IMPROVED RELATION FOR CALIBRATION OF FIFTH WHEEL BUMP INTEGRATOR IN INDIAN CONDITIONS

Lalita Jangpangi, H.Lokeshwar and Y.C.Tewari
Central Road Research Institute (CSIR-CRRI), India
lalita157@gmail.com; hlokeshwor@gmail.com & yogesh.crri@gmail.com

ABSTRACT

The roughness of road surface is an important measure for road surface condition evaluation and a key factor in determining its riding quality. As such, road roughness measurement has received a considerable attention from road and airport agencies / authorities as it affects the safety of the individuals using roads, riding quality of the roadway, the pavement loading and the vehicle operating cost. In India, riding quality is largely being measured by one of the response type instruments called Bump Integrator (BI), which are either towed type / Fifth Wheel mounted on the vehicle itself. The measurements obtained from BI must be correlated to the standard roughness scale by calibration. For calibration of BI, the first class profilometre called Dipstick is commonly used and the relation equation $UI = 630\ (IRI)^{1.12}$ is applied for correlation with BI values, where UI = Bump Integrator Roughness in mm / km while IRI = International Roughness Index in m/km. Based on the testing of a large number of Fifth Wheel BIs, it has been found that the percentage error of calibrated roughness w.r.t. reference roughness is very high particularly for lower roughness levels by using the above standard relation equation. In this paper, an improved relation equation is proposed for the calibration of BIs in Indian conditions. Using the proposed relation equation, better / improved relations have been derived by reducing the percentage error of calibrated roughness w.r.t. reference roughness.

1. INTRODUCTION

Roads are public utilities for providing speedy, safe and comfortable ride to the road users. The roughness of road surface is an important measure of road condition and a key factor in determining riding quality. Road surface evaluation has received considerable attention from highway and airport agencies / authorities as road roughness affects the safety of the individuals using highway, riding quality of the roadway, the pavement loading and the vehicle operating cost. One of the factors affecting fuel consumption of vehicles is road roughness. High roughness can cause quicker wear and tear of tyres and may necessitate frequent replacement of spare parts connected with the braking system, clutch and the gear box of vehicles, thus roughness of roads is an important parameter. The roughness of a pavement forms an important input into any Pavement Management System in deciding upon the maintenance strategies to be applied on the road surface. As the road roughness increases, it leads to more criticism from the public due to uncomfortable ride and the increased road user cost.

2. MEASUREMENT OF SURFACE ROUGHNESS

The roughness of pavement surface is commonly designated as unevenness index value and is expressed in surface roughness, measured by a 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 system and are extensively used in the country for measurement of roughness.

The indigenous version of Towed Fifth Wheel Bump Integrator device is the Automatic Road Unevenness Recorder (ARUR) Fig. 1. This equipment consists of a trailer towed by vehicle. A standard pneumatic tyre wheel inflated to a tyre pressure of 2.1 kg/sq.cm. 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 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 30 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 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 travel on wheel path. For measurement of roughness, one measurement in each lane is recommended for riding comforts evaluation.

FIGURE 1Automatic Road Unevenness Recorder (ARUR)

3. CALIBRATION OF BUMP INTEGRATOR

Roughness of a pavement is indicative of its riding quality and level-of-service. The 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 standardization 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. Calibration equipment commonly employed is Dipstick (1).

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:

$$UI = 630\ (IRI)^{1.12}$$

Where, UI = Bump Integrator Roughness in mm / km

IRI = International Roughness Index

A number of test sites, 8 to 10, of straight sections of length 200 to 300 m, of different roughness level covering a wide range of spectrum of 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 end 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 by Dipstick 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 or three sets of observation a correlation between the reference roughness and roughness measured by the bump integrator is established through regression analysis and calibration equation is developed (2). From these relations the calibrated roughness values are obtained. Calibration equation and calibrated values obtained from calibration of a typical ARUR are shown in Figure 1 and table 1 respectively.

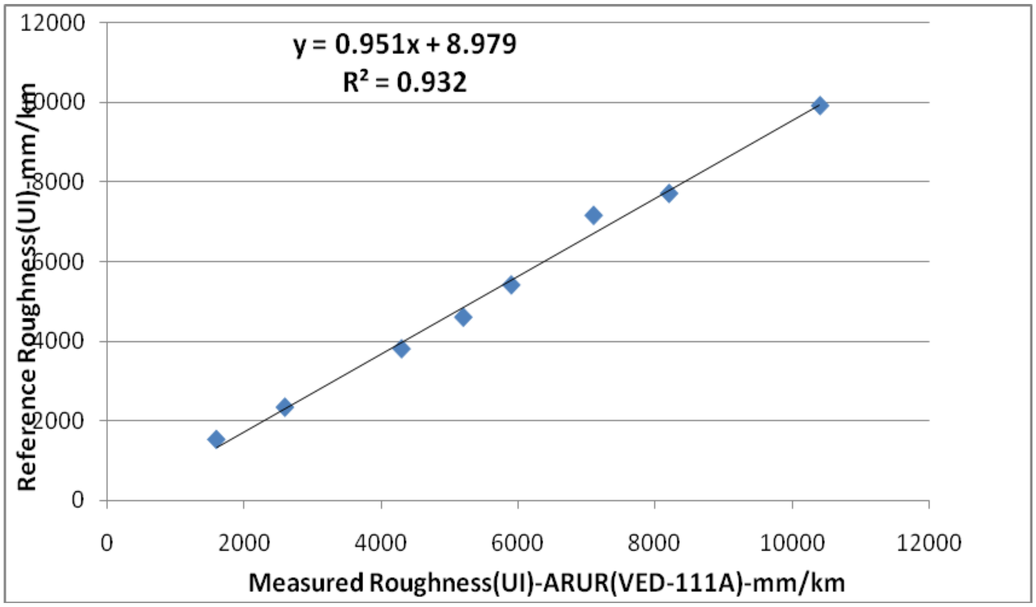

FIGURE 1 Measured Roughness vs. Reference Roughness

TABLE- 1 Unevenness Index (UI) Data

Test Site No.	IRI-Dipstick Data(mm/km)	Measured UI-ARUR-VED No.111A(mm/km)	Reference UI-Dipstick(mm/km)	Calibrated UI-ARUR-VED No.111A(mm/km)
1	2.20	1600	1524	1531
2	3.22	2600	2334	2484
3	4.98	4300	3804	4098
4	5.90	5200	4599	4954
5	6.82	5900	5410	5620
6	8.76	7100	7161	6761
7	9.36	8200	7712	7807
8	11.72	10400	9921	9899

METHODOLOGY

80 Bump integrators data has been used (3). For calibration purposes, a number of road sections having different roughness levels ranging from very smooth to very rough road surface were selected. ARUR Is run at a constant speed of 30 km/h and roughness data is acquired.

Dipstick is used to record roughness in terms of IRI (m/km). IRI is converted into Reference UI (unevenness index) using formula 630 $(IRI)^{1.12}$. Based on the roughness observed through Bump Integrators and roughness observed by Dipstick, the calibration equation is developed through regression analysis for determining the corrected / calibrated roughness.

Percentage error is calculated. New reference data was calculated using new factor. New factor was taken as average BI data divided by dipstick data. New factor for roughness 2000mm/km is found to be approximately 600 and new factor for roughness above 2000mm/km is found approximately 770.This new factor is used to find out new reference data. Calibration curve is drawn and regression equation is taken. New percentage error is calculated. Comparison of Percentage Errors between Reference Roughness and Calibrated Roughness using Conventional Factor and New Factor is shown in Table-2.

TABLE 2 Comparison of Percentage Errors between Reference Roughness and Calibrated Roughness using Conventional Factor and New Factor

Dipstick data (m/km)	BI mean	Reference roughness	Calibrated roughness	% error	Factor	New reference roughness	New Calibrated roughness	New % error
1.75	1000	1179	1001	15.0	571.42	1053	1116	-5.9
2.49	1580	1750	1609	8.0	634.53	1499	1551	-3.4
3.46	2551	2529	2627	-3.8	737.28	2674	2698	-0.8
4.51	3476	3404	3597	-5.6	770.73	3486	3490	-0.1
5.7	4408	4425	4574	-3.4	773.33	4406	4388	0.4
6.45	5250	5082	5457	-7.4	813.95	4986	4954	0.6
7.53	5522	6044	5742	5.0	733.33	5821	5768	0.9
8.47	6571	6895	6842	0.78	775.79	6547	6477	1.1
9.64	7600	7970	7920	0.63	788.38	7452	7360	1.2
10.41	8247	8687	8599	1.0	792.21	8047	7941	1.3
Avg.of first two ≈ 600 **Avg.of 3rd-10th reading ≈ 770**								

6. CONCLUSIONS AND FUTURE DIRECTIONS

By using low roughness constant for low roughness and higher roughness constant for high roughness, percentage error of calibrated roughness w.r.t. reference roughness is drastically reduced. This relation equation can be readily applied in professional practice to develop accurate and reliable calibration equation for Bump Integrator. It is recommended to use roughness constant 600 for roughness up to 2000mm/km IRI and roughness constant 770 for roughness above 2000mm/km IRI.

For roughness up to 2000mm/km, UI=600*IRI

For roughness above 2000mm/km, UI=770*IRI

REFERENCES

1. Guidelines for surface of Highway pavements (IRC 2004).
2. Standardisation of Axle Mounted Roughness measuring system for Andhra Pradesh PWD.
3. Various calibration reports on 5th wheel Bump Integrators submitted to various agencies by CRRI.