BS EN 13036-8:2008

Road and airfield surface characteristics — Test methods —

Part 8: Determination of transverse unevenness indices

ICS 93.080.10; 93.120

National foreword

This British Standard is the UK implementation of EN 13036-8:2008.

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

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Foreword

This document (EN 13036-8:2008) has been prepared by Technical Committee CEN/TC 227 “Road materials”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2008, and conflicting national standards shall be withdrawn at the latest by September 2008.

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Introduction

Road profile transverse unevenness affects safety and ride comfort. Transverse uneveness demands can differ from one road to another and are highly related to the speed limit, the kind of traffic, the climatic conditions, the accepted comfort limits, etc. Road profile transverse unevenness is consequently key information for acceptance of newly laid pavements and for road maintenance management systems.

Road profile transverse unevenness encompasses a variety of aspects, such as: the crossfall of the transverse profile, irregularities or different defects in the transverse profile (steps, ridges/dips and edge slumps) and the longitudinal ruts in the wheel paths caused by the traffic.

The measurement of road transverse unevenness has been a subject of much research for more than 70 years, resulting in many different measuring methods. Measurement devices can be split into:

- stationary equipment, such as e.g. the straightedge for irregularities and longitudinal ruts or rod and level for crossfall in single profiles,

- dynamic equipment, such as e.g. the profilometer, which is dependant on the characteristics of the device, suitable for measuring all mentioned aspects for single profiles as well as section (mean) values.

This European Standard has been written to be used in conjunction with the European Standards EN 13036-6 (Profilometer) and EN 13036-7 (Straightedge).

1 Scope

This European Standard defines the different transverse unevenness indices of the pavement surface of roads and airfields and the appropriate methods of evaluation and reporting.

The indices have been defined principally independent of the measurement device.

This European Standard focuses on transverse unevenness measurements for the following three purposes:

- indices to provide a means for quality control of pavement surfaces of newly laid pavements, especially with respect to crossfall and the evidence of irregularities due to improper laying and/or compacting action.

- indices to be used for evaluating the condition of pavements in service as part of routine condition monitoring programs. They are intended to detect transverse deformations caused by the traffic, pavement wear or subsurface movement.

- indices to be used for resurfacing activities on pavements in use.

The parameters and evaluation methods are applicable both for roads and airfields.

2 Normative references

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

EN 13036-6:2008, *Road and airfield surface characteristics — Test methods — Part 6: Measurement of transverse and longitudinal profiles in the evenness and megatexture wavelength ranges*

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
acquisition repetition interval
travelled distance between two consecutive transverse profile measurements

3.2
bias
difference between the expectation of the test results and an accepted reference value

NOTE Bias is the total systematic error as contrasted to random error. There may be one or more systematic error components to the bias. A large systematic difference from the accepted reference value is reflected by a large bias value (see ISO 3534-1).

3.3
crossfall
transverse gradient across a section or full width of a pavement measured perpendicular to the centre line

NOTE Crossfall can be expressed as a percentage, a ratio (e.g. 1 to 30) or as an angle to the horizontal. By convention, it is positive when the right end of the profile is lower than its left end for right hand traffic and the opposite for left hand traffic.

3.4
edge slump
deviation of the pavement edge below a straight reference line

3.5
irregularity
any deviation of a surface from the straight reference line

3.6
layer
structural element of a pavement laid in a single operation

3.7
pavement
structure composed of one or more layers of selected material designed to carry traffic

3.8
pavement surface or surface course
upper layer of the pavement that is in contact with the traffic

3.9
precision
closeness of agreement between independent test results obtained under stipulated conditions

NOTE Precision depends only on the distribution of random errors. The measure of precision is usually computed as a standard deviation of the test results. Less precision is reflected by a larger standard deviation (see ISO 3534-1).

3.10
repeatability
maximum difference expected between two measurements made by the same machine, with the same tyre, operated by the same crew on the same section of road in a short space of time, with a probability of 95 %.

3.11
ridge
any deviation above a straight reference line

3.12
dip
any deviation below a straight reference line

3.13
rut/pothole
any deviation below the straight reference line, normally in the wheel path

3.14
rut depth
greatest deviation of the transverse profile of a pavement surface and a virtual straight reference line of length L sliding on the surface of the profile within the limits of the analysed width, by leaving one edge of the rut towards the other edge.

NOTE 1 The length of the virtual reference should be mentioned within the results.

NOTE 2 Rut depth is normally expressed in millimetres.

3.15
section
length of road between defined points (e.g. location references, specific features or measured distances) comprising a number of subsections over which a continuous sequence of measurements is made

3.16
step
vertical displacement from the straight reference line

3.17
theoretical water depth
difference in elevation between a horizontal reference line going through the highest point of a transverse profile at the low side of the wheel path and the deepest point in the wheel path

NOTE 1 Theoretical water depth is normally expressed in millimetres

NOTE 2 Theoretical water depth is an indicator of the risk of aquaplaning. The theoretical water depth in a depression or dip is often called “pond depth”.

3.18
transverse profile
intersection between the road surface and a reference plane perpendicular to the road surface and to the lane direction

3.19
trueness
closeness of agreement between the average value obtained from large series of test results and an accepted reference value

NOTE The measure of trueness is usually expressed in terms of bias (8.3) and reflects the total systematic error as contrasted to random error. There may be one or more systematic error components to the trueness. A large systematic difference from the accepted reference value is reflected by a large value (see ISO 3534-1).

3.20
wheel paths
area of a pavement surface where the large majority of vehicle wheel passages are concentrated (see Figure 1)

4 List of symbols

X is the crossfall;

I_S is the step height;

I_R is the ridge height;

I_D is the dip depth;

I_E is the edge slump;

R_R is the rut depth right wheel path;

R_L is the rut depth left wheel path;

W_R is the theoretical water depth right wheel path;

W_L is the theoretical water depth left wheel path.

5 Parameters

5.1 General

The transverse profile can be characterized by the following parameters (see Figure 1):

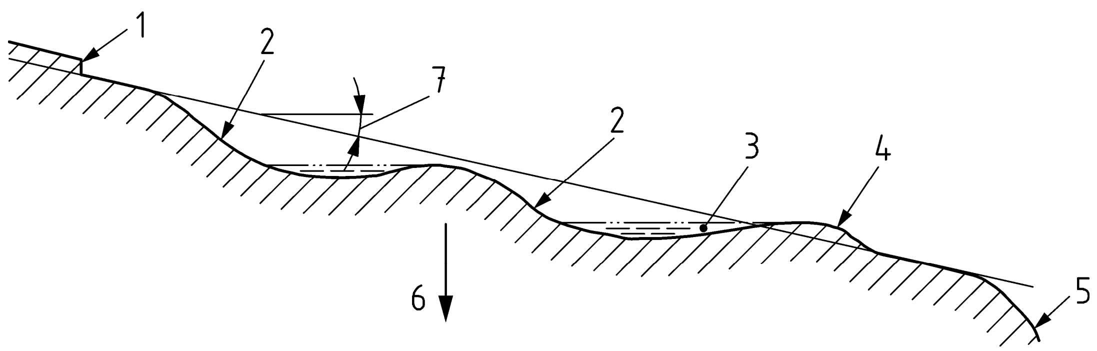
— the crossfall X of the transverse profile;

— the heights of the different irregular defects in the transverse profile, such as ridges/dips, steps and edge slump, the so-called irregularities I;

— the rut depth R in the wheel paths caused by the traffic;

— the theoretical water depth W in the ruts.

In the following the calculation principles of each of these parameters will be explained.



Key

1 step
2 rut
3 water depth
4 ridge/bump
5 edge slump
6 gravity

7 crossfall

Figure 1 — Schematic overview of the different characteristics of transverse unevenness

5.2 Crossfall X

Pavements are designed with a crossfall for traffic safety reasons, namely to make it possible to safely pass curves with different radius and for water drainage purposes.

Crossfall mean X is defined as the angle between the horizontal and the regression straight line through the transverse road profile fixed by at least seven measurement points across that profile. In literature this is often called the regression-line definition.

New pavements can be measured with a straightedge as described in Annex A.

5.3 Irregularities

Irregularities can be caused by improper laying and/or compaction in the construction phase or by deformations caused by the traffic, pavement wear or subsurface movement during the normal use of the pavement.

In the following the different types, such as steps, ridges/dips and edge slump, will be explained.

5.3.1 Step height I_S

The calculation principle of the step height I_S is shown in Figure 2.

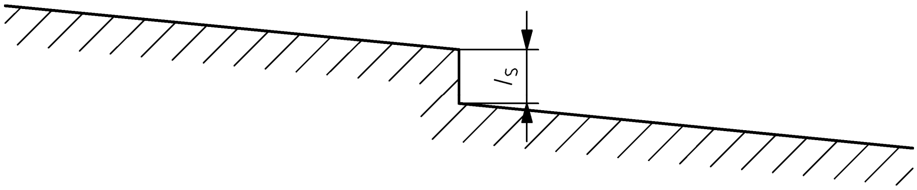


Figure 2 — Transverse profile of a pavement surface showing step height I_S

5.3.2 Ridges/dips, respectively I_R, I_D

The ridge I is defined as the distance between a straight reference line and the highest point of the ridge, see Figure 3.

When $I/p > 1$ there is a ridge; at lower ratio there are bumps.

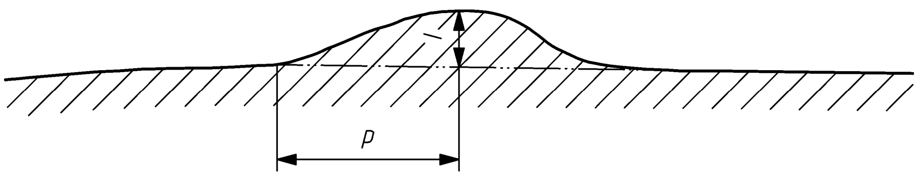


Figure 3 — Transverse profile of a pavement surface showing ridge height I_R

For calculation of the depth of dips the same principle can be used, with the difference that the distance between the straight reference line and the deepest point of the dip is measured.

5.3.3 Edge Slump I_E

The calculation principle of the edge slump I_E is shown in Figure 4.

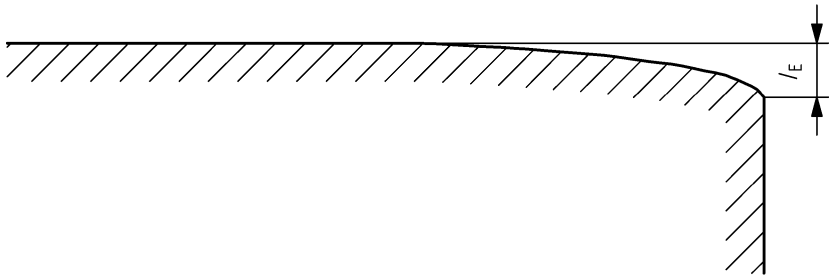


Figure 4 — Transverse profile of a pavement surface showing edge slump l_E

5.4 Rut depth R

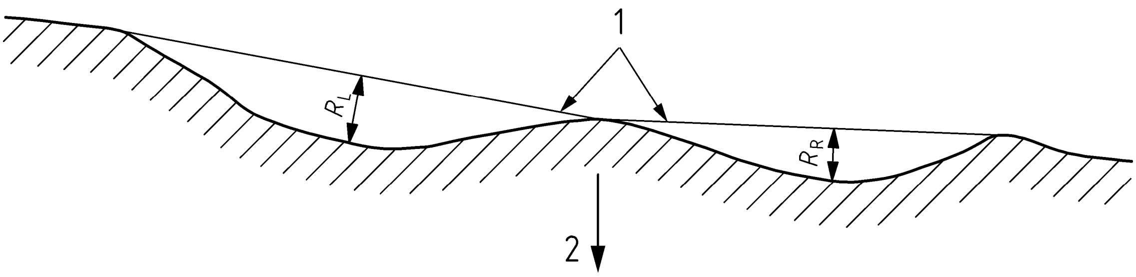
Ruts in the pavement surface manifest as a continuous depression in a longitudinal direction in the area of the wheel paths.

For traffic safety the rut depth, as well as the theoretical water depth is limited to a certain value, to avoid aquaplaning in wet conditions and to ensure sufficient lateral stability of vehicles with trailers (especially by a lane change).

Rut depth is determined per wheel path. In the common situation of two wheel paths per lane, rut depth values are notated as R_R and R_L (see Figure 5). In countries where studded tyres are used more than two wheel paths can occur due to wear from studs and deformation from heavy traffic. The transverse location of the wheels differs between heavy traffic and standard vehicles.

The rut depth is defined as the greatest deviation of the transverse profile of a pavement surface and a virtual straight reference line of length < L > sliding on the surface of the profile within the limits of the analysed width, by leaving an edge of the rut towards the other edge. In literature this method is often called the “Straightedge method”.

Usually the length of the virtual straight reference line is about 1,5 m to 2,0 m (about half the width of the lane). The length of the virtual straight reference line shall be mentioned with the results.



Key

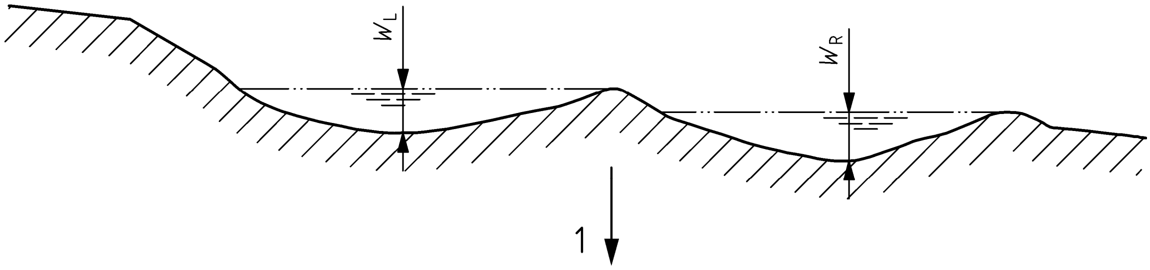
1 virtual straight reference line

2 gravity

Figure 5 — Transverse profile of a pavement surface showing the rut depths R_R and R_L

5.5 Theoretical water depth W

The calculation principle of the theoretical water depth is shown in Figure 6. Theoretical water depth can be calculated separately for both wheel paths.



Key

1 gravity

Figure 6 — Transverse profile of a pavement surface showing the calculation of the theoretical water depth W_R and W_L

6 Measurement devices and their application

6.1 Measurement devices

The following measuring devices shall be used:

- profilometer, a dynamic device suitable for measuring single profiles indices as well as sections (mean) values, as described in EN 13036-6,
- straightedge, a static device suitable for measuring single profile indices, as described in EN 13036-7 and Annex A;
- measuring equipment that is proven to fulfil the required specifications such as rod and level.

Transverse unevenness measurements are performed for different purposes. These purposes can be categorised as:

- new works and quality control of roads and airfields;
- road monitoring on pavements of roads and airfields in use;
- resurfacing activities on pavements of roads and airfields in use.

These purposes may have their own specific limitations to the execution and accuracy of the measurements. The combination of measurement devices and purposes for different indices is given in Table 1.

Table 1 — Recommended measurement methods for the different indices

Parameters	Profilometer	Straightedge	Rod and level
Crossfall	X	X[a]	X
Irregularity	X[b]	X	
Rut depth	X	X	
Theoretical water depth	X		

[a] with levelling

[b] irregularities can only be measured with profilometers which measure almost continuously over the transverse profile

The measurement device to be used for single profile measurements or measurements of section mean values shall be calibrated according to EN 13036-6:2008, 5.3.4.

6.2 Measuring single profiles

6.2.1 Crossfall

Positioning of the device for measuring the crossfall shall be such that the measurements will be taken over the full width of the lane. Any deviation of this requirement shall be reported.

6.2.2 Irregularities

Positioning of the device for quality control of new works shall be such that the irregularity can be adequately measured.

6.2.3 Rut depth and theoretical water depth

Positioning of the device for condition monitoring of ruts shall be such that the related ruts will be within the reach of the device over the whole section length.

6.3 Measuring sections of a unit of length (e.g. 100 m)

6.3.1 Irregularities

Local defects may be identified following a random selection or a selective one. Selective measurements shall be precisely described and reported.

6.3.2 Crossfall, rut depth and theoretical water depth

The crossfall, rut depth or water depth section mean value shall be calculated by taking the arithmetic mean value of a number of measured single profile measurements over the section.

Measurements for new works control, quality control and road monitoring shall have an acquisition repetition interval (travelled distances between two consecutive transverse profile measurements) of 10 m or less. Measurements for resurfacing activities shall have an acquisition repetition interval of 5 m or less.

NOTE Due to inhomogeneities over the length of a road section, the index value may vary from form cross section to cross section, therefore the distance between two consecutive profile measurements should be limited.

The measured values for each single profile shall be stored.

7 Evaluation and analysis

Measuring values for irregularities, ruth depth and theoretical water depth shall be analysed with a minimum resolution of 0,01 mm and reported with a minimum resolution of 0,1 mm.

Measuring values for crossfall shall be analysed with a minimum resolution of 0,01 % and reported with a minimum resolution of 0,1 %.

The way of evaluation and analysis depends on the application of the data.

Some recommendations:

— before analysing measurement results, an interval control shall be executed;

- for resurfacing activities a list of irregularities of the surface (ridges/dips etc.) and their occurrences shall be produced from the measurement results;
- For crossfall care is needed to decide whether all measurements over the full width of the lane will be used in the calculation of the regression. In case of edge slump the part where the road edge falls shall be discarded;
- Rut depth may be reported as a single observation from a transverse profile or as an average value of more observations within a section. If an average value is reported the standard deviation of the single values over the section shall be reported additionally. If the contiguous depths in a rut over a road length of 10 m or more are greater than 25 mm the location shall be reported;
- If present, attention is needed for the thickness of the road markings (thermoplastic). A correction should be performed for the thickness of the road markings, as if the road marking was not present.

8 Accuracy

8.1 General

Many different factors may contribute to the variability of transverse unevenness measurement results, either being results of single profiles or mean values for a given section length. The main factors are the equipment used, the crew (experience, carefulness), and the length positioning accuracy (chainage).

Due to these factors measured values may differ to some extent from the true value or any agreed reference value. These deviations, in statistical terms called the accuracy, are composed of a combination of random error (precision component) and a common systematic error (trueness component) (see ISO 3534-1).

This European Standard focuses only the accuracy of the equipment.

NOTE The accuracy of a production of transverse unevenness data, for example for monitoring, also incorporates the effects of the crew and the length positioning. A special European Standard will deal with this subject in the future.

8.2 Precision

From the measurement device to be used for measurements of single profiles as well as for section mean values, the precision in terms of repeatability *r* shall be known.

The repeatability *r* is the maximum difference expected between two measurements made by the specific device, using the same crew, on the same profile, respectively section of road, in a short space of time, with a probability of 95 %.

The repeatability *r* of single profile measurements shall be calculated as 2,8 times the standard deviation of a large number (at least 10) repeated measurements at usual operational speed of at least 10 different single profiles located on representative road sections.

The repeatability *r* of section mean values shall be calculated as 2,8 times the standard deviation of a large number (at least 10) repeated measurements at usual operational speed of at least 10 different representative road sections of 100 m.

NOTE The repeatability *r* of section mean values (e.g. 100 m sections) is dependent on the combination of standard deviation for a single profile, the number of profiles used, and to some extent also on the homogeneity of the measured phenomena over the section length. Since section mean values consist of a number of individual single profile measurements, the overall standard deviation will be less than of a single profile.

8.3 Trueness

From the measurement device to be used for measurements of single profiles as well as for section mean values, the trueness in terms of bias shall be known.

NOTE 1 The trueness of a measurement method is of interest when it is possible to conceive a true or almost true value for the property being measured. For transverse unevenness measurements this is actually the case.

The bias is the difference between the expected value of single profile measurements or section mean values and an accepted reference value.

The bias shall be calculated as the maximum relative difference between the average value obtained from a large number (at least 10) of repeated measurements at usual operational speed of at least 10 single profile or 10 different representative road section of 100 m and their true value or any agreed reference values. If appropriate, for small measuring values, a minimum bias can be determined.

NOTE 2 As an example for rut depth bias can be formulated as 10 % of the measured value and a minimum of 0,5 mm.

It may be assumed that the bias for section mean values will be equal to the bias for single profiles.

The true or agreed reference value for a single profile or section mean values shall be measured with a device which is at least 3 times more accurate.

NOTE 3 In case of so-called round robin tests, by lack of a better approach, the average of all applied devices can be taken as the best estimate.

9 Safety

Safety measures shall maintain safe working conditions in accordance with current regulations, to ensure the safety of the other road users, including measures to control traffic as necessary.

All equipment shall be operated safely and shall be fitted with safety equipment in accordance with the relevant procedures and regulations.

10 Report

The test report shall include the following information:

a) name of the organization carrying out the tests;

b) name of the person(s) carrying out the tests;

c) identification of the measurement device and its speed;

d) results of validation exercise for the device;

e) time and date of the tests;

f) weather conditions during the tests;

g) pavement surface description;

h) location of the pavement;

i) any pertinent remarks about the site, surface or test procedure;

j) for crossfall:

- definition of the section length;
- number of measured transverse profiles per section;
- calculated average value and corresponding variation coefficient per section;
- repeatability and bias of the measuring error of the measuring device;
- information whether the crossfall measurements have been taken over the full width of the lane or over a smaller width;

k) for irregularities:

- definition of the section length;
- number and types of irregularities per section;

l) for rut depth:

- definition of the section length;
- number of measured transverse profiles per section;
- calculated average value and corresponding variation coefficient per section of both rut depth and length of virtual straight reference line used;
- repeatability and bias of the measuring error of the measuring device;

m) for theoretical water depth:

- definition of the section length;
- number of measured transverse profiles per section;
- calculated average value and corresponding variation coefficient per section;
- repeatability and bias of the measuring error of the measuring device.

Annex A
(normative)

Measurement of indices of transverse unevenness and irregularities with a straightedge

A.1 Measuring using the straightedge

A.1.1 General

Irregularities in the surface profile of a pavement can be measured using the straightedge method in accordance with EN 13036-7. The straightedge method is suitable for measuring individual irregularities.

A.1.2 Sampling frequency, covered measurement/analysis width

For construction control and testing at the end of the warranty period the measured length/width for investigating irregularities in a pavement shall be equal to 3,0 m. The straightedge shall be moved laterally to ensure that the maximum deviation(s) is/are identified.

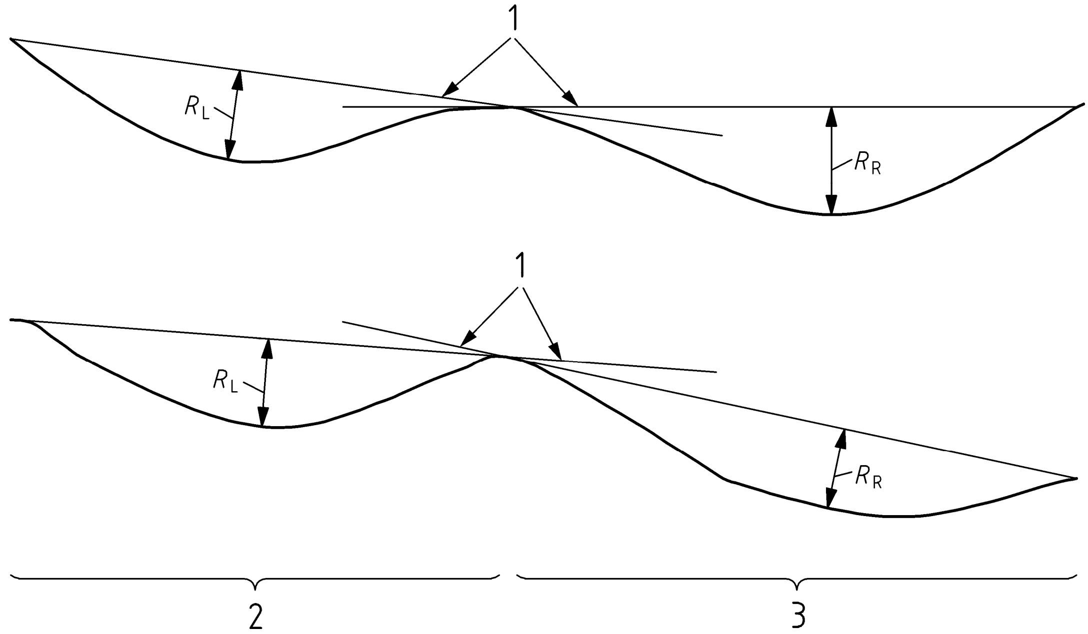
For measurements carried out on in service pavements different spans (longer and shorter, depending on the geometric characteristics and width of the roadway) are permitted. The straightedge shall be moved to ensure that the maximum deviation(s) is/are identified.

A.1.3 Method of measurement

A.1.3.1 Method of measuring rut depth R

One part of the straightedge shall be placed on the highest point to the left of the rut and another part of the straightedge shall be placed on the highest point to the right of the rut (see Figure A.1). The rut depth shall be measured using the specified wedges to the deepest point in the profile.

NOTE The lateral position and the length of the straightedge will influence the values.



Key

1 straightedge

2 rut in left, wheel path

3 rut in right, wheel path

Figure A.1 — Transverse profile of a pavement surface showing some irregularities

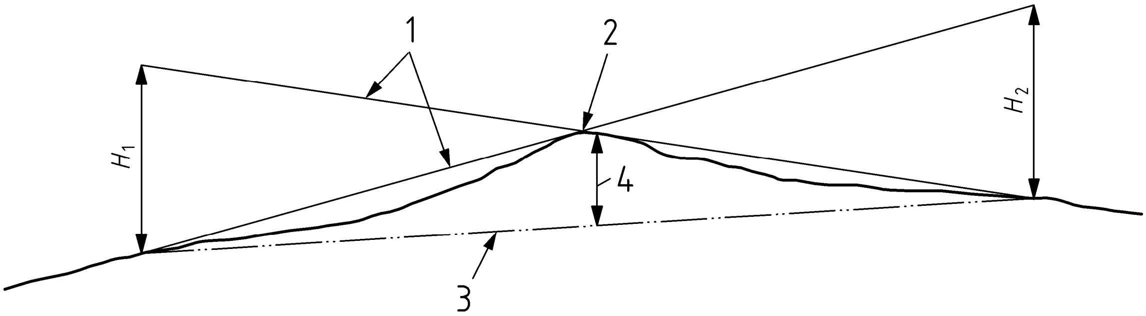
(maximum rut depth at R_L and R_R)

A.1.3.2 Method of measuring crossfall

Crossfall is defined as the angle between the horizontal and a straightedge placed on the pavement surface, perpendicular to the centreline.

A.1.3.3 Method of determining ridges I_R

The standard straightedge can be used to measure the height of ridges (see Figure A.2). The mid-point of the straightedge shall be placed on the topmost point of the ridge. Then the vertical distance between the end of the straightedge and the surface shall be measured H_1. By geometry the ridge height can then be assumed to be half the end height. In order to overcome situations where the reference line is not horizontal, a measurement shall be taken on the opposite side of the ridge H_2. The ridge height shall then be taken as half of the average of the two readings: ¼ (H_1 + H_2).



Key

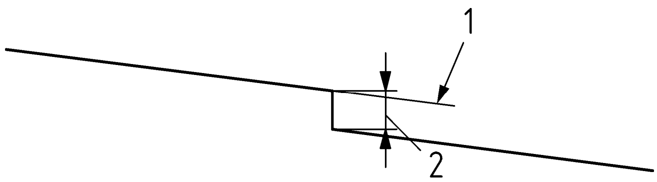
1 straightedge
2 mid point
3 reference
4 ridge height I_R

Figure A.2 — Measurement of ridge height using a straightedge I_R

A.1.3.4 Method of measuring steps I_S

The method of measuring steps using a straightedge is shown in Figure A.3. The straightedge shall be placed on the higher pavement surface and in such a way as to produce the minimum overhang necessary to carry out accurate measurements. The step I_S shall be determined by measuring the vertical difference between the upper and lower surfaces. The measurement shall be made as close to the junction between the two surfaces as possible and shall exclude any fillets that may reduce the measured step height artificially.

NOTE Steps can be caused by a variety of construction faults but are usually found at the longitudinal joints between adjacent lanes.



Key

1 straightedge
2 step height, I_S

Figure A.3 — Measurement of step heights using a straightedge

A.1.3.5 Method of measuring edge slump I_E

Edge slump can be measured with a straightedge as shown in Figure A.4. The straightedge shall be placed on the upper pavement surface and in such a way as to produce the minimum overhang necessary to carry out accurate measurements. The edge slump I_E shall be determined by measuring the maximum vertical difference between the straightedge and the extreme outer edge of the layer.

NOTE Edge slump is a common problem when laying concrete pavements and is particularly important for use of slip-form paving machines, as it is an early indicator of poor mix quality. It is also a common problem on flexible pavements with narrow shoulders and steep ditches.

Key

1 straightedge

2 edge slump, I_E

Figure A.4 — Measurement of edge slump using a straightedge I_E

A.2 Reporting of results

A.2.1 Test report

The test report shall contain the following information as a minimum:

A.2.1.1 General information

a) reference to this document;

b) test date;

c) site location details including start and end location.

A.2.1.2 Measurement device data

a) reference number of straightedge;

b) measurement span (total width covered) (if applicable).

A.2.1.3 Measured values

a) for I and R, according to specific values requested;

b) rut/pothole depth values (left and right wheel path) at individual locations R_L and R_R;

c) ridge/bump heights at individual locations I_R;

d) crossfall at individual locations X;

e) step heights at individual locations I_S;

f) edge slump values at individual locations I_E.

Bibliography

[1] ISO 3534-1, *Statistics — Vocabulary and symbols — Part 1: General statistical terms and terms used in probability*

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