International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 02 | Feb-2018 www.irjet.net p-ISSN: 2395-0072

FLEXIBLE PAVEMENT EVALUATION USING PROFILOMETER FOR UNEVENNESS

Durgesh Kumar Singh[1], Prof. (Dr.) P. J. Gundaliya[2]

[1]*Final year M.E. Student, Civil Engineering Department, L.D. College of Engineering, Ahmedabad, Gujarat, India*
[2]*Prof. Civil Engineering Department, L.D. College of Engineering, Ahmedabad, Gujarat, India*

Abstract - *Surface unevenness of a pavement has been recognized to be an important parameter for determining maintenance and rehabilitation needs for road networks. To determine roughness and rutting condition, road agencies use equipment which have high initial cost that will give more survey cost. However, most road agencies, especially for local governments, frequently monitor and determine the pavement condition through visual inspections. This study introduces a new Profilometre for more effective data collection and real-time monitoring of the pavement roughness.*

The measured profile data in the proposed Profilometre can be immediately converted to a summary roughness index such as the IRI. The unevenness information is simultaneously displayed on an onboard computer in real time. This study also presents profile measurement experiments to verify the accuracy of the new Profilometre for roughness data collection and demonstrates its benefits to pavement monitoring of local roads through an application case study.

This study will focus measurement of unevenness with developed Profilometre, including the hardware design, software development and data analysis.

Key words: Unevenness, Profilometer, International Roughness Index (IRI)

1. INTRODUCTION

India is having the second largest road network in all over the world and having more than 60% low volume roads. Low volume roads in the rural areas face serious problems due to absence of timely maintenance resulting from stringent budget availability. For proper management of these roads, scientific pavement management tools are necessary. Right maintenance treatment is to be given to the right place at the right time.

All roads are designed with a finite life, usually defined by the traffic that the road can carry in terms of the cumulative number of equivalent standard axles. Once this design traffic has been carried, or as a result of premature distress caused by some environmental influence, the road usually needs to be rehabilitated.

Prior to any rehabilitation design being carried out, it is necessary to fully assess and evaluate the condition of the road pavement and to identify the reasons for the distress. The time and resources required for these types of investigation are generally limited and costly and thus it is essential that the appropriate information be gathered and that it is presented in a systematic and complete manner.

Road smoothness, or roughness, is one of the most important road functional characteristics because it greatly affects ride quality and vehicle dynamic load. It is also closely associated with vehicle operating costs, such as fuel consumption, tire wear, and vehicle durability. Therefore, establishment of methods for measurement and evaluation of road smoothness is a common concern of highway state agencies.

Many techniques are available for measuring road smoothness, most of which measure the vertical deviations of the road surface along a longitudinal line of travel in a wheel path, known as the profile. The American Society of Testing and Materials (ASTM) standard E-867 defines roughness as the deviations of a pavement surface from a true planer surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads, and drainage.

Road profile measurements started with straight edge devices in the early 1900s, and they have evolved to vehicles that can measure the road profile while travelling at normal traffic speed. These equipments measure longitudinal profiles, which provide vertical elevation as a function of longitudinal distance along a prescribed path. The equipment used to measure roughness of pavements varies across highway agencies.

The International Roughness Index (IRI) is the index most widely used in the USA for measuring road roughness. Since 1990, FHWA has required state highway agencies to submit the roughness values of the Highway Performance Monitoring System sections in IRI. The American Society of Testing and Materials (ASTM) standard E-1926 defines the standard procedure for computing IRI from longitudinal profile measurements.

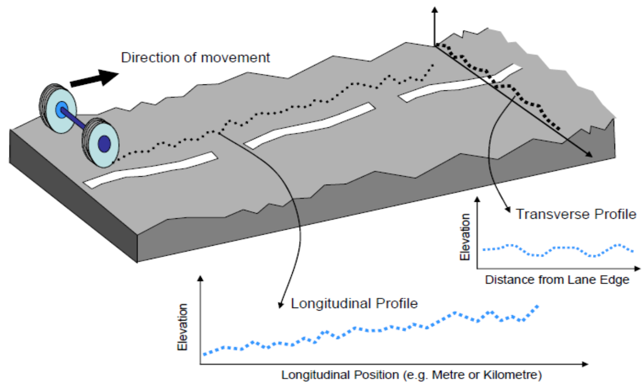
1.1 UNEVENNESS

It is always desirable to have an even surface, but it is seldom possible to have such a one. Even if a road is constructed with high quality pavers, it is possible to develop unevenness due to pavement failures. Unevenness affects the vehicle operating cost, speed, riding comfort, safety, fuel consumption and wear and tear of tyres.

Basically unevenness of the pavement are divided into two groups:

Longitudinal unevenness (roughness)

Transversal unevenness (rutting)

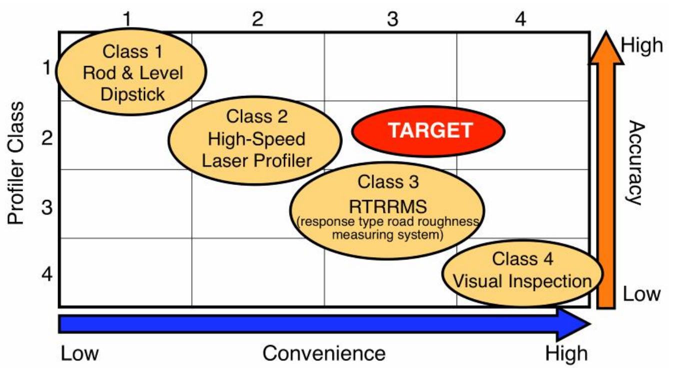


1.2 PROFILOMETER

Road pavement Profilometer uses a distance measuring laser (suspended approximately 30 cm from the pavement) in combination with an odometer and an inertial unit (normally an accelerometer to detect vehicle movement in the vertical plane) that establishes a moving reference plane to which the laser distances are integrated. The inertial compensation makes the profile data more or less independent of what speed the Profilometer vehicle had during the measurements, with the assumption that the vehicle does not make large speed variations and the speed is kept above 25 km/h or 15 mph. The Profilometer system collects data at normal highway speeds, sampling the surface elevations at intervals of 2–15 cm (1–6 in), and requires a high speed data acquisition system capable of obtaining measurements in the kilohertz range.

The data collected by a Profilometer is used to calculate the International Roughness Index (IRI) which is expressed in units of inches/mile or mm/m. IRI values range from 0 (equivalent to driving on a plate of glass) upwards to several hundred in/mi (a very rough road). The IRI value is used for road management to monitor road safety and quality issues.

2. AIM OF THE STUDY



3. THE INTERNATIONAL ROUGHNESS INDEX (IRI)

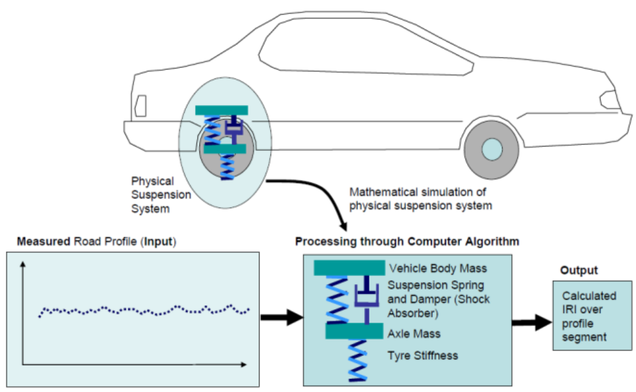
The International Road Roughness Measurement Experiment was held in Brazil in 1982, to develop an International roughness index (IRI) for exchanging data, and to publish guidelines for measuring roughness on a standard scale. IRI was the first widely used profile index where the analysis method is intended to work with different type of profiles. IRI is reproducible, portable and stable with time. The IRI was mainly developed to match the response of passenger cars, but subsequent research has shown that IRI correlates well with other vehicles such as light trucks and heavy trucks. IRI is highly correlated to three vehicle response variables;

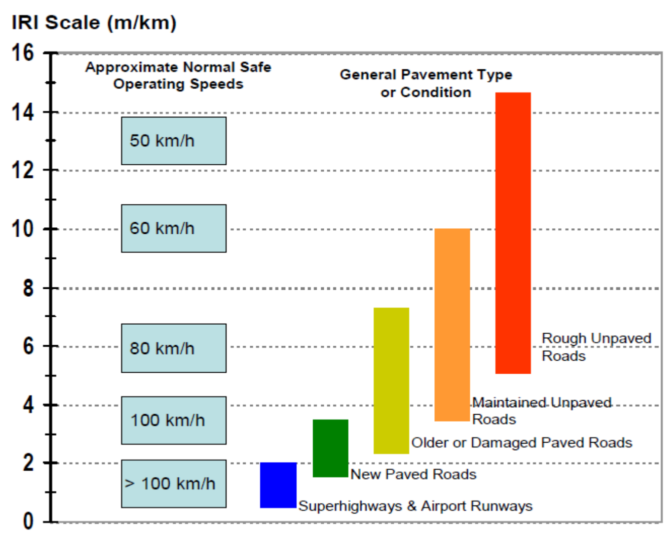
1. Road meter response,

2. Vertical passenger acceleration

3. Tire load.

The IRI is a mathematical model applied to a measured profile. This model simulates a quarter car systems (QCS) travelling at a constant speed of 80 km/hr. The IRI is computed as the cumulative movement of the suspension of the QCS divided by the travelled distance, the unit of the index is m/km or inch/mile. Figure shows the QCS model.





4. CRITICAL LITERATURE REVIEW

The following are the previous research review based on application of engineering project.

Akira Kawamura et.al. (2016) study focuses on a method for providing basic information about road roughness and IRI on municipal roads, which may assist and improve the implementation of PMS in municipalities. The overall objectives of this study are as follows.

To introduce the principle of a new compact road profiler to measure IRI and roughness condition of municipal roads in different cities during different seasons.

To introduce the use of GIS and Japan digital road map (DRM) so as to visualize the survey results linking landuse and road classification.

To develop statistical analyses and evaluation methods based on a comparison study using local cities, road classes, road directions, wheel paths and different conditions of road roughness. Kitami Institute of Technology developed a new, cost-effective, time-stable, and easily workable compact mobile Profilometer (MPM) to address the demand known as "system with two accelerometers for measuring profile, enabling real-time data collection" (STAMPER). The new system consists of two small accelerometers, a global positioning system (GPS) sensor, an amplifier and a portable computer. A small GPS sensor can be placed at any corner of a vehicle's front panel to obtain travelling speed and measurement position. Two small accelerometers are mounted on the sprung and unsprung masses on the suspension system of a survey vehicle. A transducer converts the strain of accelerometers into the electrical signal, and then the information of road evenness is displayed on a PC screen in real-time.

Josef Zak et.al. (2016) research project was to develop a free to use and modify program capable to calculate IRI and roughness properties of pavement layers from point cloud data and statistically evaluate whether the point cloud data commonly acquired on sites are so high-quality that they can be used for the surface smoothness parameters calculation. The comparison was done with the methods broadly used to measure pavement roughness – rod and level and IRI – precise levelling. The following are the key conclusions and findings from this study.

The most important conclusion from this project, in the authors' opinion, is that the point cloud data commonly acquired on the site may be used to calculate the surface smoothness properties such as IRI and roughness. The standard deviation of IRI calculated from a point cloud was found to be lower than the standard deviation of IRI calculated from the longitudinal profile measured with precise levelling.

The histogram descriptor was used to analyze the rectified slope and roughness. Class widths were determined using Freedman and Diaconis's law. The Pearson type IV distribution was found to provide a reasonable approximation of both rectified slope and roughness histograms. The distribution parameters may be used for the data comparison.

Nebojša Radović et.al. (2016) examines the existing methods for measurement and model for prediction of pavement surface roughness and evaluation of the road network condition in the Republic of Serbia in total length of 13 191,34 km.

The pavement roughness measurement done by the portable laser profilers installed on the ARAN (Automatic Road ANalyzer) multifunctional vehicle for road network data collection.

Equipment is based on contact-free scanning of the values of vertical acceleration of the measuring axle's un-sprung mass and the values of vertical acceleration of the sprung mass of the vehicle's body. Modelling of pavement roughness development simultaneously comprises effects of different pavement distress types and relative effects of traffic volume, pavement strength, pavement structure type, pavement age and ambiental characteristics.

Pavement roughness development model is expressed with the following equation in the HDM-4 model :

$\Delta RI = Kgp + \Delta RIs + \Delta RIc + \Delta RIr + \Delta RIt + \Delta RIe$

where

Kgp - calibration factor of general surface roughness development,

ΔRI - gradual increase of pavement surface roughness,

Kgm - development calibration factor for environmental component.

Factors representing gradual increase of pavement surface roughness due to:

- ΔRIs - structural pavement deterioration
- ΔRIc - cracking,
- ΔRIr - rutting,
- ΔRIt - potholes,
- ΔRIe - climate effects.

Manish Pal et.al. (2014) 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 conversional 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.

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

$(BI)_{32} = 0.956(BI)v + .842V - 25.544 (R^2 = .958)$
where,

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

$(BI)_v$ = BI value at Operating speed V.

Yuchuan Du et.al. (2014) Established an IRI estimation model based on regression analysis. Based on the multiple linear fitting model and velocity correction model, we developed a coupled system that can record the real-time Z-axis acceleration in different pavement conditions, at different times, and with different values for various other parameters. The variation in the in-car Z-axis acceleration caused by road roughness can be regarded as a combination of the vibration produced by different mechanical components, and thus the vertical acceleration is strongly correlated with the IRI. The quarter-car model was a LTI system and the mean squared value of the power spectral density could represent the equivalent amplitude of signals, which can represent the size of the signal amplitude, and thus we used a regression method to model the variation in the Z-axis acceleration and the IRI .We used the power spectral density sequence of the Z-axis acceleration to model the IRI. An innovative feature of the measurement process was that multiple local accelerations were considered in order to improve the goodness of fit of the model.

Yaxiong (Robin) Huang et.al. (2013) in the TxDOT Construction Division, Materials and Pavement Section, has successfully developed a new rut measurement system based on high-speed 3D measurement technology that can provide accurate rut measurement from continuous transverse profiles.

VRUT is a high-speed, multifunctional device capable of capturing high-resolution 4.3 m (14-ft) wide range images and intensity images at speeds from 16 to 113 km/hr (10 to 70 mph). VRUT can detect lane stripes, pavement edges, curbs, and roadside vegetation, and can identify the actual wheel paths for correct rut measurement.

(a) (b)

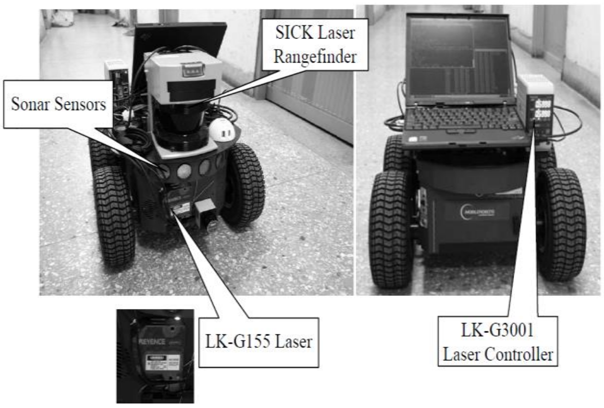
Shahbaz khana et.al. (2013) A systematic study was initiated on the permanent deformation development involving a flexible pavement designed as per Indian practice. The paper brings out the details of this evaluation study and also features the capabilities and applications of Indian APTF in the issue.

The Profilometer consists of an aluminium frame that spans the cross sectional width of the test section resting on legs on either side of the test section. A measuring head containing the laser head is attached to the beam of the frame via a motorised carriage and moves along the length of the beam taking readings every 10 mm over a total length of 2.56 m.

They found out to be best fitting the scatter with a equation as shown below and R2 value of 0.978

y = -2E-05x4 + 0.0024x3 - 0.0841x2 + 1.2918x + 0.8128
Where y and x are rut depth in mm and number of passes

Jia-Ruey Chang et.al. (2009) conducted In this paper, author test an autonomous robot can be used to measure the International Roughness Index (IRI), a description of pavement ride quality in terms of its longitudinal profile. A ready-made robot, the Pioneer P3-AT, was equipped with odometers, a laptop computer, CCD laser, and a SICK laser ranger finder to autonomously perform the collection of longitudinal profiles. ProVAL (Profile Viewing and Analysis) software was used to compute the IRI. The preliminary test was conducted indoors on an extremely smooth and uniform 50 m length of pavement. The average IRI (1.09 m/km) found using the P3- AT is robustly comparable to that of the commercial ARRB walking Profilometre. This work is an initial step toward autonomous robotic pavement inspections. They also discuss the future integration of inertial navigation systems and global positioning systems (INS and GPS) in conjunction with the P3-AT for practical pavement inspections.



By the study of this paper they found that , there is no accelerometer mounted on P3-AT since test path is very level, pavement surface is very smooth and the vertical displacement measurement by the P3-AT occurs when the unit is at rest.

5. SUMMARY

The computation of IRI is based on a mathematical model called a quarter-car model.

The quarter car is moved along the longitudinal profile at a simulation speed of 80 km/h (50 mph). The mathematical model calculates the suspension deflection of the quarter car using the measured profile displacement and standard car structure parameters. The simulated suspension motion is accumulated and then divided by distance travelled to give an index with unit of slope (m/km or in/mi), which is called IRI. Most States are using IRI derived from profiler measurements to evaluate pavement condition, and some States are using it for construction quality control for individual projects.

ACKNOWLEDGEMENT

I would like to thank to my Guide Prof. (Dr.) P. J. Gundaliya, Professor, Civil Department (Transportation Engineering) L.D.C.E, for his moral support, constant unceasing encouragement, critical evaluation, suggestion, constant untiring guidance and affection during the entire span of my post-graduation study.

REFRENCES

[1] H.M. Ngwangwa a, P.S. Heyns a, H.G.A. Breytenbach b, P.S. Els b,(2014) "Reconstruction of road defects and road roughness classification using Artificial Neural Networks simulation and vehicle dynamic responses: Application to experimental data" Journal of Terramechanics.

[2] Jia-Ruey Chang, Yung-Shuen Su, Tsun-Cheng Huang3 Shih-Chung Kang and Shang- Hsien Hsieh,(2009) "Measurement of the International Roughness Index (IRI) Using an Autonomous Robot (P3-AT)" 26th International Symposium on Automation and Robotics in Construction (ISARC 2009).

[3] Manish Pal, Rumi Sutradhar,(2014) "Pavement Roughness Prediction Systems: A Bump Integrator Approach" International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering Vol:8, No:12.

[4] Mehran Mazari , Daniel D. Rodriguez ,(2016) "Prediction of pavement roughness using a hybridgene expression programming-neural network technique" Journal of traffic and transportation engineering 2016.

[5] Nebojša Radović, Igor Jokanović, Bojan Matić, Miloš Šešlija,(2016) "A MEASUREMENT OF ROUGHNESS AS INDICATOR OF ROAD NETWORK CONDITION – CASE STUDY SERBIA" ISSN 1330-3651(Print), ISSN 1848-6339 (Online) (2016).

[6] Nueraihemaitijiang Abulizi , Akira Kawamura, Kazuya Tomiyama, Shun Fujita,(2016) "Measuring and evaluating of road roughness conditions with a compact road profiler and ArcGIS" Journal of traffic and transportation engineering 2016.

[7] Shahbaz khana , M.N. Nagabhushanaba , Devesh Tiwarica, P.K. Jainda (2013) "Rutting in Flexible Pavement: An approach of evaluation with Accelerated Pavement Testing Facility"2nd Conference of Transportation Research Group of India (2nd CTRG).

[8] Yaxiong (Robin) Huang, Todd Copenhaver and Phillip Hempel,(2013) "Texas Department of Transportation 3D Transverse Profiling System for High-Speed Rut Measurement" Journal of Infrastructure Systems, Vol. 19, No. 2, June 1, ASCE.

[9] Zhu Nan-nan, Zhang Jun,(2016) "Surface roughness measurement based on fiber optic sensor" journal Elsevier Measurement (2016).