

Pavement Roughness Prediction Systems: A Bump Integrator Approach

Manish Pal, Rumi Sutradhar

Abstract—Pavement surface unevenness plays a pivotal role on roughness index of road which affects on riding comfort ability. Comfort ability refers to the degree of protection offered to vehicle occupants from uneven elements in the road surface. So, it is preferable to have a lower roughness index value for a better riding quality of road users. Roughness is generally defined as an expression of irregularities in the pavement surface which can be measured using different equipments like MERLIN, Bump integrator, Profilometer etc. Among them Bump Integrator is quite simple and less time consuming in case of long road sections. A case study is conducted on low volume roads in West District in Tripura to determine roughness index (RI) using Bump Integrator at the standard speed of 32 km/h. But it becomes too tough to maintain the requisite standard speed throughout the road section. The speed of Bump Integrator (BI) has to lower or higher in some distinctive situations. So, it becomes necessary to convert these roughness index values of other speeds to the standard speed of 32 km/h. This paper highlights on that roughness index conversational model. Using SPSS (Statistical Package of Social Sciences) software a generalized equation is derived among the RI value at standard speed of 32 km/h and RI value at other speed conditions.

Keywords—Bump Integrator, Pavement Distresses, Roughness Index, SPSS.

I. INTRODUCTION

PAVEMENT indices are the key measures for better understanding of the present condition, serviceability and performance of the pavement. Roughness is widely regarded as the most important measure of pavement indices which affects safety, comfort, travel speed, vehicle operating costs etc. Therefore, it has been considered as one of the key factors to make a decision for further road works. Recent literature regarding optimization of pavement maintenance strategies also addresses roughness as an important indicator that affects lifecycle costs of a road stretch.

But evaluation of roughness of pavement surface is very difficult as it also depends on the working principal or strategy of measuring instruments in addition to the actual road surface conditions. Different instruments have been developed by different agencies and standardized at different manner for the collection of pavement roughness data. Among various instruments, Towed Fifth Wheel Bump Integrator is the most popular equipment being used by several organizations in developing countries because it is affordable, simple and quite

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easy to operate. It also needs less frequent maintenance and calibration technique. But this instrument is standardized to a particular speed value of 32km/h. That means for accurate roughness result the surveyor have to drive this instrument at a speed of 32km/h. If the speed changes from 32km/h, the instrument will show different values of roughness and this value will not match with the actual profile of the road surface. That's why it is mandatory to maintain the constant speed of 32km/h throughout the road. But sometimes it is not possible to retain this constant speed in field due to traffic variance, sharp horizontal curve, steep gradient, narrow path etc. Somewhere it needs to increase or decrease the vehicle speed while driving a long travel distance. Therefore, it becomes very essential to negotiate this drawback of Bump Integrator instrument so that it may possible to evaluate the RI value even it is operated in any speed other than its standard speed of 32km/h. Some correlations between BI values of surface roughness at standard speed and BI values of surface roughness at various speeds have been presented in this paper.

II. SOME HIGHLIGHTS ON EXISTING WORKS

A group of researcher worked on road roughness and its measurement. Most of them preferred response-type road roughness measuring systems which estimate pavement roughness from correlation equations. Using several case studies, they have shown how the bias created by speed fluctuations affects the road roughness. Most of the calibration systems recommend to maintain a constant survey speed or to keep the speed within a certain range. But carrying out a survey with this speed constraint may not always be possible due to the existence of traffic control devices and heavy traffic flow. Therefore, these systems may produce a significant bias in roughness measurement because of survey speed fluctuations. A simplified regression relationship for IRI with bump integrator reading and survey speed as explanatory variables is developed using ROMDAS bump integrator [1]-[6].

Few researchers worked on the distress of road pavement. They presented the timely identification of undesirable distress in pavements at network level using pavement management system summarizing the implementation of a condition prediction or methodology using different techniques to forecast cracking, raveling, rutting and roughness for Low Volume Roads (LVR) in India [7]-[10].

Presently Artificial Neural Networks (ANN) is broadly used by researcher to analyzed the Long Term Pavement Performance (LTPP) database to predict the international roughness index (IRI) in rigid flexible and rigid pavements.

Different pavement roughness parameters such as initial IRI value, age, faulting, traffic data, and transverse cracking data for different severity levels (low, medium, and high) were used as input data set for development of ANN model in most of the studies [11]-[15].

III. BUMP INTEGRATOR

It is an automatic Road Unevenness Recorder, an indigenous device developed by CRRRI (Central Road Research Institute). It comprises of a standard pneumatic wheel mounted within a rectangular frame with single leaf spring on either side. Spring dashpots mounted on the leaf spring provide damping for the suspension. An integrating unit is there which is mounted on one side of the frame and integrates the unevenness in cm. For the measurement it is towed by a jeep at a constant speed of 32km/h under standard tyre pressure of 2.1kg/cm² along the designated wheel path. Bumps in cm and corresponding road length in terms of wheel revolution pulses are displayed / recorded on a panel board. The wheel runs on the pavement surface and the vertical reciprocating motion of the axle is converted into unidirectional rotary motion by an integration unit. The accumulation of this unidirectional motion is recorded by operating electronic sensors incorporated in the circuit, once for every 10mm of accumulated unevenness.

IV. WORK METHODOLOGY

A no. of dataset is required to test the BI value at different speeds. In this regard total 15 PMGSY road stretches of 225m are selected at Melagarh subdivision at west district of Tripura, India. Roads are such way selected that other parameters which affects roughness value and riding comfort ability such as soil characteristics, materials properties, traffic condition, etc. are same for all stretches and the stretches should be consists of noticeable surface undulations. During case study, it is noticed that the speed change during BI test usually differs in between 20km/h to 50km/h in low volume roads in Tripura due to traffic variance, sharp horizontal curve, steep gradient, narrow path etc. So, it is decided to conduct BI tests with speeds varying from 20km/h to 50km/h with an increment of 5km/h and for correspondence the standard speed value of 32km/h is also considered. For bump integrator reading, first the total stretch is marked properly. Then at starting point i.e. at 0 distance, the BI reading is adjusted to "0" cm. The instrument is driven over the stretch with a speed of 20km/h and after crossing the end point marking; BI reading is taken and noted. The result of bump integrator is generated in terms of count per km, which is the accumulation of the number of pulses in the total stretch. Same test is repeated considering the speeds as mentioned above. During analysis, BI values of 10 stretches (among 15 stretches) are used for developing the models and rests 5 are used for validating the equations. Using SPSS software linear Regression analysis is done for developing correlation models. Table I shows the result of BI tests at 20, 25, 30, 32, 35, 40, 45 and 50km/hr speed. Some individual equations are developed

with the BI value of standard speed of 32 km/h against the BI values of above mentioned speeds. But it is required to generalize the equations to expand the measuring area and for universal use of bump integrator instrument. So, using multiple linear regression analysis by SPSS, a generalized model is developed. For validation of the models, percentage error is calculated which may be regarded as reliable.

V. RESULT AND DISCUSSION

It is observed that for every stretch, BI value at 20km/hr speed is highest conversely BI value at 50km/hr is lowest. With the increase of speed, BI value is consequently decreasing. This phenomenon can be focused to the fact that when the Bump Integrator wheel travels at higher speed it tends to miss out micro and small distresses on the pavement surfaces, showing lesser BI values. On the contrary, when it travels at lower speeds, it follows the actual profile of the road surface and the wheel covers both micros as well as large-scale irregularities and hence indicates higher BI values. Graphs are plotted between the observed values taking speeds as abscissa and corresponding BI values of roughness as coordinates. From the graphs (Fig. 1) it is observed that for all operating speeds, BI values forms almost distinct straight lines with a descending order slope. Table II shows the equations at corresponding speeds with satisfactory R² values. The generalized equation derived by multiple linear regression analysis is established between the observed BI values at standard speed as the dependent variable and the observed BI values at a particular speed of operation as the independent variable and that particular speed as another independent variable (1).

$$(BI)_{32} = 0.956(BI)_V + 0.842V - 25.544 \quad (R^2 = 0.958) \quad (1)$$

where,

(BI)₃₂ = BI value at standard operating speed of 32 km/hr.

(BI)_V = BI value at Operating speed V.

For validation of these equations, BI values at 32km/hr are calculated using the individual equations as well as the generalized equation for the rest 5 stretches. The percentage of error is calculated for both cases following (2).

V = Operating speed in km/hr.

$$\% \text{ deviation} = \frac{((\text{Observed } (BI)_{32}) - (\text{Calculated } (BI)_{32})) \times 100}{\text{Observed } (BI)_{32}} \quad (2)$$

It may be observed from Table III that there was not much variation between the BI values with those of the predicted values using individual and generalized equations. The Mean percentage error of the values with the developed individual and generalized equations were -2.219 and -2.439 respectively. Thus the equations were found to be satisfactory for predicting BI values when the data could not be collected at standard operating speed of 32km/hr. Also it was observed that the individual equations were more accurate than the generalized equation.

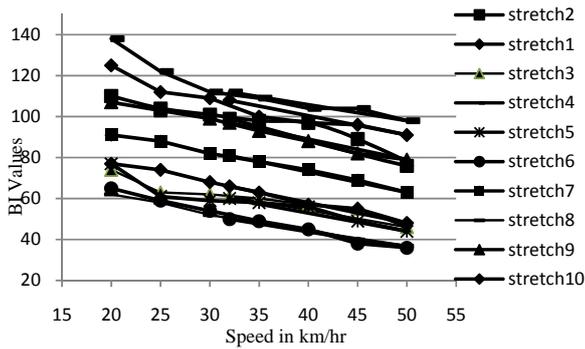


Fig. 1 BI values on different stretches at different speeds

VI. CONCLUSION

Generally Bump Integrator is used to determine road roughness measurements. But this instrument is not free from speed constraint and is not suitable for any survey speed or speed fluctuations. This limitation produces a significant bias in roughness measurement if the survey speed is not properly maintained at standard speed of 32km/h. In present study an attempt has been taken to develop an equation for the conversion of fifth wheel Bump Integrator values from different speed to a standard speed of 32 km/hr. In this regard some individual equations are derived to convert BI value at a speed of 20km/hr, 25km/hr, 30km/hr, 35km/hr, 40km/hr, 45km/hr & 50 km/hr. But it is required to establish a generalized equation so that we can convert BI values of any speed other than the speeds mentioned above. Using SPSS software the generalized equation is derived as:

$$(BI)_{32} = 0.956(BI)_V + 0.842V - 25.544 \quad (R^2 = 0.958) \quad (3)$$

After validation with all the derived equations mean percentage error found by individual and generalized equations are -2.21965 and -2.439789 respectively, which are very negligible. It is observed that the BI values of roughness decreases significantly with the increase in operating speed of the Bump Integrator.

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