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Road and airfield surface characteristics — Test methods — Part 8: Transverse unevenness and irregularities, definitions, methods of evaluation and reporting

Road and airfield surface characteristics — Test methods — Part 8:

Determination of transverse uneveness

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Contents

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Foreword

This document (prEN 13036-8:2016) has been prepared by Technical Committee CEN/TC 227 “Road materials”, the secretariat of which is held by DIN.

1 Introduction

Road surface unevenness affects safety, ride comfort, environmental impact and technical condition. When a road has been in use the surface gets deformed and worn due to the traffic load. Contributing causes of surface degradation are time in use, the traffic load, weather/climate conditions, geological conditions, used aggregate/materials as well as the strength of the road construction. To simplify quantifying the degree of deformation and wear, indicators have been developed that are based on the transverse (perpendicular to the direction of traffic flow) and longitudinal (parallel to the direction of traffic flow) profile. Requirements on the transverse unevenness can differ from one road to the other and are highly related to the speed limit, the kind of traffic, the climatic conditions and the accepted comfort limits, etc. Transverse road profile unevenness is consequently a key information for acceptance of newly laid pavements and for road maintenance management and planning systems. The transverse unevenness encompasses aspects, such as: irregularities in the transverse profile including the longitudinal ruts in the wheel paths caused by the traffic.

Measurement devices measuring the transverse profiles can be divided into two groups:

- Slow or stationary equipment’s, such as the straightedge for irregularities and longitudinal ruts.
- Dynamic equipment that can measure in traffic speed, such as profilometer’s, which are, dependant on the characteristics of the device, suitable for measuring multiple profiles as well as longer road sections and networks.

2 Scope

This European standard specifies the mathematical processing of digitized transverse profile measurements to produce evenness indices. The document describes the calculation of the indices rut depth and ridge height and the appropriate methods of evaluation and reporting.

The quantified evenness indices derived from this standard are useful support for quality control of pavement surfaces of newly laid sections, especially with respect to the evidence of irregularities due to improper laying and/or compacting actions, for evaluating the condition of pavements in service as part of routine condition monitoring programs, and finally as indices to be used for maintenance planning for resurfacing activities on pavements in use. The derived indices are portable in the sense that they can be obtained from transverse profiles measured with a variety of instruments.

3 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.

prEN 13036-6, *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*.

ISO 3534-1, *Statistics — Vocabulary and symbols — Part 1: Probability and general statistical terms*.

4 Terms and definitions

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

4.1 sampling interval

travelled distance between two consecutive transverse profile measurements (raw data for calculating acquisition repetition interval)

4.2 acquisition repetition interval

distance corresponding to interval between two consecutive reported measured results (low level, e.g. 100 mm)

4.3 reporting repetition interval

distance corresponding to the longitudinal interval between two consecutive reported measurement results of transverse profiles (higher level, e.g. 20 meter)

4.4 transverse acquisition sampling interval

distance between two consecutive data points in a discrete transverse profile measurement in transverse direction (sensor spacing)

NOTE If the distances between the sensors are not equal, the mean value is calculated.

4.5 bias

the 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).

4.6 pavement

a structure composed of one or more layers of selected material designed to carry traffic or aircraft

4.7 pavement surface or surface course

upper layer of the pavement that is in contact with the traffic or aircraft

4.8 precision

the 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).

4.9 repeatability

the variation in measurements made by the same machine, under the same condition, operated by the same crew on the same section of road in a short space of time.

4.10 rut depth

describes the transverse unevenness. It is calculated as the greatest deviation of the transverse profile of a pavement surface and a virtual straight reference line. Different definitions of rut depth can be used and are described in this standard. Rut depth is normally expressed in mm.

4.11 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.

4.12 transverse profile

describes the geometrical shape of the road surface in the transverse direction. It is the intersection between the road surface and a reference plane perpendicular to the road surface and to the lane direction. The profile is described by measurement points.

4.13 trueness

the 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 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).

4.14 wheel paths

the area of a pavement surface where most vehicle wheel passages are concentrated (see Figure 1)

5 List of symbols

I_R is the ridge height;

R_L is the rut depth in left wheel path;

R_R is the rut depth in right wheel path;

R_{TTU} is the total unevenness for whole transverse profile;

R_{SW} is the sliding wire rut depth at any transverse position of the profile.

6 Parameters

6.1 General

Different measures calculated from the transverse profile can be used for different purposes. The unevenness of the transverse profile can be characterized by the following parameters:

I_R is the ridge height;

R_R is the rut depth in right wheel path;

R_L is the rut depth in left wheel path;

R_{TTU} is the unevenness for whole transverse profile;

R_{SW} is the sliding wire rut depth for the whole transverse profile

I_R is the ridge height.

In Figure 1 the parameters are illustrated related to their position in a transverse profile.

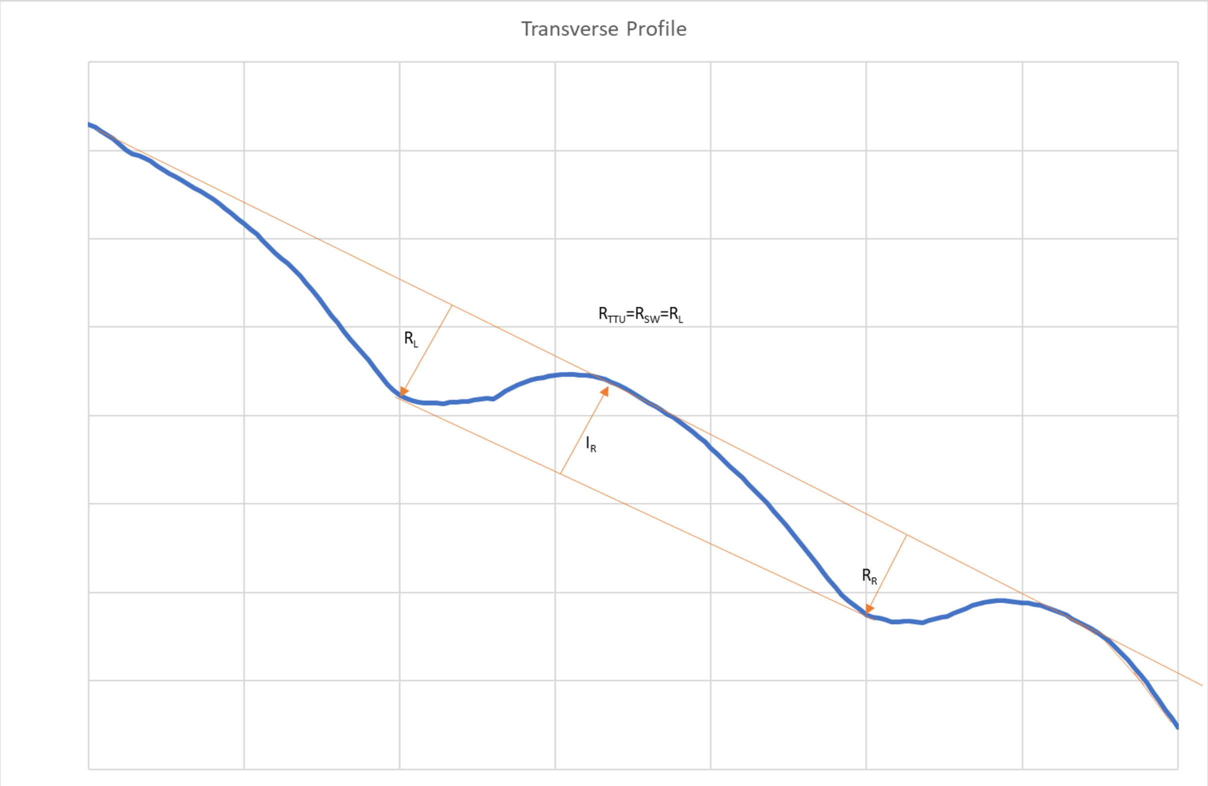

Figure 1 — Overview of different characteristics of transverse unevenness.

The requirement of needed accuracy, resolution, physical width and spacing of the measurement points that characterise the transverse profile is selected according to EN 13036-6:2008. A description of the different definitions can be seen in Figure 2. The standard handles classes of:

- vertical resolution of transverse profiling (sensor resolution);
- transverse acquisition sampling interval of transverse profiling (#sensors in transverse direction);
- transverse sampling interval of transverse profiling (longitudinally) (raw data for calculating acquisition repetition interval);
- acquisition repetition interval of transverse profiling (longitudinally) (lowest level of transverse profile for calculation of rut depth, typical 0,1 m to 1 m);
- reporting repetition interval of transverse profiling (longitudinally) (the reporting interval of rut depth, section mean values, typical 10 m to 100 m).

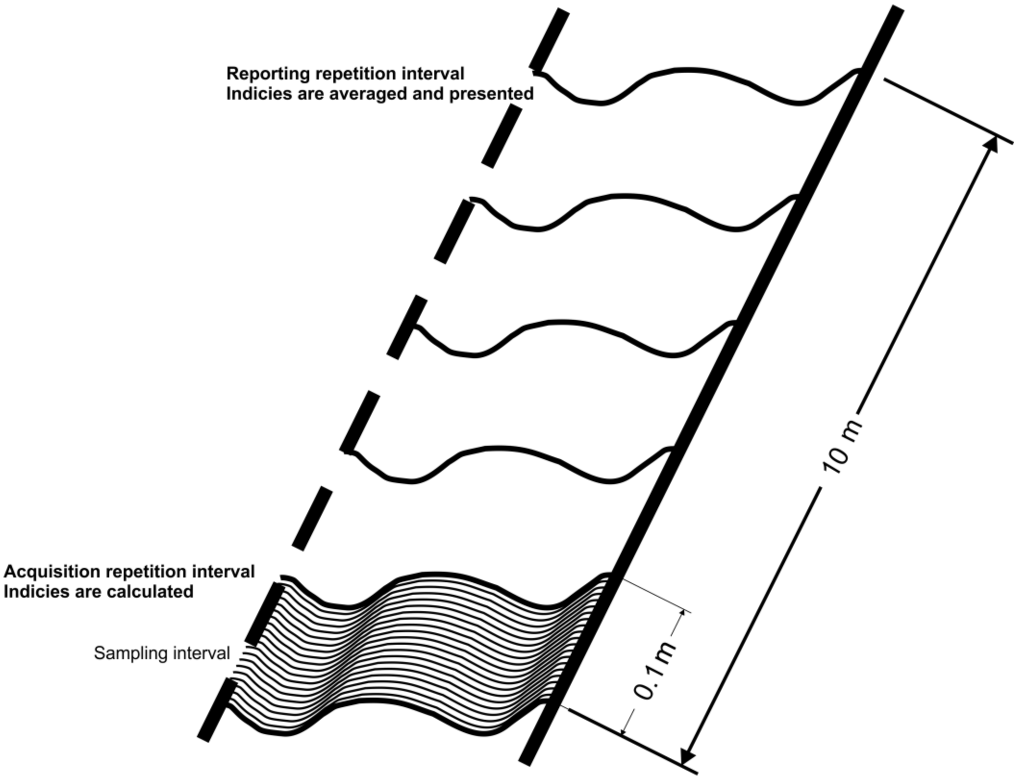

Figure 2 Description of the terms sampling interval, acquisition repetition interval and reporting repetition interval.

6.2 Transverse profile with a high speed profilometer

The most common way to obtain and characterise the transverse profile is with a high speed profilometer. When characterising the transverse profile, for the purpose of transverse unevenness, the texture should have a minimal effect of the results. Today there are two possible techniques used for high speed profilometers, point laser sensors and scanning laser sensors.

A typical point laser sensor is working with a high frequency (32 kHz) and the “raw” readings from the sensor should be averaged at the acquisition repetition interval to filter out the influence of the texture and noise in the sensor. For a point laser, at least 50 readings per 0.1 m should be used to filter out the texture and eliminate the noise in the sensor. An average of the readings is used for each sensor to measure the shape of the transverse profile for the acquisition repetition interval.

The scanning laser technique have a high resolution of measurement points in the transverse direction in contrast to the point lasers. To describe the transverse profile, one has to filter the data. The filtering of the transverse profile (at acquisition repetition interval) has two purposes, to eliminate the effect of the texture and to get rid of noise in the sensor. The raw transverse profile sometimes has a transverse sampling interval smaller than 1 mm that is influenced of the texture and the noise in the sensor. The raw transverse profile should be filtered with a 150 mm three-pole low pass butterworth filter (forward reverse). To eliminate edge effects of the filter the raw profile should first be mirrored (see Figure **3**) before filtering and after filtering at least 150 mm at each side of the profile should not be used for transverse unevenness calculations. E.g. a 4 000 mm wide raw profile can be used to characterise a 3 700 mm wide profile at the acquisition repetition interval.

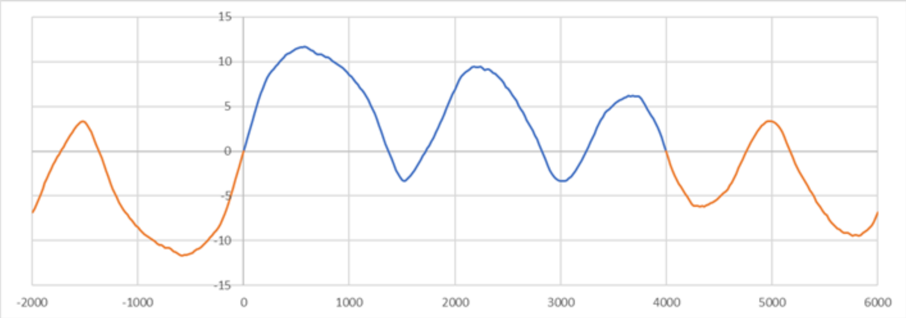

Figure 3 The blue profile is the original profile. The orange expansion is the mirroring.

6.3 Rut depth (*R*)

Ruts in the pavement surface manifest as a continuous depression in a longitudinal direction in the wheel paths. The macrotexture of the surface is not a part of the rut depth and should be eliminated (by filtering) in an appropriate way (as described in chapter 6.2). The filtering technique can differ depending on the equipment and the sensor used.

Rut depth is an indicator of the technical condition of the surface and can arise from vehicle wear (especially from studded tyres) or depression from heavy traffic.

For traffic safety, the rut depth, in combination with crossfall, 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).

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.

Different definitions of rut depth are described below. Different rut depth definition or method of calculating rut depth is more suitable to use for certain purposes. The table below shows an overview of recommended use of the different rut depth measures in various situations.

	Main purpose	Reporting repetition interval	Measurement method
Sliding wire rut depth	Benchmarking Network inventory Resurfacing activities on pavements in use	Typical 10 m or 20 m	Profilometer
Total transverse unevenness	Network inventory Quality control of newly laid pavement	Typical 10 m or 20 m	Profilometer Straight edge[1]
Left and right rut depth	Network inventory Resurfacing activities on pavements in use	Typical 10 m or 20 m	Profilometer Straight edge[1]
Ridge height	Network inventory	Typical 10 m or 20 m	Profilometer

[1] On surfaces not suitable for profilometer.

6.3.1 The Sliding Wire Rut Depth method (R_{SW})

The calculation of the lowest level of rut depth is done according the surface wire method on the transverse profile at the acquisition repetition interval. The rut depth is defined as the greatest deviation between a two meter (or as close as possible to two meter) virtual reference wire when the ends of the wire is attached at the profile. The deviation shall be measured perpendicular from the straight wire to the transverse profile. The wire slides or moves one step at a time (each measurement point) from left to right on the entire width of the transverse profile and the rut depth is calculated for each position. The greatest rut depth of all possible lateral positions represents the result (rut depth) at the acquisition repetition interval, see Figure 4. The result at the reporting repetition interval is an arithmetic average of the rut depths for reporting repetition interval.

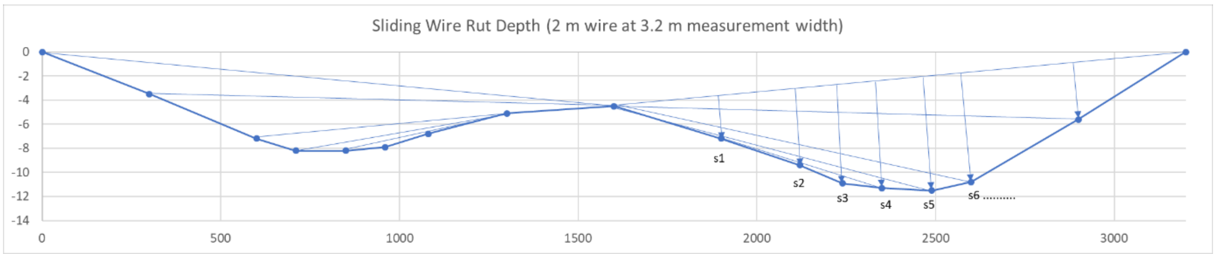

Figure 4 Sliding wire rut depth calculated at a 3.2 m wide transversal profile. $R_{SW3.2}$=s5.

6.3.2 The Total Transverse Unevenness method (R_{TTU})

The calculation of the total transverse unevenness is done according the surface wire method on the transverse profile at the acquisition repetition interval. The unevenness is defined as the greatest deviation between a virtual reference wire when the ends of the wire is attached at the start and end of the profile and when the wire rests on any high points in between. The deviation shall be measured as the greatest perpendicular distance from the straight wire to the transverse profile. The greatest distance between the wire and the profile represents the result (rut depth) at the acquisition repetition interval. The result for the reporting repetition interval is an arithmetic average of the rut depths at acquisition repetition interval. An index is used to indicate the length of the wire used in the calculation, e.g. $R_{TTU3.2}$=11.3 mm for a 3.2 m wide transverse profile.

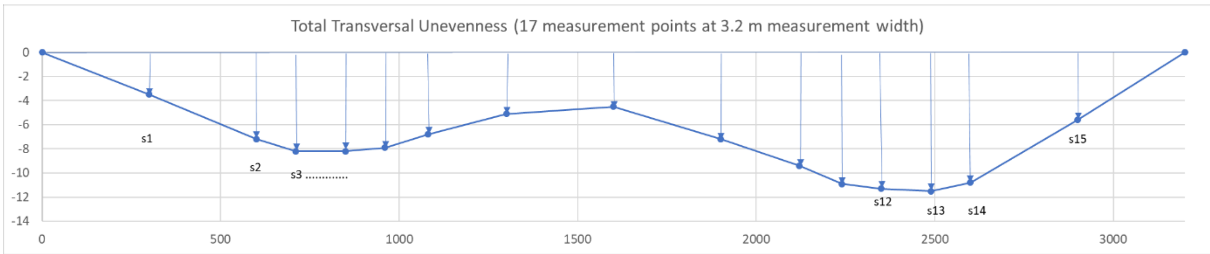

Figure 5 Total transversal unevenness calculated at a 3.2 m wide transversal profile. $R_{TTU3.2}$=s13.

6.3.3 The Left and Right Rut Depth method (R_L and R_R)

The calculation of rut depth is done according the surface wire method on the transverse profile at the acquisition repetition interval. The rut depth is defined as the greatest deviation between a virtual reference wire when the ends of the wire is attached at the profile. The length of the wires shall be defined as half of the total length plus 10%. It will give an overlap of 20 % of the total length in the middle. E.g. a 3.2 m wide transverse profile will give a wire length of 1.92 m for the left and right side. The deviation shall be measured as the greatest perpendicular distance from the straight wire to the transverse profile. The greatest distance between the wire and the profile represents the result (rut depth) at the acquisition repetition interval. The result for the reporting repetition interval is an arithmetic average of the rut depths at acquisition repetition interval. An index is used to indicate the length of the wire used in the calculation, e.g. $R_{L1.9}$=10.2 mm for a 3.2 m wide transverse profile where 1.92 m is used in calculation.

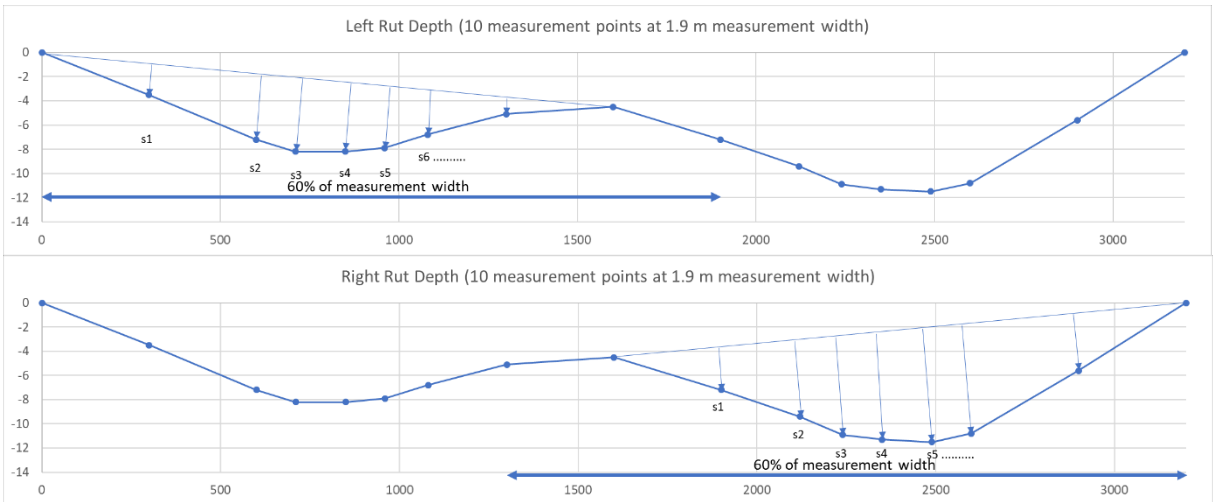

Figure 6 Left and right rut depth calculated at a 3.2 m wide transversal profile. $R_{L1.9}$=s3, $R_{R1.9}$=s5.

6.3.4 Ridge Height (I_R)

Ridge height is an indicator of the unevenness of the transverse profile. Rut depth is not the major problem at the secondary road network because of the low volumes of cars and heavy vehicles. Other defects appear at the secondary roads as edge slope from depression from heavy traffic which not necessary can be detected by rut depth indices. Ridge height can be used in combination with rut depth to better characterise the transverse unevenness for that category of roads.

The calculation of ridge height is done by attaching a wire under the transverse profile at the position of the central two meters of the profile at the acquisition repetition interval. The greatest perpendicular distance between the wire and a measurement point in the profile will represent the ridge height at the acquisition repetition interval. The result for the reporting repetition interval is an arithmetic average of the ridge height at acquisition repetition interval.

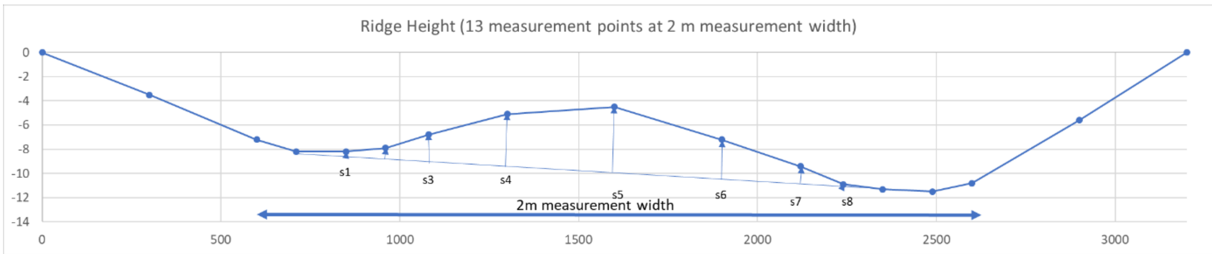

Figure 7 Ridge height calculated at a 3.2 m wide transversal profile. I_R=s5.

7 Measurement devices and their application

7.1 Measurement devices

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

— new works and quality control;

— road monitoring on pavements in use;

— resurfacing activities on pavements in use.

These purposes may have their own specific limitations to the execution and accuracy of the measurements. The equipment is chosen with regard to the right specification for the assignment according EN 13036-6:2008.

The measurement device to be used for single profile measurements or measurements of section mean values shall be calibrated according to prEn 130367-6 chapter 5.3.4. Safety at measurement should have high priority and therefore should a profilometer be used where it is possible. However, a profilometer is not suitable for measurement at all surfaces. Those surfaces can be controlled by a straight edge, see Annex A.

7.2 Measuring single profiles

7.2.1 Transverse unevenness

Transverse positioning of the device for condition monitoring of transverse unevenness shall be such that the related ridges will be within the reach of the device over the whole section width. Special care should be taken to avoid measuring at road markings which will increase the value for the indices.

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

7.3.1 Transverse unevenness

The transverse unevenness section mean value shall be calculated by taking the arithmetic mean value of a number of measured single profiles (described as acquisition repetition interval of transverse profiling) measurements over the section.

The acquisition repetition interval should be chosen according the type of assignment according EN 13036-6:2008. A frequently used acquisition repetition interval is 0.1 m.

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

The measured values for each single profile (acquisition repetition interval of transverse profiling) shall be stored.

8 Evaluation and analysis

Measuring values shall be analysed with a minimum resolution of 0.1 mm for rut depth.

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

Some recommendations:

— before analysing measurement results, a data control must be executed;

— for resurfacing activities, a list of irregularities of the surface (ridges/bumps/dips, etc.) and their occurrences shall be produced from the measurement results;

— 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;

— typical levels of rut depth for trigger of maintenance action is 10 mm to 20 mm, depending on road category.

— If present, special attention is needed for the thickness of the road and airfield markings (thermoplastic). First and foremost, try to avoid measuring at the markings and at second hand make a correction for the thickness of the road markings, as if the road marking was not present.

9 Accuracy

9.1 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 calibration of the equipment, the crew (experience, carefulness), the measuring position in transverse direction as well as the length positioning.

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.

9.2 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 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 mean section length (e.g. 100 m) values 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 consists of a number of individual single profile measurements the overall standard deviation will be less than of a single profile.

9.3 Bias

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 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 profiles or 10 different representative road sections of 100 m and their true value or any agreed reference value. If appropriate for small measuring values a minimum bias can be determined.

NOTE 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 as good as the tested device.

NOTE 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.

10 Safety

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

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

11 Report

The test report shall include the following information:

a) the name of the organization carrying out the tests;

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

c) identification of the measurement device and its speed;

d) the time and date of the tests;

e) weather conditions during the tests;

f) the pavement surface description;

g) the location of the section

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

i) for all transverse unevenness indices:

  — definition of the section reporting length;

  — class of equipment according EN 13036-6:2008

  — lateral position of the device

  — type of unevenness indices and measurement width

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 at surfaces where a profilometer cannot operate.

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 (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.

Figure is missing

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 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).

Figure is missing

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.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

d) reference number of straightedge;

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

A.2.1.3 Measured values

f) for I and R, according to specific values requested:

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

h) ridge/bump heights at individual locations I_R;