INTERNATIONAL STANDARD

ISO 10844

Second edition
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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
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 10844 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*, in cooperation with ISO/TC 22, *Road vehicles.*

This second edition cancels and replaces the first edition (ISO 10844:1994), of which it constitutes a technical 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 may 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, 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 ISO 10844:1994, 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/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.

This International Standard is a revised version of ISO 10844:1994, 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/WG 42 for analysis before the next periodical review.

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

ISO 10844 is quoted in several International Standards (e.g. ISO 362, 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/road noise emissions.

The surface design given in this International Standard:

— produces consistent levels of tyre/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;

— 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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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 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 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 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 Refer to 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 63 mm to 500 mm of centre wavelengths

NOTE Peak-to-peak amplitudes normally vary in the range 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/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 0,63 mm to 50 mm of centre wavelengths

NOTE Peak-to-peak amplitudes may normally vary in the range 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/road interface. Surfaces are normally designed with a sufficient macrotexture to obtain suitable water drainage in the tyre/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 (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 Definition from 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

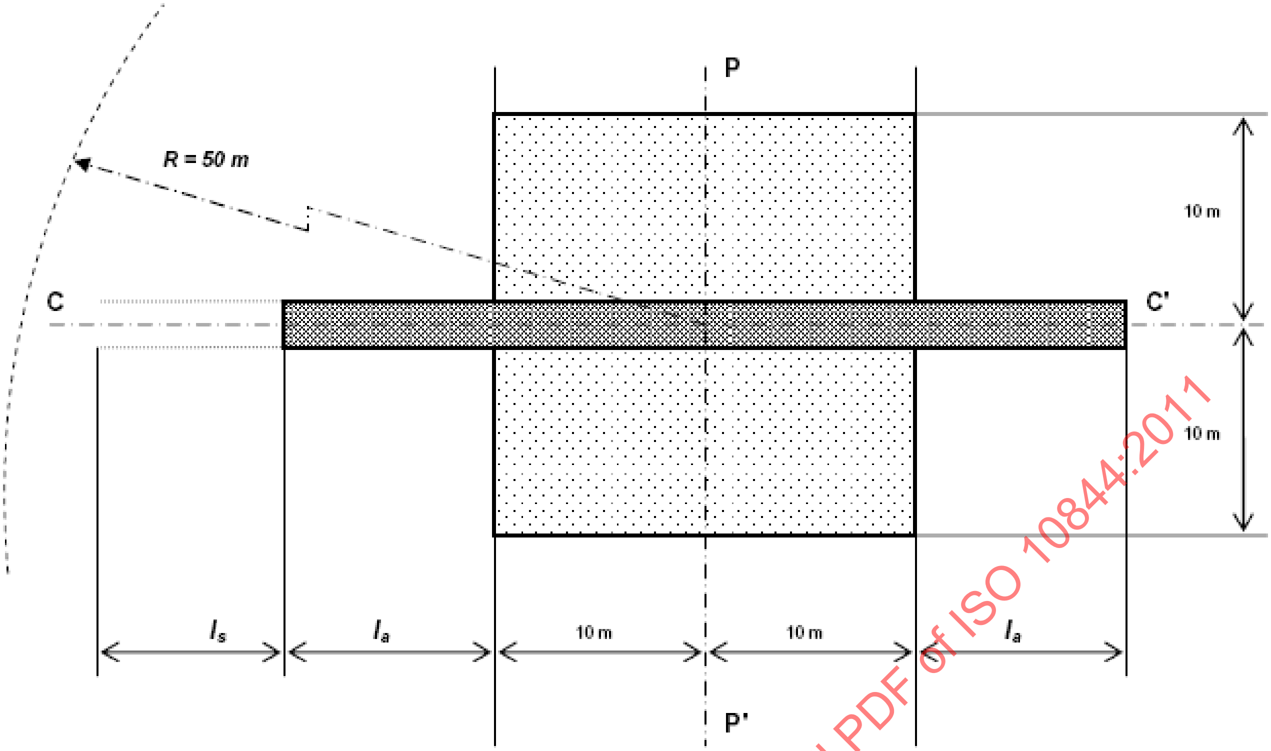
NOTE Adapted from ISO 13473-1:1997, 3.5.4.

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
A	propagation area
dotted area	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 centered 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, trucks	For long vehicles with rear engine, having a distance of more than10 m between 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 362-1of the test track according to the purpose of this requirement

NOTE 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

a) 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.

b) 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 may 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);

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

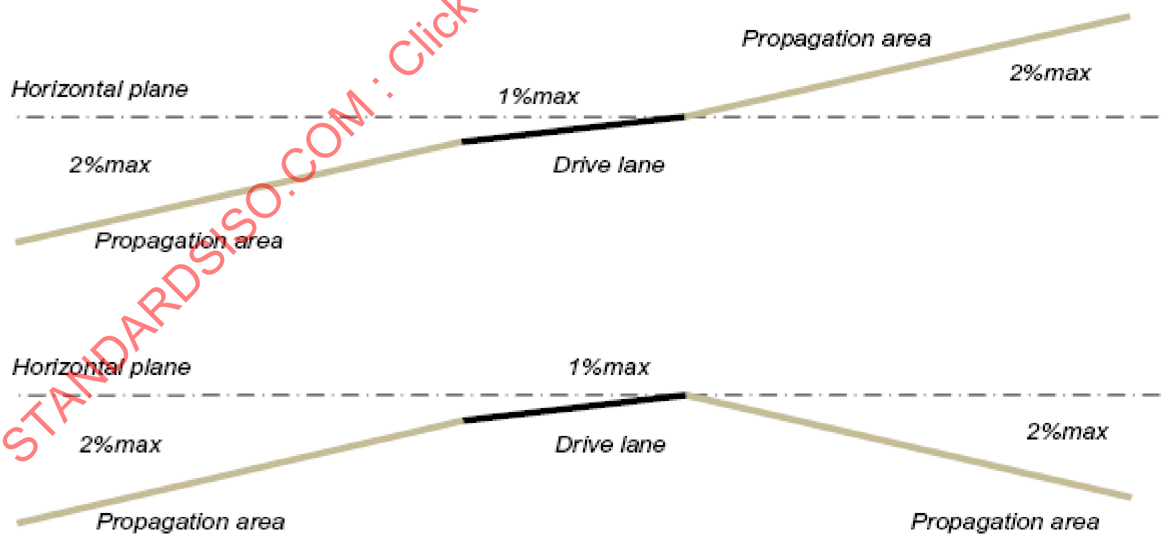
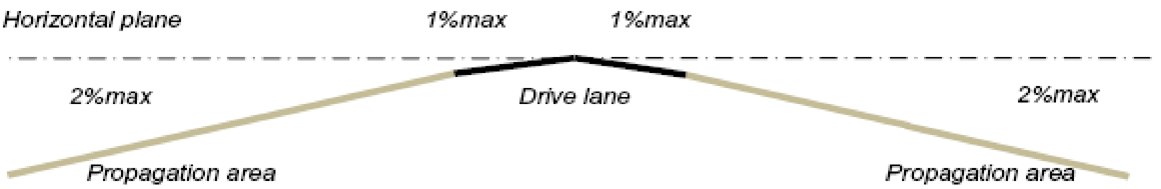


Figure 2 (*continued*)



Key

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 $0_{0}^{+0,02}$ m (see Figure 3).

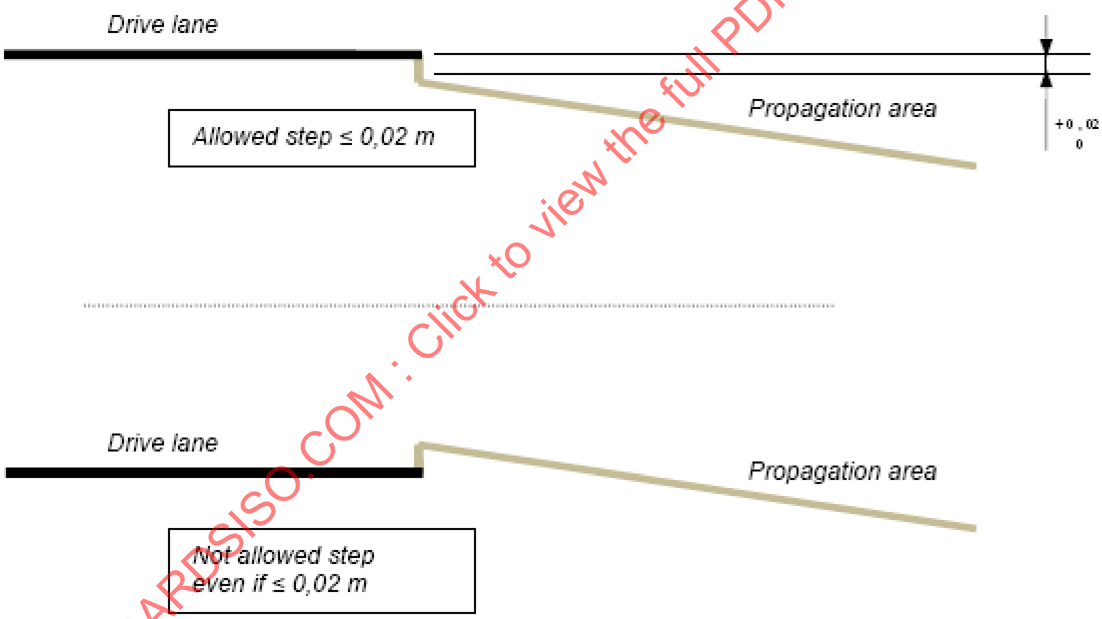


Figure 3 — Propagation area – Steps or discontinuities

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 or equal than 30 mm,

e) have a Mean Profile Depth 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.

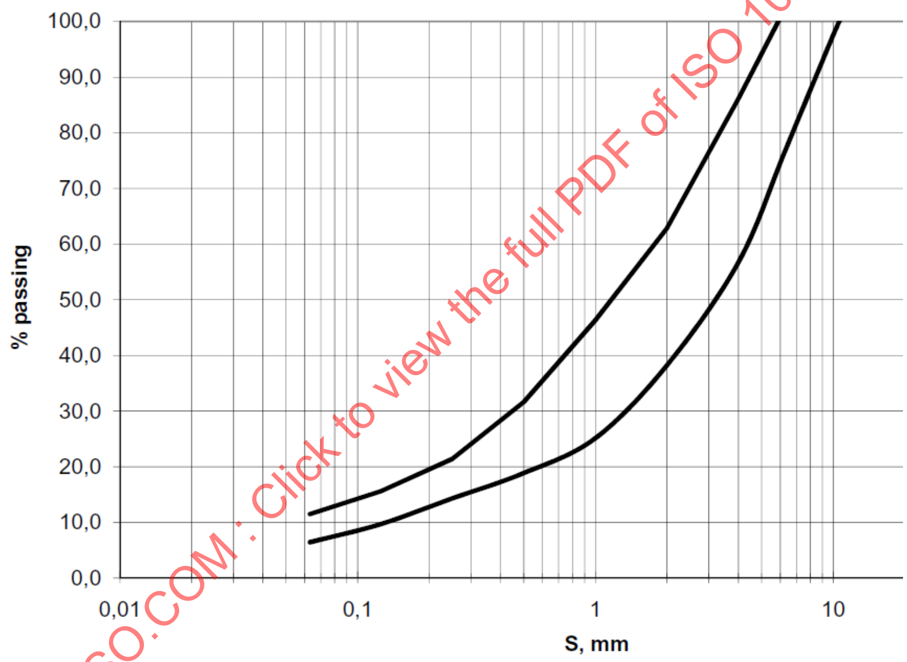


Figure 4 — Sieving curve area

NOTE Until more results for validation are available, END_T is not part of the normative part of this International Standard. The present state of the art with respect to this method is described in Annex A but is restricted to cases where no elastic material (rubber, polyurethane, etc) is applied in the top layer or sub-layers except for modification of bitumen by less than 1 % by mass of the total mix. Polymer-modified bitumen allows higher termperature operation and reduced surface wear.

4.4 Conformity tests

a) The surface properties for each requirement shall be determined at the following occasions before the acceptance of the track (refer to Table 2);

b) During the periodical checking of the track (refer to Table 2);

c) 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);

d) For sound absorption, texture, 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;

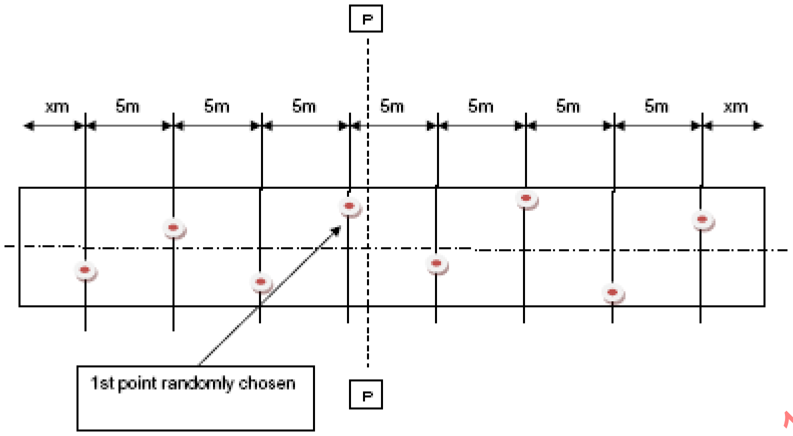


Figure 5 — Measurement positions on test track, example for l = 40 m

e) After 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.

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.
Texture		× MPD 0,5 mm ± 0,2 mm	N.A.	× MPD 0,5 mm ± 0,2 mm 2 years[a]	N.A.
Absorption		× (8 % max)	× (10 %max)	× (8 % max) 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 (as per 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 construction or 1 000 passes after 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 length and 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 13473-3 for END_T. The measurement instrumentation shall meet the requirements of class DE defined in ISO 13473-3.

Additional details to ISO 13473-1 — MPD shall be measured in the wheel tracks of the driving lane and the following two options may 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 (refer to ISO 13472-4).

5.2.2 Texture profile data pre-processing

Removal of spike data is necessary. For details refer to ISO/TS 13473-6.

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 information required for construction approval or periodical inspection, whatever is applicable.

Example:

a) General information

- Owner
- Contractor's name
- Date of 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 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 providing 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/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 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 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 13473 and be expressed as levels re. 1 µm in decibels.

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

$$\Delta L_{tx,\lambda} = L_{tx,\lambda} - L_{tx,ref,\lambda} \tag{A.1}$$

Values for the $L_{tx,ref,\lambda}$ 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 in mm	$L_{tx,ref,\lambda}$ in dB	f in 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

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

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

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

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

Table A.3 — Values for the reference noise levels

Index i	f **in Hz** (one-third octave)	L_{mi} **in 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 **in 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 $\Delta L_{\text{tx,5 mm}} = L_{\text{tx,5 mm}} - L_{\text{tx,ref,5 mm}}$

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

A.7 Calculation of END_T

$$END_T = 10 \lg(A/B) \text{ dB} - C \quad \text{(A.5)}$$

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 measured one-third-octave-band spectrum

λ in mm	$L_{tx,\lambda}$ in 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 in mm	$\Delta L_{tx,\lambda}$ in dB	f in 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	1111

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}, Equation (A.2) can be evaluated as:

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

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

Index i	f in Hz	$\Delta L_{\text{tx},i}$ in 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	1000	2,7

— Calculate the term B

Using the values from Table A.3 for the $L_{\text{m}i}$, Equation (A.3) can be evaluated as:

$$B = 1{,}56 \times 10^7$$

— Calculate the term C as follows

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

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

— Calculate END_T:

END_T can now be evaluated with Equation (A.5):

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

$$= -0{,}4\ \text{dB}$$

Hence, based on the texture data, the example surface is expected to be 1,6 dB noisier 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 may alter the texture such as rotating steel brushes, high pressure water spray etc. The dust should be sucked off or brushed off.

Salt may 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 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/road noise levels measured on the test surface increase slightly during the first 6 months to 12 months after 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 may be affected.

The stiffness of the base and sub grade 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 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 fulfilment of the specification at the first attempt. Any other construction practice may 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 sub-base shall ensure stability and evenness according to best road construction practice.

IMPORTANT — In the practices illustrated by the following examples, coring is used because ISO 10844:1994 required void content or absorption. Today, void content is replaced by non-intrusive methods.

C.3 Example from Germany

C.3.1 Sub layers

a) New construction of a test track

In the case of a completely new road construction, base and sub-base 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

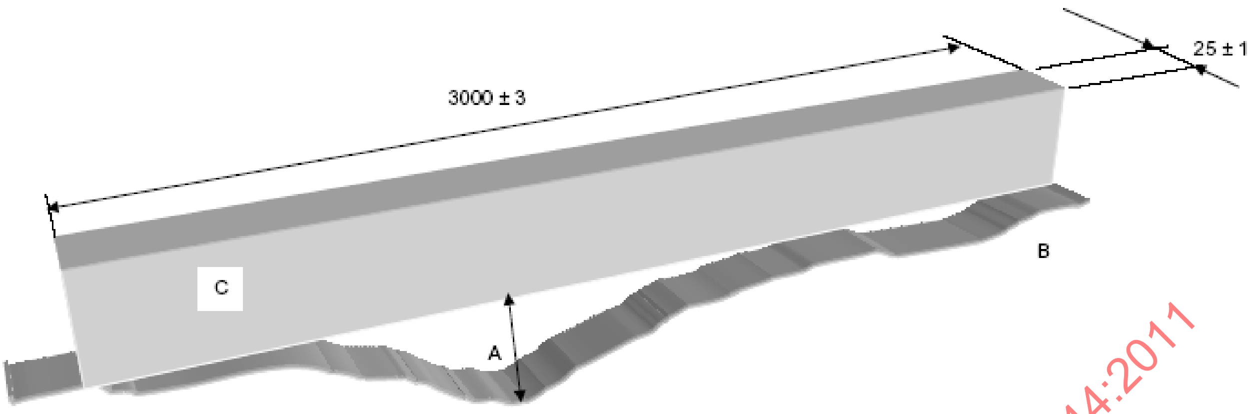


Figure C.1 — To check the unevenness using the straightedge method

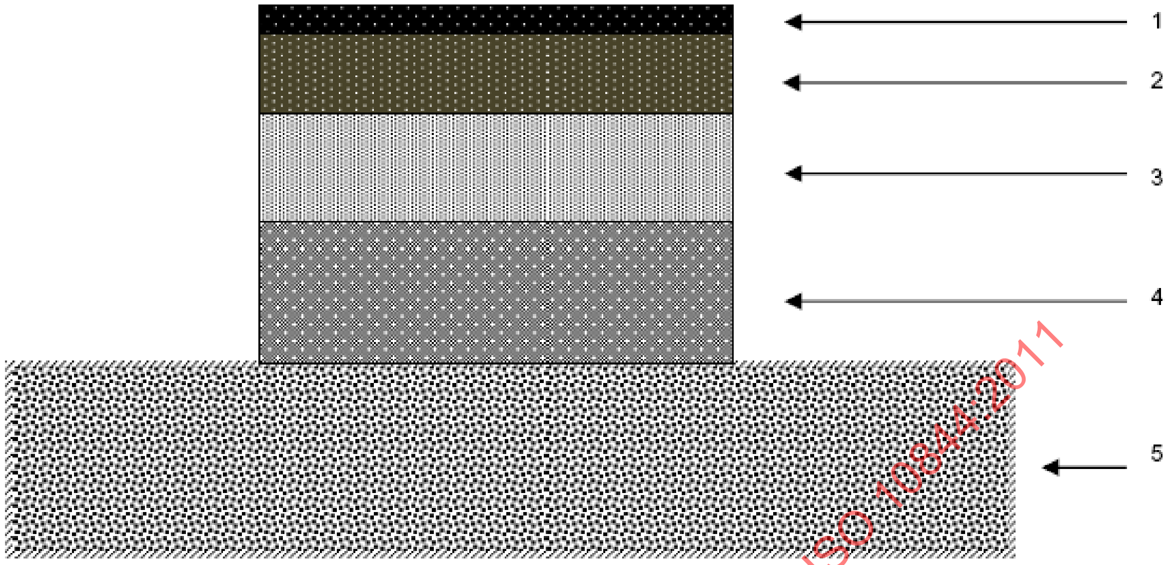
NOTE 1 For checking the 2 mm requirement, the distance between the straightedge and the surface can be measured using a staggered gauge with steps of 0,1 mm as described in EN 13036-7. If laser profilometer is used, care shall be taken to obtain equivalent result, i.e. not considering very localized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

NOTE 2 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)]: $E_{v2} \geqslant$ 150 MN/m^2;

— For the natural soil[2)]: 60 MN/m^2 $\leqslant E_{v2} \leqslant$ 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 EN 13286-47[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 sub-base (first layer / tout venant)
4 Subgrade (mix granulat base course)
5 Natural soil or soil stabilised by lime E_{v2} XX

Figure C.2 — Schematic of the layers - Recommended value for E_{v^2}

NOTE 3 Depending of the Young's Modulus of the natural soil (E_{v2}) asphalt sub-base, sub-grade will be 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 asphalt binder and sub-base must 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.

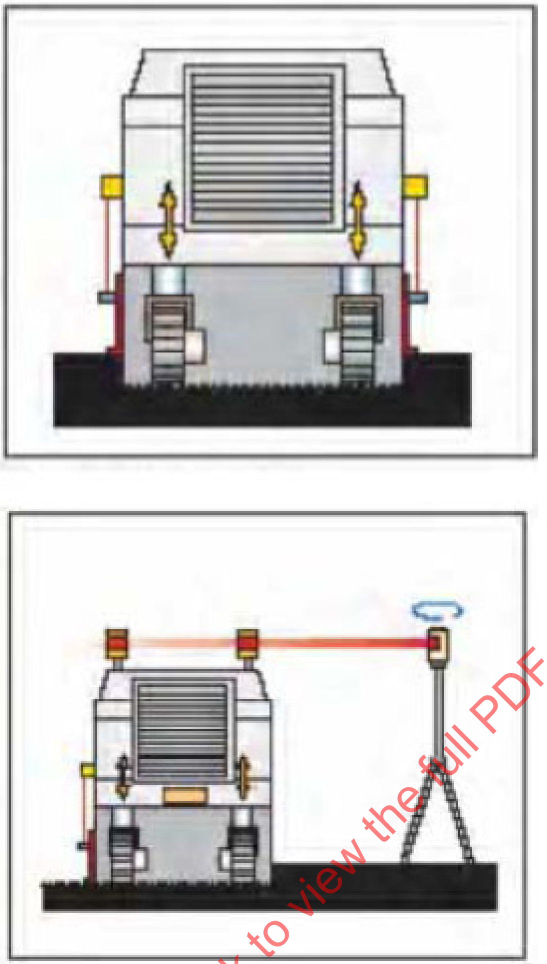


Figure C.3 — Renewal of the asphalt concrete top layer (wearing course)

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 must be avoided. Firm adhesion between the new top layer and the milled plane must 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; moraine has not 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, (EN 13043; see also 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 maximum chipping size shall be 8 mm nominal (tolerances in the range 6,3 mm to 10 mm as per 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 less than 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 local supply, but shall not exceed 0,09 mm.

The filler fraction fines of the crushed rock ($\leqslant$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 may be 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:

— $\leqslant$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 size grading of the mineral components of the mixture is given in Table C.1.

Table C.1 — Example of size grading of 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	100,0	100,0	100,0	100,0	100,0		
[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 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.

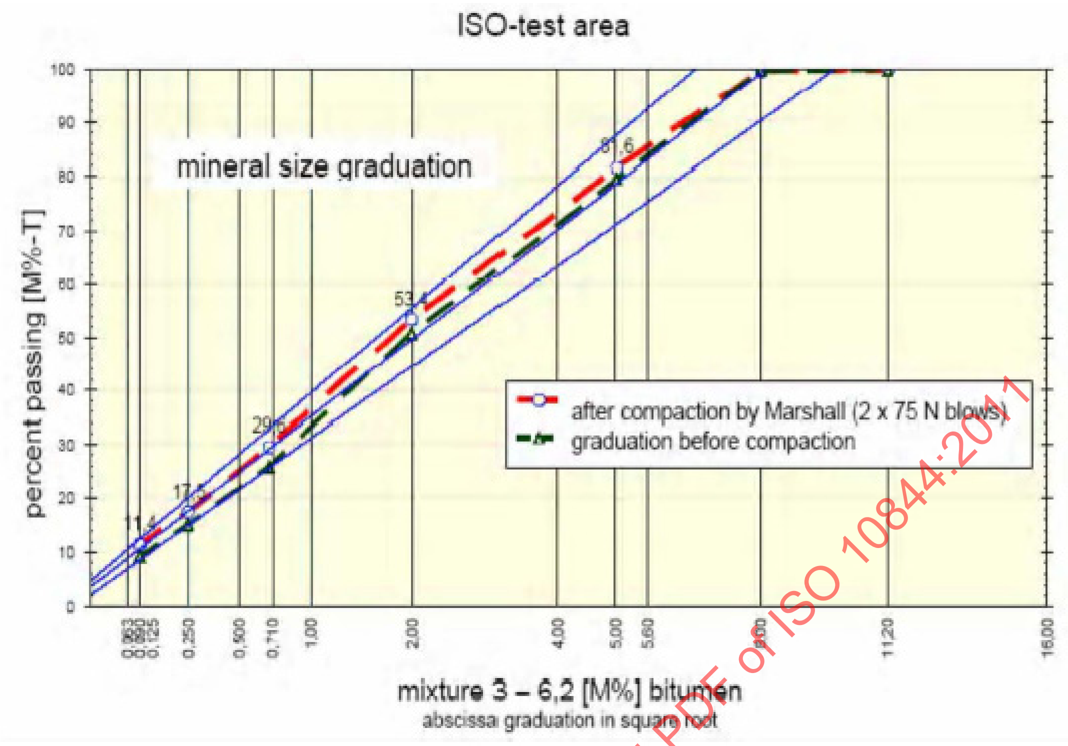


Figure C.5 — Mixture tolerance

The grading curve fits the following equation:

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

where

P is (the amount passing the sieve, expressed as percentage by mass) mass % passing the sieve

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 values		Tolerances
	By total mass of mix	By mass 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

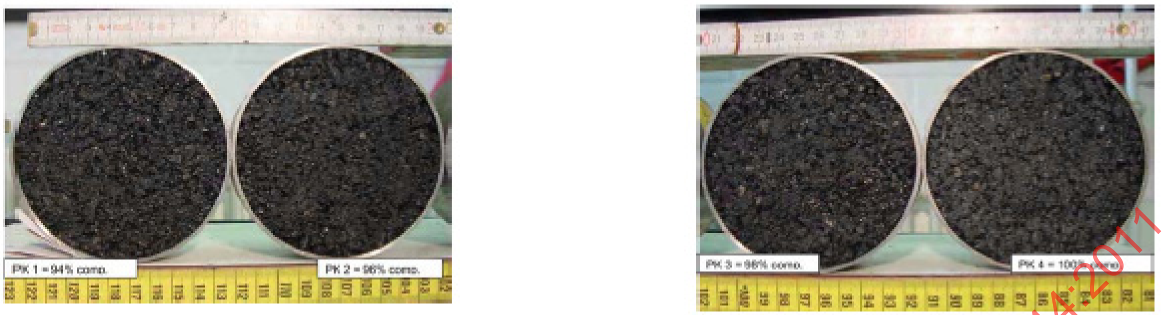


Figure C.6 — Example for compaction sample

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).

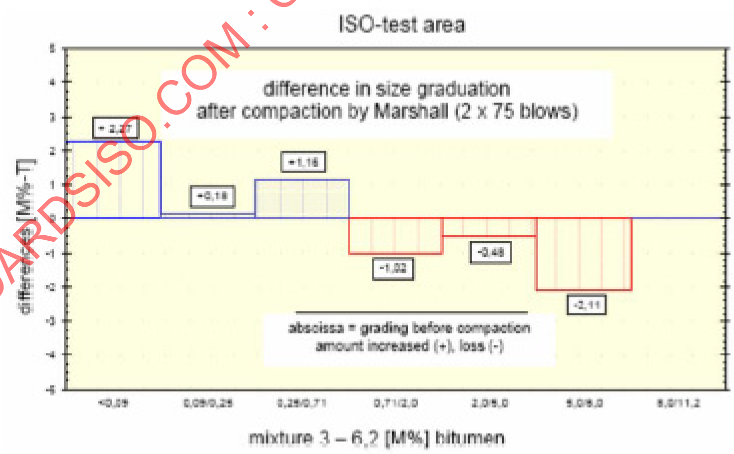


Figure C.7 — Illustration of fragmentation of larger aggregates into smaller ones by Marshall compaction

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

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

and

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

The five couples (ε_{M-F}, ε_{B+F},) must 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:

- grain size distribution,
- and bulk density,
- and grain shape,
- and surface roughness.

The sequence of a mix design is presented as an example, which is valid for asphalt concrete 0/8 mm according to ISO 10844.

NOTE 1 M%T is the percentage by mass 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 may 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

	Mineral type/fraction	Eff.spec. Density in g/cm^3	M %	volumes 4:3 in cm^3/100 g	Weight In g for specimen
M%T					
1	2	3	4	5	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					
106,38	Asphaltic mixture		100,00	*39,554	1260

Eff. Spec. density ρ_R		g/cm^3	2,528
Bulk density ρ_A		g/cm^3	2,380
Air voids $H_{bit.}$		Vol.-%	6,62
Compaction by Marshall 2x50 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	$V_{M\text{-}F}$	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	41,6
			filler	bitumen

* Column 5 selected the change from M % to Vol.-%

* The reciprocal of 39,554 × 100 = 2,528 g/cm^3 = specific density of mixture

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

Five Marshall samples of increasing mortar volume (1) - (5) subjected to two different compactions:

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

— increased compaction: 2 × 75 (blows),

to take into account the higher axle loads of heavy trucks on the test track, (to) and obtain 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

	Mineral type/fraction	Eff.spec. Density in g/cm^3	M %	Volumes 4:3 in cm^3/100 g	Weight In g for specimen
M%T					
1	2	3	4	5	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
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	Grtstone-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	Limestone<0,09	2,729	5,97	2,188	75,2
1,17	Limestone>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 mixture		100,00	*39,803	1260

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 2x50 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

$$\varepsilon_{(M-F)} = \frac{V_F + V_B + V_L}{V_{M-F}} \quad [1] \quad 0,364$$

$$\varepsilon_{(B+F)} = \frac{V_F + V_B}{V_{M-F}} \quad [1] \quad 0,302$$

proportion filler: bitumen	F:B = const.	M %	58,4	41,6
			filler	bitumen

* Column 5 selected the change from M % to Vol.-%

* The reciprocal of 39,803 × 100 = 2,512 g/cm^3 = specific density of mixture

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 result 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.

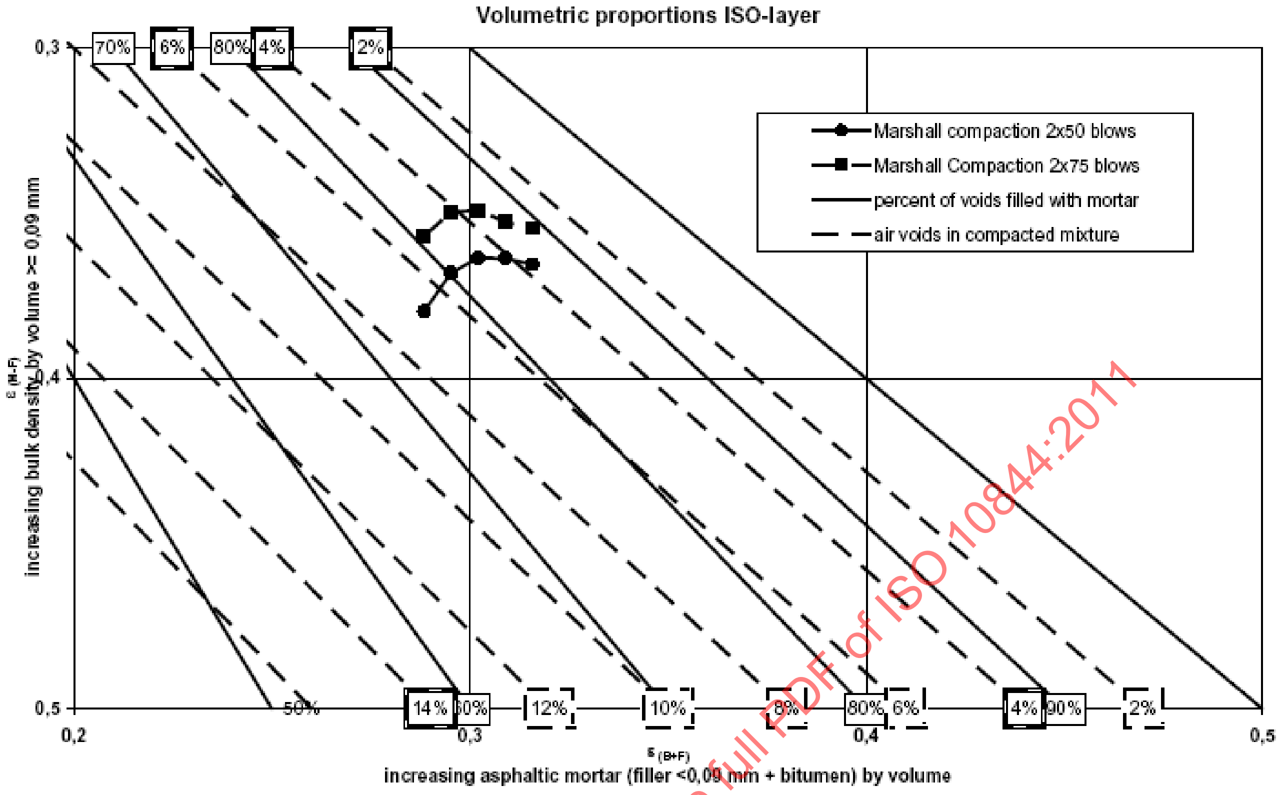


Figure C.8 — The ε_{B+F}, ε_{M-F} curves

It is advisable to repeat this procedure of the Marshall test, with the Marshall samples which have identical compositions, but which are produced with a non standard 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 weight,

— Filler ±1 % of its own weight,

— Sand ±1 % of its own weight,

— Chippings ±1 % of its own 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 construction machinery and their usage

a) Cutter(s): Only precise levelling cutters can be deployed, cutting line distance 6 mm with precision control engineering as a prerequisite for the evenness and uniform thickness of the new layer. The old surface must 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 able to be processed cold.

   Self-adhesive jointing tapes are not suitable.

b) Paver (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 must 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, refer 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 may not reverse in the measuring field, because this leaves measurable bumpiness. For the same reason, vibration compaction in the 2nd passes is only admissible after static pre-compaction.

   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 must completely cover the whole lane width.

   The roller width must exceed half of the track width.

   Thus two steel rollers are required per lane.

   Service weight 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 1st roller train. Damped vibration can also be applied for this purpose; the rollers must be equipped with controllable vibration equipment: e.g. frequency 50 Hz, amplitude $\leqslant$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 $\geqslant$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 may not be accessed until they have cooled down completely. The radiometric probe must 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 are only possible at least 24 h later.

The importance of the sub layers is to provide the necessary stability and evenness (see C.3.1 sub layer). 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 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 weight 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 may 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 must 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 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; 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 CBR (California Bearing Ratio) value and the road classification 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 must 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

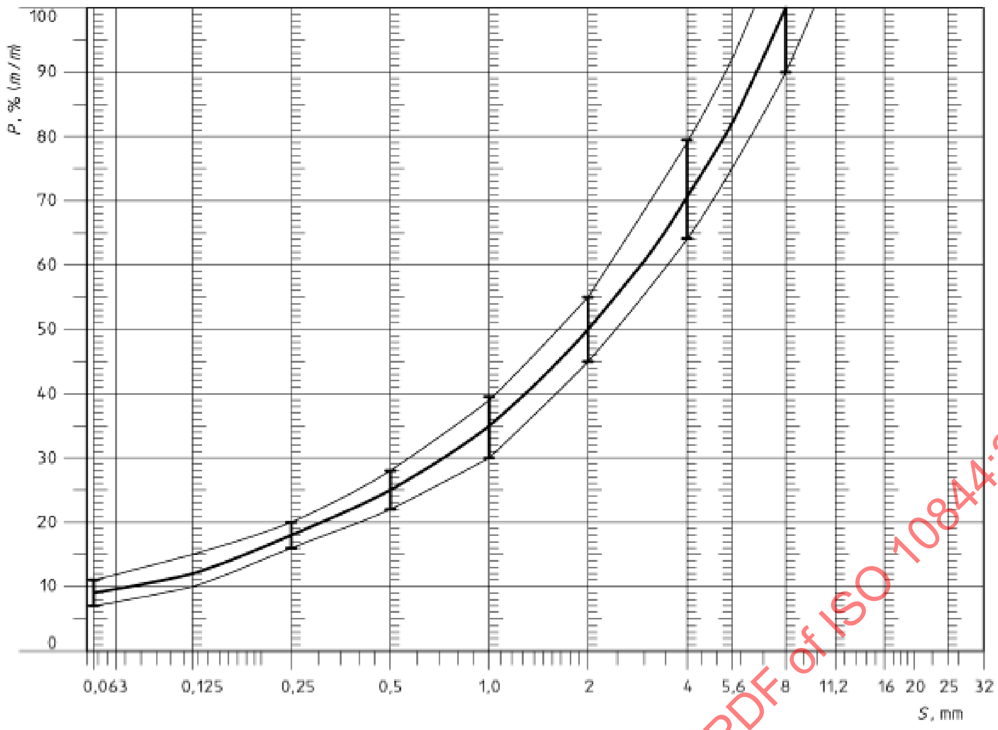
The mixture design should be processed in the following order:

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

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

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

4) 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 procedure.

1) 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 mixture composition for stones, sand and filler. The amount of filler should not be changed, even if the binder content changes.

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

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

4) 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.

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

6) The common range of asphalt content which satisfies tolerance of 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 values		Tolerances
	By total mass of mixture	By mass of the aggregate	
Stones, S_M > 2mm	47,6 %	50,5 %	±5 %
Sand 0,063mm < S_M < 2mm	38,0 %	40,2 %	±5 %
Filler S_M < 0,063mm	8,8 %	9,3 %	±2 %
Binder (bitumen)	5,8 %	N.A.	±0,5 %
Max. 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 %		
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 stability against traffic, resistance against abrasion and effects caused by the climate:

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

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

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

4) 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.