Analysis of Roughness Index of a Flexible Pavement Using Profilometer: A Review

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Abstract-
For the maintenance of road network and need for migration requirement the unevenness of the pavement is the important parameter. To identify roughness and toughness and for determining, inspecting and positioning of pavement most of the highway agencies use the method of visualization inspection. This study with more accurate collection of data and real time inspection of pavement unevenness represents a new Profilometer.This proposed Profilometer can be used to convert IRI into roughness index. The proper information of unevenness in together with real time can be displayed on computer at the same time. This study on broad view also approved the accuracy of profilometer in terms of data collection. This study is also beneficial for the inspection of road's pavement in local area and will help a lot for future plan in view of durability. This study mainly basis on design of hardware, software development, data analysis along with measurement of unevenness with the help of developed profilometer.

Key words: Unevenness, Profilometer, InternationalRoughness Index (IRI)

I.INTRODUCTION

India is also popular for its road connectivity and it contains 2nd largest road network in the world also more than 60% of the road are of low traffic density. In rural area, low traffic roads with low budget for their constructions, lack of maintenance time to time are facing with many serious problems. For proper management of these roads we need latest scientific pavement management equipment. For avoidace of any accident there is urgent need of proper maintenance, proper treatments of road at the right time. All roads are designed for estimated life time. In general it has been taken by trafficvolume equivalent to cumulative number axis. Roads are always constructed with the help of standard design traffic protocol.For completing any rehabilitation design, position of road's pavement should be properly and accurately evaluated and all drawback should be removed to avoid any negative incidents are the need of the hours.For these types of inspection the required resource and time in generally are limited and costliest. Hence it is very important to collect each pin of information and try to make a proper plan of implementation to inspect successfully, economically and timely.

Out of many constructive characteristics the smoothness and roughness characteristics of road are very much important because it affects the quality of travel and speediness of vehicle. It also decides the cost of vehicle operating like consumption of fuel, durability of wheel tyre, endurance of vehicles and many others. That's why it is the highest concern of Highway authority for finding the technology in order to improve measurement and evaluation of the smoothness of the road.

There are several technology available for the measurement of road safety out of these the most usable is single way with longitudinal line on the surface which is used for the measurement of vertical deviation popularly known as "Profile". American Society of Testing and Materials (ASTM) standard E-867 defines 'Roughness's as condition parameter used to measure deviations from the intended longitudinal profile of a road surface, with characteristic dimensions that affect vehicle dynamics, ride quality and dynamic pavement loading.During the starting decades of 90s the measurement of road profile was done with the help of 'Straight Edge Devices' and that was specially developed for those vehicles which measures 'Profile' during the travel with traffic speed.Different Highway agencies have different types of roughness measure instruments.

The International Roughness Index (IRI) is the index which is used on large scale in United States of America for the measurement of the road's roughness.After 1990, Highway agencies of FHWA felt the urgent requirement of IRI index for the measurement of the performance of Highway under different section of roughness.This is very much important either for inspecting the unevenness of road or for checking the quality and durability of road.This is always required for the purpose of implementing plane surface but having this is impossible. If we construct road with high quality of pavers then due to failure of pavement it might be possibility to reduce unevenness. Unevenness affects many things like operating cost of vehicles, vehicle speed, comfortness of passenger, road safety, consumption of fuel etc. Unevenness mainly defines as the measure of unevenness which is basically used for the cumulative measure of vertical undulation of the surfaces which are pavements and are recorded per unit horizontal length of the road. An unevenness index having value less than 1500 mm/km can be considered as good while a value less than 2500 mm/km can be considered as satisfactory up to speed of 100kmph and value greater than 3200 mm/km can be considered as uncomfortable even for 55kmph.

In general there are two types of unevenness of pavement:

1. Longitudinal Unevenness
2. Transversal Unevenness

Figure: 1Pavement failure (Source-Google)

1.2 PROFILOMETER

Road pavement profilometer, also called profilograph uses a distance measuring laser (suspended approximately 30cm from the pavement) in combination with an adometer and an inertial unit that establishes a moving reference plane to which the laser distance are integrated. The inertial compensation makes the profile data more or less independent of what speed the profilometer vehicles had during the measurement, with the assumption that the vehicle does not make large speed variation and the speed is kept above 25kmph or 15mph. The profilometer system collects data at normal highway speeds, sampling the surfaces elevation at interval of 2-15 cm (1-6 inch) and requires a high speed data acquisition systems capable of obtaining measurements in the kilohertz range Profilometer are also measuring the pavements cross slope, curvature, longitudinal gradients and rutting.The data collected by a profilometer is used to calculate the International Roughness Index (IRI) which is expressed in unit of inches/miles or mm/m. IRI values range in between 0 to 100. The IRI value is used for road management to monitor road safety and quality issues.

II. AIM OF THE *S*TUDY

The focus of this study is to measure the difference in erosion depth of pavement with the help of profilometer. By inspecting the unevenness with the help of profilometer we can improve the highway and as a result can improve the life of vehicles, comfortness and can make the road more durable and in turns can improve the quality of roads.

III. THE INTERNATIONAL ROUGHNESS INDEX (IRI)

The IRI was defined as a mathematical property of a two-dimensional road profile (a longitudinal slice of the road showing elevation as it varies with longitudinal distance along a travelled track on the road). As such, it can be calculated from profiles obtained with any valid measurement method, ranging from static rod and level surveying equipment to high-speed inertial profiling systems. The IRI is calculated from the road profile. This profile can be measured in several different ways. The most common measurements are with Class 1 instruments, capable of directly measuring the road profile, and Class 3 instruments, which use correlation equations. Using World Bank terminology, these correspond to Information (IQL) 1 and IQL-3 devices, representing the relative accuracy of the measurements. A common misconception is that the 80 km/h used in the simulation must also be used when physically measuring roughness with an instrumented vehicle. IQL-1 systems measure the profile direction, independent of speed, and IQL-3 systems typically have correlation equations for different speeds to relate the actual measurements to IRI.IQL-1 systems typically report the roughness at 10–20 m intervals; IQL-3 at 100m+ intervals.

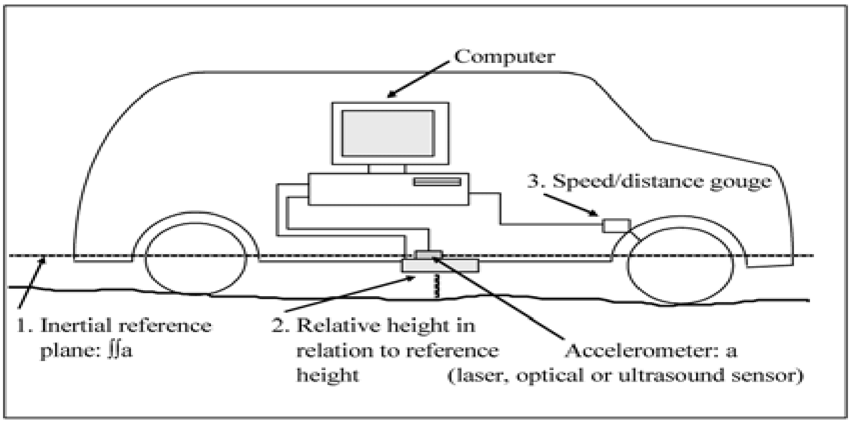

Figure 2: Inertial Profilometer (Source-Google)

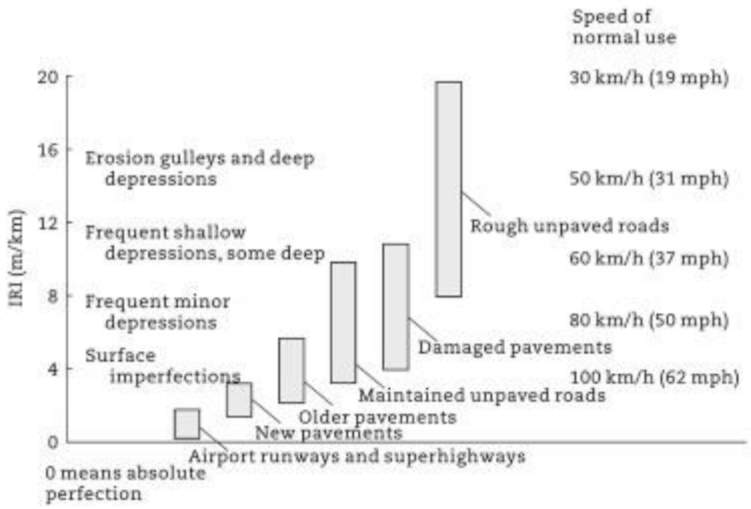

Figure 3: IRI Roughness Index (Source- Google)

IV. CRITICAL LITERATURE REVIEW

The previous research review based on application of engineering project is mention below.

Akira Kawamura et.al. (2016) study basis on a methodfor 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 afree 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 leveling. 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 leveling.
- 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.

NebojsaRadovic et.al. (2016) examines the existingmethods 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:

ΔRI= Kgp + ΔRIs + ΔRIc + ΔRIr + ΔRIt + ΔRIewhere

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 lowvolume 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(R2 = .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 estimationmodel 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 -axis acceleration in different pavement conditions, at different times, and with different values for various other parameters. The variation in the in- car -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 -axis acceleration and the IRI .We used the power spectral density sequence of the - 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 TxDOTConstruction 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.

Shahbazkhana et.al. (2013) A systematic study wasinitiated 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 pass.

V. CONCLUSION

We can evaluate IRI with the help of mathematical model which is popularly known as 'Quarter Core Model'. One quarter core runs with the speed of 60kmph in parallel with pavement along longitudinal direction. The mathematical model finds the suspension definition of quarter core by the use of measured profile, displacement and standard core structure parameter.

The approach consisted of a sensor (initially ultrasonic but later laser) which measures the height of the vehicle relative to the road. An accelerometer is double integrated to give the height of the sensor relative to datum. The difference between the two is the elevation profile of the road. This elevation profile is then processed to obtain the IRI. The most common approaches see the IRI measured in each wheel path. The wheel path IRIs needs to be combined to obtain the overall IRI "roughness profile" for the lane.

VI. ACKNOWLEDGEMENT

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