IRC: SP: 16-2004

GUIDELINES FOR THE SURFACE EVENNESS OF HIGHWAY PAVEMENTS

(First Revision)

THE INDIAN ROADS CONGRESS
2004

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Published by

THE INDIAN ROADS CONGRESS
Jamnagar House, Shahjahan Road,
New Delhi-110011
2004

Price Rs. 100/-
(plus packing and postage)

IRC: SP: 16-2002

First Published	:	March, 1997
First Revision	:	June, 2004
Reprinted	:	February, 2007
Reprinted	:	June, 2009

Printed at India Offset Press, A-1, Mayapuri Ind. Area, New Delhi-110 064
(500 copies)

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1. INTRODUCTION

Surface evenness of highway pavements refers to the regularity of surface finish both in longitudinal and transverse directions. Almost in all major highway works executed, control of surface evenness has been introduced as a mandatory requirement. The existing standards and tolerances of surface evenness are prescribed in IRC Special Publication 16-1977 which was based on the Report of the IRC Subcommittee on Surface Characteristics of Pavements. The Subcommittee was constituted by the Specifications and Standards Committee in November, 1968 under the Convenorship of Shri Mahabir Prasad. The Subcommittee presented its Report in 1975 and was endorsed by the Specifications and Standards Committee in its meeting held on 5th January, 1976. Later the Report was approved by the Executive Committee and the Council at their meetings held on 14th April, 1976 and 27th August, 1976 respectively which was printed as IRC:SP:16-1977.

The Flexible Pavement Committee (H-4) in its meeting held on 23rd September, 2000 (personnel given below) decided to revise the above mentioned document because of improvements observed in the surface evenness and roughness values of the wearing surface of highway pavements due to introduction of high level of sophistication and mechanization in road construction. The Committee assigned the work of preparing the draft document to Shri R.S. Shukla who gathered the evenness and roughness data from various projects and prepared the draft. The draft was discussed by the Flexible Pavement Committee in their meetings held on 10th February, 2001, 1st September, 2001, 17th May, 2002 and 16th November, 2002 and necessary modifications were incorporated.

Personnel of Flexible Pavement Committee (H-4) from 2000 to 2002

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Dr. S.S. Jain	....	Member-Secretary

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Corresponding Members

Sukomal Chakrabarti
Dr. P.K. Jain
S.K. Nirmal
Smt. A.P. Joshi
R.S. Shukla

The newly constituted Flexible Pavement Committee (personnel given below) considered the modified draft in its meeting held on the 1st August, 2003 and authorized the Subgroup comprising Shri S.C. Sharma, Dr. L.R. Kadiyali and Shri R.S. Shukla to finalise the draft for sending to Highways Specifications and Standards (HSS) Committee. The draft was finalized by the Subgroup in its meeting held on the 17th October, 2003.

Personnel of Flexible Pavement Committee (H-4) from 2003 to 2005

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Dr. S.S. Jain	....	Member-Secretary

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Dr. P.K. Jain
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The Manager (Bitumen), HPC, Mumbai

The draft was discussed by HSS Committee in its meeting held on 20th December, 2003 and finalised with some modifications to be incorporated. The Executive Committee of the IRC in its meeting held on 21th December, 2003 approved the modified document for placing before the Council. The document was finally approved by the Council in its 170th meeting held on the 8th January, 2004 for printing with editorial corrections. This document presents the First Revision of IRC:SP:16-2004 "Guidelines for Surface Evenness of Highway Pavements".

2. IMPORTANCE OF SURFACE EVENNESS

2.1. Surface evenness affects vehicle speed, comfort, vehicle operating cost and safety and hence needs to be given careful consideration during initial construction and subsequent maintenance.

2.2. The standard recommended for surface evenness enables the engineer to exercise control over the quality of construction.

2.3. Standards have also been prepared for the road roughness of different types of surfaces to enable an evaluation of the condition of the surface and prioritize and establish further maintenance intervention levels.

3. MEASUREMENT OF SURFACE EVENNESS AND ROUGHNESS

3.1. Measurement of Surface Evenness

3.1.1. **Metre straight edge** : The measurement and checking of surface evenness can be done by a 3-metre straight edge during construction soon after the completion of a short stretch. In case of layers involving bituminous pavements or cement concrete pavements extra care is needed to rectify the defects before the material cools down/sets.

The 3-metre straight edge is made of steel or box type aluminum alloy bar, with sectional dimensions of 75 mm x 125 mm. The edge should be perfectly straight and free from rust or other defects.

Depressions under the straight edge are measured with a graduated wedge. The wedge shall be metallic. The dimensions are: 600 mm long base, 30 mm thickness and 30 mm height at one end tapering to 1 mm at the other. Graduations are provided at the hypotenuse and on the sides in mm, relative to the height from the base. These graduations are meant to read undulations upto 25 mm with a least count of a minimum of 3 mm. The wedge is provided with a handle of suitable length for facilitating measurements in standing position.

For recording undulations in the longitudinal profile, the straight edge is put longitudinally in the middle of each traffic lane along a line parallel to the centre line of the road. For a single lane road measurement of unevenness is made on both sides of the center line.

The straight edge is placed at the starting point, wedge inserted between it and the test surface where the gap is maximum and recorded. The straight edge is then slided forward for about half of its length, i.e., 1.5 metre and wedge reading repeated. The straight edge need not always be moved forward but may be moved backward and forward to record the maximum undulations existing at a location. The undulations in excess of the permissible magnitude shall be marked with paint to be rectified immediately.

3.2. Measurement of Surface Roughness

The roughness of pavement surface is commonly designated as Unevenness Index Value and is expressed in surface roughness is measured by a bump integrator.

3.2.1. **Bump integrator** : Either towed fifth wheel bump integrator or car-mounted bump integrator can be used for measuring the road roughness. These are response type road roughness measuring systems and are extensively used in the country for measurement of roughness.

Towed Fifth Wheel Bump Integrator

The indigenous version of this device is the Automatic Road Unevenness Research (ARUR). The equipment consists of a trailer towed by a vehicle. A standard pneumatic tyre wheel inflated to a tyre pressure of 2.1 kg/sqcm is mounted within the trailer chassis, with a single leaf spring on either side of the wheel supporting the chassis. Two dashpots provide viscous damping between chassis and axle. The frame is provided with a counter weight at the front to make the device practically free from the effects of the vertical motion of the vehicle. A mechanical integrator makes cumulative measurements of the unidirectional vertical movement of the wheel relative to the chassis. The distance travelled is measured by a distance measuring unit. The test is conducted at a speed of 32 ± 1 km/hour. Unevenness/roughness Index is defined as the ratio of the cumulative vertical displacement to the distance travelled and is expressed in mm/km.

The equipment is driven over the road surface at a speed of 32 ± 1 km/hour, keeping steady motion and avoiding swerving. The observer will activate the main switch fitted on the panel board at the beginning of the section and switch it off at the end of the section. The readings of the revolution counter and integrating counters are noted and entered in the data sheet.

The bump integrator values are recorded when the wheel revolution counter records 460 units which correspond to 1 km. The brief description of the road surface is also noted as the observer travels over the surface. The fifth wheel should preferably travel on wheel path. For measurement of roughness, one measurement in each lane is recommended for riding comforts evaluation.

Car-Mounted Bump Integrator

The car-mounted integrator consists of an integrating unit as provided in the fifth wheel Bump Integrator. The integrating unit is fitted with the rear axle and mounted in the rear portion of the car or rear floor of a jeep.

There are two sets of counters, one each for measurement of bumps and distance along with a switch on the panel board. Only one set of counter is used at a time. The advantage of having two counters is that one may be kept in use while the other is kept stand-by and will display the data of the previous run. In addition, the switching of the counters with the help of toggle switch provided in the panel board gives data exactly kilometre-wise. The power is drawn from the car itself.

The differential movement between the rear axle and the body of the vehicle due to road unevenness is measured by the upward vertical motion of a wire which is transmitted into unidirectional rotatory movement of the pulley of the integrator unit. There is an arrangement in the integrating unit for converting the rotational movement into electric pulses which is recorded by the counters. One count in electro-magnetic counter corresponds to 25.4 mm relative movement between axle and floor of the vehicle. One count in distance counter corresponds to 20 m length of distance travelled.

The road roughness is affected by the vehicle speed. A bump gets magnified if the vehicle speed is not maintained. Vehicle load is another factor which influences the roughness measurement. For getting the realistic values the vehicle speed must be maintained at 32 ± 1 kmph. The laden weight of the vehicle is also standardized. While taking measurements the vehicle should carry maximum three passengers. It should be ensured that the outer vehicle wheel travels on the wheel path.

3.2.2. **Calibration of bump integrator** : Roughness of a pavement is indicative of its riding quality and level-of-service. The roughness values provide an important impact in taking decision for surface improvement and maintenance measures. It is, therefore, necessary that the measurements are accurate and reliable. However, in response type devices, significant variations are often encountered in roughness measurement. Physical changes in the instrument, like, wearing of the tyre, braking or replacement of leaf spring, replacement of clamping unit, towing hitch, etc. may lead to large variations in the machine output.

Thus, in order to ensure repeatability and reproducibility of measurement by the same machine and consistency in measurement from different machines, it is essential that the response of the device to the road surface roughness should be correct. Initial standardisation and subsequent recalibration of response type devices are essential. The new measurements obtained from the response type devices must be correct to the standard roughness scale by calibration. Procedures for Calibration equipment commonly employed are:

- Dipstick
- MERLIN-Machine for Evaluating Road Roughness using Low Cost Instrument
- Rod and Level

A brief description of the above calibration equipments including procedure for their use is given in ***Annexures 1, 2 and 3*** respectively.

A number of test sites, 8 to 10, of straight sections of length 400 to 500 m, of different roughness level covering a wide range of spectrum of surface roughness ranging from very smooth to very rough are selected. Care is taken to ensure that sufficient approach length on either side is available to attain vehicle test speed before entering the starting point of the test section. The entire length of all selected sites should have uniform riding quality and free of surface defects. For better visibility, wheel paths are marked with a road marking paint. Both the starting and the ending point of each site are also marked clearly so that the operator can identify the starting and ending point of the section during data recording. Section roughness and the corresponding reference values for each section are recorded through any of the above mentioned calibration devices for developing the calibration. At each test site a number of runs are made till at least three sets of consistent data are obtained. Average of the three values is taken as the representative roughness value of the section.

The device to be calibrated also run on the identified sections and the roughness is measured. Based on these two sets of observations a correlation between the reference roughness and roughness measured by the bump integrator is established. From these relations the corrected roughness values are obtained.

4. RECOMMENDED STANDARDS FOR SURFACE EVENNESS OF HIGHWAY PAVEMENTS

4.1. The recommended maximum permissible unevenness values for different types of surfaces are given in Table 1. These values are to be used in conjunction with the maximum permissible frequency values given in Table 2.

TABLE 1. MAXIMUM PERMISSIBLE SURFACE UNEVENNESS FOR ROAD PAVEMENTS

Type of surfacing	Maximum Permissible Surface Unevenness	
	Longitudinal profile 3-m straight edge (mm)	**Transverse profile camber template (mm)**
1. Surface Dressing	10	8
2. Open Graded Premix Carpet*	8	6
3. Mix Seal Surfacing	8	6
4. Semi-Dense Bituminous Concrete	6	4
5. Bituminous Concrete	5	4
6. Cement Concrete	5	4

* These values are for mechanized construction. For manual construction, the tolerances may be increased by 2 mm

TABLE 2. MAXIMUM PERMISSIBLE FREQUENCY OF SURFACE UNEVENNESS IN 300 M LENGTH IN LONGITUDINAL PROFILE

S. No.	Type of Surface	Unevenness (mm)	Maximum number of Surface Unevenness	
			NH/SH	MDR and other lower category of roads
1.	Surface Dressing	8 - 10	20	40
2.	Open Graded Premix Carpet	6 - 8	20	40
3.	Mix Seal Surfacing	6 - 8	20	40
4.	Semi-Dense Bituminous Concrete	4 - 6	20	40
5.	Bituminous Concrete	3 - 5	15	30
6.	Cement Concrete	4 - 5	15	30

4.1.1. The longitudinal profile shall be checked with a 3-metre straight edge at the middle of each traffic lane along a line parallel to the central line of the road. The maximum permissible number of surface unevenness in longitudinal profile in 300 m length shall be as given in Table 2.

5. RECOMMENDED STANDARD FOR ROUGHNESS VALUES

5.1. The maximum permissible values of surface roughness measured with a bump integrator for different surfaces are given in Table 3.

5.2. Newly constructed surfaces are expected to give roughness values corresponding to 'Good' category while the values under 'Average' and 'Poor' category indicate level-of-service and intervention level for maintenance. Surfaces with very low roughness values loose skid resistance and are not desirable from safety considerations. Such surfacings should receive prompt attention for restoring frictional resistance.

TABLE 3. MAXIMUM PERMISSIBLE VALUES OF ROUGHNESS (MM/KM) FOR ROAD SURFACE

S. No.	Type of Surface	Condition of Road Surface		
		Good	Average	Poor
1.	Surface Dressing	< 3500	3500 - 4500	> 4500
2.	Open Graded Premix Carpet	< 3000	3000 - 4000	> 4000
3.	Mix Seal Surfacing	< 3000	3000 - 4000	> 4000
4.	Semi-Dense Bituminous Concrete	< 2500	2500 - 3500	>3500
5.	Bituminous Concrete	< 2000	2000 - 3000	> 3000
6.	Cement Concrete	< 2200	2200 - 3000	> 3000

6. QUALITY CONTROL

6.1. Strict quality control measures shall be exercised for the achievements of the recommended values of surface finish both in terms of unevenness and 'Good' category roughness as measured by a Straight Edge and Bump Integrator respectively.

Annexure-1

DIPSTICK FOR CALIBRATION OF BUMP INTEGRATOR

1. INTRODUCTION

This specification covers the details of use of dipstick for the calibration of Bump Integrator.

2. EQUIPMENT

Dipstick is a fully integrated data collection and processing system that measures and records road profiles accurately and quickly. The equipment consists of the following:

- Dipstick road profiler
- Micro computer
- RS 232 interface
- Software library for automatic calculation of IRI, F - Numbers, True Profile plots and other standards
- All cords and accessories

Sequential elevation differences are recorded automatically by the on - board computer. Recorded information is then transferred to a PC or compatible computer for analysis.

Software is included to calculate and print various profile statistics including the International Roughness Index (IRI), as well as the individual point elevation and local surface curvatures. A continuous scaled plot of surface profile can also be produced with a printer that has IBM Graphics. For correlation with 5th Wheel Bump Integrator Values, the following relation may be used:

$$BI = 630\,(IRI)^{1.12}$$

Where, BI = Bump Integrator Roughness in mm/km

IRI = International Roughness Index

3. PROCEDURE

The Dipstick Profiler stands on two support legs. The operator simply "walks" the Dipstick along a survey line alternately pivoting the instrument about each leg. In less than an hour, one technician can measure, record and analyze upto 600 equally spaced, co-linear elevation points to an accuracy of ±0.15 mm per reading. Dipstick surveys take less than half the time and are more accurate than both optic and laser surveys. Data analysis is fully computerized.

Two digital displays show the elevation difference between the Dipstick two support legs. Each elevation difference reading is measured and automatically recorded.

Audible and visual signals alert the operator when each measurement is complete. An optional manual trigger is also available to allow the operator to initiate the recording of each reading.

Annexure-2

'MERLIN' FOR CALIBRATION OF BUMP INTEGRATOR

1. SCOPE

This specification covers the method for use of MERLIN (Machine for Evaluating Road Roughness using Low Cost Instrument) for calibration of Bump Integrator.

2. EQUIPMENT

MERLIN has a rigid frame 1.8 metre long with a wheel in front, a curved foot at the rear and a probe mid-way between the two which rests on the road surface. If the road surface was perfectly smooth, the probe would always lie on a straight line between the bottom of the wheel and the rear foot. On an uneven road surface the probe would usually be displaced above or below the line. A computer simulation shows that the spread of these displacements could be used to estimate on the standard roughness scale.

To measure the displacements, the probe is attached to a pivoted arm, at the other end of which a pointer moves over a chart. The arm has a mechanical amplification of 10 so that a movement of the probe of 1 mm will produce a pointer movement of 10 mm.

3. PROCEDURE

The roughness of a section of the road is measured by wheeling MERLIN along the road with the frame raised. Once every wheel revolution, the frame is lowered so that the probe and rear foot touch the ground and the resulting pointer position is recorded as a cross on the chart. Two hundred measurements are made to produce a histogram. The rougher the road surface, the greater is the variability of displacement. The speed of displacement has been found to correlate well with road roughness as measured on roughness scale. The width of the central 90 per cent of the histogram is measured from the chart and this can conveniently be converted directly into roughness from conversion equations that are available.

REFERENCES

1. Road Research Laboratory - Report No 229, 1996
2. World Bank Technical Paper No 45.

Annexure-3

ROD AND LEVEL METHOD

1. INTRODUCTION

This specification covers the rod and level method for the calibration of bump integrator.

2. EQUIPMENT

The equipment required are as under:

- Dumpy level
- A Graduated Rod

3. PROCEDURE

3.1. The procedure is as follows:

- A line close to the road centerline preferably at wheel path, is randomly selected.
- Elevation in mm at every 300 mm interval for a 120 metre long sections corresponding to the minimum and maximum wavelength which affects significantly the dynamic response of a negotiating vehicle are taken.

Since the vertical deviation in rod profile occur both in positive as well as negative directions they tend to average out over long distances. Two methods of profile analysis are used to avoid this cancellation and summarize meaningfully the deviations.

3.1.1. **Root - mean - square deviation (RMSD)** : In this method, the amplitudes of the deviations are squared and averaged for the specific wavelength so that the values remain positive. The positive square root of the average is reported as RMSD for the specified wavelength.

3.1.2. **Average rectified deviation (ARD)** : In this method, the absolute amplitude of the deviations are averaged for the specified wavelengths so that the value remains positive. The average is reported as the ARD for the specified wavelength.