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Development Of Low Cost Road Roughness Using Measuring

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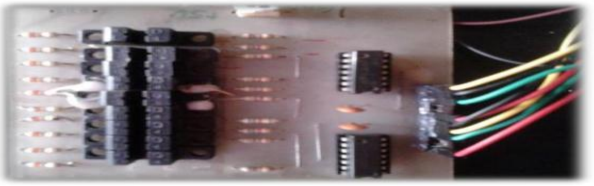
ABSTRACT

Today road and transport authorities around the world collectively spend large sums of money each year enhancing and maintaining their road networks. Road users in the majority of countries around the world continue to desire better and smoother roads, despite pressure on road authorities to further reduce expenditure. This pressure is brought about, because funding for road infrastructure is only one of the many priorities competing for Government funds. Pavements cannot be managed to the degree desired by decision makers, unless detailed accurate information and analysis supports the system. Road roughness data is considered one of the most important aspects of road condition information used in practice in pavement management systems. At present in the market, we have various roughness measuring equipments starting from costliest equipment such as ARAN laser (which uses laser beam to measure the roughness) to moderately costly Bump integrator (which uses the bump counts made by the probe wheel), to cheaper equipment such as MERLIN (which uses the slope value of the wheel to calculate the roughness). In the present research work, an attempt is made to develop low cost roughness measuring equipment and to check its reliability and repeatability to minimize the calibration error. It is calibrated using Bump integrator.

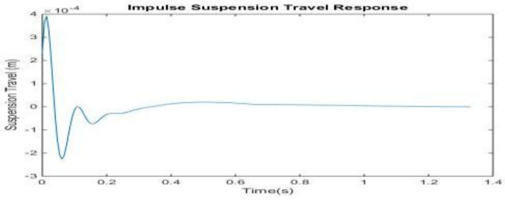
INTRODUCTION

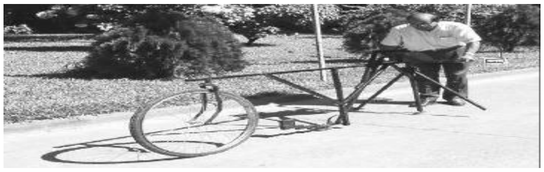
Road roughness is the deviation of a road surface from a true planar surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads, and pavement drainage. Roughness is primarily related to serviceability, structural deficiencies and road deterioration. It is one of the key indicators to evaluate road performance and condition. Roughness affects safety, comfort, travel speed, vehicle maintenance and vehicle operating costs. Roughness is the factor that most influence user's evaluation when rating ride quality. A more detailed definition is provided by Paterson (1987), where roughness is described as a composite distress comprising components of deformation due to traffic loading and rut depth variation, surface defects from spalled cracking, potholes, and patching, and a combination of aging and environmental effects. The roughness data collected over a period of time will help in building up the data bank. This data bank is the basic essence of any pavement management system A pavement management system allows fund managers to defend budget requests and to evaluate quickly and accurately they implications of alternative funding profiles on the resulting condition of the highway (Kennedy and Butler 1996).The need to measure roughness has brought a wide of instruments on the market, covering range from rather simple devices to quite complicated systems. In the past decades, roughness measurement instruments had become the everyday tools for measuring road roughness. The majority of States now own pavement roughness measurement systems. There are many proven methods for analyzing and interpreting data similar to the measurement results obtained from these systems. There are several causes of pavement roughness: traffic loading, environmental effects, construction materials and built-in construction irregularities. All pavements have irregularities built into the surface during construction, so even a new pavement that has not been opened to traffic can exhibit roughness. The roughness of a pavement normally increases with exposure to traffic loading and the environment. Short-wavelength roughness is normally caused by localized pavement distress, that is, depression and cracking, at the same time the long-wavelength roughness is normally caused by environmental processes in combination with pavement layer properties.



A metal sensor is used to measure the number of revolutions made by the probe wheel. The tail end of the sensor is attached to the circuit board. To record the number of bumps, ten slots are made and a metallic strip is attached to the probe wheel. These slots are coded to record the movement of the probe wheel

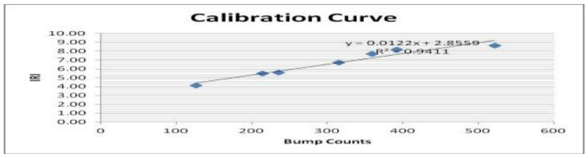
The unevenness of the terrain can be statistically described by roughness indices [17]. Roughness indices are an important indicator of pavement conditions. Over time, pavement conditions can have an adverse effect on vehicle costs, safety, vehicle handling, and on road users [17]. Roughness can be defined as changes in road profile heights for wavelengths ranging from 0.5 m to 50 m [18]. The majority of proposed roughness indices result in an estimate reflecting the ride quality of longitudinal road profiles by evaluating the comfort, safety, or the dynamic loading due to the excitations of the road on the vehicle. Some indices rely on physical measurements of the vibrational response of the vehicle while others use a simplified mathematical vehicle model to obtain a response of the vehicle due to the road.Since the Quarter-Car model used in the calculation of the IRI is LTI, the convolution integral can be used to solve for the suspension response as a function of the road excitation, which is briefly reviewed here. First consider a single event, specifically a unit impulse that occurs at time *ti*. Next, consider the response of the suspension at some later time, *tj*. The response of the suspension travel to this unit impulse is defined as the unit impulse response, *h(tj – ti)* such as that shown in Figure 3. As the time elapsed between a particular response and an excitation increases, there is an oscillation and overall decrease in the magnitude of the impulse response.Fatigue is caused by cyclic changes in stress or strain. Fatigue is the resulting damage caused from the cyclic loading of a component [33],[34]. The damage process can consist of the generation of cracks, the propagation of cracks, and the failure of the component. Usually, a crack develops when the component experiences localized plastic deformation on a region of max stress. Over time, as the component endures a variable and cyclic loading history, the crack length increases, indicating prolonged damaged and eventual failure. To calculate fatigue life, there are three approaches that are commonly used. These approaches consist of the stress-life approach, the strain-life approach, and the crack growth approach. The data obtained from 15 stretches were used for the analysis. Out of which, 6 stretch data were used for arriving at the calibration equation for Multiple Wheel Unevenness Indicator, 8 stretch data for developing Pavement Performance Model 08 stretches are located and the wheel paths (left wheel path and right wheel path) are marked to ensure that the two equipments (MERLIN AND MULTIPLE WHEEL UNEVENESS INTEGRATOR) traverse the same wheel path during the testing. Firstly, MERLIN is made to run along the wheel path. For every test section 4 runs were made (2 on left wheel path and two on the right wheel path) to achieve the accuracy.





ROAD ROUGHNESS

Though there is not a single definition for pavement roughness, it is generally defined as an expression of irregularities in the pavement surface that affects the ride quality of the vehicle. American Society of Testing and Materials (ASTM) definition (E867) for roughness is "The deviations of pavement surface from a true planer surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads and drainage, for example, longitudinal profile, transverse profile and cross slope". However it is found that the drainage and ride quality is unrelated to each other. Roughness is an important indicator of pavement riding, comfort and safety. However the different wave lengths on the surface profile affect differently on the ride quality depending on vehicle characteristics and driving speed.

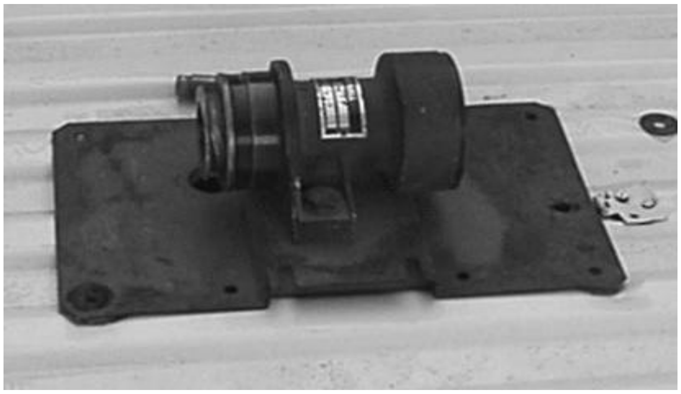


Generally, roughness may cause due to one or more of the following factors;

- construction techniques,
- Traffic loading. (For example repeated loads in a channelized area may cause pavement distortion by plastic deformation),
- environment effects,
- construction material, and
- non uniform initial compaction and built in construction irregularities.

Short wave length roughness is normally caused by localized pavement distresses such as depressions and cracking. On the other hand long wave length roughness is normally caused by environmental process in combination with pavement layer properties.

The MERLIN is a **M**achine for **E**valuating **R**oughness using **L**ow-cost **IN**strumentation. The Transport Research Laboratory (TRL) of United Kingdomdevised this equipment. The Merlin manual of TRL is enclosed herewith for reference (Appendix -2).Merlin is simple low-cost roughness measurement instrument that can be manufactured locally. The instrument can be used for direct roughness measurement or for calibrating other equipment like Bump Integrator. In RHD Merlin is used for calibrating purpose. It consists of a metal frame 1.8 meters long with a wheel at the front, a foot at the rear and a probe midway between them which rests on the road surface. The probe is attached to a moving arm, at the other end of, which is a pointer that moves over a chart. The Merlin is wheeled on the road and at every turn of the wheel the position of the pointer is recorded on the chart to build up a histogram. The width of the histogram can be used to give a good estimate of roughness in terms of International Roughness Index (IRI).The critical measurements are the ratio of the long and short sections of the moving arm that must be 10. If there is any deviation from this ratio, a correction factor must be used to obtain the correct roughness from the Merlin measurement. As an example, if the ratio of the sections of the moving arm is 9.75 then the movement of the pointer will be less by a factor of 0.975 (9.75/10). Therefore, the width of the histogram (D) will have to be increased by a multiplying factor of 1.03 (10/9.75) to get the correct roughness



ACTIVITIES INVOLVED

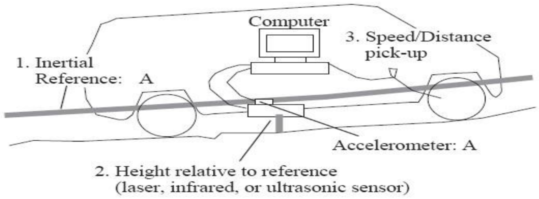
The roughness survey requires several activities of which each one has the effect on the other. The activities are as follows.

Calibration of CNS Farnell Distance Odometer: During the actual survey bump readings are noted after travelling every 0.5-km of road. Therefore a correct calibration of the distance odometer is required.

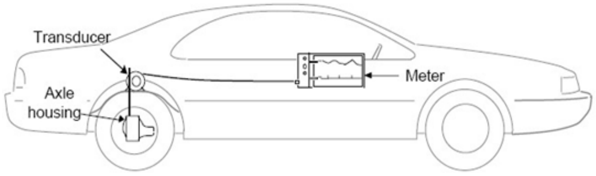
Doing the Merlin Exercise: This is done to get the correct roughness of a particular portion of a road so that if a vehicle fitted with a Bump Integrator is run over that portion, the relative bump counts for the known roughness could be known. In this way if the relative roughness and bump counts of say 10 sites of different roughness are known, then a relationship between the roughness and bumps can be established by doing a regression analysis.In RHD generally 10 to 11 sites are surveyed with Merlin to obtain the actual roughness of individual site. The sites are initially selected in such a way to give varying roughness low and high. Each survey vehicle is then run on those sites to obtain the bump counts against the corresponding roughness of sites and lastly the regression analysis is done to get the relationship of roughness and bump counts of individual vehicle.

Selection of site: Selection of site is very important because sites should be of varying roughness low and high. It may be difficult to get the road with low roughness and similar the case with high roughness. However, from the experience it was seen that roads of low roughness like 2.00 IRI were available and on the high range 8.00 to 8.50 or 9.00 were also available. Use the bump integrator and the distance odometer during site selection. When driving upon a test site have the bump integrator on and keep the distance odometer open. Note down the bump counts for every 0.5-km. The more the bump counts the more will be the possible roughness.

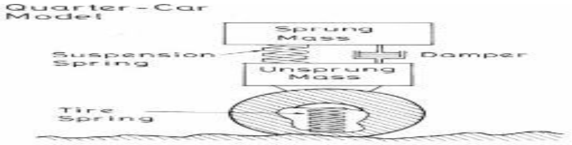
The Merlin has two feet, 1.8m apart which rest on the road surface along the – wheel track whose roughness is to be measured. A movable probe is placed on the road surface mid – way between the two feet and the Merlin measures the vertical distance, y, between the road surface under the probe and the centre point of an imaginary line joining the bottom of the two feet. There is a marker in the front wheel and when it touches the ground the Merlin is said to be in Normal position. When it is in normal position the reading is noted in the given chart which is kept in the Merlin machine. To determine the roughness usually 200 measurements are made. Then the Merlin reading is converted to IRI scales using 'Calibration Scale'.However, the undulations in surface of a road consist of as a mixture of surface waves of different Wave lengths. The sensitivity of the IRI scale varies with wavelength and it is the highest for waves of around two meters. The sensitivity of the Merlin is also high at these wave lengths and that is way it gives a good estimate of IRI. Merlin is used to calibrate Bump Integrator, Because of the different wave length sensitivities, it is important to calibrate the bump integrator on a range of test sections whose surfaces are typical of the surfaces which the bump integrator is going to measure. When Merlin is used to take roughness measurements, following factors have to be taken into consideration; When the Merlin is used to measure the roughness of a test section for calibrating a vehicle – mounted bump integrator, it is important to ensure that both measuring devices are working in the same wheel tracks.

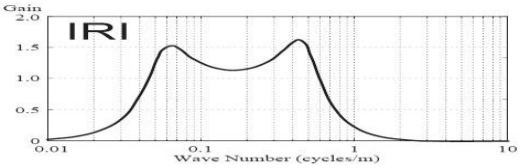


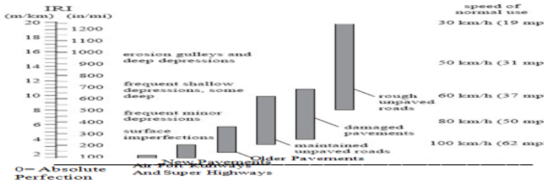
Response Type Road Roughness Measurement (RTRRM) systems record the cumulative displacement of an axle relative to the body of the vehicle induced by the roughness of the road. The measure of vehicle response is very similar in its frequency content to the acceleration on the vehicle body, so it is highly correlated to ride vibration. This type of device sometimes called as road meters.Vehicle vibration response could act as a better roughness index compared with the true profile because it directly relates to the discomfort a vehicle user is more concerned.



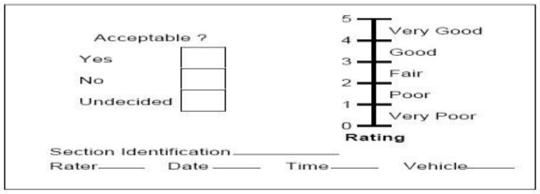
It is essential to follow the under mentioned procedures, otherwise the results that we get will not be accurate. The vehicle should be driven smoothly preferably at a speed of 32 km/h, on the test section without creating spurious input signals to the instrument through acceleration, deceleration and braking. The weight of vehicle affects the roughness measure. Though some weight variation is unavoidable, such as weight due to fuel, other reasons, for instance having another passenger, shall be avoided. Roughness measurements increase with tire pressure. Tires should be checked and maintained at a regular pressure, preferably recommended by the vehicle manufacturer. Tire imbalance and out of roundness also cause to distort the roughness measurement. Mechanical linkages, springs and shock absorbers are the main components which affect the response of RTRRMS. They should be regularly inspected and serviced. The BI readings are finally converted to IRI values which are in m/km unit.

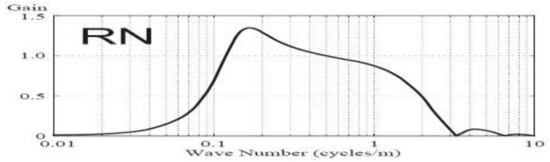


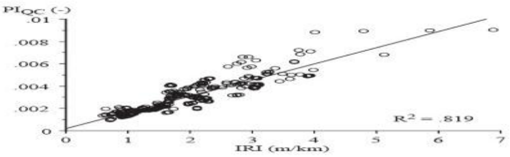




Present Serviceability Rating (PSR), Present Serviceability Index (PSI) and Mean Panel Rating (MPR) The AASHO 840 Road Test developed a definition of pavement serviceability, the present serviceability rating (PSR), which is based on individual observation and that is subjective. The PSR is defined as 'The judgment of an observer as to the current ability of a pavement to serve the traffic it is meant to serve. The following figure shows a rating a person rates a road on a scale of 0 to 5. As PSR is based on passenger interpretations of ride quality, it generally reflects road roughness because roughness largely determines ride quality. Figure 2.9 illustrates Present Serviceability Rating scale.

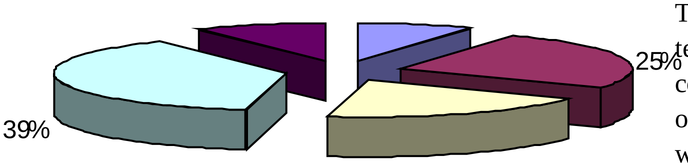


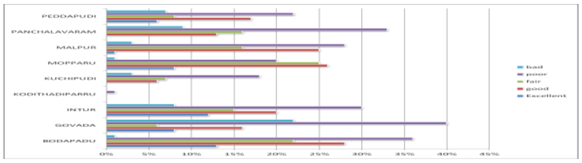


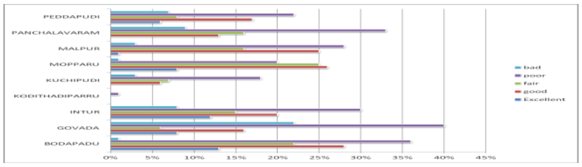


Roughness Measuring Devices.

Vehicle mounted bump integrator is the equipment which is widely used in INDIA. In regular intervals these bump integrators are calibrated using the profiler, MERLIN. The Use Of Roughness Measurements The planning division of Road Development Authority classifies the Core National roads based on ride quality which is measured in terms of IRI values as per the table 1 (network summary report). Annually, the core National Road Network is categorized to five parts in terms of roughness. An example for years 2015 and 20016 is given in the table 1 and figure 12 illustrates it for year 2016.







The data for 2016 and 2017 reveal that; The category of excellent and good condition of Core National Road network in terms of Roughness is in increasing trend. In year 2016, it is about 31% while in 2017 it is about 33%, Western, Central and Southern provinces contribute more for the above improvement, and the category of bad percentage is in decreasing trend in all the Provinces except in Central Province. IRI is also used as one of the input parameters for Highway Development and Management (HDM) software which is used for Pavement Management System (PMS) in INDIA. In addition to roughness indices, structural number, cracking area, raveled area, potholes, edge break area and skid resistance are also used for inputs for HDM package. Further, usually IRI is measured in a road just before it is overlaid with asphalt and just after overlaying in order to calculate the savings of Vehicle Operating Cost (VOC). Then the saving is used for economic analysis of road project to derive Net Present Value (NPV) and Benefit Cost Ratio (BCR) etc.

CONCLUSION

Merlin and auto levels are normally considered to be simple devices for measurement of road roughness. An attempt has been made in this study to design and develop a new device. Experiments have been carried out using this device and at the same time using other two types of equipments on the same road stretches. The results of the experiments on road roughness in terms of IRI using these three devices have been compared among the three methods considered. It is observed that auto level has an error% of 3.95% when compared with the IRI values obtained from Merlin. All the three instruments have its unique importance in the calculation of the road roughness.The upgrade MWUI was tested for calibration error and satisfactorily proved that it served that both repeatability and reproducible. the calibration developed and its variation was assumed as linear regression analysis is conducted between the IRI values obtained the calibration equation for MWUI obtained it as

IRI= 0.0122 (bumps counts)+ 2.8592

the distress parameters, age , traffic volume and rainfall data were considered for the development of the model developed for roughness is as follows

ui = 1519 + 3.73 (crk) + 3.27 (patch) + 11.34 (rd) + 0.92 (ravel) + 0.24 (traffic)

By the regression analysis it was observed that the parameters viz. age of the pavement and rainfall were statistically insignificant in prediction of roughness. it was also observed that the distress parameters and traffic were significant at 95% confidence level. also, as distress increases, the roughness value increases.

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