Road Pavement Condition Modelling

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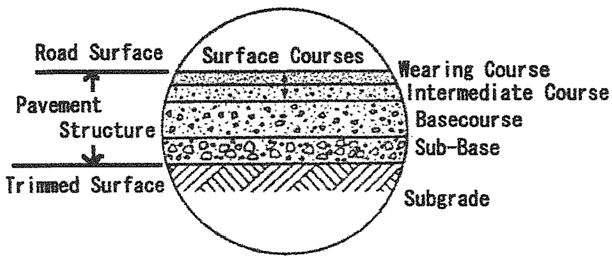
Abstract

There are many factors contributing to road users' discomfort – pavement roughness, rutting and its strength. Brand new pavement provides satisfactory level of comfort, however without efficient maintenance plan, they deteriorate below required level of service in short amount of time. Most road users experience discomfort travelling on poorly maintained road pavement. It is MRWA's job to provide quality service to road users as a government agency. MRWA uses sets of mathematical expressions to predict deterioration of the pavement, triggering maintenances and its effects. Effects of various pavement treatments play important role in planning efficient maintenance programme for the life cycle of a pavement. This study aims to improve mathematical expressions used to predict treatment effects, using the maintenance data collected over the past few years.

1.0 Background

1.1 Definition of Pavement

Pavement is a multi-layered structure to supplement the natural strength of the soil foundation. Construction of pavement is necessary because natural soil is rarely strong enough to support the repeated applications of wheel loads without significant deformation.



1.2 Deterioration of Pavement

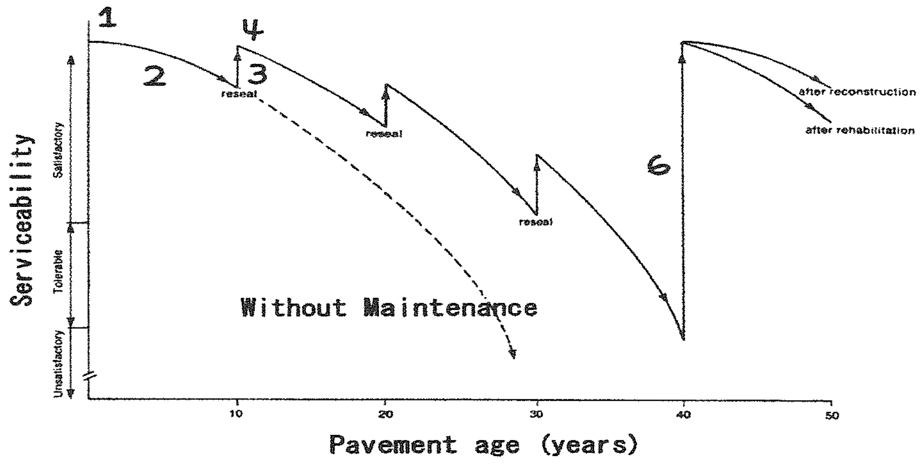
Newly constructed pavement deteriorates exponentially with time. Deterioration of pavement is inevitable and occurs due to interactions of following factors:

- Fatigue from repeated applications of vehicle loads
- Deterioration in the stone aggregate shapes
- Removal of aggregates of certain size
- Creation of voids
- Loss of strength and adhesion in the binding material

1.3 Life Cycle of Pavement

Life of a pavement begins at the completion of construction and recycles when rip & remake is done. Following describes the life cycle of a pavement:

1. Completion of construction
2. Deterioration period until condition drops below level of service required
3. Appropriate maintenance treatment
4. Reset condition to appropriate value following the treatment
5. Deterioration period – repeat 2→4
6. Reconstruct or Rehabilitate when economically more viable



2.0 The Data

A pavement's condition is generally reflected by three parameters – Roughness, Rutting and Strength. MRWA has been collecting each of the parameters along every length of their road network at the end of every financial year since 1998. Each parameter interacts with one another to induce unwanted vibrations to the vehicle.

2.1 Roughness

2.1.1 Definition of Roughness

Roughness is the deviation of a pavement surface from a true planar surface with characeristic dimensions that affect vehicle dynamics, ride quality, dynamic loads, and drainage, for example, longitudinal profile, transverse profile, and cross slope (American Society of Testing and Materials Definition – E867). It is defined over an interval of profile as summary of deviations that occur instead of roughness at a point. Mainroads uses 100 m profile intervals.

There are different indices to represent different types of roughness. International Roughness Index (IRI) is the world widely accepted index, which includes a moving average and a quarter car filter.

2.1.2 Measurement of Roughness

Roughness is measured as a longitudinal displacement from a datum, by an equipment called Profilometer – a vehicle mounted system. It includes an accelerometer, height transducers and recording software.

Longitudinal acceleration profile is measured by the accelerometer which can be integrated once to obtain a slope profile and twice to obtain a displacement profile. The displacement profile obtained is then added to the height of the vehicle measured by the height transducer. This is the elevation profile of the road, which is automatically recorded by the system. Additional software allows automatic calculation of IRI from the elevation profiles.

2.2 Rutting

Rutting is the depth of a wheel-track worn out by the habitual passage of vehicles, having units of length. It is measured by the same profilometer used to measure roughness.

Rut depth sensors measure the height difference between wheel paths and crown of the pavement as seen in the figure.

At MRWA, Measurements are taken every 50mm and averaged to every 20m section.

2.3 Strength

Strength reflects on the stiffness of the pavement and the ability of the pavement to resist to deformation under impact loading. It is represented by the vertical deflection measured under the impact of a falling weight.

A vehicle towed instrumentation called Falling Weight Deflectometer is used to measure strength of the pavement. Load produced by a rolling vehicle wheel is simulated by dropping large weight. A circular load plate transmits the load pulse to the pavement. Deflection sensors located radially from the centre of the load plate measures vertical deflection of the pavement in response to the load.

2.4 Problems with the data

There exists problems with the data due to the nature of the data collecting method and the large network area covered. In order to interprete collected data, it is crucial to understand the following problems :

1. Misalignment of SLK distances each year
   SLK distances along the road are represented by pegs at defined interval for urban roads. However for metropolitan roads, It is not feasible to use pegs to define distance along the road. Instead, Landmarks such as buildings, intersections are used to represent the SLK distances along the road. This leads to slight misalignment of SLK distances for data acquisition every year.

2. Presence of storm drains
   Features of the road along its length such as presence of storm drains and manholes cause significant vibrations in the vehicles that drive over them. Unusually high roughness may result from sections of the road containing such features.

3.0 Exploratory Analysis of Data

3.1 Confirming location of work done

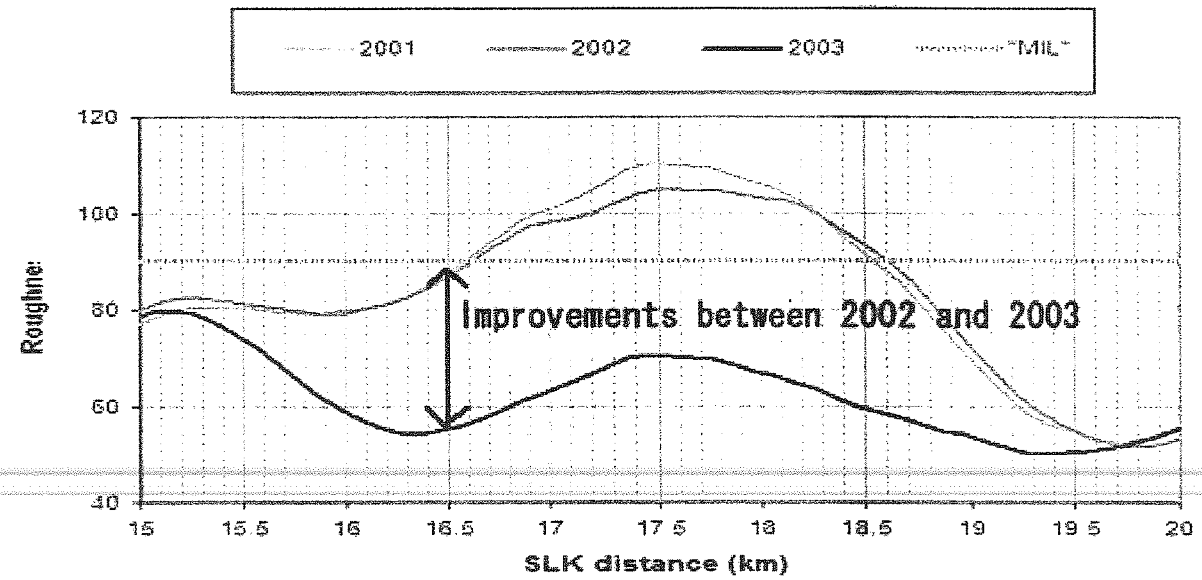
Road maintenance is responsibility of contractors to MRWA and they are required to submit an Operational Road Plan twice a year, which is the list of proposed treatments by road and position along the road. Work-done document which lists treatments that have been applied is also required to be submitted at the end of every financial year.

For the purpose of this project, sets of condition data prior to and preceeding the treatment is required – confirming the location of work done.

Following procedures have been taken to confirm the location of work done.

1. Locate section of a road on which treatment has been applied from the Work-Done document
2. Locate the same section of the road on Running Roughness, Running Ruttings and Running Strength data.

3. Observe any improvements in the condition parameters – Obvious improvements between two successive years indicate application of a treatment.



4. Record the location of the road and treatment that has been applied.
5. Collect data prior to & preceeding the treatment year for the recorded location of the road

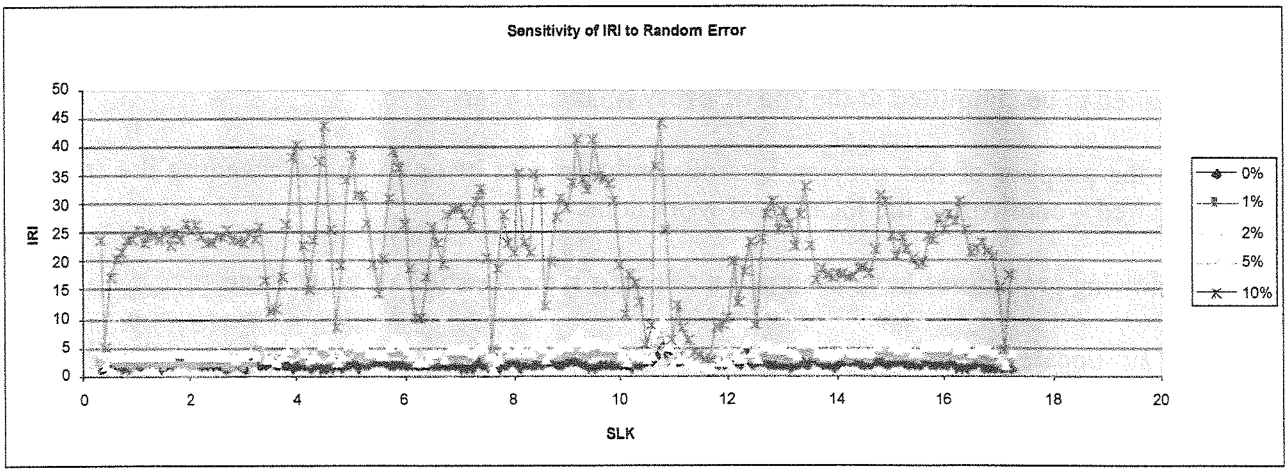
The procedure is repeated for every treatment listed in the Work-Done document, to produce convenient data for the purpose of analysing.

3.2.1 Sensitivity Analysis of IRI filter

International Roughness Index takes elevation profiles of the road and applies filters to produce single index which indicates roughness of the road for the profile interval. In order to varify how sensitive the filtering process is to random errors in the measurement of longitudinal profile, sensitivity analysis has been carried out. It was also questionable that the fluctuations in the Running Roughness resulted from the filtering procedure.

Sensitivity analysis was simply carried out by introducing percentage random errors to the raw longitudinal profile. IRI was then calculated using the software ROADRUF.

Following shows the graphical result of sensitivity analysis:



3.2.2 Interpretion of sensitivity analysis result

From the sensitivity analysis, It can be seen that even small random error (~10%) results in amplification of IRI by approximately great amount (~multiple of 10). Observed sensitivity can be explained by the increase in accumulation of suspension motion, as variations in the elevation of the road becomes greater – that is standard deviation of the elevation profile increases with introduction of random errors.

If all of the elevation values in a measured profile are increased by constant percentage instead of random errors, then the IRI would increase by exactly same percentage (Michael W. Sayers & Steven M. Karamihas, 1998).

4.0 Statistical Analysis

Statistical Analysis is to be carried out using mathematical software packages such as MATLAB.

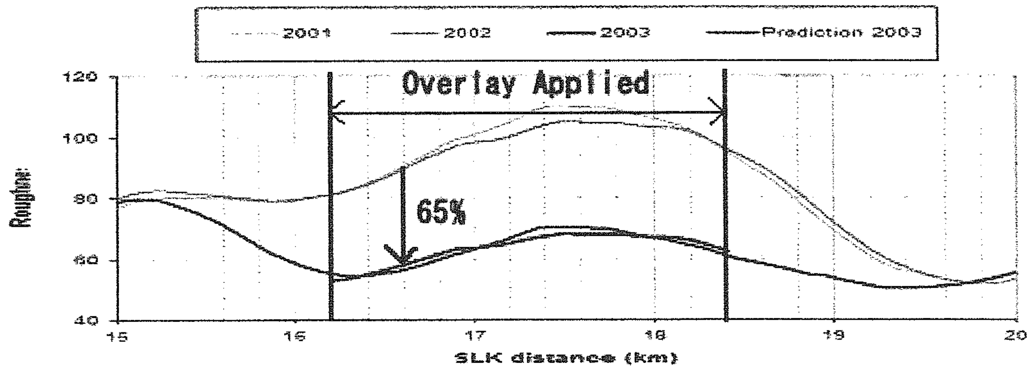
5.0 Overview of results and comparisons

From the statistical analysis of the data, following three categories of reset rules would be derived.
(Examples taken from Report DM402, HTC Infrastructure Management Ltd, New Zealand).

- Absolute reset – Resets to an absolute value

Eg: Roughness after rip and remake is reset to 2.5 m/km IRI

- Relative reset – Resets to a percentage of the existing value



Eg:Rutting after thin asphalt overlay is reset to 65% of previous value

- Expression reset – Expression is used to reset a given parameter

Eg: Reset of roughness after a reseal is given by the following expression:

$$RIa = Rib + max[0, max[0.3(5.4 - Rib), 0.5]] - 0.0066ACX$$

Where RIa = Roughness after seal in IRI [m/km]
Rib = roughness before seal in IRI [m/km]
ACX = area of index cracking in percent

In order to test the useability of the reset rules derived, comparisons will be made to current reset rules used at MRWA. Percentage error between theoretical reset values (for both MRWA & Thesis model) and actual reset values in order to clarify the accuracy of each model.

6.0 Implications for further studies

Roughness, Rutting and Strength of pavement is not only affected by their age. In regions with significant seasonal variations, temperature and moisture content play significant role on the pavement conditions.

Further studies into effects of temperature and moisture content in the pavement, and incorporating the result into reset models could provide Mainroad with more accurate pavement life cycle model.

7.0 References

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