollers shall be equipped with controllable vibration equipment, e.g. frequency 50 Hz, amplitude ≤ 0,3 mm, only on the front roller lining, the rear roller lining runs without vibration. Further "roller passes" are performed only statically for ironing out. The number of these depends on the degree of compaction. Oscillation leads to greater compaction efficiency, yet has a negative influence on the surface texture, therefore is not suitable for test tracks.

C.3.3.2 Description of the top layer construction process

Asphalt mixture: Mix designs require particular precision, which goes beyond the usual traffic infrastructure requirements. (Mix designs are dealt within a separate text module).

The top layer should be laid during dry weather; surface temperature is ≥10 °C.

Once a suitable mixture is designed by means of the above described Marshall method, one can apply the mixture on the (sub) under layer. It is recommended to provide run-up stretches of approximately 25 m to 30 m in length for an optimum adjustment of the laying train.

The actual measurement drive line has a length of 20 m/30 m on (both) each side(s) of the microphones line, in total 40 m/60 m (for long vehicles, see Clause 4).

The thickness of the top layer shall be 35 mm ± 5 mm. It shall be uniform over the whole drive lane.

Run-up stretches of about 25 m minimum are recommended for an optimal adjustment of the laying train.

Finishers should be used, which provide a high initial compaction.

Tracked finishers equipped with a high-efficiency compaction plate and which are guided on both sides by a levelled wire are suitable.

Also, other high-tech techniques (e.g. with laser beam guiding) that avoid the creation of unevenness or megatexture (see Figure C.9) can be used.

The laid areas cannot be accessed until they have cooled down completely. The radiometric probe shall be operated from the edge.

Check the void content of the top layer using a radiometric probe for density measuring over the complete time that the ISO top layer is being laid. Continuous measurements should be taken under a defined measurement schedule; the results should be recorded after every steel roller pass. The same applies to registering the temperature of the bituminous mixture and compaction.

For appropriate cooling of the newly made surface, the first measurement to check the surface characteristics is only possible at least 24 h later.

The importance of the sublayers is to provide the necessary stability and evenness (see C.3.1, sublayer). The way to achieve this is the responsibility of the contractor and depends on local geotechnical characteristics.

C.3.3.3 Compaction requirements for the top layer

Testing by coring on trial sections previously built on the same basement in order to check the compliance of all parameters.

Compaction shall be at maximum in the range of 98 % to 100 %; 100 % is recommended.

Figure C.9 — Megatexture caused by functioning of finisher

Compaction of the mixture should start when its temperature is typically 140 °C to 150 °C. A compaction of 98 % compared to the Marshall compactness should be strived for, but the lesser passages of the rollers, the better in order to keep some macrotexture. One should use steel rollers of the same model, with a mass of 80 kN up to 100 kN, arranged in pairs (see Figure C.10).

Figure C.10 — Assembly train — Finisher and two rollers, first static compaction passage

— Their combined width should be at least the whole lane width. The rollers should follow the finisher at a constant distance and at the same speed. They should never reverse in the measuring field, as this operation can cause unevenness. Only static compaction should be applied during the first passage. A second battery of rollers should follow the first one at a certain distance. The rollers in the second battery can compact with damped vibration. The vibration shall be controllable, e.g. a frequency 50 Hz and an amplitude of up to 0,3 mm is suitable. It is not recommended to use oscillating rollers with the horizontal processing of the surface, because it smooths the track and reduces the macrotexture. Only the leading rolls (of the second battery of rollers) should vibrate vertically.and the rear rolls should not, as this would possibly generate megatexture in the surface. The density of the top layer should continuously be monitored by means of a radiometric probe, i.e. measurements should be done after each steel roller pass. Possible additional passages of rollers should again be without vibration.

IMPORTANT — The newly laid top layer should not be walked on before the complete cooling off of the surface, as it could be damaged irreparably (see Figure C.11).

Figure C.11 — Megatexture on test track caused by walking over in hot surface

C.4 Example from Japan

C.4.1 General

The asphalt pavement thickness is designed using the California Bearing Ratio (CBR) value and the road classification is based on traffic volume. CBR test is described in ASTM D1883.

In order to make sure that the hot mixture has the required properties, selection of materials and determination of the grading of aggregate and amount of asphalt shall be carefully conducted.

Aggregate to be used should be fully dried, heated to an appropriate temperature, and thoroughly mixed. The hot mixture should be evenly spread and compacted while retaining a high temperature to achieve the prescribed density. The pavement should be constructed in such a manner that the finished surface is smooth and has good texture.

C.4.2 Mixture design

C.4.2.1 Design process

The mixture design should be processed in the following order.

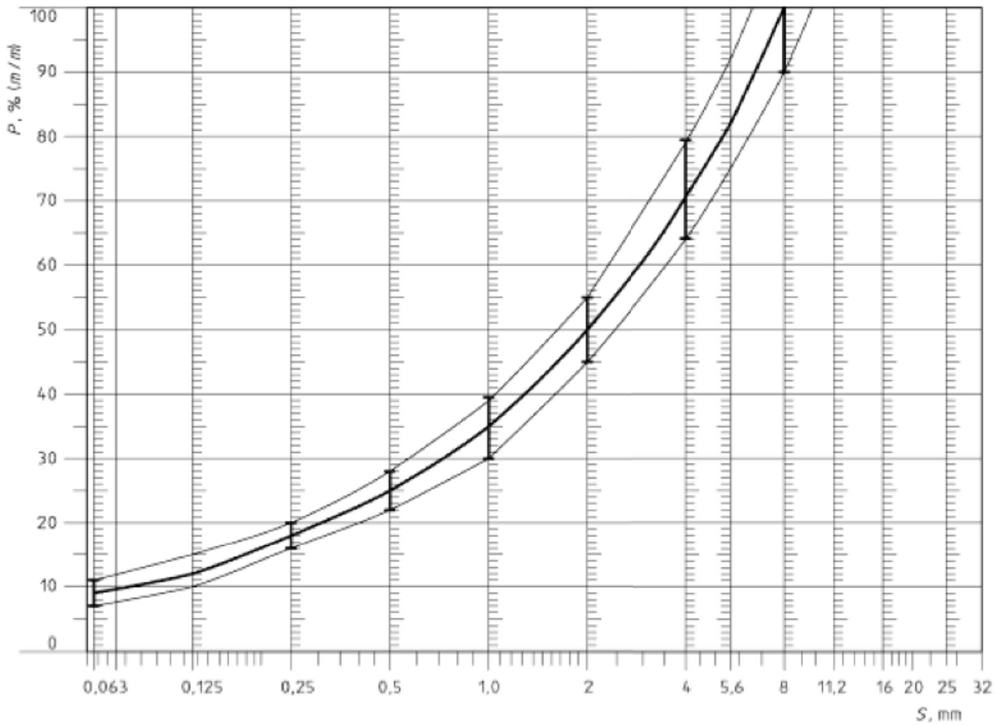
a) Materials with prescribed quality should be selected in consideration of their availability for the) Materials with prescribed quality should be selected in consideration of their availability for the necessary amounts.

b) The mix proportion of each aggregate should be decided by the grading curve shown in Figure C.12.

c) The design asphalt content corresponding to the chosen grading of aggregate should be determined according to the procedure described in C.4.2.2.

d) A tentative mixture proportion should be determined in an asphalt plant for the cold feeder and the hot bin to conduct a trial mixing. The results of the trial should be compared with the standard values of the Marshall test. Actual construction situations at the site should be investigated and a tentatively determined laboratory mixture design should be modified to obtain the job-mixture formula if necessary.

Sieve size in mm



NOTE This grading curve is equivalent to the sieving curve shown in Figure C.5. Difference is only in the abscissa graduation, semi log compare vs. square root in Figure C.5.

Figure C.12 — Grading curve of the aggregate in the asphalt mixture with tolerances

C.4.2.2 Determination of the design asphalt content

The design asphalt content corresponding to the proportion of aggregate to achieve proper grading should be determined by the following procedures.

a) Within the range for asphalt content for selecting mixtures as indicated in Table C.5, Marshall test specimens of asphalt mixtures should be prepared, with the asphalt content varying with an interval of 0,5 %.

   Marshall test should be conducted to determine the binder content after deciding the mixture composition for stones, sand, and filler. The amount of filler should not be changed, even if the binder content changes.

b) The Marshall test specimens should be made with standard two-sided compaction of 2 × 50 blows.

c) The density, stability, and flow value of the specimens should be measured to calculate the percentage of air voids and voids filled with asphalt.

d) The test results should be plotted using an arithmetic scale to indicate the asphalt content on the axis of abscissa, and the density, percentage of air voids on the axis of the ordinate.

e) The range of asphalt contents which satisfies an air void between 4 % and 5 % can be found from the curve drawn.

f) The common range of asphalt content which satisfies the tolerance of the binder content in Table C.5 should be obtained, with the median value being taken as the design asphalt content for a general case.

Table C.5 — Design guidelines

	Target value		Tolerance
	Total mass fraction of mixture	Mass fraction of the aggregate	
Stones (S_M > 2 mm)	47,6 %	50,5 %	±5 %
Sand (0,063 mm < S_M < 2 mm)	38,0 %	40,2 %	±5 %
Filler (S_M < 0,063 mm)	8,8 %	9,3 %	±2 %
Binder (bitumen)	5,8 %	N.A.	±0,5 %
Maximum chipping size	8 mm		6,3 mm to 10 mm
Binder hardness (pen)	40/60, 60/80, 80/100		
Polished stone value (PSV) (see Reference [5])	> 50		
Compactness, relative to Marshall compactness	98 %		
NOTE S_M is square mesh sieve size.			

C.4.3 Paving

C.4.3.1 General

The surface and binder courses should be carefully constructed, with special attention paid to the following points, as the quality of both courses has a significant influence on the stability against traffic, resistance against abrasion, and effects caused by the climate.

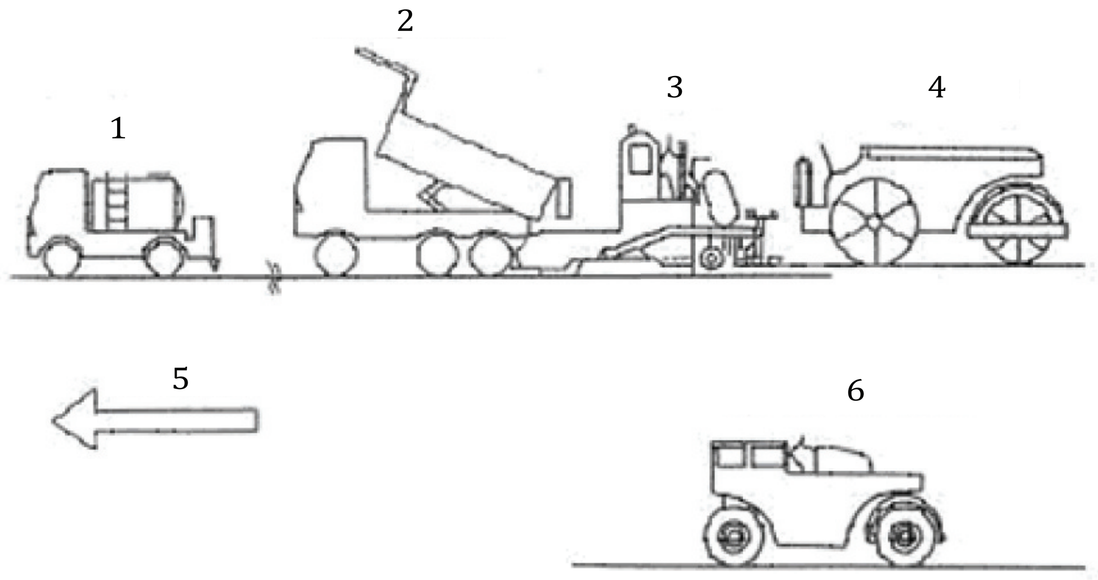
a) The courses should be constructed conforming to the correct cross-section and vertical profile, and in a smooth manner.

b) Courses should have a density as large as possible.

c) Texture should be uniform, corresponding to the grading of the mixture.

d) Transverse joints, longitudinal joints, and joints abutting structures should be thoroughly compacted and adhered to each other.

Figure C.13 is an example of the fleet of equipment used for road construction.



Key

1 distributor
2 dump truck
3 finisher
4 steel roller
5 direction
6 pneumatic tyre roller

Figure C.13 — Example of the fleet of equipment used for road construction

C.4.3.2 Spreading

A tack coat should be applied to the surface prior to spreading. For the hot mixing method, it is essential to complete the construction before the mixture has cooled. Accordingly, the mixture should be evenly spread out immediately after it is delivered to the construction site to obtain an appropriate profile.

The mixture should generally be spread by means of an asphalt finisher, although it can be spread manually in small areas where it would be difficult to operate a large piece of equipment, such as access areas, enfolded areas, and sections with small curvatures.

Attention should be paid to the following points during the spreading.

a) Temperature of the mixture spreading should be over 140 °C, although it can be dependent on the viscosity of the asphalt.

b) Spreading operation should not be conducted under windy conditions in winter, even if the temperature is above 5 °C.

c) The spreading operation shall be immediately terminated if it begins to rain during the operation.

C.4.3.3 Compaction

The hot mixture should be compacted immediately after spreading. It should be thoroughly compacted to achieve its prescribed density. Compaction should be conducted using a steel roller and a pneumatic tyre roller.

Breakdown rolling operation should be conducted under a temperature as high as possible, making sure that there is no deformation of the mixture and no hair-line cracks developed.

Second rolling should immediately follow the breakdown rolling and be thoroughly conducted.

Finish rolling should be conducted while it is still possible to erase roller marks. The typical speed of a steel roller is 2 km/h to 3 km/h and that of a pneumatic tyre roller is 6 km/h to 10 km/h.

Compaction operations should be conducted in the following order:

a) breakdown rolling (1 to 2 back and forth runs), with a steel roller;

b) second rolling (8 to 10 back and forth runs), with a tyre roller;

c) finish rolling (1 to 2 back and forth runs), with a steel roller.

C.4.4 Examples of the actual construction of test tracks in Japan

Forty test tracks in Japan were investigated in terms of the mass of aggregate and the measurement results of the test tracks which fulfil the tolerance of Figure C.12 are shown in Table C.6.

Table C.6 — Mass of aggregate (40 test tracks in Japan)

	Max.	**Min.**	**Average**
Stones (S_M > 2 mm)	54,5 %	46,9 %	52,2 %
Sand (0,063 mm < S_M < 2 mm)	43,9 %	36,6 %	39,0 %
Filler (S_M < 0,063 mm)	10,4 %	7,5 %	8,8 %
NOTE S_M is square mesh sieve size.			

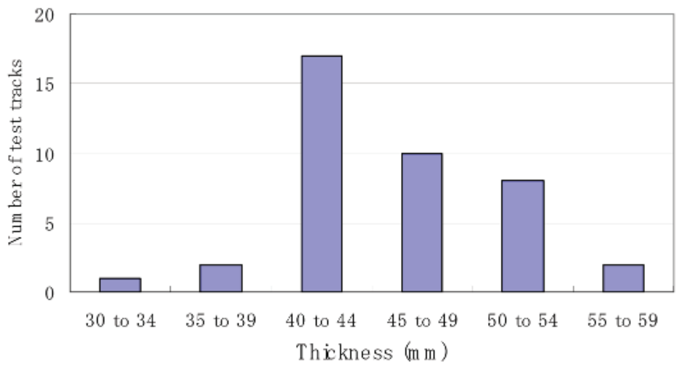


Figure C.14 — Top layer thickness of ISO test tracks in Japan (40 test tracks in Japan)

Coring work is usually conducted on the site in order to check the compaction and the thickness. The target compaction is 98 % to 100 %.

The mean ISO test track surface compaction value at a site, which is determined by cores taken at the site, ranges from 96 % to 99,5 % over 53 sites with the grand average value of 97,5 %.

When ambient temperatures are high, current ISO test track surfaces tend to be heavily damaged by heavy vehicles, because only straight asphalt is permitted to be used as binder under the requirement of this International Standard. It is recommended to avoid the acceleration noise tests when the surface temperature is 50 °C or higher. Polymer-modified asphalt can be one of the solutions to this problem.

NOTE See Reference [21].

C.5 Example from USA

Mix design

Superpave mix design procedure according toAASHTO MP2:

— N-design of 60 gyrations;

— maximum aggregate size of 9,5 mm (8 mm maximum not available);

— aggregate quality requirements;

— use of lime: permissible up to 1 % mass fraction of aggregates;

— Los Angeles Abrasion Criteria: percentage loss of the coarse aggregate by the LA Abrasion test (AASHTO T 96) shall not exceed 48 % except that, for Sandstone and Blast Furnace Slag, the LA Abrasion shall not exceed 55 %;

— clay content: amount of clay material, as indicated by the sand equivalent, measured on the aggregate passing the No. 4 (4,75 mm) sieve as determined by AASHTO T 176, shall be no less than 45 %;

— Recycled Asphalt Pavement (RAP): forbidden;

— gradation;

Table C.7 — Sieve size control point

	Control point (percentage passing)	
Sieve size	**Minimum**	**Maximum**
No. 200 (75 µm)	6	12
No. 16 (1,18 mm)	30	60
No. 4 (4,75 mm)	75	100
9,5 – maximum	95	100

NOTE This mix has no Restricted Zone and up to 5 % can be retained on 9,6-mm sieve.

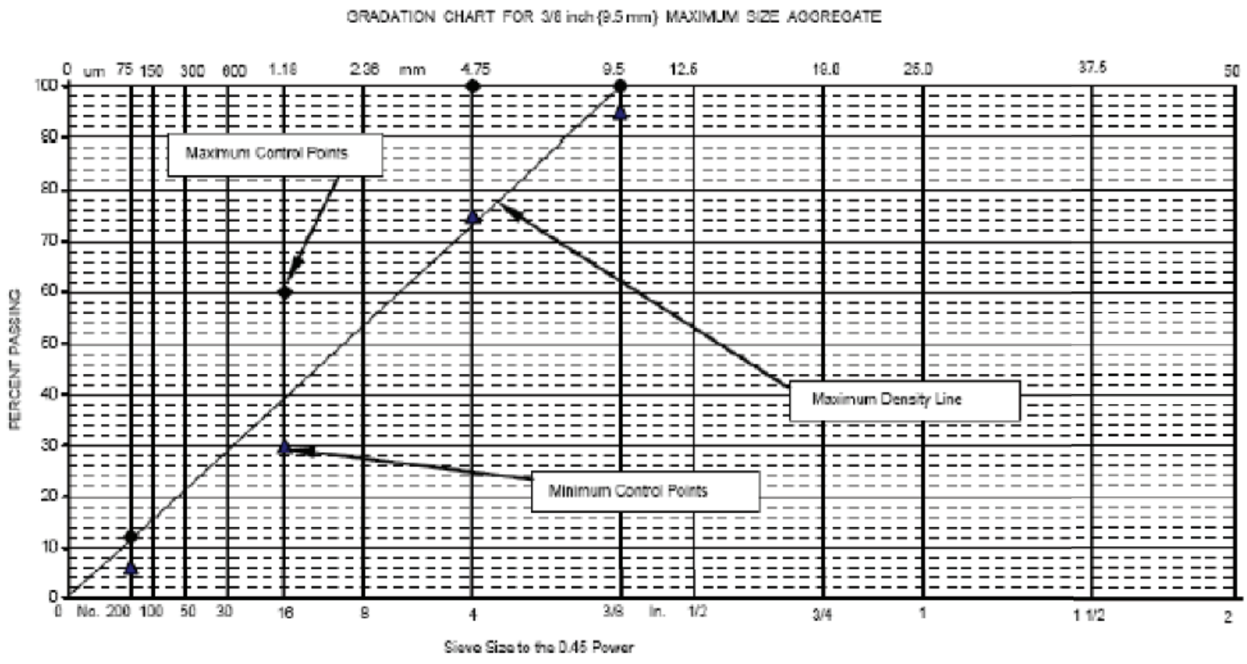


Figure C.15 — Graduation chart

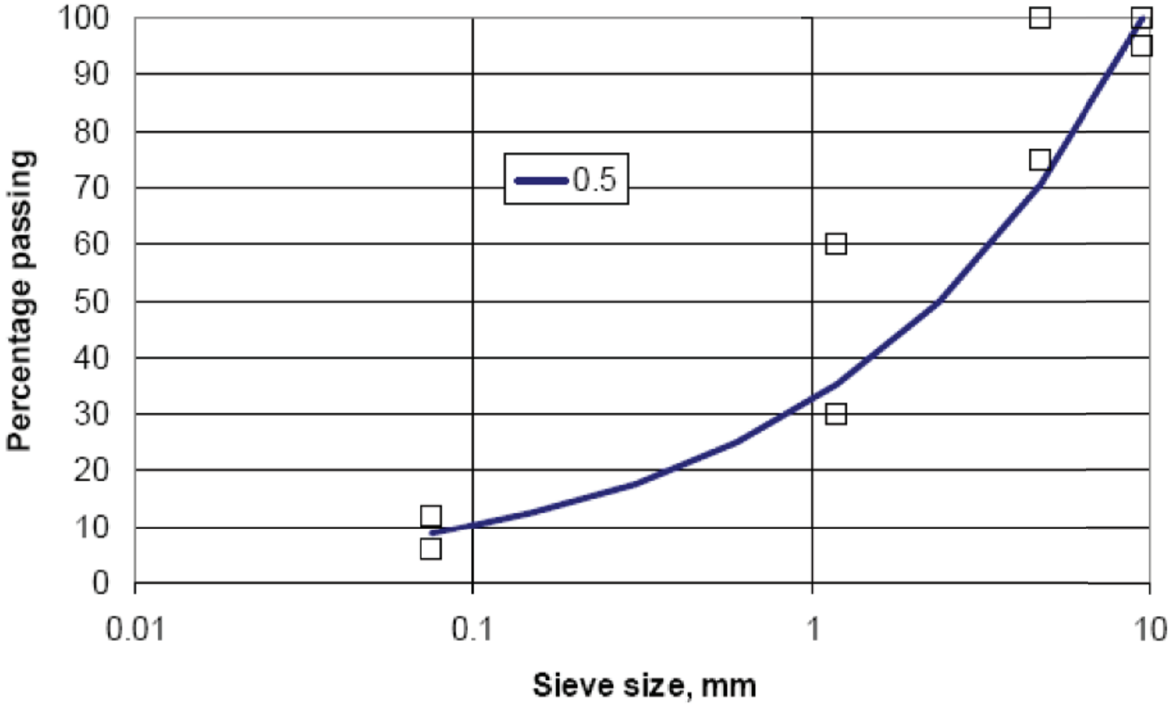


Figure C.16 — Aggregate graduation

- Coarse Aggregate Angularity: 85/80;
- Fine Aggregate Angularity: minimum 45;
- asphalt binder selected as per climatic zone (modified allowed) [PG76-22];
- design air voids = 4 %;
- VMA = 16,5 to 18;
- binder content ≥5,9 %;
- dust proportion: 0,9 to 2,0;
- moisture resistance: tensile strength ratio (TSR) ≥0,8;
- rutting test requirement: depending on traffic density and axle load.

C.5.1 Construction

1) Mixing temperature shall not exceed 180 °C (target 135 °C to 145 °C).

2) Compaction thickness (minimum and maximum): The final surveyed thickness of completed sections shall average no more than 5 mm from the specified target with a standard deviation within the section of no more than 2,5 mm.

3) Trial mixes: At least 20 t of uniform trial mix will be produced and placed by the contractor by spreader and compacted in the vicinity of the track at the thickness and location as directed.

4) All test sections shall be compacted to a target density of 94 % of Theoretical Maximum Density (TMD, Rice density). The mean absolute deviation shall not exceed 1,2 % from 94 % of the TMD.

C.6 Example from The Netherlands

The Netherlands test tracks was build according to the present ISO guideline, more specific the sieving curve was used.

The ISO guideline is very close to the Netherlands standard for dense asphalt concrete 0/8 mainly used in cities.

a) Mix design:

   1) on sieve 8 mm: 0 % to 6 %;

   2) on sieve 5,6 mm: 10 % to 30 %;

   3) on sieve 2 mm: 52 % to 58 %, target = 55 %;

   4) on sieve 63 µm: target of 100-8 (density filler/2 700), minimum of 0,5 %, maximum of +1 %;

   5) bitumen content (on 100 % mineral): 6,6 % to 7,0 %;

b) Performance requirements:

   1) Marshall stability >7 000;

   2) Marshall flow: 2,0 to 4,0;

   3) Marshall quotient >2 500;

   4) void content (check with weight test) <4,0 %;

c) Building properties of The Netherlands test track:

   1) stone type: “Bestone” (granite type with improved PSV and good “sticking”);

   2) supply: 2 mm to 6 mm (21,6 %) and 4 mm to 8 mm (34,3 %), a total of 55,9 %;

   3) measured:

      i) sieving curve: C8 (2,3 %), C5,6 (17,9 %), C2 (54,7 %), 0,063 (92,3 %), bit (6,7 %);

      ii) composition of 2,0 mm to 0,06 mm:

         — crushed sand (75 %) and fine sand (25 %);

         — 20,0 mm to 0,5 mm (55 %), 0,5 mm to 0,18 mm (30 %), 0,18 mm to 0,06 mm (15 %);

      iii) filler: 7,7 % (type “wigras 40K” about 6,1 % and own dust about 1,5 %);

      iv) bitumen: 6,7 % (on 100 % mineral), type straight 70/100;

   4) laying temperature: 130 °C to 140 °C;

   5) compaction: steel roller with factor (defined load/width [diameter]^2) about 0,4;

   6) void content: 2,4 % to 3,0 %.

Annex D
(informative)

Improvements on ISO 10844:1994

First edition (ISO 10844:1994**) technical method**	**Improvements in this International Standard**	**Effect of improvements**
Straight bitumen	Polymer modified Bitumen allowed	Improved stability of acoustic properties over time due to reduced surface wear. Bitumen can be chosen to match the climatic conditions of the track.
Flatness and smoothness required but not defined	Flatness and smoothness defined with test method	Quality control of track in the megatexture to unevenness ranges improved. Uneveness limited by specification.
Texture specification by sand patch mean texture depth (MTD)	Measurement of texture by machine fulfilling ISO 13473-3	Reduced variation in measurements due to differences in hand process. Elimination of the possibility to manipulate the results.
Texture (MTD) specification one-sided	Bounded texture specification	Eliminates the possibility of the texture becoming large. Acoustically, this reduces the variation in loud direction.
Sieving curve informative	Sieving curve normative as MPD chosen as texture descriptor	Reduction in variation.
Absorption implied by void content or directly measured by core samples with a limit of 10 % average over band	Absorption measured by *in situ* device with specification of 8 % in each 1/3 octave band.	1) *In-situ* testing vs. destructive testing eliminates the cracking and repair concerns. 2) Performance requirement on absorption eliminates the possibility that a track can meet void content but not meet the expected absorption. 3) Change in absorption specification provides control of the track and provides reduced variation between different test sites, i.e. that some of the tracks are less noisy than others.

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